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NASA's Science Activation Program

Achievements and Opportunities

Margaret A. Honey, Kenne A. Dibner, and Tiffany E. Taylor, *Editors*

Committee to Assess Science Activation

Board on Science Education

Division of Behavioral and Social Sciences and Education

A Consensus Study Report of

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Preface

It is an honor to be asked to direct a consensus study for the National Academies of Sciences, Engineering, and Medicine, and to have conducted this study at the request of the National Aeronautics and Space Administration (NASA) made this work both personally and professionally meaningful. NASA stands at the forefront of scientific discovery and exploration, and the agency's willingness to leverage its expertise and deploy its engaging assets to advance learning in science, technology, engineering, and mathematics (STEM) is admirable.

NASA's work in the area of education and public engagement needs to be pursued with the same level of depth and care as its scientific research. There is a great deal that we know from the fields of behavioral, cognitive, and neuro sciences about how people learn. We know, for example, that engagement is key, not just in terms of interest, but in terms that are meaningful and relevant to learners and that build on and enhance their prior knowledge and skills. We know that for educational innovations such as technologies, curricula, visualizations, and data models to be effective, they need to engage learners actively and provide easy ways for novices to get started (low floor), as well as ways for learners to work on increasingly sophisticated projects over time (high ceiling). The recent National Academies study *How People Learn II* contains the most up-to-date information on individual and cultural variations in learning, as well as the broad range of sociocultural factors that impact how learning takes root. In short, we have an abundance of evidence on which to draw in designing the highest-impact learning opportunities.

The National Academies consensus studies are designed to foster a rigorous process of debate, dialogue, and collective thinking about the issues at hand. They are deeply anchored in two distinct, but related kinds of expertise—what is known from published, peer-reviewed research studies and what is embodied in the professional wisdom and experience of committee members. The process results in a report that reflects the deliberations, contributions, and consensus of all committee members.

The Committee to Assess Science Activation comprised an extraordinarily talented group of individuals who brought to the table deep knowledge of relevant bodies of work in fields that included planetary science, earth science, space science, education policy, teaching and learning, collective impact, and science education, along with their good humor, dedication, and willingness to roll up their sleeves and accomplish a great deal in a very short amount of time. We were fortunate to have an extraordinary group of talented colleagues with whom to work on this project, and we thank each of them for their substantial contributions.

We also wish to thank the leadership and staff of NASA's Science Activation Program, along with their education partners, all of whom participated in a number of meetings designed to help the committee understand their desired outcomes and where the opportunities and challenges reside. We know we speak for the entire committee when we say we appreciate their transparency, their willingness to field endless questions, and their patience in helping us understand the important motivations behind NASA's investments in and commitment to this work.

Finally, all National Academies projects are driven and supported by a team of extraordinarily talented staff and leaders. From organizing meetings, to managing committee logistics, to tracking conversations and decisions, to pushing our collective work to ensure that it would be as rigorous and comprehensive as possible, the staff are professionals who know how to deliver with care and quality. We thank all of them for their support and wisdom.

We reflect all of the voices of the committee when we say that working on this project has been inspiring. NASA's Science Mission Directorate is full of exceptional people doing transformative work. The agency's desire to engage its people and use its resources to further the public's—especially young people's—understanding and love of science is a mission that will help ensure the importance of the agency's work for generations to come.

Margaret Honey
Chair, Committee to
Assess Science Activation
Kenne A. Dibner
Study Director

Acknowledgments

The Committee to Assess Science Activation was charged with providing a "concise" assessment of the National Aeronautics and Space Administration's (NASA's) Science Activation (SciAct) Program and, as such, was asked to do the work of a full National Academies of Sciences, Engineering, and Medicine consensus study on a shortened timeline. In order to achieve this task, a number of people devoted time and energy to supporting our work. We owe a sincere debt of gratitude to all involved.

First, we wish to extend a thank you to this project's sponsors. Throughout this process, Kristen Erickson of NASA's Science Mission Directorate, her colleague Lin Chambers, and her other coworkers at NASA were on hand to provide resources, answer committee questions, and offer insight. We are profoundly grateful for their support.

Over the course of the study, we heard from many individuals who were able to shed light on the SciAct portfolio or relevant external issues. We appreciate all SciAct awardees who took time out of their schedules to provide the committee with insight on their projects, and we also value the contributions of the scholars who presented to the committee so that we might bring in outside expertise.

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their review of this report: Alphonse T. DeSena, Jr., ATD Discern, LLC, Arlington, VA; Cristin Dorgelo, President and CEO, Association of Science-Technology Centers; Noah Weeth Feinstein, Department of Curriculum and Instruction, University of Wisconsin–Madison; Jill L. Karsten, Directorate for Geosciences, National Science Foundation; Makenzie Lystrup, Civil Space, Ball Aerospace; Christopher F. McKee, Physics Department, University of California, Berkeley; Cathy Olkin, Institute Scientist, Southwest Research Institute; Rajul Pandya, Thriving Earth Exchange, American Geophysical Union; Darryl N. Williams, Science and Education, The Franklin Institute; Laurence R. Young, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology; and Susan A. Yoon, Teaching Learning and Leadership Division, University of Pennsylvania.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report, nor did they see the final draft before its release. The review of this report was overseen by Michael Lach, The University of Chicago, and Claude Canizares, Massachusetts Institute of Technology. They were responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

The committee wishes to extend its gratitude to the staff of the Division of Behavioral and Social Sciences and Education (DBASSE), in particular to Heidi Schweingruber, director of the Board on Science Education, whose strategic thinking and dedication helped ensure a timely and impactful report; to Tiffany Taylor, who went above and beyond in her supportive role to draft text, edit chapters, and serve as a full partner throughout this process; and to Jessica Covington, whose expert and efficient administrative leadership enabled smooth meetings and report production. Kirsten Sampson Snyder of the DBASSE staff deftly guided us through the National Academies review process, and Rona Briere and Allie Boman provided invaluable editorial assistance. Yvonne Wise of the DBASSE staff oversaw the production of the report.

Finally, the committee wishes to thank Margaret Honey, study chair, for her skilled leadership and clear vision on this tight timeline. Every once in a while, this process results in an unforeseen ancillary benefit: a lifelong friendship. It has been both a pleasure and an honor to work closely with Margaret, and this assessment was truly strengthened by her expertise and wisdom.

Kenne A. Dibner,
Study Director
Committee to Assess
Science Activation

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Summary

As one of the leading federal science, technology, engineering, and mathematics (STEM) agencies of the United States, the National Aeronautics and Space Administration (NASA) has an important role to play in the landscape of STEM education. Education programs in NASA's Science Mission Directorate (SMD) are one of the major ways that the agency has engaged the public in the excitement of NASA's science missions. In 2015, NASA SMD created the Science Activation (SciAct) Program to increase the overall coherence of SMD's education efforts; to support more effective, sustainable, and efficient use of SMD science discoveries for education; and to enable NASA scientists and engineers to engage more effectively and efficiently in the STEM learning environment with learners of all ages. As SciAct transitions into its second round of funding, it is important that NASA take stock of the status of the portfolio and consider how it might be improved. To this end, NASA asked the Board on Science Education at the National Academies of Sciences, Engineering, and Medicine to conduct a review of the SciAct portfolio. In response to this request, the Board on Science Education convened a committee of experts to

> Assess the SMD's Science Activation (SciAct) Program's efforts toward meeting the following objectives: (1) enable STEM education, (2) improve U.S. scientific literacy, (3) advance national education goals, and (4) leverage efforts through partnerships. The review will provide an independent, authoritative forum for identifying and discussing SciAct issues in Earth

and Space Science related to NASA SMD's SciAct Program and will include the following:

> Concise written assessment of the status of the SMD Science Activation Program including feedback on improving the program. The assessment will be based on evidence gathered by the committee at its in-person and virtual meetings and on established principles for evidence-based science education as summarized in previous reports from the Board on Science Education. The committee's assessment final report may include findings and conclusions related to management of and priorities for the next phase of the program, including the identification of any gaps in the SciAct approach, given new advances in science education pedagogy and recent Decadal recommendations. The assessment will be subject to review in accordance with the National Academies institutional policies.

To accomplish this task, the committee reviewed documentation of the SciAct Program including descriptions provided by NASA, the solicitation for proposal, and evaluation reports from individual projects in the portfolio. We also heard input from NASA staff associated with the SciAct Program and from awardees.

HISTORY, VISION, AND OBJECTIVES OF THE SciAct PROGRAM

SciAct represents a new approach to education and outreach in SMD. Previously, SMD supported its education and public outreach efforts by allocating at least 1 percent of the budget of each science mission to education and outreach (known as the 1% model), by offering awards through solicited or unsolicited proposals (e.g., Global Learning and Observation to Benefit the Environment [GLOBE] Implementation Office), or by including education and outreach as elements of a major research-enabling program (e.g., suborbital science). Although the 1 percent model had many strengths, one consequence was a lack of coordination across mission activities, leading to duplications of efforts and potentially inequitable distribution of educational resources. Additionally, it was not clear that the education and outreach activities were responsive to the needs of educators and learners nor that they helped to advance broader national goals for STEM education. The new approach taken in SciAct is designed to address these issues. The vision of the SciAct Program is

> to share the story, the science, and the adventure of NASA's scientific explorations of our home planet, the solar system, and the universe beyond, through stimulating and informative activities and experiences created by experts, delivered effectively and efficiently to learners of many backgrounds via proven conduits, thus providing a return on the public's investment in NASA's scientific research.

A central focus of this vision is to leverage NASA's science discoveries for education and enable NASA scientists and engineering to engage more effectively with learners of all ages. To achieve this vision, SciAct has identified four primary objectives:

1. *Enable STEM education*. SciAct intends to support STEM education through the mobilization of NASA's existing resources and assets. Practically, this means that awardees are tasked with translating NASA assets into educational use by creating new materials that can be used by learners or educators, and into programs that will allow learners and students to engage with NASA assets.
2. *Improve U.S. scientific literacy*. Similar to the enable STEM education objectives, NASA awardees are expected to translate NASA assets so that they support the development of participants' science literacy. SciAct currently measures science literacy via the continuation of the Science and Engineering Indicators Survey, which measures one specific aspect of science literacy.
3. *Advance national education goals*. SciAct is pursuing this objective primarily through activities that provide professional development to in-service educators, provide authentic science experiences for learners, target specific underrepresented populations either through direct engagement or by providing resources and professional development to educators in areas with high percentages of these groups.
4. *Leverage efforts through partnerships*. SciAct pursues this objective by supporting awardees in their partnerships in local communities, while also developing collaborations across the portfolio.

Further, SciAct documentation defines NASA assets and resources as including:

- exciting science and engineering content that engages audiences and motivates them to learn more;
- subject matter experts (SMEs), including scientists and engineers, who ask compelling scientific questions and then find ways to answer them within the environment of space;
- real-life participatory and experiential opportunities (includes student collaborations, e.g., suborbital balloon experiments and other student launch opportunities); and
- other science programs in NASA's infrastructure (e.g., GLOBE, Night Sky Network).

To better understand the links among the vision, objectives and portfolio activities, the committee developed a logic model that built on the existing SciAct Program model, but provides more detail about potential connections among NASA assets, SMEs, the activities of individual projects, project outcomes, and portfolio-level outcomes. The committee used this logic model to inform its review of SciAct's vision and objectives. The committee concludes

CONCLUSION 1: The National Aeronautics and Space Administration has a unique role to play in the science, technology, engineering, and mathematics education landscape, but the current four objectives for the Science Activation Program are too broad and do not appropriately reflect that role.

CONCLUSION 2: The four current Science Activation Program objectives are general enough to inform a vision for the program, however they lack specific, actionable targets. As currently stated, the objectives are so broad that they obscure a clear understanding of how awardees' contributions aggregate toward desired outcomes.

CONCLUSION 3: Improving science literacy at the national level is one of the four Science Activation (SciAct) Program objectives. We do not have evidence that there is a centrally agreed-upon definition of science literacy across the projects. While, the approach to measuring science literacy at the national level that SciAct is currently using reflects one approach to measuring science literacy, it does not fully reflect the most up-to-date conceptualizations of science literacy.

CHARACTERIZING THE PROJECTS IN THE SciAct PORTFOLIO

Currently, 24 awards (or projects) are still in progress that constitute the SciAct Phase 1 portfolio. Awardees will have an option to extend their funding by 5 years into Phase 2 of the program (potentially at different levels) beginning in 2020, and opportunities for new projects will be afforded through SMD's Research Opportunities in Space and Earth Sciences (ROSES) grant solicitation. The current suite of projects addresses topics from the four primary NASA science disciplines: heliophysics, earth science, planetary science, and astrophysics. The awardees include museums and science centers, universities, a community college, a K–12 school district, research institutes, and educational foundations. The 24 projects engage a variety of audiences, including families, K–12 students and teachers, adults, children, and teens in formal education, informal education, and community settings. Overall, about half of SciAct projects engage learners in informal learning environments, such as museums and out-of-school programs, and half engage learners in formal educational settings, primarily through K–12 schools and teachers. One-third of the SciAct projects have created digital resources for learners, both exclusively and as part of more comprehensive projects.

Across the portfolio, projects have established partnerships with scientific experts, educational experts, community organizations, professional organizations, museums and other informal learning institutions, K–12 school districts, universities and colleges, and multimedia platforms as a means of creating and disseminating learning programs and resources. Furthermore, some projects have cross-collaborated in a variety of capacities, whether to broaden their dissemination efforts or to leverage each other's expertise in using NASA data/resources and developing learning resources. Because SciAct has identified leveraging partnerships as one of its primary objectives, these partnerships and collaborations are a high priority for the SciAct Program administration; and metrics about partnerships and cross-collaboration are documented as a part of each project's monthly report to NASA SMD.

NASA SMD has strongly encouraged all projects to use NASA SMEs in some capacity within their projects. SMEs are engaged in SciAct projects in a variety of roles, from providing scientific and technical expertise to educational teams to actively participating in SciAct programming by sharing stories, presenting scientific and technical information, and leading program activities. SciAct projects are using NASA scientific content, data, science mission activities, or technologies as the basis for their educational programs and resources. The wide geographic distribution of programs, activities, and available materials makes SciAct projects well positioned to be a valuable asset to communities, which are local to their respective institutions.

Each project has an outside evaluator who works with the project leadership to evaluate the project's activities and whether they are producing the intended outcomes. Currently, there is no comprehensive evaluation at the portfolio level.

In examining the nature of the projects in the current SciAct portfolio, the committee concludes that:

CONCLUSION 4: The National Aeronautics and Space Administration (NASA) has developed a portfolio of diverse projects reaching a broad range of communities across the United States that utilize NASA's resources.

CONCLUSION 5: The Science Activation (SciAct) Program has placed an emphasis on no longer funding education work attached to individual missions. This has eliminated redundancy, but it has also resulted in some missions not being represented comprehensively. The current SciAct portfolio is not consistently incorporating assets from new missions.

CONCLUSION 6: In general, the Science Activation approach has enabled development of partnerships with groups external to the National Aeronautics and Space Administration (NASA) with expertise in education and learning that provide added value for NASA.

CONCLUSION 7: The Science Activation approach to evaluation focuses on evaluating individual projects without adequate attention to how evaluation can inform the whole portfolio. Project evaluators support individual projects and are surfacing important insights that could benefit the portfolio. Among the evaluators, there is interest in contributing to a broader understanding of what is working well, what can be improved, and where there are opportunities that can be further leveraged across the portfolio. However, there are limits, given the current design and program resources, to how much this is possible.

CONCLUSION 8: Interactions among the projects to date have allowed principal investigators and evaluators to share ideas across projects in ways that were unanticipated in the original design. These kinds of collaborations can be built upon and strengthened in the future.

EXAMINING PROGRESS TOWARD SCIACT'S VISION AND OBJECTIVES

The committee examined the work of the 24 awards in the SciAct portfolio in greater detail in order to understand how each project contributes to the larger objectives of the portfolio. Because the current portfolio objectives are very broad, the committee focused on four key themes that are linked to the stated objectives but are closer to the actual activities of the projects:

1. enhancing STEM learning,
2. leveraging NASA assets,
3. broadening participation, and
4. developing networks.

Projects employ a variety of approaches to supporting STEM learning and leveraging NASA's assets. They also vary in how explicit they are in articulating the assumptions about how learning occurs that undergird the design of their project activities. The committee also noted that there does not appear to be a portfolio-wide strategy for how NASA's assets should be used, especially in the case of SMEs. The existing program model SciAct employs does not clearly show how NASA assets (i.e., content, SMEs, existing infrastructure) and research on learning come together in the *design* of project activities (e.g., outreach events, educator professional development, and infrastructure resources), and also how these activities are organized to support *teaching and learning* in ways that are expected to lead to positive outcomes in STEM education.

SciAct's mission is to deliver activities and experiences to *learners of many backgrounds* and to leverage scientist-educator partnerships that have demonstrated *diverse, broad, and deep national education and communications impact*. It is clear that the existing SciAct portfolio reaches large groups of learners across different regions, abilities, age groups, and race and ethnicities, among other facets of diversity. While reach is one dimension of broadening participation, there are other facets of the work that are equally important to consider, such as whether projects are fully accessible to all learners, regardless of their abilities. From the committee's investigation, it is unclear whether appropriate attention is being given to other dimensions of broadening participation, such as inclusion, equity, and accessibility.

The committee also found that the SciAct portfolio is currently functioning as a dissemination network, wherein NASA resources and project innovations are disseminated to learners directly. However, the committee observed that the current SciAct Program also has elements that may support its capacity to function as a learning network that enhances the existing awardees' activities and affords opportunities to share what is learned with the larger community of scholars and developers in STEM education. Building this kind of network would require additional investments to create the infrastructure needed to support ongoing communication and collaboration among projects.

In summary, in examining the SciAct portfolio's progress toward the current objectives, the committee concludes

CONCLUSION 9: While science, technology, engineering, and mathematics learning is in the foreground as a Science Activation goal, there is no explicit link between theories of learning and how the National Aeronautics and Space Administration assets are used (e.g., transmission models, inquiry-based practices). There is a range of design intervention strategies that are used across the portfolio. Each project uses different theories of learning in its project design and often that theory of learning is not made explicit.

CONCLUSION 10: Current research on learning emphasizes the importance of learner-centered and community-centered instructional design and practices. Awardees have had uneven success at mobilizing the National Aeronautics and Space Administration assets while also being responsive to the needs of learners and communities.

CONCLUSION 11: Given the portfolio's emphasis on the value of subject matter experts, the portfolio lacks a coordinated effort to incorporate evidence-based practices in translating their expertise in developing and implementing educational materials and learning experiences (e.g., translating datasets, engaging in public outreach).

CONCLUSION 12: While broadening participation is a stated intention of Science Activation (SciAct), it is not clearly defined, nor is there evidence that awardee activities have uniformly had an impact in this area. Integrating goals related to broadening participation throughout SciAct projects would require explicit assessment beyond counting the numbers of participants from various groups.

CONCLUSION 13: The projects that are part of the Science Activation portfolio use a variety of design strategies to translate the National Aeronautics and Space Administration's assets—subject matter experts, media assets, scientific instruments, datasets, etc.—to support learning in science, technology, engineering, and mathematics. However, there are limited mechanisms for gathering, synthesizing, and sharing these innovations across the portfolio or for learning from cases of success or failure.

RECOMMENDATIONS FOR MOVING INTO PHASE 2 OF THE SciAct PROGRAM

The Committee to Assess Science Activation was charged with two primary tasks: (1) assessing SciAct's progress toward meeting its four primary objectives, and (2) offering feedback on improving the SciAct Program. The committee was struck by the considerable value of the SciAct portfolio of investments in the national landscape of efforts to support STEM learning and engagement. The scope and diversity of SciAct projects are reaching a wide swath of learners across the country, and projects are employing a myriad of strategies for engaging potential participants. At the same time, the committee noted several ways that the SciAct Program can be improved. Phase 2 of the program offers a natural inflection point for initiating a reflection process and determining how existing projects might be improved and what additional projects might augment the current portfolio in strategic ways. One key issue is to refine the objectives for the SciAct portfolio and better articulate the connections among NASA's assets, the specific activities of the projects and the desired outcomes for projects and the portfolio as a whole. The committee concludes

CONCLUSION 14: The Science Activation Program is at an important inflection point in its history. The second phase of the program presents

an opportunity for iterative improvement and refocusing on both the individual project level and the portfolio as a whole.

CONCLUSION 15: While continuing existing awards may allow for continuity and support an environment of collaboration and partnership among existing awardees, lack of competition or opportunities to fund new projects may stifle the evolution of the portfolio.

Based on its conclusions and with an eye toward continuing and enhancing the good work that is already under way, the committee offers several specific recommendations for moving forward.

RECOMMENDATION 1: Science Activation (SciAct) should go through a visioning process that brings the portfolio up to date with current research on learning and design, the new federal science, technology, engineering, and mathematics (STEM) plan, and evidence-based approaches to broadening participation. This process should also consider how SciAct fits within and contributes to the larger STEM education ecosystem and should provide the foundation for developing actionable and measureable portfolio goals.

RECOMMENDATION 2: Science Activation should articulate how it expects that the portfolio will leverage National Aeronautics and Space Administration assets, how partnerships and networks will be built, and how these actions will lead to desired, measurable outcomes.

RECOMMENDATION 3: Science Activation (SciAct) must consider whether the development of a coordinated learning network of awardees across its portfolio is a program priority. If it is a priority, then the program must provide the necessary infrastructure to support a more active network of projects. At the very least, SciAct needs to develop more systematic mechanisms for projects to share best practices and learn from successes and failure.

RECOMMENDATION 4: Science Activation should use the opportunity provided by Phase 2 to reflect on the current portfolio within the context of the new vision, goals, and logic model. This process should critically review and guide existing projects, be explicit about the rationale and criteria for including new projects, and consider how best to integrate them into the existing portfolio. One important area for consideration is how to ensure that underserved communities receive more focused attention in the next phase of the program.

RECOMMENDATION 5: Science Activation (SciAct) should deepen its commitment to broadening participation by using evaluation measures that go beyond counting numbers of individuals who represent specific groups. In order to do this, SciAct must identify ways that the portfolio as a whole could draw upon and implement evidence-based strategies for broadening participation.

RECOMMENDATION 6: Science Activation should build ongoing opportunities for dialogue with the National Aeronautics and Space Administration Science Mission Directorate's missions and scientists.

RECOMMENDATION 7: Science Activation should create an independent mechanism to obtain ongoing, real-time advice from individuals with expertise in learning and design, the larger policy context of science, technology, engineering, and mathematics (STEM) education, partnering with local communities, broadening participation in STEM, and science content relevant to the missions of the National Aeronautics and Space Administration Science Mission Directorate. Among other responsibilities, these experts should inform the new visioning and planning process.

> **RECOMMENDATION 7a: With input from these experts, Science Activation (SciAct) should consider whether and how a portfolio-level evaluation could strengthen the focus of the program and ensure that projects in the portfolio are effectively meeting overarching SciAct Program goals and objectives.**

1

Introduction

Not since the launch of Sputnik has the United States seen such tremendous attention to the value and importance of science, technology, engineering, and mathematics (STEM) education. In a world with rapidly expanding technologies and increasingly complex political and social challenges, Americans are expected to able to put STEM knowledge and skills to work in their daily lives. Recognizing this, major stakeholders in America's STEM landscape—from federal agencies to private enterprise to local communities—are investing in efforts to enhance STEM education and stimulate public engagement in STEM issues. As one of the country's leading STEM agencies with a brand that resonates deeply with the American public, the National Aeronautics and Space Administration (NASA) has a particular role to play in helping America realize the promise of STEM education.

In an effort to harness the potential of NASA's resources, NASA's Science Mission Directorate (SMD) underwent a significant restructuring of STEM education-related activities in 2013. The new portfolio of competitive award investments, NASA SMD's Science Activation (SciAct) Program, endeavors to increase the overall coherence of SMD's efforts in support of more effective, sustainable, and efficient use of SMD science discoveries and learning experiences. One of SciAct's stated goals is to enable NASA scientists and engineers to engage more effectively and efficiently in STEM learning environments with learners of all ages.

In 2019, SciAct is nearing the end of its first funding cycle. As SciAct transitions into its second round of funding, it is important that SciAct stakeholders take stock of their work, address challenges, and plan for the future. A few critical questions emerge: How is SciAct designed, structured, and

BOX 1-1
Charge to the Committee

An ad hoc committee will assess the SMD's Science Activation (SciAct) Program's efforts toward meeting the following objectives: (1) enable STEM education, (2) improve U.S. scientific literacy, (3) advance national education goals, and (4) leverage efforts through partnerships. The review will provide an independent, authoritative forum for identifying and discussing SciAct issues in earth and space science related to NASA SMD's SciAct Program and will include the following:

> [A] concise written assessment of the status of the SMD Science Activation Program including feedback on improving the program. The assessment will be based on evidence gathered by the committee at its in-person and virtual meetings and on established principles for evidence-based science education as summarized in previous reports from the Board on Science Education. The committee's assessment final report may include findings and conclusions related to management of and priorities for the next phase of the program, including the identification of any gaps in the SciAct approach, given new advances in science education pedagogy and recent Decadal recommendations. The assessment will be subject to review in accordance with the National Academies' institutional policies.

implemented to address its stated goals? What modifications can be made to current program elements to improve its efficacy? What should SciAct stakeholders consider when making changes to the existing program? Finally, what is NASA's role in supporting STEM education in the United States, and how well is SciAct positioned to fulfill that role?

In order to address these questions, NASA tasked the Board on Science Education (BOSE) of the National Academies of Sciences, Engineering, and Medicine with conducting a review of the SciAct portfolio. In response to NASA's request, BOSE convened the Committee to Assess Science Activation (see the committee's charge in Box 1-1). The 14-member committee included individuals with expertise in earth science, space science, planetary science, collaborative models and partnerships, collective impact, education policy, and learning and teaching in science and engineering (see Appendix B for biographical sketches). In this report, the committee provides a comprehensive review of the SciAct portfolio and offers recommendations for improving the program.

CONTEXT OF THIS REPORT

NASA is one of many entities (i.e., agencies, institutions, and organizations) working to improve educational experiences and opportunities in STEM for learners of all ages. To address its charge, it was important for the committee to understand the complex education landscape in which NASA SciAct operates, and the contextual factors that NASA should consider in order to define SciAct's appropriate role in STEM education nationally. This section briefly describes the U.S. education system as it relates to the role of the federal government. Additionally, it reviews the current STEM education context in the nation, and why it is appropriate for NASA to have a specific role in this domain.

Federal Involvement in STEM Education

In the United States, state, local, and tribal governments are primarily responsible for public preK–12 education. The federal government does not set a national curriculum and it cannot mandate state or local participation in federal programs. Yet, even with limited authority over public education, the federal government is uniquely positioned to augment ongoing efforts in the formal education system through legislation and funding. The federal government also plays an important role in informal education, providing management and financial support for many museums, aquariums, planetariums, zoos, science centers, libraries, and after-school programs. Moreover, the government can shape how different parts of the education system interact, for example, by calling for the blending of best practices across different education communities (e.g., informal and formal) to ensure that consistent, high-quality education experiences are uniformly afforded across the entire system (National Science and Technology Council, 2018).

Several federal agencies receive funding through Congress in support of their STEM education-related programs, research, and activities, including the Department of Education, the National Science Foundation (NSF), the Department of Defense, the Department of Health and Human Services (i.e., National Institutes of Health), the Department of Commerce (i.e., National Oceanic and Atmospheric Administration [NOAA]), the Department of Energy, the Department of Transportation, the Department of Agriculture, and the Environmental Protection Agency, as well as NASA. These agencies support STEM education in a number of ways, including but not limited to sharing expertise in science, developing programs and curricular materials that foster engaging opportunities for learners to understand the nature of science, offering in-service training and instructional resources to teachers, and funding university-based research and development and research on STEM education (American Association for the Advancement of Science, 2018; National Science and Technology Council, 2015).

In 2016, the most current year with available data, 163 STEM education programs and activities were in operation across all federal agencies. The National Science and Technology Council's Committee on STEM

Education (CoSTEM)[1] is an interagency body responsible for coordinating STEM education programs, investments, and activities across federal agencies, and developing and implementing a STEM education strategic plan, to be updated every 5 years. The Subcommittee on Federal Coordination in STEM Education (FC-STEM)[2] advises and supports the work of CoSTEM in developing strategic investments in STEM education and in formulating and implementing the strategic plan. Historically, the primary objectives for federal investments in STEM education have been to (1) increase the number of STEM degrees, (2) prepare people to enter the STEM workforce, and (3) support STEM education research and development (Granovskiy, 2018). Indeed, the latest 5-year strategic plan for the federal government's efforts in STEM education emphasized STEM workforce development and STEM literacy as top national priorities (National Science and Technology Council, 2018).

In the last decade, annual federal investments in STEM education have remained relatively stable ranging from $2.8 billion to $3.4 billion (Granovskiy, 2018). NSF, the Department of Health and Human Services, and the Department of Education are the major federal sponsors in STEM education both in terms of number of programs and total investment, but other agencies, such as NASA and NOAA, have education agendas as part of their missions. In fiscal 2019, NASA received $155 million for its STEM education and public outreach activities. Of this amount, $110 million was directed toward the Office of STEM Engagement (formerly the Office of Education) and $45 million was directed toward the SMD, which houses the SciAct Program (American Institute of Physics, 2018).

The National Landscape of STEM Education

Understanding the potential contributions of the SciAct portfolio requires an understanding of the current landscape of STEM education. Recent data indicate that while Americans' basic STEM skills have modestly improved over the past two decades, other countries are doing a better job of preparing their students in science, mathematics, and engineering fields, indicating the growing need for improvements in STEM education in the United States (National Science Board, 2018; National Science and Technology Council, 2018). To help meet this need, national education goals have evolved over the past two decades to reflect new science,

[1] See https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/costem_charter_signed_01-31-11.pdf.

[2] FC-STEM, chartered in 2014, is a committee of members from 11 federal agencies and the Smithsonian Institution: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/NSTC/CoSTEM-FCSTEM-%20Charter-0114-SIGNED.pdf.

mathematics, and engineering education standards and new evidence on how people learn.

New research on the nature of learning across the life span has led to greater understanding of the factors that shape learning and what this means for the design of learning experiences. Learning is influenced by the knowledge, motivation, and cultural experiences of the individual, but also by the cultural and social characteristics of the learning environment (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018a). Learning is a dynamic, ongoing process, during which the learner actively constructs their own understanding through social interactions with other learners and with teachers or facilitators. Research also confirms that learning occurs across multiple spaces over the life span, not solely in formal school settings (National Research Council [NRC], 2009). Indeed, much of NASA's programming occurs in these informal settings. For more information on informal learning environments, see Chapter 4 of this report.

These insights about learning have led to new standards for STEM education that call for learners not just to accumulate factual knowledge, but to be able to deploy their knowledge in meaningful ways. For example, in 2012, the National Academies released *A Framework for K–12 Science Education*, which articulated a new vision for science education in which leaners actively engage in science and engineering practices over multiple years of school to deepen their understanding of the core ideas inherent in these disciplines and make connections to cross-cutting concepts (NRC, 2012a). The *Framework* outlines core ideas in the physical sciences, life sciences, earth and space sciences, and engineering, as well as the cross-cutting concepts that are relevant across these disciplines (i.e., structure and function or cause and effect). It also describes the science and engineering practices that scientists and engineers employ in their work and that learners should engage in as they learn science and engineering. The *Framework* was the impetus for the development of new K–12 science standards, the Next Generation Science Standards (NGSS), which have been adopted or adapted by 44 states, reaching about 71 percent of U.S. students (National Science Teaching Association, 2019). The NGSS and similar standards outline a set of performance expectations that integrate the vision of the *Framework* into statements that articulate the ways students will demonstrate competency. It is important for federal science agencies, including NASA, to be aware of advances in the understanding of learning and of current efforts to improve science education through new standards.

STEM Education at NASA

NASA has been a long-standing stakeholder in science and engineering education with programs dating back to its authorizing legislation in 1958.

This legislation established the agency's responsibility to ensure that the United States remains a leader in space exploration, scientific discovery, and aeronautics research. Additionally, this legislation codified NASA's obligation to effectively share knowledge of the atmosphere and space with the public, thus providing a return on the public's investment in NASA science and engineering.

NASA's involvement in STEM education is supported by the science, engineering, and exploration missions of the agency, and NASA's notable assets offer a rare opportunity to contribute to the STEM education landscape. These assets include state-of-the-art facilities; cutting-edge technology; awe-inspiring missions; expert astronauts, scientists, and engineers; and a wealth of images, data, scientific findings, and compelling narratives from more than five decades of spaceflight missions. These exceptional resources provide opportunities for students, teachers, and the general public to engage meaningfully with the latest science and engineering advancements, as well as to learn about new science discoveries and to acquire new skills in STEM. Additionally, NASA's resources are especially well suited to inspiring and motivating learners. Missions involving human spaceflight, as well as missions such as the James Webb Space Telescope and Mars Exploration Rovers, are powerful ways to naturally pique learners' interest. The search for life beyond Earth and the exploration of the moon and Mars are intrinsically attractive to learners, with the potential to motivate them to pursue eventual careers in STEM areas. Moreover, NASA is more widely known to the U.S. public than any other federal science agency, and has the convening power to facilitate the creation of partnerships among mission scientists, educators, and communications specialists that can serve as one avenue for bringing the expertise and enthusiasm of scientists into the public domain. NASA's many assets uniquely position it among the federal agencies involved in STEM education and strongly support its role as a key resource for the motivational and content aspects of learning in STEM subjects.

The bulk of STEM education activities at NASA are in the Office of STEM Engagement and the SMD. Traditionally, these two units have employed different approaches to developing and implementing STEM education projects (NRC, 2008). In the case of SMD, a percentage of funds from the major science mission budgets was originally devoted to supporting education activities related to each mission. However, in an effort to improve coordination and maximize collaboration across education and communications activities at NASA, SMD undertook significant restructuring of its STEM education related activities and established the SciAct Program in 2015. This program was established as a collective comprised of 27 competitively selected awardees to further enable NASA scientists and engineers to engage more effectively and efficiently with learners of all ages, and to foster more effective, sustainable, and efficient use of SMD science discoveries.

Prior to the establishment of the SciAct Program in 2015, the SMD implemented its education and public outreach (E/PO) activities primarily through two means[3] (National Aeronautics and Space Administration, 2010, p. 70). First, an SMD directive issued in 1993 called for each flight mission to allocate at least 1 percent of its total mission budget, excluding the cost of launch vehicles, to E/PO activities (1% model). The second method supported E/PO projects through awards from solicited (e.g., GLOBE Implementation Office) or unsolicited proposals, or as elements of a major research-enabling program (e.g., suborbital science).

The 1 percent model implemented in individual missions mobilized earth and space scientists in a wide range of activities, from speaking at public forums or in classrooms to publishing web content to providing professional development. For example, in early 2015, the New Horizons mission focused on setting the stage for the upcoming first-ever flyby of Pluto through a variety of events called "Plutopaloozas." These public events were staged at museums and science centers throughout the country, providing educational activities for children and adults. Each event featured several mission scientists and engineers who provided first-person accounts of mission planning and its scientific foundations.

In the past 25 years at NASA, more than 100 missions, on average, have been in development, in operation, or in extension, with equal numbers of education teams funded in those missions under the 1 percent model. Such a large number of teams made coordination across mission activities difficult, leading to duplication and fragmentation of efforts, and potentially inequitable distribution of educational resources. Additionally, under this model, it was difficult to demonstrate impact of the educational efforts related to highly valued goals in education (e.g., systemic improvements and activities that are closely aligned with learners' needs). Given that the mission education activities did not always leverage education resources within and outside NASA, their reach and potential to go to scale were presumably limited.

In 2013, two separate events occurred that would precede the development of the current SciAct portfolio. First, the release of the 2015 President's Budget showed a dramatic loss of funding for these activities. Additionally, the release of the 2013 CoSTEM report[4] prompted SMD to develop a more efficient internal structure for its program in an effort to

[3] See https://smd-prod.s3.amazonaws.com/science-pink/s3fs-public/atoms/files/2010SciencePlan_TAGGED_0.pdf.

[4] See https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf.

strengthen its contribution to the national efforts to make progress on improving STEM education. This coincided with an internal clarification on the distinction between education and communications at NASA.[5]

With the approval of the SMD Management Council and subsequent approval of the Office of Management and Budget (OMB), SMD restructured its approach to E/PO and established one desired outcome and four overarching objectives for its education-related endeavor: (1) enable STEM education, (2) improve U.S. scientific literacy, (3) advance national education goals, and (4) leverage efforts through partnerships (for more information on these goals and the vision of SciAct, see Chapter 2 of this report). Additionally, SMD appointed Kristen Erickson as the director for science engagement and partnerships to oversee and provide strategic direction for the SciAct Program. Under the leadership of Dr. Thomas Zurbuchen, associate administrator for the SMD, the current iteration of SciAct was developed and implemented.

SciAct aims to further enable scientists and engineers to engage more effectively with learners of all ages. In addition to recognizing the essential role of the agency's subject matter experts (SMEs), it places emphasis on the needs of learners and educators; independent evaluation as practiced in the field of STEM education; and collaboration with external partners who deliver learning and instruction more systemically or directly to leverage their expertise for greater and more extensive impact.

After issuing an open call through a NASA Cooperative Agreement Notice (CAN, or a solicitation for proposals), and carrying out a subsequent competitive process of selection, SMD awarded 27 multiyear cooperative agreements in 2016 for a maximum of 10 years: projects are awarded a 5-year base award, and have one 5-year option to extend their agreements. Currently, there are 24 awards (or projects) still in progress that constitute the SciAct Phase 1[6] portfolio (see Appendix A for more information on the 24 projects). These projects leverage SMD's astrophysics, earth, heliophysics, and planetary science content and experts to engage learners of

[5]Education comprises activities designed to enhance learning in science, technology, engineering, and mathematics (STEM) content areas using NASA's unique capabilities, while communications comprises the comprehensive set of functions necessary to effectively convey and provide an understanding of the program, its objectives and benefits to target audiences, the public, and other stakeholders. This includes a diverse, broad, and integrated set of efforts intended to promote interest and foster participation in NASA's endeavors and to develop exposure to and appreciation for STEM (e.g., media services, multimedia products and services (including Web, social media, and nontechnical publications), and public engagement (outreach) activities and events).

[6]The committee notes that in order to delineate timeframe, it refers to SciAct's "Phase 1" as the first 5 years of SciAct programming. The committee refers to "Phase 2" to signify the next 5 years of programming, to commence in 2020.

all ages in STEM, in both formal and informal settings (see Chapter 3 of this report for more discussion of the portfolio). Additionally, internal collaboration and coordination among the funded projects, as well as infrastructure support, have been put in place to promote overall coherence. Decisions on which projects will continue during Phase 2 of the program (potentially at different levels) will be made in 2020, and opportunities for new projects will be afforded through SMD's Research Opportunities in Space and Earth Sciences (ROSES) grant solicitation, an annual omnibus solicitation for proposals across all disciplinary areas in SMD.

The establishment of the SciAct Program has enabled SMD to make a more concerted effort in contributing to the national STEM education agenda and enhancing operational effectiveness and efficiency, which is the focus of this report. However, a recent midterm review of NASA's planetary science investments revealed that some of NASA's assets are not optimized as much as they might be under this new model (National Academies of Sciences, Engineering, and Medicine, 2018d, pp. 77–78). These assets include NASA missions' results and mission science experts when it comes to defining and providing science content within the E/PO activities, as described earlier in this chapter. This report considers this finding in the context of how SciAct can best leverage its considerable assets while also meeting the needs of the communities it serves.

Summary

Based on current national priority areas, federal science agencies have been encouraged to incorporate STEM education more explicitly into their programs, to prioritize policies and practices that place an emphasis on expanding the STEM workforce, and to develop methods and metrics to collect data and track the effectiveness of the STEM programs (National Science and Technology Council, 2018; Office of Science and Technology Policy, 2017). Indeed, these priorities are relevant to SMD's education mission; therefore, this request for an expert assessment of the SciAct Program to establish priorities for the next phase of the program is timely. National agendas will continue to shape the involvement of federal agencies in STEM education, highlighting the importance of demonstrated efforts (e.g., periodic expert portfolio reviews) to provide compelling justifications for budgeted STEM activities at these agencies going forward. Lastly, given that NASA is one of many federal stakeholders in the STEM education landscape, it is critical for the agency to consider its goals, objectives, and strategy for uniquely contributing to this space.

PREVIOUS REVIEWS OF NASA EDUCATION ACTIVITIES

The National Academies has a long history of providing strategic advice to NASA and other U.S. government agencies on scientific and technical matters. A snapshot of some of the reports produced in the last decade as a result of these relationships is shown in Box 1-2. At the request of NASA, NOAA, and the U.S. Geological Survey (USGS), the first decadal survey in earth science was conducted by the Space Studies Board (NRC, 2007). Since the 1960s, the National Academies has been asked to conduct these types of studies for federal agencies, and in particular, they have been instrumental in helping NASA to strategically plan for 10 or more years into the future, as it relates to identifying and prioritizing research areas, leading-edge scientific questions, the observations required to answer these questions, and the missions required to facilitate those observations. In recent history, a number of decadal surveys have been conducted by the National Academies in the areas of astronomy and astrophysics (NRC, 2010), life and physical sciences (NRC, 2011a), planetary sciences (NRC, 2011b), and solar and space physics (NRC, 2013b), and again in earth science (NASEM, 2017).

In the area of STEM education, the National Academies has carried out several previous efforts to review and evaluate both NASA's and NOAA's education activities. Beginning in 2008, the Board on Science Education of the National Academies was asked to conduct a review and evaluation of NASA's precollege science, technology, and mathematics education program (housed in NASA headquarters' Office of STEM Engagement, formerly the Office of Education) as mandated by the NASA Authorization Act of 2005 (P.L. 109-555 Subtitle B-Education, Sec. 614).[7] A 12-member expert committee was appointed to carry out this study, which focused on four areas: (1) the effectiveness of the overall program in meeting its defined goals and objectives, (2) the quality and educational effectiveness of the major components of the program, (3) the funding priorities in the program, and (4) the extent and effectiveness of coordination and collaboration between NASA and other federal agencies invested in science, technology and mathematics education (NRC, 2008).

The committee concluded that NASA's strengths were its efforts to reach underrepresented groups, its effectiveness in raising awareness of the science and engineering of its missions among K–12 students and teachers, and its demonstrated commitment to funding K–12 STEM education activities. However, the report also highlighted the following barriers to the overall effectiveness of the program: program instability, lack of rigorous evaluation and funding for it, lack of a strategic plan, lack of in-depth experiences to support learning of STEM content, and the nature of science and engineering, budget fluctuations, and lack of systemic coordination with other federal agencies to draw on needed expertise in STEM education project design. The committee also identified a set of recommendations across four broad areas deemed important for improving NASA's efforts

[7] See https://www.congress.gov/109/plaws/publ155/PLAW-109publ155.pdf.

BOX 1-2

National Academies Reports on STEM Activities at Federal Agencies: 2007–2017

2007: *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (study conducted by the Space Studies Board)

2008: *NASA's Elementary and Secondary Education Program: Review and Critique* (study conducted by the Board on Science Education)

2010: *NOAA's Education Program: Review and Critique* (study conducted by the Board on Science Education)

2010: *New Worlds, New Horizons in Astronomy and Astrophysics* (study conducted by the Board on Physics and Astronomy and the Space Studies Board)

2011: *Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era* (study conducted by the Space Studies Board and the Aeronautics and Space Engineering Board)

2011: *Vision and Voyages for Planetary Science in the Decade 2013-2022* (study conducted by the Space Studies Board)

2013: *Solar and Space Physics: A Science for a Technological Society* (study conducted by the Space Studies Board and the Aeronautics and Space Engineering Board)

2013: *Review of the Draft 2014 Science Mission Directorate Science Plan* (study conducted by the Space Studies Board)

2013: *Preparing the Next Generation of Earth Scientists: An Examination of Federal Education and Training Programs* (study conducted by the Board on Earth Sciences and Resources)

2014: *Sharing the Adventure with the Student: Exploring the Intersections of NASA Space Science and Education: A Workshop* (workshop conducted by the Space Studies Board and the Board on Science Education)

2017: NASA Science Mission Directorate Expert Meetings (convenings conducted by the Board on Science Education and the Space Studies Board)

2017: *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observations from Space* (study conducted by the Space Studies Board)

in elementary and secondary STEM education: (1) defining the nature of NASA's role in K–12 STEM education, (2) ensuring continuous improvement of projects, (3) establishing partnerships to harness expertise in education, and (4) leveraging information and communications technology more effectively. It is important to note that the SMD's work, including SciAct, is largely separate from the STEM education efforts emerging from the Office of STEM Engagement, and therefore the above conclusions and recommendations on NASA's precollege education portfolio do not necessarily reflect the state of the activities within SMD's education portfolio.

More recently, in 2013, the National Academies conducted an assessment of NASA's 2014 SMD Science Plan to gauge the agency's responsiveness to the guidance outlined in the recent NRC decadal surveys (NRC, 2013b). In 2014, the National Academies convened a workshop to explore promising approaches for effectively translating NASA's missions and scientific discoveries into formal and informal science learning experiences for students and teachers in the K–12 education space (NRC, 2015). In 2017, a series of expert meetings was organized by the National Academies that afforded the space for NASA scientists to hear from education specialists on ways to develop curriculum materials bearing life-relevant content and on ways to leverage subject-matter experts to foster better student engagement in science classrooms (see Box 1-2). The Board on Science Education of the National Academies has been involved in all of the efforts related to federal STEM education programs, and thus was well positioned to undertake this new request to assess the education portfolio of NASA's SciAct Program.

THE COMMITTEE'S APPROACH TO THE CHARGE

Unlike traditional consensus studies at the National Academies, the work of this committee revolved primarily around assessing a current program model by applying committee members' expertise to analyze different facets of SciAct's design and implementation. In this report, the "evidence" considered by the committee is not published in peer-reviewed journals, but is the physical and oral documentation of the current program design as provided to the committee. In this section, we provide key notes on our interpretation of the charge, and we detail our processes in order to describe in depth the evidence we considered in our effort to assess SciAct and make recommendations for NASA going forward. We conclude by describing how we organized this report.

Interpreting the Charge

In the early phases of this committee's work, it was necessary to first delineate the task at hand. In consultation with the sponsor, the committee made a series of decisions defining the boundaries of this assignment that have implications for the content of our work. First, this report does not assess the individual efforts of the 24 SciAct projects in meeting the program's four objectives, but rather considers the impact of the portfolio as a whole (see Appendix A for descriptive information on all 24 projects). The cooperative agreement process utilized by SciAct affords opportunities for proposals that may have a clearly articulated, narrow focus to be considered for sponsorship without the requirement to address every objective in the CAN. In this way, SciAct seeks to leverage individual project expertise within the collective of the portfolio to yield resources and opportunities that are scientifically accurate, grounded in current education research, reflective of the needs of the education community, and more deeply aligned with science and engineering processes. The committee was charged with conducting an assessment of SciAct's aggregate program efforts, and not of the specific efforts of individual projects. Moreover, the committee took care not to inadvertently endorse or critique individual project efforts; for this reason, we do not comment on the efficacy of individual project approaches to meeting SciAct goals but rather attempt to characterize trends in the portfolio.

Additionally, this assessment is not designed to compare the effectiveness of SciAct Phase 1 in relationship to the 1 percent model, or any other NASA programming. As a result, the committee declines to make any summative statements about whether or not this model is "better" than its predecessor: Rather, we attempt to make sense of the design and implementation of SciAct in its first phase on its own merits. We consider how well SciAct is positioned to meet its stated goals and objectives, as well as whether or not those goals and objectives are appropriate for the scope of this portfolio, among other questions delineated in our charge.

GATHERING AND ASSESSING THE EVIDENCE

In order to obtain the evidence necessary to complete this review, the committee held a number of open-session conversations with members of the SciAct portfolio, as well as several experts on various aspects of STEM education. In the first meeting of the committee, we heard testimony from Kristen Erickson, director, science engagement and partnerships at NASA SMD, who provided a comprehensive overview of the history of SciAct, its efforts to reorganize, and the current shape and status of the portfolio. For the PowerPoint slides used by Ms. Erickson in her presentation, see Appendix C on The National Academies Press Webpage at http://www.nap.edu/25569. Ms. Erickson was supported by Dr. Lin Chambers, Science Activation integration manager. Later in that first meeting, the committee heard from three SciAct awardees, who discussed the goals and implementation of their projects: Denise Smith of the Space Telescope Science Institute, Alex Young of NASA Goddard, and Theresa Scherwin of the Institute of Global Environmental Strategies. Throughout the evidence-gathering process, in order to select presenters from the SciAct community of awardees, the committee solicited recommendations from Ms. Erickson in consultation with Dr. Chambers.

Following the first in-person committee meeting, the committee held several virtual conversations with other SciAct awardees, who were able to provide further insight into their awards and how they fit into the SciAct portfolio. These conversations were organized around themes within the portfolio identified by Ms. Erickson and Dr. Chambers (see Appendix C at http://www.nap.edu/25569), and as with the in-person presentations, presenters were identified from among the awardees by Ms. Erickson and Dr. Chambers. We held three separate conversations on these topics:

1. On awards that disseminate information to the public, we heard from Rachel Connolly of WGBH and PBS Learning Media; Ariel Anbar of Infiniscope at Arizona State University; and Jon Miller from the University of Michigan, who is responsible for measuring SciAct's progress on its science literacy goal.
2. On engaging diverse audiences in STEM, we heard from Paul Dusenberry, working with libraries from the Space Science Institute; Kevin Czajkowski working with educators at the University of Toledo; Denise Kopecky with the Challenger Centers from the Challenger Center for Space Science Education; and Paul Martin Arizona State University, who works with museums.
3. On the issue of connecting NASA infrastructure, we heard from Kay Ferrari of the Solar Systems Ambassadors Program at the NASA Jet Propulsion Laboratory (NASA JPL), and Emily Law from the Solar Systems Treks Program also of NASA JPL. Finally, in order to understand SciAct awardee's efforts to communicate with one another, Andy Shaner of NASA conducted a virtual tour of the SMD E/PO, an online communication space.

At our second in-person meeting, we heard from individual project evaluators (and their principal investigator counterparts) who detailed their efforts to evaluate their awards' work toward meeting the goals of SciAct. The committee heard from Jackie Delisi of the Education Development Center and project investigator Leigh Peake of the Gulf of Maine Research Institute, Eric Banilower of Horizon Research and Robert Winglee from the University of Washington, and Martin Storksdiek of Oregon State University and Rachel Connolly from WGBH. In order to augment committee expertise on critical issues, the committee heard testimony from Carol O'Donnell of the Smithsonian Institution, who discussed efforts to leverage federal-level funds through local partnerships. In order to center conversations around diversity, equity, inclusion, and access, both Louis Gomez of the University of California, Los Angeles and Julie Johnson of the National Science Foundation offered testimony on best practices and consideration for prioritizing equity in network models.

Finally, the committee reviewed SciAct documentation for evidence of the portfolio's design and implementation. These documents included

SciAct's promotional and communication materials, as well as internal documents that describe how the work of awardees is intended to meet specific SciAct objectives. The committee extensively reviewed the CAN, as well as each of the awardees' project summaries, ongoing monitoring data, and evaluation reports. The committee also reviewed the SMD E/PO Website in an effort to better understand the support resources available to awardees, as well as the cadence and tenor of awardees' online interactions across projects. The committee also reviewed the agendas and briefing documents associated with the last few years of SciAct's annual principal investigator meetings so as to understand the nature of those week-long events. Where appropriate, the committee will describe these documents and their contents in greater depth later in this report.

As noted, this report varies from traditional National Academies' consensus studies in that the charge to the committee did not call for a large synthesis of disparate bodies of literature. Instead, the committee was asked to rely on its collective expertise to assess the current SciAct portfolio of an education program in a federal agency, a task that required deep expertise in content areas ranging from federal education policy to STEM engagement and learning to the inner workings and functionality of NASA itself. In assessing the portfolio, the committee took care to conduct a full review of all the documents and artifacts described above. When reaching conclusions and developing recommendations, the committee drew on multiple streams of evidence: Wherever possible, the committee considered oral testimony in conjunction with documents or artifacts in order to make a claim. Where oral testimony alone was used as the basis of a finding, the committee collaborated to ensure collective agreement on how the evidence was interpreted; that is, one individual's recollection was not sufficient evidence to support a claim. More specifically, the committee took particular care to not offer judgment where evidence was not adequate: In these cases, the committee attempted instead to identify or outline issues and considerations for SciAct to take into account when planning for the future without recommending a specific course of action. As a result of these deliberate processes, all conclusions and recommendations outlined in this report reflect the full consensus judgment of the Committee to Assess Science Activation.

Throughout these deliberative processes, committee members were asked to formulate assessments of the existing portfolio (as well as suggestions for the future) by applying their understanding of the best available research evidence and the current state of their respective fields. Given the nature of the charge, it was not feasible for the committee to do an extensive review of all of the research that is relevant to STEM education. For this reason, the report does not provide detailed descriptions of individual studies. Instead, the committee relied on broadly accepted theoretical approaches that are based on large bodies of research across multiple fields that examine learning and teaching. Much of this research is summarized in previous reports from the National Academies. This body of National Academies work includes two reports that examine research on learning, drawing from cognitive science, the learning sciences, developmental psychology, social psychology, cultural psychology, educational psychology, sociology, and anthropology: *How People Learn: Brain, Mind, Experience, and School* (NRC, 2000) and *How People Learn II: Culture, Contexts, and Cultures* (NASEM, 2018a). It also includes major consensus studies that reviewed evidence on effective approaches to STEM education: *America's Lab Report* (NRC, 2006), *Taking Science to School* (NRC, 2007), *Learning Science in Informal Environments* (NRC, 2009), *STEM Integration in K–12 Education* (National Academy of Engineering and NRC, 2014), *Science and Engineering in Grades 6–12* (NASEM, 2019), and *Learning through Citizen Science* (NASEM, 2018b). The committee notes that these literatures are expanding: As SciAct makes decisions about how to plan for the future, it is critical to note that, as with any science, findings that emerge from the best available and most current evidentiary bases will shift with time.

AUDIENCES FOR AND ORGANIZATION OF THE REPORT

The committee expects that this report will be of interest to several audiences. First and most immediately, the committee hopes that this report will serve the needs of NASA SMD and the SciAct community so that leadership can assess and plan for the future. Second, we expect this report will be of interest to other NASA personnel and other stakeholders invested in NASA's work in STEM education and engagement. We also expect that this report could serve as a useful template for other federal agencies with their own investments in STEM education and engagement. Finally, this report is intended to be accessible to the taxpaying public: To the extent that NASA is publicly funded, it has an obligation to serve the interests of the American people. This report is an attempt to help SciAct meet that potential.

This report is organized into six chapters, with three appendixes. Chapter 2 describes the committee's understanding of the vision and objectives of SciAct, detailing how it operationalizes its overarching goals and assessing how the portfolio is poised to address those goals. Chapter 3 characterizes the current portfolio, describing the logic undergirding the current organization of the awards and describing the breadth of SciAct programming. Chapter 4 presents our assessment of the SciAct portfolio according to key themes that connect to the overarching program goals and reflects most of the activities across the constituent projects, beginning with a discussion of STEM learning and leveraging NASA assets in the portfolio. Particular attention is paid to how these features currently function in the Phase 1 portfolio and considerations for future planning based on the research literature. Chapter 5 continues our assessment of key themes by focusing on broadening participation and collective learning within the portfolio. In Chapter 6, we conclude the report with a set of recommendations for SciAct based on the committee's expertise. Given the conclusions drawn by the committee over the course of this report, the committee is confident that careful consideration and implementation of these recommendations can help SciAct continue its good work into the future. Appendix A provides individual descriptions of each of the 24 SciAct awards. Appendix B contains biographical sketches of committee members and staff. Appendix C includes the PowerPoint slides used by Kristen Erickson in her presentation to the committee and are available on The National Academies Press Webpage at http://www.nap.edu/25569.

2

Vision and Objectives

As mentioned in Chapter 1 of this report, one major component of the committee's statement of task was assessing Science Activation's (SciAct's) progress toward its stated goals. In order to do this, the committee first needed to fully understand how the National Aeronautics and Space Administration (NASA) is conceiving of the work of SciAct: that is, what the stated goals of SciAct are, and how those goals relate to the U.S. agenda for science, technology, engineering, and mathematics (STEM) education, as well as how well positioned SciAct is to address these goals. In this chapter, we consider how NASA articulates the goals and objectives of the SciAct portfolio, and offer insight into how the SciAct portfolio fits into the larger landscape of work in STEM education in the United States. This conversation will set the stage for our later discussions of the implementation of SciAct's work, helping to provide a framework for our assessment of SciAct's strengths and challenges.

SCIACT'S CENTRAL VISION

In order to understand the role of NASA's SciAct Program within the broader domain of STEM education in the United States, the committee looked to multiple sources of evidence for documented descriptions of NASA's vision for SciAct. According to SciAct's documentation, its vision is

> To share the story, the science, and the adventure of NASA's scientific explorations of our home planet, the solar system, and the universe beyond, through stimulating and informative activities and experiences created

> by experts, delivered effectively and efficiently to learners of many backgrounds via proven conduits, thus providing a return on the public's investment in NASA's scientific research.[1]

Embedded in this statement are multiple assumptions about the role and value of NASA that are important to understand. First, it is clear from this statement that part of the impetus for engaging in STEM education related work is to provide a "return on the public's investment" in NASA. In this way, SciAct is positioning itself as a mechanism for NASA to be *in service to* the public that goes beyond its science-related mandates. Along these same lines, embedded in this vision is the notion that NASA science can contribute in productive ways to science education work more broadly. NASA's work has the potential to excite and engage the public in ways that can support STEM learning. The committee recognizes that these core tenets are central to how NASA understands the role and purpose of the SciAct portfolio, and it is within this context that NASA has devised its objectives for SciAct, designed its portfolio, and implemented its awards.

When the committee attempted to understand how SciAct sought to put this vision into practice, it turned to the SciAct Cooperative Agreement Notification (CAN), which describes the portfolio strategy. The CAN notes that part of the rationale for SciAct is to "increase the overall coherence of the Science Mission Directorate (SMD) science education program leading to more effective, sustainable, and efficient utilization of SMD science discoveries and learning experiences and to meet overall SMD science education objectives. *Fundamental to achieving this outcome is to enable NASA scientists and engineers to engage more effectively with learners of all ages* [emphasis added]" (National Aeronautics and Space Administration, 2015). Here, the committee notes another core tenet behind the current design and implementation of SciAct: Engaging NASA subject matter experts (SMEs, or "NASA scientists and engineers") with learners is central to supporting NASA's goals for science education, and it is essential that this engagement is effective or strategic toward the organization's stated goals and objectives. When these tenets were viewed in concert with one another, the committee was able to see how NASA understands both its role in and obligation to supporting STEM education in the United States; that is, NASA is funded by the nation's taxpayers, and as a result, it is incumbent upon the agency to support the nation's commitments and goals as they relate to STEM. These public investments have led to an untold number of discoveries and innovations in the STEM fields, and one way that NASA can be of service to the public is to share

[1] See https://www.SMDEPO.org.

the fruits of these investments as a mechanism for supporting STEM education. NASA's SMEs are viewed by the agency as one of the primary vehicles for facilitating education and engagement work. Taken together, these tenets form the foundation upon which the SciAct portfolio is designed, implemented, and evaluated.

SciAct's Four Overarching Objectives

Resting on this foundation, SciAct has identified four primary objectives for the portfolio:

1. enable STEM education,
2. improve U.S. scientific literacy,
3. advance national education goals, and
4. leverage efforts through partnerships.

Further, SciAct documentation defines NASA assets and resources to include

- exciting science and engineering content that engages audiences and motivates them to learn more;
- SMEs, including scientists and engineers, who ask compelling scientific questions and then find ways to answer them within the environment of space;
- real-life participatory and experiential opportunities (which includes student collaborations, e.g., suborbital balloon experiments and other student launch opportunities); and
- other science programs in NASA's infrastructure (e.g., GLOBE, Night Sky Network, etc.)

SciAct awardees are regarded as NASA partners who bring educational expertise in designing and delivering the mechanisms for target audiences to learn and understand science content related to the four disciplines of NASA's SMD (heliophysics, earth science, planetary science, and astrophysics). For more detail on the ways in which the current SciAct portfolio addresses this task, see Chapter 3 of this report.

SciAct intends for the work of individual project awards to aggregate toward achieving the four objectives above; that is, no one project is supposed to accomplish all of these objectives on its own. In this section, we describe each of these objectives in greater detail, and consider each in light of SciAct's resources and position in the STEM education landscape. Chapter 3 of this report will delve more deeply into how projects are positioning themselves to support these four objectives.

Objective 1: Enable STEM Education in All 50 States

The SciAct CAN describes this objective by noting that

> NASA SMD is privileged to continue to support the Nation's education efforts. Our unique contribution is through our scientific content, access to our SMEs, use of education professionals, and access to authentic participatory access-to-space opportunities. These "inputs" . . . drive the process that the science education providers will help enable.

The committee notes that this first objective is, in some ways, a restatement of SciAct's vision statement: SciAct intends to support STEM education through the mobilization of NASA's existing resources and assets. Practically, this means that awardees are tasked with translating NASA assets for educational use by creating new materials that can be used by learners or educators and incorporated into programs that will allow learners and students to engage with NASA data and SMEs. In fact, the importance of engaging SMEs is made explicit in that awardees are required to use at a minimum one SME and report monthly on SME involvement in their projects. For SciAct awardees, this objective is further defined as "enable STEM education *in all 50 states*," an objective that prioritizes widespread implementation. The CAN calls out the need to balance this objective with meeting the needs of local communities.

Currently, SciAct measures its progress toward this objective by using geographic dissemination as a portfolio-wide metric to assess the reach of programs and products. Additionally, it counts the number of SMEs participating in the portfolio's work. The committee notes that these metrics *characterize* the portfolio's work; that is, they speak to the volume and distribution of SMEs engaged in the work, and they describe who is being reached through SME participation. These metrics do not, however, measure whether the awards are, in fact, enabling STEM education, because they do not capture the extent to which educational activities (not to mention teaching and learning) are actually occurring as a result of the awards or the engagement of SMEs. The committee notes that the phrasing of this objective makes it particularly challenging to quantify: What is meant by "enable STEM education"? Is STEM learning occurring as a result of participation in the projects? Or is this objective trying to capture the quantity of resources and assets NASA is disseminating? The committee observes that while the idea of *enabling STEM education* captures NASA's vision for SciAct, it is too broad to be measurable with respect to the impact of the SciAct portfolio.

Objective 2: Improve U.S. Scientific Literacy

According to SciAct documentation, this objective is motivated by the notion that a scientifically literate population is necessary to support the nation's economic development, and that NASA has a role to play in improving the nation's science literacy. In order to understand how SciAct expects to support U.S. science literacy, the committee investigated how awards self-report their own progress toward this objective.

SciAct uses one of its awardees (the continuation of the Science and Engineering Indicators data collection that tracks science literacy at the national level) to assess the portfolio's progress toward this objective. This project furnished documentation that helped the committee understand how SciAct is operationalizing the term "science literacy." Based on this evidence, the committee finds that SciAct understands science literacy as

> three related dimensions: (1) a vocabulary of basic scientific constructs sufficient to read competing views in a newspaper or magazine, (2) an understanding of the process or nature of scientific inquiry, and (3) some level of understanding of the impact of science and technology on individuals and on society. . . . the combination of a reasonable level of achievement on each of these three dimensions would reflect a level of understanding and competence to comprehend and follow arguments about science and technology policy matters in the media (Miller, 1998, pp. 205–206).

Unfortunately, this metric is not connected to the articulated outcomes of the other individual SciAct projects and, further, does not measure some aspects of science literacy.

To the extent that SciAct positions the improvement of science literacy as one of its primary objectives, the committee feels it is important for SciAct to draw upon the most recent scholarly assessments of how science literacy is defined, enacted, and measured.[2] Recent research on science literacy posits that the term should encompass more than just basic knowledge of science facts. Indeed, contemporary definitions of science literacy have expanded to include understandings of scientific processes and practices, familiarity with how science and scientists work, a capacity to weigh and evaluate the products of science, and an ability to engage in civic decisions about the value of science. Although science literacy has traditionally been seen as the responsibility of individuals, individuals are nested within communities that are nested within societies—and as a result, individual science literacy is limited or enhanced by the circumstances of that nesting.

In accordance with Miller's (1998) definition, there are three aspects of science literacy common to most applications of the term: content knowledge, understanding of scientific practices, and understanding of science as a social process. However, the committee notes that there are four additional aspects of science literacy that, while less common, provide important

[2]The text in this section draws heavily on *Science Literacy: Concepts, Contexts, and Consequences* (National Academies of Sciences, Engineering, and Medicine, 2016).

insight into how the term has been used: foundational literacy, epistemic knowledge, identifying and judging scientific expertise, and dispositions and habits of mind. Given this range of aspects, it is not surprising that there is no clear consensus about which aspects of science literacy are most salient. The committee notes that depending on the context, different aspects of science literacy may be more or less important or desirable.

Expanding contemporary perspectives on science literacy encompass the ways that broader social structures can shape an individual's science literacy. Indeed, contemporary scholarship is beginning to push back against the common understanding that science literacy is or should be seen only as a property of individuals—something that only individual people develop, possess, and use. Research on individual-level science literacy provides invaluable insight, but it likely offers an incomplete account of the nature, development, distribution, and impacts of science literacy within and across societies. Societies and communities can possess science literacy in ways that may transcend the aggregation of individuals' knowledge and accomplishments.

Science literacy can also be expressed in a collective manner; that is, resources are distributed and organized in such a way that the varying abilities of community members work in concert to contribute to their overall well-being. Community science literacy does not require that each individual attain a particular threshold of knowledge, skills, and abilities; rather, it is a matter of that community having sufficient shared capability necessary to address a science-related issue. Research in this field is still emergent, though documented cases of communities' efforts to leverage collective science knowledge, skills, and abilities in pursuit of science-related policy outcomes abound: examples of these cases include, among many others, efforts by the LGBT community to impact AIDS treatment policy (Epstein, 1995), families collaborating to confirm the existence of cancer clusters (Brown, 1993), and community monitoring of the effects of fracking on local watersheds (Kinchy, Jalbert, and Lyons, 2014). Because community science literacy requires that communities organize and call upon a diversity of knowledge bases and skill sets present in their collective, research can now document the ways in which communities can capitalize on individuals' respective strengths in attaining their goals.

In terms of measurement, research on science literacy at the individual level has largely assessed individuals' knowledge using content knowledge assessments and measures of understanding of scientific principles administered through large public surveys. These widely used surveys have provided valuable insight into science knowledge, but constraints on length and demands for comparability over time and across nations mean that they may be limited in what they can capture about science literacy. Most of the literature on science literacy assesses the relationship between science knowledge and attitudes toward, perceptions of, and support for science, but there is a growing body of literature on additional contemporary perspectives beyond literacy and these include science capital (at the individual and community levels), science agency and identity, and science engagement (Archer et al., 2014, 2015; Calabrese Barton and Tan, 2010; Carlone and Johnson, 2007; Vossoughi and Vakill, 2018). These newer frameworks have particular implications for the types of interventions that would be most effective for increasing public participation in and engagement with science, which are both articulated goals in the vision statement of NASA SMD. Additionally, this highlights the importance of measuring the full range of science literacy dimensions in order to reliably understand the impact of SciAct on U.S. science literacy.

In the context of SciAct, individual awardees do not consistently document outcomes related to the dimensions of science literacy identified by Miller (1998). Some projects track audience exposure to and/or experience with authentic NASA science about the Earth, the solar system, and the universe, which potentially contributes to science literacy but is just one facet of a complicated picture. Approximately half of the projects measure the change in content knowledge in the audiences engaged; only three projects attempt to gauge contextual issues, such as attitude, behavior, and identity, and none considers science literacy in the context of a community. Moreover, even if all awards were consistently measuring outcomes, the number of factors contributing to science literacy at the national level mean that it is extremely challenging to isolate SciAct as the sole contributing factor to whether or not Americans are becoming more or less science literate.

As the space agency of the United States, it is indeed laudable for NASA to use its unique and inspirational assets and SME's to advance public science literacy. However, given both the multifaceted nature of the concept, as well as the unlikelihood that a national measure would be able to isolate SciAct's impact, there are a number of concerns that prevent this objective from being fully actionable and measurable for the SciAct portfolio.

Objective 3: Advance National Education Goals

Because of NASA's participation in the integrated work of federal agencies in supporting STEM education (Federal Science, Technology, Engineering, and Mathematics (STEM) Education Five-Year Strategic Plan [Committee on STEM Education, 2013]), it makes sense that NASA would endeavor to support the educational goals outlined in the plan. The SciAct CAN emphasizes supporting four priority areas from this strategic plan:

1. **Improve STEM instruction:** Prepare 100,000 excellent new K–12 STEM teachers by 2020, and support the existing STEM teacher workforce.

2. **Increase and sustain youth and public engagement in STEM:** Support a 50 percent increase in the number of U.S. youth who have an authentic STEM experience each year prior to completing high school.
3. **Enhance STEM experience of undergraduate students:** Graduate 1 million additional students with degrees in STEM fields over the next 10 years.
4. **Better serve groups historically underrepresented in STEM fields:** Increase the number of students from groups that have been underrepresented in STEM fields who graduate with STEM degrees in the next 10 years, and improve women's participation in areas of STEM where they are significantly underrepresented.

In its review of project activities, the committee found that SciAct is pursuing this objective primarily through activities that

- provide professional development to inservice educators (15 projects);
- provide authentic science experiences for students or citizens (23 projects); and
- target specific underrepresented populations either through direct engagement or by providing resources and professional development to educators serving students from underrepresented populations (11 projects).

While SciAct is currently tracking how individual projects support some of the specific goals in the Committee on STEM Education (CoSTEM) reports, there is currently no mechanism to measure how the work of the portfolio is aggregating toward the constellation of CoSTEM goals. Moreover, given the diversity and breadth of these goals, attempting to measure SciAct's progress would require a considerable investment of resources. As a result, the committee finds that while *advancing national education goals* broadly informs the SciAct Program vision and some project activities support this objective, this objective is not measurable with respect to the SciAct portfolio overall.

In 2018, CoSTEM released a new strategic plan with three new goals[3]

1. **Build strong foundations for STEM literacy** by ensuring that every American has the opportunity to master basic STEM concepts, including computational thinking, and to become digitally literate. A STEM-literate public will be better equipped to handle rapid

[3] See https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf.

technological change and will be better prepared to participate in civil society.

2. **Increase diversity, equity, and inclusion in STEM** and provide all Americans with lifelong access to high-quality STEM education, especially those historically underserved and underrepresented in STEM fields and employment. The full benefits of the nation's STEM enterprise will not be realized until this goal is achieved.
3. **Prepare the STEM workforce for the future**—both college-educated STEM practitioners and those working in skilled trades that do not require a 4-year degree—by creating authentic learning experiences that encourage and prepare learners to pursue STEM careers. A diverse talent pool of STEM-literate Americans prepared for the jobs of the future will be essential for maintaining the national innovation base that supports key sectors of the economy and for making the scientific discoveries and creating the technologies of the future.

Because these new goals were delineated after the fact of SciAct's creation, the current portfolio of awards was not assembled to respond to the most current CoSTEM report. As the program moves forward and projects are added to the portfolio, it is important to consider how SciAct might align with these new national goals.

Objective 4: Leverage Efforts Through Partnerships

This objective, unlike the other three top-level science education objectives, is programmatic and potentially strategic in nature. The most explicit rationale for including *leveraging efforts through partnerships* as a program objective is offered through reference to the CoSTEM report (Committee on STEM Education, 2013, p. 7). SciAct's CAN includes the following quote from the report:

> Although the Federal Government plays an important role in STEM education, it cannot achieve success by itself. To effectively leverage its investments, the Federal Government must coordinate its efforts strategically and collaborate with non-Federal partners to support institutional, state, and local efforts. Local and state education agencies, institutions of higher education, professional and scientific societies, philanthropic and corporate foundations, aquaria, botanical gardens, museums, science centers, after-school providers, and private industry, for example, play potentially significant roles in growing our Nation's STEM education pipeline and creating pathways to STEM.

Essentially, the rationale referenced here points to the reality that the federal government is but one of many institutions that has a role to play in

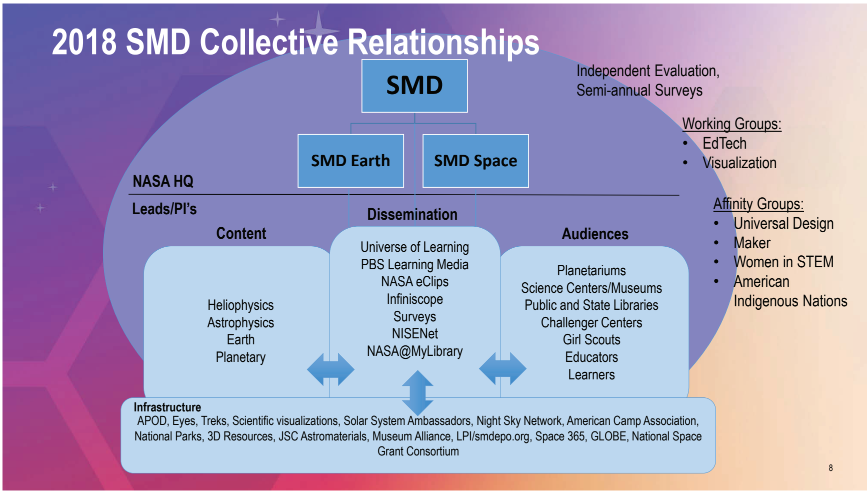

FIGURE 2-1 The Science Mission Directorate's collective relationships.
SOURCE: See https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/SciAct%20for%20NASEM%20Assessment%20040819%20final_formatted.pdf.

promoting STEM education and that working independently of these other institutions would miss an opportunity to broaden the impact of federal investments.

In its review of SciAct documentation, the committee identified two broad goals that NASA appears to have for SciAct partnerships: disseminating NASA SMD assets and broadening participation in STEM.[4] The committee turned to SciAct's own documentation of the relationships across projects for greater clarity on how SciAct intends to leverage partnerships (see Figure 2-1).

Figure 2-1 depicts a partner ecosystem made up of content partners, listed on the left of the figure (e.g., NASA Heliophysics, NASA Earth); dissemination partners, listed in the center of the figure (e.g., PBS Learning Media, NISENet); audience partners listed center right on the figure (e.g., planetariums, Girl Scouts, libraries); and infrastructure partners, listed at the bottom of the figure (e.g., Night Sky Network, American Camp Association). This partner ecosystem suggests the particular forms of partnership valued in SMD—those that directly leverage and aim to disseminate NASA SMD assets. These kinds of partnerships involve connections between

[4]In the following chapters, we discuss the issue of broadening participation—how it is understood in the SciAct portfolio, how it is measured, how the concept could be better operationalized—in depth. Despite the committee's observation that broadening participation in STEM is one of SciAct's stated (but unofficial) aims, it is worth noting that Figure 2-1 does not explicitly describe the ways that leveraging partnerships will lead to broadened participation.

content partners who work with dissemination partners who connect with audience partners, and potentially leverage existing infrastructure partners.

Leverage efforts through partnerships can be measured in multiple ways, particularly with more specific framing of partnership expectations going forward. Strategically, this objective is central to how the SciAct Program is envisioned and designed. However, SciAct is not currently using any portfolio-level mechanism to measure its progress toward this objective.

SUMMARY

At its core, the SciAct Program aims to bring unique NASA expertise and assets, including people, missions, products, data, and scientific results, to a diversity of learners effectively and efficiently. The SciAct awardees represent a critical piece of that vision by providing the educational expertise to translate NASA science to different types of learners and users. The committee applauds the aspirations of the SciAct Program overall and finds that three of the top-level science education objectives—enable STEM education, improve U.S. scientific literacy, and advance national education goals—describe ends to which the program wishes to contribute, including the desire to contribute to the larger education agenda of the federal government agencies. These objectives essentially inform the SciAct Program vision. The fourth objective, leverage efforts through partnerships, is a central programmatic objective and potentially a strategic goal that can be defined more specifically going forward.

CONCLUSION 1: The National Aeronautics and Space Administration has a unique role to play in the science, technology, engineering, and mathematics education landscape, but the current four objectives for the Science Activation Program are too broad and do not appropriately reflect that role.

CONCLUSION 2: The four current Science Activation Program objectives are general enough to inform a vision for the program, however they lack specific, actionable targets. As currently stated, the objectives are so broad that they obscure a clear understanding of how awardees' contributions aggregate toward desired outcomes.

CONCLUSION 3: Improving science literacy at the national level is one of the four Science Activation (SciAct) Program objectives. We do not have evidence that there is a centrally agreed-upon definition of science literacy across the projects. While, the approach to measuring science literacy at the national level that SciAct is currently using reflects one approach to measuring science literacy, it does not fully reflect the most up-to-date conceptualizations of science literacy

3

Characterizing the Current Portfolio

The Science Activation (SciAct) portfolio includes 24 current projects that together are intended "to increase the overall coherence of the Science Mission Directorate (SMD) science education program leading to more effective, sustainable, and efficient utilization of SMD science discoveries and learning experiences and to meet overall SMD science education objectives." According to the Cooperative Agreement Notice (CAN) for SciAct, fundamental to achieving this outcome is to "enable National Aeronautics and Space Administration (NASA) scientists and engineers to engage more effectively with learners of all ages" (National Aeronautics and Space Administration, 2015).

In this chapter, we provide a detailed overview of the SciAct Program, with particular attention to the program's design and outputs. First, we describe the committee's understanding of how the SciAct portfolio operates by articulating a logic model that builds on our description of SciAct's four top-level science education objectives (see Chapter 2). Additionally, this chapter highlights common features across the 24 sponsored projects; how the portfolio addresses broadening participation in science, technology, engineering, and mathematics (STEM); the current approach to program evaluation, and collaboration within the current portfolio. The chapter concludes with a summary of the current characteristics of the program and considerations for continuous improvement.

THE LOGIC OF THE SciAct PORTFOLIO

In order to understand the implementation of the current SciAct portfolio, the committee first attempted to understand how SciAct is designed to work toward its four top-level objectives (described in Chapter 2). As part of this work, the committee used all available evidence to create a logic model that explains how the components of SciAct are intended to function in pursuit of its stated objectives. Logic models are a common way to illustrate the linkages among program goals, objectives, and activities. For the overall SciAct portfolio, a logic model can serve as a guide for both planning and assessing the role of individual projects in meeting high-level goals and long-term impacts. A critical component of any logic model, and project planning overall, is ensuring that goals and objectives are measurable and relevant to the planned activities.

The current iteration of SciAct is designed for awardees to work in collaboration, in order to strengthen the outcomes of the overall portfolio. Based on its understanding of the available evidence, the committee designed the following logic model to illustrate the strategy for utilizing SciAct awardees as the mediating agents for transforming NASA assets into activities that serve the desired objectives (see Figure 3-1).

As the logic model in Figure 3-1 depicts, the SciAct awardees leverage NASA people and products (i.e., the logic model inputs) to develop educational programming and products (i.e., the logic model activities in the top box) for a variety of learner audiences. These activities result in learner experiences and resources (i.e., the logic model outputs) that are designed to achieve project-specific outcomes (i.e., the logic model short-term outcomes in the top box). At the SciAct portfolio level, project-specific evaluations, sharing of experiences among projects, and topical working groups (i.e., the logic model activities in the bottom box) result in increased dissemination of SciAct project products and portfolio-wide evaluation data (i.e., the logic model outputs in the lower box). Dissemination and evaluation data are intended to lead to better educational products across all projects and also to build a network of awardees to strengthen the portfolio as a whole (i.e., the logic model short-term outcomes in the bottom box).

Both the project-level and portfolio-level outcomes should further the logic model's long-term impacts, which in this case map to the four NASA SMD top-level science education objectives from the CAN. Individual projects have external evaluators who characterize the linkage between project outputs and short-term outcomes. While these outcomes are all related to the overall SciAct Program objectives (i.e., long-term impacts), the four objectives as stated are quite broad. As a result, it is difficult to measure these long-term outcomes in a meaningful way, and it is difficult to demonstrate a causal link between the short-term outcomes and any ob-

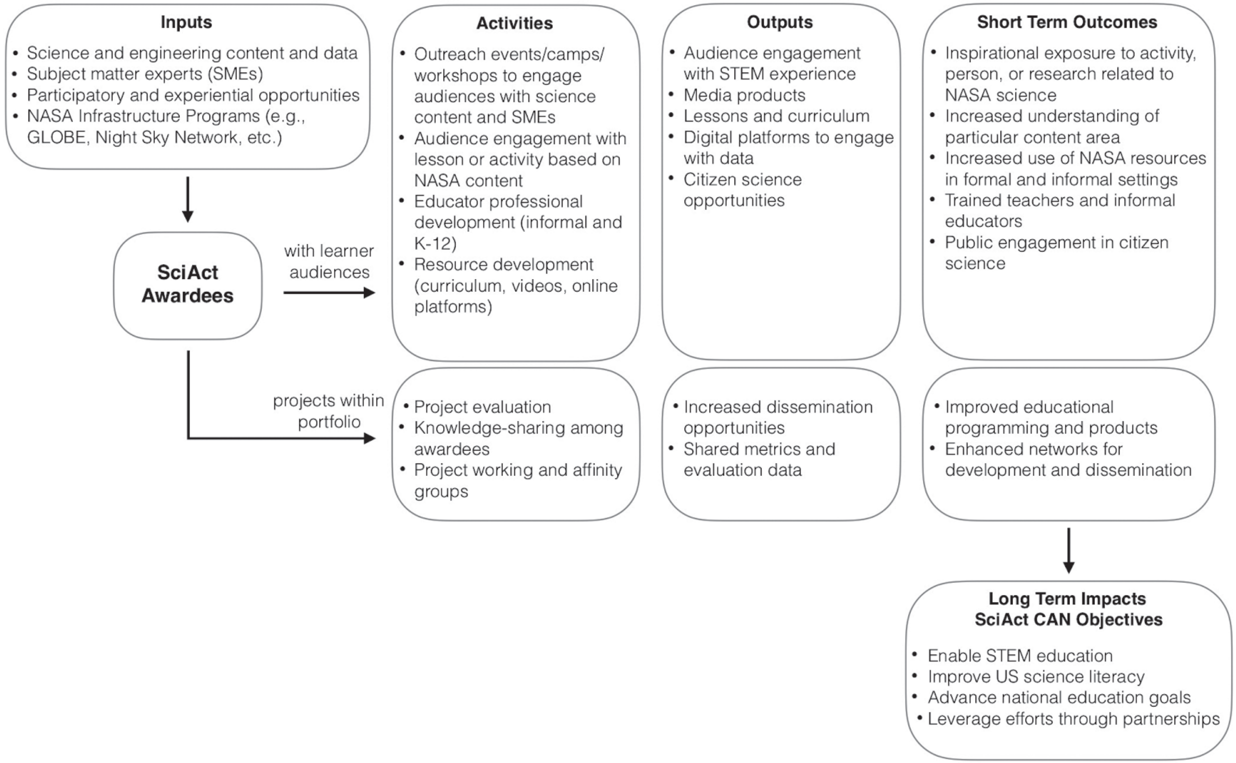

FIGURE 3-1 SciAct logic model as understood by the committee.
SOURCE: Adapted from the Cooperative Agreement Notice (CAN), descriptions of the program presented to the committee, and awardees' project descriptions and annual reports.

served changes in the long-term outcomes given the relatively modest size of the SciAct Program. To clearly communicate expectations from portfolio projects and assess progress toward meeting high-level objectives, the program must employ realistic long-term objectives that link to clear, concise, and measurable outcomes.

DESCRIBING THE CURRENT PROJECTS

In order to understand how the work of SciAct awardees aggregates toward meeting SciAct's objectives, it was incumbent upon the committee to learn about the work of the individual projects. While a full investigation of the efficacy of the awards was beyond the scope of this project (see Chapter 1 of this report), the committee did endeavor to characterize themes and commonalities across awardees (for an award-by-award description of the portfolio, see Appendix A). In this section, we describe the array of projects in the portfolio with an eye toward painting a picture of SciAct's on-the-ground presence.

SciAct was initiated in 2015 with 27 funded projects that address topics from the four primary NASA science disciplines: heliophysics, earth science, planetary science, and astrophysics. SciAct projects are distributed among the different science disciplines as follows:

- astrophysics: 3,
- earth science: 6,
- space science: 7, and
- cross-disciplinary: 8.

The SciAct projects focus on engaging a variety of audiences, including families, K–12 students and teachers, adults, children, and teens in formal education, informal education, and community settings.[1] The awardees include museums and science centers, universities, a community college, a K–12 school district, research institutes, and educational organizations and foundations. Overall, about 50 percent of SciAct projects engage learners in informal learning environments (such as museums, libraries, summer camps, out-of-school programs, in-home, and neighborhood or community spaces), and 50 percent of SciAct projects engage learners in formal educational settings, primarily through K–12 schools and teachers. One-third of the SciAct projects have created digital resources for learners, both exclusively and as part of more comprehensive projects. For example, a project led by the WGBH Educational Foundation, *Bringing the Universe to America's Classrooms*, creates media-based educational materials for K–12 audiences.

[1] See https://science.nasa.gov/infographic.

The project led by the Space Telescope Science Institute, *NASA's Universe of Learning*, is enabling educational use of astrophysics mission data and is providing participatory experiences by creating multimedia and immersive experiences, as well as designing exhibits and community programs and providing professional learning experiences for pre-service educators. Almost all of the projects list 11- to 18-year-olds as their target audience, and about one-half of the projects (15 out of 24) also cite 5- to 10-year olds among their targets. Additionally, about 50 percent of SciAct projects provide professional development opportunities and/or resources for K–12 educators. For a description of SciAct products, see Box 3-1.

All of the SciAct projects have established partnerships with scientific experts, educational experts, community organizations, professional organizations, museums and other informal learning institutions, K–12 school districts, universities and colleges, and/or multimedia platforms as a means of creating and disseminating learning programs and resources. Furthermore, some projects have cross-collaborations in a variety of capacities, whether to broaden their dissemination efforts or to leverage each other's expertise in using NASA data/resources and developing learning resources. These partnerships and collaborations are a high priority for the SciAct Program administration, and metrics about partnerships and cross-collaboration are documented as a part of each project's monthly report to NASA SMD.

A primary component of all SciAct projects is that they leverage NASA assets and infrastructure, including but not limited to

- NASA science content and data,
- NASA space and airborne platforms,
- NASA subject matter experts (SMEs) (i.e., scientific and technical personnel),
- NASA Wavelength online catalog (see http://nasawavelength.org),
- independent product review and assessment (see http://nasareviews.strategies.org),
- NASA Volunteer Networks (see http://solarsystem.nasa.gov/nnw/home.cfm),
- NASA Scientific Visualization Studio (see http://svs.gsfc.nasa.gov),
- NASA Eyes on Solar System and related products (see http://eyes.nasa.gov),
- NASA 3D Resources (see http://nasa3d.arc.nasa.gov),
- Space Grant (see http://www.nasa.gov/offices/education/programs/national/spacegrant/about/index.html),
- GLOBE (see http://www.globe.gov),
- Earth to Sky with National Parks (see http://earthtosky.org),
- Astronomy Picture of the Day (see http://apod.nasa.gov),

BOX 3-1
Describing Current SciAct Projects

The SciAct portfolio consists of 24 currently active projects* that use NASA data and content, subject matter experts (SMEs), and/or NASA infrastructure programs (e.g., GLOBE, Night Sky Network, etc.) in combination with different educational and engagement approaches to address SciAct Program goals and objectives. SciAct projects focus their educational activities on different learner audiences and different kinds of learning environments, including:

- children (ages 1–10),
- adolescents (ages 11–14),
- teens (ages 15–18),
- adults, and
- K–12 educators.

SciAct awardees are developing and delivering NASA science-focused educational resources and programs in a variety of formats to a diversity of learners in both formal and informal learning environments. Examples of these products include

- online exploratory activities that align with the Next Generation Science Standards/*A Framework for K–12 Science Education* and use NASA data and SMEs;
- professional development programs for K–12 educators that include online astronomy and planetary science content, a week-long STEM immersion experience at a NASA facility, in-person training in using student curricula, and ongoing opportunities to connect with astrophysics and planetary SMEs;
- interactive data-visualization software designed to visualize the entire known universe and portray ongoing efforts to investigate the cosmos;
- program that trains teachers, 4-H leaders, and community members on climate change concepts, culturally responsive curriculum, and environmental observing protocols (integrated with GLOBE) relevant to local climate change issues in face-to-face and online courses;
- space-themed simulations for middle school students that take place in a fully immersive Space Station and Mission Control environment;
- live broadcasts/webcasts of telescope images of eclipses along with educational programming in English and Spanish;
- development of library programs centered around high-profile NASA, Earth, and celestial events;
- development of an earth science high school online course and internship program that uses NASA's earth-observing satellites as a catalyst;
- faculty-led undergraduate research projects, professional development opportunities for middle and high school educators, and community STEM events to engage with southern Appalachia region's public schools and the Eastern Band of the Cherokee Indians tribal schools, and local community colleges and universities.

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*See https://science.nasa.gov/science-activation-team.

- NASA Mapping and Modeling Project (see http://www.lmmp.nasa.gov),
- other NASA communications infrastructure, including Web and social media sites.

SciAct has strongly encouraged all projects to use NASA SMEs in some capacity within their projects, but the extent of that engagement varies considerably across projects. Notably, regular project reporting to SMD by each project requires a listing of SMEs that participated in the project during the specified time period. SMEs consist of NASA-employed or NASA-supported scientists and engineers who have participated in NASA science missions and thus are doing, or have done, NASA science and engineering research and/or mission implementation. SMEs are engaged in SciAct projects in a variety of roles, from providing scientific and technical expertise to educational teams to actively participating in SciAct programming by sharing stories, presenting scientific and technical information, and leading program activities. This use of human capital gives NASA a unique ability to utilize its "funds of knowledge" by pipelining the scientific discoveries made by NASA scientists and engineers to the public.

SciAct strongly encourages all its projects to be "enabled by NASA's research and missions" and to use NASA resources that are already being produced, thus contributing to furthering NASA's overall educational mission. Most of the SciAct projects are using NASA scientific content, data, science mission activities, or technologies as the basis for their educational programs and resources. Five projects are leveraging the GLOBE Program, an international science and education program that provides students and the public worldwide with the opportunity to participate in data collection and the scientific process by developing new GLOBE applications. One SciAct project is focused solely on collecting national data on scientific literacy and thus is not directly leveraging specific NASA assets or infrastructure.

As noted in previous chapters, the SciAct Program effectively replaces educational programming that was previously funded as a part of each science mission. This approach enables NASA SMD to manage and evaluate educational activities more cohesively, and it eliminates duplicate projects. However, the committee notes that SciAct does not currently maintain a real-time way to engage the ongoing discoveries and excitement associated with NASA's science missions (see Chapter 4 for a discussion of the value of NASA's science missions). While the committee believes that the move away from mission-specific education efforts allows for an approach to STEM education that is able to address learners' needs more directly, it is important to also highlight that there are additional educational opportunities that could emerge from engaging with NASA's science missions in an ongoing way.

The NASA brand gives the agency access to many national and local partners and stakeholders to assist in reaching broad and diverse audiences of all ages. NASA employs many of the world's leading researchers in heliophysics, astrophysics, planetary science, and earth sciences and engages in some of the most ambitious research to date. SciAct projects are expected to leverage these assets for educational and public engagement activities to meet the overarching program goals. Furthermore, once SciAct projects were selected and awarded, each project essentially became another NASA asset for others to leverage. Thus, the SciAct projects are encouraged to collaborate as part of a network of educational projects, capitalizing on one another's strengths, to achieve SciAct Program goals (for more on how SciAct functions as a network, see Chapter 5). As the committee heard in the presentation of Kristen Erickson's, NASA's SMD director, this breadth of partnerships brings new external education providers and other entities into the "NASA family," which expands the kinds of expertise in NASA's extended wheelhouse.

SciAct's employment of the Cooperative Agreement funding mechanism gives principal investigators (PIs) and NASA the ability to adapt within the project timeline to make changes as they learn what topics are piquing public interest and what activities and resources are most effective. This adaptive approach gives the program members the ability to be nimble, which has proven to be another asset for SciAct.

SciAct's infrastructure (including its internal web communication portal, SMDEPO.org) allows it to coordinate efforts across the country and between research groups. Considering the geographic spread of SciAct projects, SciAct can reach a wide range of audiences across the United States. SciAct projects area based as far west as California, as far north as Alaska, as far east as Maine, and as far south as Texas, with numerous locations in between. This variety of locations gives SciAct the ability to reach diverse populations based on race, ethnicity, and socioeconomic status. For more information on this infrastructure, see descriptions of cross-portfolio communication in Appendix C of this report (see http://www.nap.edu/25569).

The wide geographical distribution of programs, activities, and available materials holds potential for SciAct to serve as a valuable asset to communities, which are local to their respective institutions. People in some locations may be engaged by solar physicists (heliophysics), while another group of participants may meet with scientists who look for evidence of past life on Mars or likelihood of life on Europa or Titan (planetary science).

BROADENING PARTICIPATION IN THE SciAct PORTFOLIO

Broadening participation in STEM is a stated priority for the SciAct Program, though it is not one of the four main objectives. The 2013 Federal Science, Technology, Engineering, and Mathematics (STEM) Education Five-Year Strategic Plan, drafted by the National Science and Technology Council (NSTC) Committee on STEM Education (CoSTEM), included the priority area "Better Serve Groups Historically Underrepresented in STEM Fields: Increase the number of students from groups that have been underrepresented in STEM fields that graduate with STEM degrees in the next 10 years and improve women's participation in areas of STEM where they are significantly underrepresented." Moreover, the 2018 CoSTEM Strategic Plan maintains and re-emphasizes this focus on broadening participation in STEM. The SciAct CAN notes this CoSTEM priority, and it is included as part of the top-level SMD science education objective "advance national education goals."

Despite this emphasis, only 9 of the 24 currently active SciAct projects include some diversity metrics in their evaluation plans and reports to SMD. The metrics reported by these 9 projects include number of resources accessible to underrepresented groups, number of events in underrepresented communities, increase in percentage of participants enrolled in STEM degree programs, and increase in Spanish-language resources. In some cases, the metrics are not specific (e.g., "adequately serve groups historically underrepresented in STEM fields by making educational resources more accessible to diverse learners throughout the country"). Fifteen of the 24 currently active SciAct projects do not include diversity metrics in their evaluation plans, although some of these projects do report numbers of underrepresented participants in their programs or other similar metrics in their monthly and/or annual reports. Overall, the metrics reported vary by project and there do not appear to be targets established by SMD to better understand what success looks like for broadening participation from SMD's perspective.

We know from current research that increasing diversity alone does not lead to improved outcomes without substantive and deliberate efforts for inclusion (Sherbin and Rashid, 2017). Diversity coupled with inclusion can increase students' self-confidence and self-efficacy, thus having a positive impact on their classroom performance (Ruggs and Hebl, 2012). As SMD continues to refine the SciAct Program, it is important to think about how attending to other aspects of broadening participation like inclusion (as well as supporting equity and attending to accessibility) could expand the number of people who both participate in SciAct and engage in STEM generally. Also, rethinking how projects can deliberately address diversity, equity, inclusion, and accessibility (DEIA) in their programs and evaluations will strengthen the overall SciAct portfolio in addressing national educational goals and DEIA overall. The National Science Foundation's (NSF's) Inclusion Across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science Program may be a source for best practices for both programming and evaluation efforts within a DEIA context. For further considerations on broadening participation in SciAct, see Chapter 5 of this report.

CURRENT APPROACH TO EVALUATION

Current SciAct awardees are required to have an external evaluation plan as part of their collaborative agreement. SciAct provides awardees with a checklist of required evaluation documents. The plan needs to describe the audience and need for their project, what project activities will be studied and how outcomes will be used in that process; a logic model for the plan; and the evaluation questions, design, and methods. Since each individual awardee develops its own project and evaluation, there is not currently a system for standardization and collaboration on approaches and metrics. This gives projects the opportunity to create a customized plan that best serves the individual project, and allows individual projects to set their own standards for evaluation and project improvement.

This openness to individual interpretation is mirrored in the wide variation among the annual progress reports, which range from 2 to more than 200 pages. These individualized evaluation reports make it challenging to draw conclusions across projects that could inform understanding of the performance of the portfolio as a whole. Indeed, even if it were possible to draw conclusions across evaluation reports, SciAct does not currently have a strategy for synthesizing and disseminating any emergent findings across projects. So while the committee heard presentations from project evaluators eager to contribute to a more comprehensive understanding of the portfolio, in the absence of a formal way to capture their insights, there is no incentive for evaluators to continue this work outside of their own interest.

Awardees are also required to submit an annual "quad chart" as part of the report on their progress. Quad charts provide a templatized snapshot that includes the project summary and participants, current opportunities and risks, and changes to the project plan. In addition, there are several ways for projects to report outcomes, including a mapping of evaluator outputs and measures to SciAct goals, specifically to the top-level objectives and SME interactions. These charts provide a quick, standardized way to assess the performance of the portfolio as a whole at a general level, but the diversity of projects and simplicity of metrics makes it difficult to assess the depth of the work and/or compare across projects to increase cohesion within the network.

The committee recognizes that project evaluators can serve many functions, depending on (among other things) what stage of implementation a project is in, as well as how the evaluation is designed. Evaluators may act as researchers, investigating a scholarly research question; alternatively, evaluators may act as auditors looking to see the fidelity or efficacy of project implementation. When the committee heard presentations from the individual evaluators, several PIs noted that they felt deeply supported by their evaluators as they implemented their awards. The relationship appears to provide PIs with an outside but deeply knowledgeable perspective that can be called upon to provide counsel on project design choices and other strategic concerns in a manner akin to a formative evaluation. Though this collaboration was initially unintended in the design of the SciAct portfolio, PIs were emphatic in their presentations to the committee that the support and real-time counsel of their evaluator partners was invaluable to their work.

As described above, the committee conducted a review of the program portfolio and presentations and considered the role of project evaluators as part of this process. As part of this work, the committee found that current evaluation efforts could potentially be strengthened if SciAct considered

- additional measures that provide a more detailed and refined view of the work,
- a selection of consistent measures and methods that could be used by individual projects and that could be aggregated across the portfolio, and
- sharing of project evaluation results in ways that enhance the utilization of resources across the network (rather than just as a report-out).

COLLABORATION WITHIN THE CURRENT PORTFOLIO

The SciAct portfolio consists of cooperative agreements with individual awardees who are encouraged to think and work like a collective—for example, by leveraging each other's resources and by sharing tools. The 2017 total solar eclipse served as a unifying opportunity to collaborate given that many projects had planned programming around this event. The national popularity of the event was seen by SciAct leadership as a chance to sustain public interest in NASA-related content, as well as a way to connect awardees around resources. SciAct would like to use the total solar eclipse that will be visible in the United States in 2024 as another opportunity to coordinate efforts among awardees. Coordination around an astronomical event provides a natural way for groups to feel unified and connected, whether they are directly in collaboration or not. The common thread of

NASA-related content means that there are likely collaborators within the portfolio, despite potential differences in project audiences and programs.

Awardees are in regular communication with SciAct leadership through methods that include monthly and annual reporting, quarterly scorecards to PIs, and at least one annual face-to-face session. This provides an opportunity for SciAct leadership to identify potential points of collaboration, as well as communicate desired changes and improvements in a timely manner. Efforts to foster communication among awardees include the annual PI meeting and an internal community Web portal.[2] This portal serves as a place to share project information, upload monthly reports, and schedule notable events. Posts can be made public for additional dissemination. The portal serves as a communication tool for working groups, which have formed around areas of special interest, such as education technology, girls in STEM, and visualization. The platform supports forum-style posts and commenting, and several affinity groups use other tools for collaboration, such as Google docs.

The annual PI meeting is framed less around individual project reporting and more around professional development for awardees. There is built-in collaboration time throughout the schedule. This time is likely strengthened by pre-identifying desired points of emphasis, such as citizen science, women in STEM, and collaborative tools. One outcome of the 2018 annual PI meeting was the creation of a community of practice for the evaluators of each project. This nascent group has served as a professional learning opportunity for individual evaluators, and its promise for using the collective knowledge to enhance individual projects (or the entire portfolio) is recognized but not yet realized.

SUMMARY

As described above, SciAct has designed a portfolio of awards that are utilizing a diversity of approaches in order to support STEM education across the United States. As a result of this diversity, SciAct is supporting a range of creative ways to use and engage NASA's considerable assets. Through implementation of their projects, awardees have the potential to both expand NASA's reach into new communities and bring underrepresented groups into the NASA enterprise. This commitment to supporting projects as they attempt to meet the needs of specific communities is a clear strength of SciAct's design: In allowing local needs to drive the direction of the awards, SciAct is more likely to maintain both its relevance and its potential for impact.

[2] See https://smdepo.org.

CONCLUSION 4: The National Aeronautics and Space Administration (NASA) has developed a portfolio of diverse projects reaching a broad range of communities across the United States that utilize NASA's resources.

CONCLUSION 5: The Science Activation (SciAct) Program has placed an emphasis on no longer funding education work attached to individual missions. This has eliminated redundancy, but it has also resulted in some missions not being represented comprehensively. The current SciAct portfolio is not consistently incorporating assets from new missions.

CONCLUSION 6: In general, the Science Activation approach has enabled development of partnerships with groups external to the National Aeronautics and Space Administration (NASA) with expertise in education and learning that provide added value for NASA.

CONCLUSION 7: The Science Activation approach to evaluation focuses on evaluating individual projects without adequate attention to how evaluation can inform the whole portfolio. Project evaluators support individual projects and are surfacing important insights that could benefit the portfolio. Among the evaluators, there is interest in contributing to a broader understanding of what is working well, what can be improved, and where there are opportunities that can be further leveraged across the portfolio. However, there are limits, given the current design and program resources, to how much this is possible.

CONCLUSION 8: Interactions among the projects to date have allowed principal investigators and evaluators to share ideas across projects in ways that were unanticipated in the original design. These kinds of collaborations can be built upon and strengthened in the future.

4

Assessing the Science Activation Portfolio: STEM Learning and Leveraging NASA Assets

As we have established in the preceding chapters, the Science Activation (SciAct) Program supports a wide variety of science, technology, engineering, and mathematics (STEM) activities that engage diverse audiences in both formal and informal learning environments. Project activities and products across the portfolio include but are not limited to hands-on learning experiences, science instructional resources, professional learning opportunities, and data visualization tools. Given the breadth and the diversity of these interventions, the committee sought to organize its analysis of the portfolio's work by identifying core themes that bridge the work of SciAct awardees with SciAct's desired goals and objectives.

In order to identify these themes, the committee turned to evidence provided through SciAct's presentations to the committee and other written documentation. For the PowerPoint slides used by Kristen Erickson in her presentation, see Appendix C on The National Academies Press Webpage at http://www.nap.edu/25569. While this report does not include an analysis of the 24 awarded projects themselves, the committee did review project-specific plans and evaluation reports in search of issues and concerns that were common across projects. In order to qualify as a core theme for this report, the committee needed to see evidence that (1) the issue in question was cited by SciAct as important to the work of the portfolio and (2) the majority of awardees reported implementing their projects with the issue in mind. The results of these investigations converged around four key themes that organize our analyses of the portfolio: STEM learning, leveraging—National Aeronautics and Space Administration (NASA) assets, networks, and broadening participation. It is important to note that these four themes are not meant to replace SciAct's current four objectives. They could very well serve as inspiration for future program planning; however, in the context of this report, these themes are used solely as a framework for the committee's assessment.

Additionally, the committee wishes to note that its review of literature in the following sections is intended to surface major trends and theoretical considerations within each of its four core themes. There is, however, a body of scholarship specific to each programmatic intervention within the SciAct portfolio. Given the breadth and diversity of intervention types included in the SciAct portfolio, it is beyond the scope of this study to delve into these more specific literatures (e.g. teacher professional development, citizen science, development of museum exhibitions). Projects interested in understanding the theory and evidence behind their specific intervention type should consult these respective literatures as appropriate.

In this and the following chapters, the committee addresses each of the above four themes individually. For each theme, we begin by describing major principles in the relevant research literature and what this research suggests about how project activities might lead to desired outcomes. We then examine the collection of projects in the portfolio to explore whether they are collectively employing strategies that reflect the research evidence. We conclude the discussion of each theme with our observations on considerations for future planning as SciAct moves into Phase 2 of the program. In this chapter, we provide our analysis of two of the themes—STEM learning and leveraging NASA assets.

STEM LEARNING

Projects in the SciAct portfolio employ a wide range of strategies to engage learners with STEM, and they vary widely in how explicitly they articulate the underlying logic of their project designs. While the committee does not believe that any single theory of learning should guide all of the projects in the SciAct portfolio, we do believe that it would be beneficial for projects to be explicit about their underlying assumptions about learning and how these assumptions inform the design of their activities. In addition, the design of projects needs to consider what the most current evidence on science learning suggests about effective strategies for supporting learning (also see Chapter 1 for a discussion of the current evidence base on STEM education standards and how people learn).

Principles to Consider for STEM Learning

Current research on STEM learning highlights some key principles that are important for the SciAct portfolio. First, becoming proficient in the disciplines that make up STEM is more than simply learning content. Instead, it involves engaging people in disciplinary practices, language, and tools in order for them to learn in, through, and about that discipline (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018a). This perspective informs the design of *A Framework for K–12 Science Education* (National Research Council, 2012a) and the *Next Generation Science Standards* (NGSS Lead States, 2013) that are based on it. As noted in Chapter 1, this approach as articulated in the *Framework* calls for students to engage in science and engineering practices to build deeper understanding of the natural and built worlds. Effective learning environments provide opportunities for learners to pose questions, design solutions, gather data, make inferences from that data, build explanations and arguments, and engage in communication with others. By engaging in these practices, learners build more coherent understandings over time (McNeill, Katsh-Singer, and Pelletier, 2015; National Research Council, 2012a).

Second, research clearly demonstrates the pivotal role that learners' interests, experiences, and concerns play in motivating their decisions to participate in learning activities (NASEM, 2018a). Foregrounding learners' interests, their personal agency, and the knowledge they bring to science learning opportunities is also a powerful way to interrupt or reverse deficit-based perspectives on who can learn or participate in science (National Research Council, 2009). These theories offer an assets-based perspective on learning in which extended families, parents, and community elders can play a role in designing and evaluating how NASA assets are mobilized for public engagement with science.

Finally, STEM learning occurs across a broad range of settings, timeframes, and experiences (National Research Council, 2006, 2009). This constellation of experiences is often referred to as the "STEM learning ecosystem." STEM learning ecosystems are emphasized in the 2018 National Science and Technology Council's Committee on STEM Education (CoSTEM) Strategic Plan as a top strategy for improving STEM literacy in the nation and supporting diversity, equity, and inclusion in STEM, which complement the objectives of SciAct (National Science and Technology Council, 2018). STEM learning ecosystems are commonly conceptualized as the array of learning opportunities, both physical and virtual, available to members of a community. Elements of the ecosystem can include families; school districts; state, local, and tribal governments; the federal government and its facilities; libraries; museums and science centers; community colleges, technical schools, and universities; community groups and clubs; foundations and nonprofits; faith-based organizations; and businesses (see Figure 4-1) (National Science and Technology Council, 2018; Pinkard, 2019; Traphagen and Traill, 2014). In the view of the committee, this ecological perspective is particularly important when considering the broader

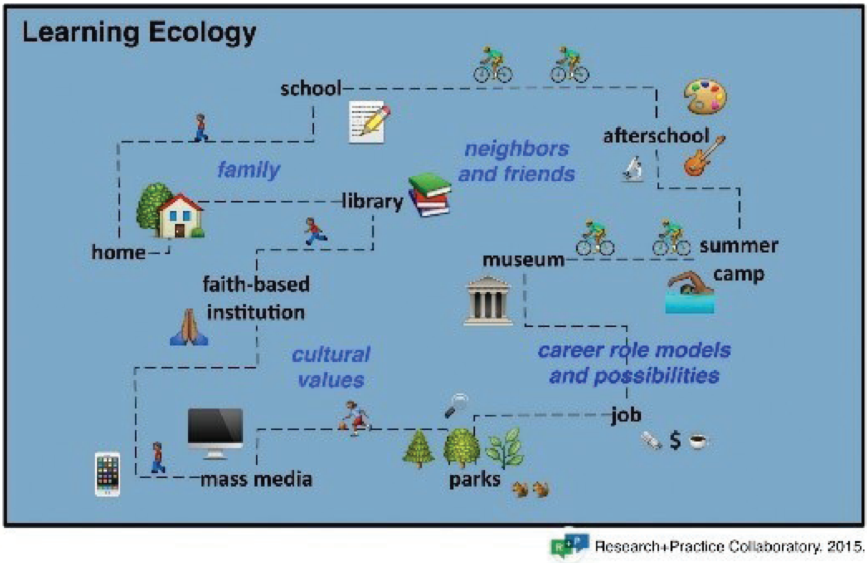

FIGURE 4-1 Institutional model of a learning ecosystem.
SOURCE: Bevan (2016).

learning ecology in which the public engages with science, particularly for learners from communities who have historically been excluded from STEM learning pathways (Bevan, 2016; Ching et al., 2016; Ito et al., 2013; NASEM, 2018a; Pinkard, 2019).

Taken together, these evidence-based conceptualizations of learning mean that providing scientific content is a necessary but not sufficient condition when designing, evaluating, and seeking to improve environments for science learning (NASEM, 2018a). Characteristics of learners and the communities in which they live, learn, and work are also necessary and are equally important to consider. Even in settings where school attendance is compulsory, learning is elective and conditioned by the interests and needs of learners (e.g., Engeström, 1991; Kohl, 1992). This is certainly also true of informal learning environments that are the focus in much of the work of the NASA SciAct portfolio. Thus, it is important to pay careful attention to learner-centered theories that focus on interests and learner agency (Azevedo, 2011, 2018; National Research Council, 2009; Renninger and Bachrach, 2015). This includes identifying assets and background knowledge or beliefs that learners bring to opportunities to engage with science practices, and including these as design considerations (González, Moll, and Amanti, 2006; NASEM, 2018b; National Research Council, 2009).

In recent years, this approach has been extended to include aspects of human-centered and participatory design as a basis for creating and studying learning environments in collaboration with community stakeholders, who have traditionally been seen as recipients of (not participants in) design (e.g., Bang and Vossoughi, 2016; Gutiérrez and Jurow, 2016). These research methods and related findings can help SciAct awardees think about how designed activities are implemented and supported, and in turn, which processes of learning and teaching are likely to be productive as NASA assets are distributed and used in a larger learning ecosystem. In summary, in designing projects that are aimed at supporting STEM learning, it is important to be explicit about the assumptions that underlie the design of project activities; to engage in evidence-based practices for project implementation; to attend to the backgrounds and needs of participants and, when possible, to collaborate with participants as mutual stakeholders (rather than just mere recipients of an experience) in the design of the learning environment (NASEM, 2018b).

Representation of STEM Learning Within the Portfolio

As noted, projects in the portfolio vary widely in the strategies they use to connect to learners. This includes variation in the venue—characterized broadly as informal or formal or both—and in the kinds of activities designed for learners. The committee found inconsistencies in the characterization of each project as focused on informal or formal settings. Consequently, the committee decided to examine more closely the provided information on all 24 projects and employ its own categorization. From the committee's process, the projects can be categorized as follows:

- formal learning settings—4 projects,
- informal learning settings—6 projects,
- informal and formal learning settings (with no connection between the formal and informal activities)—7 projects,
- informal and formal learning settings (with connection between the formal and informal activities)—6 projects, and
- no information or inappropriate information provided—1 project.

One-fourth of the current projects clearly articulate an ecological approach—making intentional connections across settings—to STEM learning. As for other projects, some learning across different learning environments may occur, but it does not appear to be an intentional goal.

Looking more closely at the specific activities of projects, there appear to be multiple strategies for connecting project design to desired learning outcomes in play as projects mobilize NASA assets. These include

- engaging learners to "get personal" with scientific concepts (e.g., bringing local perspectives on climate change into contact with global data and models);
- creating self-contained "kits" or take-home "backpacks" to support informal science learning activities in home or community settings;
- engaging with community participants across multiple generations, in order to build trust and show respect for local knowledge (important strategies for broadening participation in STEM);
- building directories (online databases) that allow educators or designers to find NASA subject matter experts (SMEs) with interests and backgrounds that match those of prospective learners (also an important strategy for broadening participation in STEM);
- creating online (i.e., computer-based) tutoring and game-like experiences for individual learners;
- utilizing SMEs to communicate science content as part of learning experiences that allow various audiences (i.e., educators, students, and the general public) to explore scientific discoveries; and
- delivering immersive learning experiences in both physical and virtual spaces.

The variety of strategies and settings described above suggests that a systematic study of (and support for) design practices that target specific learning goals and value different kinds of interaction with project stakeholders is warranted. It is unclear to the committee whether all SciAct awardees are using research and evidence in education to inform how their project activities will lead to the desired learning outcomes. For example, because online gaming, adaptive tutoring, and support for family interaction with museum or library exhibits are quite different settings for informal STEM learning, the approach that a project would employ to bring about a desired learning outcome would likely vary. Research and evidence in education can help shed light on best practices for supporting learning in each of these specific contexts.

In an effort to probe what project leaders might be learning from their work with SciAct, the committee asked each of the 24 awardees to reflect on insights and new understandings they developed related to the design of their projects. These project findings were an important source of evidence for the committee, because they indicate that awardees are making discoveries about how to design productively their projects to support learning. Findings across projects, both positive and negative, include the following:

- Despite high levels of interest, students' family and work expectations sometimes limit their ability to participate in more intensive learning experiences such as internships; on the other hand, demand often exceeds capacity for access to more intensive activities, requiring the development of online alternatives.

- NASA SMEs use language and understand life on Earth in ways that are very different from what youth, teachers, or other adults understand, leading to the need for extended negotiations over meaning.
- Time and deliberate effort are required to build trust with local communities, and this is often necessary for increasing the participation of members from underrepresented groups (e.g., working with community elders in tribal communities).
- SciAct awardees/principal investigators experienced difficulty in finding a "sweet spot" or "niche" for learner engagement that aligned local interests with global perspectives on earth and space science (e.g., local versus global data and visualizations of climate change).
- SciAct awardees occasionally changed design strategies midstream to improve implementation (e.g., adding hands-on or constructive activities to increase interest and engagement with NASA visualizations), and users adapted designs to meet local needs (e.g., local variation in how best to use SMEs and "kit" materials).
- Unanticipated collaborations have developed across SciAct projects, sometimes extending the capacity of one partner (e.g., access to larger networks of teachers or other stakeholders) or leading to entirely new projects.

Across projects, the committee finds that while many projects cite STEM learning as a goal, there is often a lack of clarity as to how projects expect that their work will bring about desired learning outcomes. Moreover, even where those plans *are* specified, they are generally not clearly aligned with the most recent evidence on how to support learning. While many positive learning outcomes are emerging as noted above, the committee believes that projects could be better positioned to support participants' learning if they more clearly delineate their expectations for the relationship between their work and desired learning outcomes.

Considerations for Future Planning

Based on our review of SciAct projects and presentations, the committee finds that the entire portfolio would benefit from more explicit use of research on learning to inform how NASA's resources are mobilized in science teaching and learning activities. Variation across SciAct projects means that projects may adopt different approaches to supporting learning with different underlying assumptions about how learning works. Making these underlying assumptions more explicit can lead to greater clarity about why and how the activities of the project are expected to bring about desired learning outcomes. This clarity can inform both the initial design of the activities and provide insight about how to improve outcomes. As discussed in Chapter 3, this explicit plan that links a project's activities to its stated goals and objectives— otherwise known as a logic model—can help serve as both a guide for making design decisions as well as a framework for assessing a project's success. In the final chapter of this report, the committee offers recommendations for how logic models—both at the project level *and* at the award level—can assist in clarifying and supporting the work of SciAct.

The committee realizes that these observations and the questions they raise about design, learning, and teaching science are complex. But we also see an opportunity to begin asking and answering these questions as the SciAct portfolio transitions into a second phase of NASA support. This would capitalize on informal collaborations across the SciAct network that appear to be emerging (see Chapter 5), and could strengthen and support a STEM learning ecology at the local, regional, or national scale.

LEVERAGING NASA ASSETS

While many scientific organizations and federal science agencies are well positioned to support learning about and through scientific practices, we noted in Chapter 1 that NASA brings a wealth of compelling assets (i.e., expert scientists and engineers, datasets, state-of-the-art technology, and data visualizations) developed in the context of the captivating human narratives about specific missions (see Box 4-1). The datasets and visualizations can be used as important tools for public engagement in scientific practices of modeling and computational thinking. In this section, we focus primarily on one of NASA's biggest assets, its SMEs, as one example of how SciAct is leveraging NASA's assets. At the end of this section, we offer considerations for future planning across different types of assets.

Principles to Consider for Using SMEs

The involvement of NASA's SMEs in projects' activities is an emphasized component of the SciAct Program. In her presentation to the committee, Director Kristen Erickson noted that one of the overarching goals of SciAct is to enable SMEs to share science with multiple audiences. This emphasis on involving SMEs in SciAct projects aligns with previous recommendations from the science-based profession and the federal government calling on scientists to engage more effectively with the public and policy makers, and for federal workers in STEM fields to volunteer their time and expertise toward improving STEM education (Berry, 2012; Leshner, 2012).

BOX 4-1
The Compelling Narratives of NASA Missions

The current and past missions of NASA tap into the public's collective imagination about the place of humans in the universe. The stories of NASA entail astonishing ambitions, daunting technological challenges, and sometimes high drama. They provide a powerful context for activating the affective and social dimensions that research shows are integral for human learning (NASEM, 2018a; NRC, 2012b). They provide a narrative backdrop for learning to which many scholars have ascribed a kind of privileged status in human cognition (Bruner, 1991; Graesser and Ottati, 1995). Indeed, research suggests that narratives may be particularly effective for motivating interest and engagement in science because in many ways scientific explanations are analogous to stories (Avraamidou and Osborne, 2009). Explanations as well as stories include protagonists/characters, a sequence of events, overcoming challenges, and ultimately some sort of resolution. In a review of the literature on narrative in science, Dahlstrom (2014) found that "narratives are often associated with increased recall [and] ease of comprehension . . . narratives seem to offer intrinsic benefits in each of the four main steps of processing information: motivation and interest, allocating cognitive resources, elaboration, and transfer into long-term memory."

The dramatic stories that NASA has to tell—from Apollo 11 and the Mission to Mars to discoveries about black holes or solar eclipses—provide such contexts for processing information and developing understanding. They humanize and help to ground what may otherwise be experienced as esoteric facts. Besides catalyzing great interest, they provide opportunities to connect the local to the global. For example, NASA images documenting global climate change can serve as springboards for investigations of local environmental changes and challenges (Whitmarsh, 2009). As new missions are added to NASA's portfolio, ongoing opportunities will be afforded to leverage the stories behind and of the mission, and to connect global, national, and regional issues and concerns in ways that can increase relevance, consequence, and meaning of science to the public.

Research on broadening participation discusses the importance of reducing social distance between people who pursue science as a profession and people from communities that have historically been excluded from STEM fields and therefore have fewer role models and mentors readily available (Malone and Barabino, 2009; Nelson, 2009). Thus, the SMEs associated with NASA and its missions represent a significant resource for bridging this gap. Role models, mentors, and other social actors are beneficial in supporting people's relationship to and interest in science, as well as supporting how to navigate and pursue science learning and practice (Jurow, Hall, and Ma, 2008). SMEs have important stories to tell about their own pathways into science, and even in short-term engagements, they can humanize science and what it is to be a scientist. Additionally, research suggests that in the context of a nonexpert audience, narratives and storytelling are more effective than traditional logical-scientific communication (Green, 2006). They support increased comprehension, engagement, and interest, and reflect the predominant way that the majority of scientific information is disseminated to nonexperts through mass media formats (Dahlstrom, 2014). Through more structured learning activities, SMEs can serve not only as inspirations, but also as role models and mentors to learners in a wide variety of ways, from supervising student summer internships in NASA labs to providing content expertise for citizen science activities. SMEs can also play key nonpublic engagement roles, which include informing the design and focus of STEM programs.

Science communication strategies used by science-based professionals often assume that the listener or learner simply lacks knowledge and the task is to inform them—often called a deficit approach. This approach, however, does not reflect what learning scientists know to be effective (NASEM, 2017, 2018a). Rather than framing this work in ways that are deficit-based (e.g., SMEs coming to communities to disseminate information and share their experiences in a one-way direction), approaches that forge bidirectional relationships, whereby community members can equally inform and inspire scientists by sharing their own relevant experiences and questions, are more effective (NASEM, 2017). There is a small but growing body of research documenting the benefits of two-way communication and engagement, much of it in the social sciences (Frickel et al., 2010). Particularly for communities historically underrepresented in STEM, SciAct could play a unique role in brokering productive engagements for SMEs that move beyond traditional public relations and dissemination approaches to more substantive strategies that involve deeper engagement with communities of learners (Ching et al., 2016). Indeed, the involvement of NASA SMEs as a participant in dialogues about science has the potential to support the development of community science literacy (see Chapter 2 for a discussion of the different dimensions of science literacy).

Indeed, science communication training that is informed by current evidence on effective communication plays a critical role in developing science-based professionals who can engage effectively with public audiences. However, both a study looking at the views on science communication training held by members of the American Association for the Advancement of Science (AAAS), and a study on the quality of training delivered by science communication trainers revealed that training of this kind focuses primarily on developing specific skills, and is only loosely based on the social science research on effective communication (Besley, Dudo, and Storksdieck, 2015; Besley et al., 2016). Efforts to enhance the science communication skills of SMEs would do better not only to focus on developing skills for information transmission but also to emphasize the effectiveness of engagement activities (i.e., public engagement can build trust and improve research and access to knowledge). Evidence indicates that when effective training and connection to appropriate audiences are included, scientists are appreciative and positive about the science communication training they receive. For example, scientists trained through the Portal to the Public (PoP) Program[1] were more likely to display science communication and engagement abilities and skills that align with evidence-based practices in informal science education and science communication, and self-reported increases in motivation to do the work in their regular profession and interest in conducting more outreach and engagement activities, as a result of participation in the program (Storksdieck, Stylinski, and Canzoneri, 2017).

Representations of Asset Use in the Portfolio

SMEs greatly enrich the scientific currency of the SciAct Program. The descriptions of projects across the portfolio identify a number of ways that SMEs are involved in providing expertise and materials for use by a variety of audiences, including

- providing datasets to be put into forums for manipulation by public audiences;
- assisting with the development of curriculum materials and exhibition content;
- providing data to be converted to public-friendly visualizations;
- mentoring interns or online learners throughout project participation; and
- acting in mission-linked, scripted roles in video productions.

In most of these cases—if not all—SMEs are working with project staff who help ensure that complex scientific information is made accessible to participants. In these cases, SMEs generally do not bring (nor do they need) additional expertise in appropriate theories of learning or of science communication to their work.

When SMEs have direct engagement with public audiences, however, they may benefit from additional expertise in learning theories and science communication strategies in order to engage effectively with the audience.

[1] Portal to the Public (PoP) is a program developed as a collaboration between Pacific Science Center, Explora, North Museum of Natural History and Science, and the Institute for Learning Innovation. The program trains and supports science-based professionals ("scientists") in outreach and engagement activities, based on the premise that scientists should engage directly and through materials-rich, hands-on activities with family audiences in ways that reflect basic understanding on how people learn and how to engage audiences in discovery-based learning.

This might include strategies for leveraging the wide range of cultural assets that different groups bring to STEM that may be different from (or even challenge) dominant cultural norms of STEM in academia and the professions (Bevan, Calabrese Barton, and Garibay, 2018).

Currently, there is little documentation of how the SMEs within SciAct are prepared to be effective science communicators with the public. One project, however, did identify an explicit mechanism for providing training to SMEs in science communication by offering Stony Brook University's Alan Alda training in science communication to the SMEs associated with the project. However, it is not clear how comprehensive the training was for all of the SMEs involved. Moreover, it was difficult to know whether or not this project represents an isolated case or if other projects are also concerned with the science communication skills of their SMEs. SciAct may want to consider strategic coordination of these efforts to support SMEs across its entire portfolio.

In terms of the use of assets beyond SMEs, SciAct projects are deploying a number of strategies. These strategies typically use some combination of mission-generated *data* or *visualizations* of these data, but there are also distinct uses of

- physical tools and associated methods of observation or measurement,
- live data or observational "feeds" that can be featured in teaching and learning activities,
- leveraging use of select NASA missions as internship sites for teachers or students (middle school or older), and
- using the occasion of a major event (e.g., solar eclipse) to engage public audiences.

It is clear to the committee that ambitious and innovative projects are under way. However, there is not yet a logic model that shows how NASA assets (i.e., content, SMEs, existing infrastructure) are being used to *design* activities (e.g., outreach events, educator professional development, and infrastructural resources), and also how these activities are organized to support *teaching and learning* in ways that are expected to lead to positive outcomes in STEM education.

Considerations for Future Planning

Exploring how NASA's assets could be integrated into public engagement programs to deepen participants' desired learning outcomes would be a major contribution of the SciAct Program. With respect to aligning global perspectives with local interests of learners, SciAct might further support the work of its awardees by creating shared tools that would enable

NASA's global science data to be synthesized more easily and made modular and useful for local and regional investigations, insights, and applications. Across the current portfolio there are a number of efforts that have increased access to NASA's resources, but greater attention could be given to ensuring that assets are intentionally employed to promote learning.

Additionally, by focusing on leveraging its unique and compelling assets within the broader science learning and education landscape, SciAct will be better positioned to demonstrate measurable impacts. For example, SciAct can support the creation of unique and engaging opportunities for learners of all ages to participate in scientific practices, including modeling, computational sciences, and other forms of inquiry. SciAct can also provide social networks, role models, and mentors that can support learners to deepen current STEM engagement experiences and seek out new pathways of engagement. These represent measurable ways for SciAct to diversify the range of opportunities to engage with STEM, in NASA-specific ways that can enrich the learning ecosystem (support its diversity, scale, and local adaptation).

Looking across projects in the SciAct portfolio, the committee could not identify a coordinated strategy across projects for how NASA assets are being used to design educational activities that have observable outputs (e.g., media products or citizen science efforts). Further, because projects were not universally making explicit the theory of learning behind their project design, it was also difficult to identify *why* these outputs might lead to STEM learning, other than through availability or exposure (i.e., very simple theories of learning or teaching). It is the view of the committee that the SciAct Program has yet to develop a logic model and theory of change (Funnell and Rogers, 2011) that can continually guide design and dissemination activities across the portfolio. A clear articulation of a logic model and theory of change could also help to develop an integrated understanding of how and why designed activities influence learning and teaching in the STEM education ecosystem at local, regional or national scale.

SUMMARY

NASA's assets are invaluable resources to support STEM learning in a variety of contexts, as illustrated by the number of ways they have been utilized within the SciAct portfolio. Some assets have been deeply integrated into the project activities to support STEM learning (e.g., data and visualization tools), whereas other assets are not being effectively mobilized as part of the current efforts. Utilizing SMEs to engage efficiently and effectively with learners is an emphasized priority of NASA SciAct and one of its predominant ways for connecting its content and discoveries to the public domain. However, engaging SMEs in effective science communication training is not pervasive across the portfolio, which has implications for the program's potential to promote STEM learning and science literacy, and broaden participation. In cultivating effective learning environments, considerations that go beyond access and exposure need to be taken into account, including the underlying theory of learning; specific project design strategies; the specific communities being engaged; whether or not an ecological approach to learning is employed; and whether there is alignment with the national vison for science, engineering, and technology education (i.e., the *Framework* and the *Next Generation Science Standards*). Additionally, a greater understanding of how the assets and outcomes are connected (i.e., an articulated logic model and a theory of change) will enhance the potential impact of SciAct's education activities in the broader STEM landscape.

CONCLUSION 9: While science, technology, engineering, and mathematics learning is in the foreground as a Science Activation goal, there is no explicit link between theories of learning and how the National Aeronautics and Space Administration assets are used (e.g., transmission models, inquiry-based practices). There is a range of design intervention strategies that are used across the portfolio. Each project uses different theories of learning in its project design and often that theory of learning is not made explicit.

CONCLUSION 10: Current research on learning emphasizes the importance of learner-centered and community-centered instructional design and practices. Awardees have had uneven success at mobilizing the National Aeronautics and Space Administration assets while also being responsive to the needs of learners and communities.

CONCLUSION 11: Given the portfolio's emphasis on the value of subject matter experts, the portfolio lacks a coordinated effort to incorporate evidence-based practices in translating their expertise in developing and implementing educational materials and learning experiences (e.g., translating datasets, engaging in public outreach).

5

Assessing the Science Activation Portfolio: Broadening Participation and Networks

In this chapter, we continue our discussion of the Science Activation (SciAct) Phase 1 portfolio assessment, focusing on the two remaining themes: broadening participation and networks. As described in the previous chapter, the committee arrived at these two themes because they emerge repeatedly as important issues for SciAct stakeholders. Indeed, each of these themes is described in SciAct materials as both central components of and desired outcomes for the portfolio's work. For this reason, the committee took care to enhance its collective expertise through invited presentations on best practices and considerations for prioritizing diversity, equity, inclusion, and accessibility in network models. Similar to our discussion in Chapter 4, for each theme we discuss principles to consider based on the current evidence base, current representation in the portfolio, and considerations for the next phase of the program.

BROADENING PARTICIPATION

SciAct's mission is to deliver activities and experiences to *learners of many backgrounds* and to leverage scientist-educator partnerships that have demonstrated *diverse, broad, and deep national education and communications impact*. In her presentation to the committee, Director Kristen Erickson emphasized that SciAct's efforts toward broadening participation are directly aligned with one of the priority areas described in the current national agenda for science, technology, engineering, and mathematics (STEM) education: "to increase diversity, equity and inclusion in STEM" (National Science and Technology Council, 2018, p. 5). Additionally, the efforts of SciAct are linked to one of the aims of the National Aeronautics and Space Administration's (NASA's) education and communications program, which seeks *to better serve groups historically underrepresented in STEM fields*. Thus, broadening participation is clearly identifiable as one of SciAct's stated commitments and values.

Principles for Broadening Participation

When education and outreach efforts are focused on broadening participation, it is important to consider four distinct aspects of the design and implementation of the program: diversity, equity, inclusion, and accessibility (DEIA). In her presentation to the committee, Julie Johnson, program director and Advancing Informal STEM Learning (AISL) Program lead at the National Science Foundation, provided definitions for each of these components. *Diversity* is defined as the wide range of differences among people and their perspectives; *equity* refers to the fair and just treatment of all members of a community; *inclusion* refers to seeking and embracing contributions from all sources, including underrepresented groups, regions, and institutions; and *accessibility* is giving equitable access to everyone along the continuum of human ability and experience. Organizations can indicate and demonstrate DEIA as a core value through expressed commitments, organizational policy, operational practices, grant-making or other program areas, and accountability mechanisms (Johnson, 2019).

The SciAct Program administrators and awardees place emphasis on reaching a **diversity** of learners. This is an important strategy, particularly because education systems are becoming more diverse. For example, the Department of Education predicts that by 2022, 54.7 percent of the U.S. student population will comprise students of color (Stevens, 2015). The importance of **inclusion** is highlighted by current research indicating that the benefits of diversity are not realized without substantive and deliberate efforts toward inclusion (Sherbin and Rashid, 2017). Simply increasing the diversity within an organization does not lead to a sense of belonging for all participants (Puritty et al., 2017). Other indicators of inclusivity within an educational organization may include the following:

- Individuals from the community that an initiative is intended to serve are involved, as partners, leaders, advisors, and staff.
- The voices and perspectives of those that an initiative is intended to serve are heard and inform decision making.
- The initiative is co-designed to address the needs and interests of the intended audience.
- The program or project staff develop and demonstrate skill in working with the full range of intended audiences.

A third element in DEIA, **equity**, is distinct from equality (Nasir et al, 2014). Equality is providing the same resources to all groups, which assumes a level playing field and posits that educational equality will be realized when the same quantity and quality of resources characterize the educational experiences of all racial groups in the United States (Parsons and Turner, 2014). However, this conceptualization leaves intact the political, economic, social, and educational barriers that some groups face. Equity, in contrast, recognizes that different resources or approaches are needed to remedy the uneven playing field in order to produce and sustain the highest-quality outcomes for everyone (Grogan, 1999; Parsons and Turner, 2014). Equity "requires commitment to strategic priorities, resources, respect and civility, as well as ongoing action and assessment of progress towards achieving specified goals" (Johnson, 2019). Furthermore, incorporating equity into educational programs may require greater use of culturally responsive or other equity-based pedagogical approaches that enhance achievements for diverse learners. It may also require specific focus on the economic diversity of the populations served, given that access to high-quality resources (e.g., curriculum, technology) is often predicated on income (Gay, 2002; O'Day and Smith, 2016).

Accessibility includes the design of products, devices, services, or environments for people with disabilities (Johnson, 2019). According to the American Alliance of Museums, accessibility also encompasses the broader meanings of compliance and refers to how organizations make space for the characteristics that each person brings. The principles of Universal Design for Learning (UDL) are important accommodations to make in order to provide educational experiences that meet the needs of all learners, thereby maximizing accessibility (Rose, 2000). Inaccessibility is the result of design choices, and sometimes these choices are linked to decisions about who is worth designing for (or with). Hence, lack of accommodations may reflect a failure to anticipate the ways in which whole groups of people (e.g., people who use wheelchairs) might approach an experience or an event, or a willful decision that people who require accessibility accommodations are not numerous enough (or important enough) to merit consideration. The concept of accessible design ensures that both "direct access" (i.e., unassisted) and "indirect access" (compatibility with a person's assistive technology, e.g., computer screen readers) are afforded.

Representation of Broadening Participation Within the Portfolio

Promotional materials for the SciAct Program refer to reaching "learners of all ages" and "being active in all 50 states." Additionally, all SciAct projects include metrics for broadening participation with regard to diversity within their evaluation plans. However, the particulars of who is served and how are defined by the awardees. Being explicit about key audiences is essential to designing programs that are truly responsive and evidence-based for engaging those audiences. Examining the materials provided for the 24 projects, the committee found that 3 awards include some information about intended demographics of participants in the project titles, and 16 awards make some mention of diverse learners or underserved or underrepresented communities within the background information for the projects. Of the latter, six project descriptions mention some aspect of particular identities, including Indigenous Alaskans, girls, Spanish-language speakers, people with disabilities, people of all socioeconomic backgrounds, and Native Appalachians. Some projects include partner organizations that represent the voices of the underrepresented audiences to be served, and some projects provide training in culturally relevant pedagogical approaches. Finally, some projects seek to educate the rest of the network on their area of expertise (e.g., how to serve learners of all ages effectively using the principles of UDL).

Looking across the portfolio, the committee found that the current SciAct projects collectively reach large groups of learners across different regions, abilities, age groups, socioeconomic levels, and race and ethnicities, among other facets of diversity. However, it is unclear to the committee whether or not the portfolio *consistently* and *intentionally* engages individuals who are representative of the entire U.S. population. Furthermore, it is unclear whether or not appropriate attention has been given to the inclusion, equity, and accessibility dimensions of broadening participation within all of the projects.

Across the SciAct Phase 1 portfolio, the committee also observed that broadening participation is largely an accountability mechanism. SciAct project evaluation plans often include goals to serve a diverse group of learners, or in particular learners from groups that are underrepresented in STEM, and milestones toward those goals are described in the project annual reports. By employing a metric crosswalk of the portfolio, the committee found evidence of commitments to reaching diverse populations with target metrics for participation by a general population of underrepresented learners or by those from a specifically defined group. Most commonly, the metrics reported denote the numbers of people from particular groups who were reached. The committee agrees that measuring the compositional diversity of key audiences reached across projects is important, because this metric can be used to demonstrate a commitment to promoting equity with respect to increasing opportunity to learn; however, as mentioned earlier, diversity targets do not sufficiently capture whether or not learning environments are inclusive. The committee believes more steps should be taken to ensure that activities within SciAct intentionally reflect this commitment (see the next section for a discussion of considerations for broadening participation that go beyond numbers of participants).

Considerations for Future Planning

In the committee's view, the second phase of the SciAct Program affords an opportunity to develop a shared understanding of DEIA across the portfolio, drawing upon the existing expertise and experience of the awardees. This phase could also be used to build capacity for attending successfully to broadening participation throughout the projects in the portfolio. The current project evaluation reports regularly describe numbers of participants from different groups, but there are other considerations for broadening participation that could be part of Phase 2 program evaluation plans:

- To what extent does the SciAct portfolio map onto the full range of DEIA dimensions?
- How are the voices of the key audience(s) for a given activity involved in the governance, planning, and implementation of the activity?
- What is the purpose of the activity and how does it further the interests and needs of the intended audience?
- To what extent do participants have access to role models and examples that increase their own confidence within the STEM domain?
- To what extent does the activity address community-based goals and issues?
- How are project implementers supported to work within a culturally responsive educational context?
- To what extent are the products and activities developed with consideration for the principles of UDL?

Critical questions to be considered for each project will vary and will require qualitative approaches to evaluation, as well as the quantitative metrics approach already in use. Moreover, the topic of broadening participation should be part of the overall visioning process and evaluation strategy (discussed in Chapter 6).

NETWORKS

When SciAct stakeholders describe the portfolio, it is regularly characterized as a network. As mentioned earlier, SciAct regularly refers to the "network" element of the SciAct portfolio as one of the strengths of the current program model, and SciAct stakeholders express interest in continuing to support this feature of the work. In practice, networks can exist in many forms, with a wide range of goals and purposes. In this section, we describe some of the relevant research on networks, and then apply this research to help us understand what kind of network SciAct currently represents, as well as what the program should consider if it wants to develop and expand its network capabilities in the future.

Principles to Consider for Building Networks

Intentionally designed networks are one strategy for collections of organizations and stakeholders to pursue a wide range of goals. In the field of education, networks may be used to support coherent policy implementation, school district change, professional learning, and development and dissemination of novel educational innovations, among other desired ends (Bryk et al., 2015; Coburn et al., 2013; Cooper, Slavin, and Madden, 1998; Culatta, 2012; Kania and Kramer, 2011; Lieberman and Wood, 2003; McLaughlin and O'Brien-Strain, 2008; Russell et al., 2015; Santo, 2017). Network development can be an intentional strategy to meet the goals held by a set of actors.

Given the number of organizational stakeholders involved in the SciAct portfolio, it is fair to characterize SciAct as an "interorganizational network." Russell and colleagues (2015, p. 93) offer the following definition for a designed interorganizational network: "An arrangement of public and private organizations, agencies, and departments that have been explicitly constituted to facilitate collective action." Such interorganizational networks seek to achieve outcomes that go beyond individual organizations or cross-organizational projects (Provan, Fish, and Sydow, 2007). An interorganizational network can pursue a range of goals, including the development of new knowledge and innovations through interorganizational coordination and design activities (Powell and Grodal, 2005; Santo, 2017; Tödtling and Trippl, 2005; Von Hippel, 2001), dissemination of innovations (Coburn et al., 2013; Rogers, 2010), sustaining innovations once they have spread (Coburn and Russell, 2008), and building capacity for problem identification within collectives (Hargadon, 2002; Santo et al., 2017).

Moreover, many networks are developed specifically to support the development of collective knowledge, innovation, and continuous improvement. These networks are known as "learning networks." Coburn and colleagues (2013) summarize a number of structural features common to learning networks. First, learning networks must be able to incorporate new (and potentially valuable) knowledge into a coordinated network "core," and this core must be set up to engage in sharing and inquiry that promotes innovation and improvement. Additionally, learning networks must include rules or norms that allow stakeholders to engage in actions that contribute to overall network learning and improvement.

In order to function as a learning network, the network needs a carefully designed and strategically implemented *infrastructure* (also referred to as the "backbone") that coordinates network activities and supports network goals (Kania and Kramer, 2011). A learning network infrastructure should include an intended structure (e.g., What do network stakeholders do and how they do it? What are shared expectations for members?); mechanisms for developing, promoting, and sustaining that structure (e.g., How will members communicate? How will they participate in the network?); and a governance model that facilitates implementation of those mechanisms (Provan, Fish, and Sydow, 2007). Common mechanisms for coordination within networks include

- communications channels (e.g. newsletters, blogs, listservs, online portals, "chats" on social media platforms),
- project and/or member directories,
- convening spaces (in-person or online),
- subgroup structures (e.g. working groups, committees, advisory groups),
- approaches for shared measurement, and
- knowledge bases that capture learning that is beneficial to the whole network (Coburn et al., 2013; Santo et al., 2016).

Developing a learning network's infrastructure is a substantial effort, so it is important to understand why networks should take on the task. Without a clear rationale for why a network is building a collective learning infrastructure, it is unlikely that the network will succeed in its efforts. Table 5-1 lists various rationales for why networks would want to build an infrastructure, and then describes their projected impacts. Of course, these projected impacts are contingent on the nature of the design and implementation of various coordination mechanisms within the network.

The rationales and projected impacts outlined in Table 5-1 do not operate independently of one another. Participation in collective learning infrastructure can lead to greater clarity around collective goals and trust among stakeholders, which support alignment around shared goals, which provides the grounds for innovation and improvement and in turn supports network impact and sustainability. At the same time, collective improvement, innovation, and impact across the network supports clarity around network goals and deeper trust among actors. All of these outcomes can foster willingness of network stakeholders to participate in activities and efforts that constitute the network infrastructure.

The SciAct Portfolio as a Network

As noted in Chapter 3, the existing SciAct Program has elements that align with a number of network types. SciAct might be considered a network of networks in that a number of the awardees themselves represent,

TABLE 5-1 Rationales for Building Infrastructure to Support Collective Learning and Their Projected Impacts

Rationale	Projected Impacts
Clarity	An infrastructure supports greater transparency across network projects. Additionally, an infrastructure helps network stakeholders understand the challenges that exist across the network, as well as the network's shared goals.
Trust	An infrastructure supports deeper relationships among network members that can lead to robust collaborations and honest conversations about challenges and needs.
Alignment	An infrastructure ensures that network stakeholders are oriented toward shared network goals.
Improvement	An infrastructure supports cross-project improvement and rigor through surfacing tacit knowledge and making it explicit; dissemination of existing approaches around shared challenges; and synthesizing effective approaches within the network.
Innovation	An infrastructure supports collaboration and trust (see above), which supports the development of novel and innovative approaches that can solve salient challenges.
Impact	An infrastructure supports clarity, trust, alignment, innovation, and improvement can lead to coordinated practices that support *overall* network impact.
Sustainability	An infrastructure supports clarity, trust, alignment, innovation, and improvement to help network stakeholders articulate a shared understanding of how to do the kind of work on which it focuses. This can enhance the sustainability of the network itself, especially in the face of changes to the landscape of support and resources.

lead, or partner with large networks of organizations and individuals across the country. Also, SciAct acts as a *dissemination network*: SciAct projects mobilize existing NASA Science Mission Directorate (SMD) assets, including subject matter experts, datasets, research findings, sensors, and platforms, so that they can reach broad audiences across the United States. SciAct also acts as an *innovation network*: Projects engage in substantive design and development work in order to transform NASA assets into tools that are useful and relevant for learners, learning environments, and education settings. By developing new approaches to teaching and learning in NASA-related STEM disciplines and circulating those approaches within the context of SciAct projects, SciAct is *both* innovating and disseminating.

The existing innovation and dissemination functions of the SciAct portfolio, however, do not speak to the degree of coordination among the many projects and whether the projects in the portfolio function as a *learning network* (see the preceding section for a description of the characteristics and value of a learning network). The committee found evidence of some level of cross-project coordination and collective learning, most notably in the annual principal investigators (PI) meeting. The PI meeting with all awardees is a 5-day convening that includes a number of activities intended to promote collective learning, collaboration, and capacity building, including:

- sharing ongoing work and approaches taken across projects,
- engaging outside experts in presentations and capacity-building workshops,
- providing opportunities for interest-driven conversations and topical sessions,
- communicating program accomplishments and future directions,
- providing opportunities for strategic planning around network-wide coordinated activities (e.g., 2017 solar eclipse and the 50th anniversary of the Apollo Moon Landing),
- disseminating updates and information from topical working groups meeting with the broader PI group.

Beyond the annual PI meeting, the committee found evidence of additional cross-project sharing and coordination within SciAct. First, SciAct convenes topical working groups where representatives from multiple projects explore issues of shared interest, including Girls in STEM, maker education, educational technology, and use of visualizations in educational programs. Secondly, projects have leveraged major events, such as the 2017 solar eclipse, to coordinate programming, share resources, and aggregate data on reach and impact. Lastly, project stakeholders are able to engage with one another in more open sharing using SciAct's online Web portal, SMDEPO (described in Chapter 3). However, despite these mutually reinforcing activities, the committee did not find evidence that sufficient connections exist to allow for and incentivize optimal sharing across the network. Furthermore, while much of the substantive communication in the network happens at the annual PI meeting and in the topical working groups, it is not clear that all members of the teams are privy to all communications. These limited mechanisms for cross-project communication constrain how much *all* network stakeholders are able to benefit from the information sharing and capacity building. Finally, as mentioned above, SciAct could be considered a network of networks; however, under its current structure, there is untapped potential for leveraging the existing partnerships to tap into and activate the collective reach of the SciAct partners and awardees.

Considerations for Future Planning

As the NASA SciAct Program moves into Phase 2, there is an opportunity to support cross-portfolio innovation and improvement proactively through development of a learning network infrastructure. Currently, projects within the SciAct portfolio can be understood as constituting a *dissemination and innovation network*, insofar as students, teachers, families, life-long learners, and others are able to engage with the educational opportunities offered by the SciAct projects, and the projects are able to transform NASA's assets into useful and relevant educational tools. However, the committee sees potential for SciAct to build on this existing network to become a true *learning network*. In order to do this, however, SciAct would need to develop mechanisms that would (1) facilitate active coordination across projects in order to build knowledge, (2) engage projects and project stakeholders in continuous improvement, and (3) surface challenges and opportunities that lead to deeper outcomes and more robust impacts.

Decisions around what kind of network mechanisms to implement, and at what point, should be contingent on overall network goals. As noted in Chapter 2, the existing SciAct Program goals likely need to become more specific if they are going to be used to guide substantive cross-project learning and improvement through a learning network approach. Until program goals become more targeted and specific, it may be difficult to determine just what kind of network approach and associated infrastructure are appropriate with regard to cross-network learning.

As the committee describes in previous sections of this chapter, building a learning network infrastructure requires a nontrivial investment of resources and capital. While the committee believes that a learning network is one way to share and develop best practices and build capacity, we note that SciAct may not need to devote a full suite of financial and personnel-based resources to achieve all its desired and stated ends. (For the committee's suggestions on how SciAct should design and implement a program model aligned to its vision, see the final chapter of this report.) However, based on SciAct's stated commitment to the network aspect of the portfolio's work, the committee believes it is important to offer considerations for future planning, should the development of a learning network be a priority for Phase 2. Below, the committee offers three possible approaches to establishing collective learning infrastructure for consideration by NASA SciAct staff, and ideally by project stakeholders, as the program moves into Phase 2.

Participatory Knowledge-Building Groups

As evidenced by some topical working groups within the SciAct network, opportunities exist to build collective knowledge through more intentional development of topical collectives that deliberately engage in surfacing, synthesizing, and sharing knowledge related to particular issues. Groups might be organized along a number of lines in terms of topics. For instance, one set of groups might be organized around content and pedagogy (e.g., teaching climate science, doing citizen science, creating inclusive and equitable learning environments) while others might be organized around process (e.g., effective approaches to creating scalable curricula, engaging in community-based partnerships, utilizing formative evaluation data). Groups would then be intentionally structured to surface knowledge from member projects that is applicable across the network (e.g., design principles, tip sheets, practice briefs, measurement repositories).

Developing, facilitating, and sustaining participation in such groups is, of course, a central challenge. One approach could involve cross-portfolio evaluation teams being responsible for these functions, another could involve the development of microgrants that support self-organization and staff time for participation among project members, or both. Most importantly, the knowledge-building process itself is as important as the direct outcomes or "content deliverables" of such groups. It is in the process of participating in knowledge development that understandings across project teams circulate, that trust is built, and that clarity and alignment across projects develop.

Strengthened Infrastructure for Cross-Network Communications

Effectively supporting learning in a network requires careful attention to communication mechanisms and routines. It can be worthwhile for the network to consider how its current communication infrastructure is operating and how it might be improved—for instance, looking at the nature and frequency of in-person cross-network convenings, communications channels (e.g., listservs, portals, project directories), and the possibility of regular, targeted SciAct virtual community calls that would elevate ongoing project approaches and challenges. In general, a key function of such communications infrastructure is to support network projects to "work in the open" (Santo et al., 2016). Open work, drawing on practices from the free/open source software community, includes practices that value transparency, collaboration, and sharing within communities of experimentation. Communications platforms can support practices of "open work," including (1) public storytelling and context setting, (2) rapid prototyping "in the wild," (3) community contribution, (4) public reflection and documentation, and (5) creation of remixable work products and data.

Shared Measurement Infrastructure

A final approach to be considered is the development of shared measurement approaches across the SciAct portfolio. This approach would need to be taken with careful consideration, and, given the complexity of implementing any form of shared measurement across network projects, would require deep knowledge of the nature of projects in terms of approaches taken and where there are in fact shared goals that lend themselves to shared measurement. Shared measurement might be viable at a macro level across all projects. However, it is more likely that supporting improvement and innovation across such varied projects, as is the case for the SciAct portfolio, can be accomplished by identifying subgroups within the portfolio that are similar enough to benefit from shared measurement on inputs and outcomes, and also considering the stage of each project, given that outcomes may be a shifting target in the case of projects that are in the design phase. For more information on this approach, SciAct could consider drawing on models of networked improvement communities that center on the use of shared measurement in service of improving outcomes on highly specified problems of practice (Bryk et al., 2015).

SUMMARY

The committee supports SciAct's continued efforts to broaden participation, and believes attention to making this commitment explicit is an important strategy for SciAct going forward. In the committee's view, the second phase of the SciAct Program is an opportunity to continue its pursuit of diversity, equity, inclusion, and accessibility across the portfolio, and to build upon the existing expertise and experience of the awardees. This phase could also be used to build capacity for successfully attending to broadening participation throughout the network.

Similarly, the committee notes that while there are some limited existing opportunities for sharing, exploring shared interests, and coordinating across projects, SciAct has yet to formally build an infrastructure for supporting collective learning. Phase 2 is a potential opportunity to support the development of a learning network, if that is in fact a desired goal.

CONCLUSION 12: While broadening participation is a stated intention of Science Activation (SciAct), it is not clearly defined nor is there evidence that awardee activities have uniformly had an impact in this area. Integrating goals related to broadening participation throughout SciAct projects would require explicit assessment beyond counting the numbers of participants from various groups.

CONCLUSION 13: The projects that are part of the Science Activation portfolio use a variety of design strategies to translate the National Aeronautics and Space Administration's assets—subject matter experts, media assets, scientific instruments, datasets, etc.—to support learning in science, technology, engineering, and mathematics. However, there

are limited mechanisms for gathering, synthesizing, and sharing these innovations across the portfolio or for learning from cases of success or failure.

CONCLUSION 14: The Science Activation Program is at an important inflection point in its history. The second phase of the program presents an opportunity for iterative improvement and refocusing on both the individual project level and the portfolio as a whole.

CONCLUSION 15: While continuing existing awards may allow for continuity and support an environment of collaboration and partnership among existing awardees, lack of competition or opportunities to fund new projects may stifle the evolution of the portfolio.

6

Recommendations for Science Activation

The committee was charged with two primary tasks: (1) assessing the Science Activation (SciAct) Program's progress toward meeting its four overarching objectives, and (2) offering feedback on improving the SciAct Program. To carry out these tasks, the committee gathered and reviewed evidence from multiple sources, including official documents from SciAct, testimony from SciAct leadership and stakeholders, and online resources for SciAct awardees. Throughout this process, committee members attempted to bring their expertise in their respective fields to bear on their understanding of the current state of SciAct organization and planning. Based on the evidence, its members' expertise, and the conclusions presented throughout this report, the committee offers, in this chapter, several recommendations for SciAct to consider. We begin this discussion by offering some insight into two areas of possible action for SciAct to consider in advance of Phase 2 of the portfolio: the need to articulate a portfolio-wide logic model and the value and utility of a portfolio-wide evaluator. We then proceed to a discussion of our specific recommendations and, where appropriate, highlight some additional critical considerations for SciAct leadership as it plans for the future.

In the process of formulating its recommendations, the committee was struck by the considerable value of the SciAct portfolio of investments in the national landscape of efforts to support science, technology, engineering, and mathematics (STEM) learning and engagement. The scope and diversity of SciAct projects are reaching a wide swath of learners across the country, and awardees are employing myriad strategies for engaging potential participants. The recommendations offered here are intended to support this good work, so that SciAct can continue to amplify and leverage the assets the National Aeronautics and Space Administration (NASA) has to offer the American public. The committee believes these recommendations, if implemented, will enable SciAct to maximize its contributions at the national and local levels and have an impact on the STEM education ecosystem more broadly.

Before presenting our recommendations, we outline some considerations for midcourse reflection on the program, based on the assessment in Chapters 4 and 5.

CONSIDERATIONS FOR MIDCOURSE PROGRAM REFLECTION

The committee's review of the SciAct Program suggests that there is a natural inflection point for initiating a reflection process as the program transitions from its first phase of funding to the second phase. Such a process can mitigate possible risks associated with a noncompetitive cycle of funding and provide an opportunity for midcourse corrections on the part of individual projects and the program as a whole. The current articulated SciAct objectives can serve as a north star for the program, driving the program's overall direction; however, as discussed in Chapter 2, the grain size of these goals is too large to facilitate a useful, constructive assessment of the program's overall impact, the individual awardees' progress, the potential design changes that could improve individual projects' effectiveness, and the SciAct Program overall.

Articulating a Logic Model

A well-articulated logic model informs the design, planning, implementation, and evaluation of programs, from small projects to large and complex initiatives such as SciAct. Moreover, it can be an extremely effective tool for facilitating the kind of reflection in which SciAct might engage in at this point in its life cycle. As we discussed in Chapter 3, logic models are a common way to illustrate the linkages among program goals, objectives, and activities. For the overall SciAct portfolio, a logic model can serve as a guide for *both* planning and designing the portfolio, as well as a tool for assessing the effectiveness of the portfolio and the role of individual projects in achieving high-level goals and long-term impacts. Further, developing a program's logic model, when done jointly by all stakeholders, including program leaders, evaluators, and participants, creates a common understanding of:

- how change will occur,
- what resources are required,

- how roles and responsibilities are distributed,
- what assumptions are at play,
- what organizational and contextual factors must be attended to, and
- what indicators will be used to assess the extent to which measurable outcomes have been achieved.

This process can sometimes cause frustration when it is perceived as "taking time to think," which takes time away from "doing the work," (Reisman and Gienapp, 2004), but without a clear explication of the steps toward the intended outcomes, it is difficult to determine whether outcomes have been achieved, and, importantly, where and how to improve. Moreover, engaging all stakeholders in the process, especially program participants, is another mechanism for broadening participation in its full meaning: diversity, equity, inclusivity, and accessibility.

For a program as complex as SciAct, where multiple awardees are operating projects that are driven by their own understanding of how they believe their work will achieve desired outcomes, developing a shared portfolio-level logic model offers an opportunity to understand the breadth and depth of SciAct in a concrete way, a device for comparing and aggregating outcomes, and a tool for identifying common challenges and potential solutions (Morariu, 2012). The logic model presented in Chapter 3 more closely reflects the underlying relationships among the inputs, activities, outputs, short-term outcomes, and long-term impacts of the SciAct Program. Additionally, the logic model invites discussion of the ways in which the program is functioning as expected, where it can be strengthened, and the degree to which it is achieving its goals. Owing to being too general, the current model in use by SciAct has limited capacity to provide this type of evaluative feedback.

As noted in Chapter 4, however, individual awardees can also benefit from more clearly articulating how they believe their projects will achieve desired learning outcomes—in effect, developing their own, project-specific logic models. Individual awardee logic models would necessarily look different, as awardees are using a panoply of different interventions to achieve different immediate outcomes, but they should all be designed in pursuit of shared high-level goals and long-term impacts. A process for engaging awardees in articulating their own logic models would include the following five stages (ActKnowledge and Aspen Institute Roundtable on Community Change, 2004):

1. Identifying Goals and Assumptions
   Identify clear, concrete, and measurable goals, and identify the preconditions necessary to achieve their goals.

2. Backwards Mapping and Connecting Outcomes
   Sometimes root cause analysis or levels of change, in this stage the steps needed to arrive at the specified outcomes are clearly spelled out, in particular defining the expectations, assumptions, and features of the change process.
3. Developing Indicators
   Determine how to measure the implementation and effectiveness of the initiative, e.g., who is changing, how many are expected to succeed, how much of a change is intended, and how long this change process should take.
4. Identifying Interventions
   Determine what activities will enable the change process identified in Step 2 to achieve the desired goals as defined by the indicators.
5. Writing the Narrative
   This final step translates the initiative from the logic model into ordinary language. This clarifies understanding and highlights the most important components.

Though briefly described, it is possible to see how engaging in the exercise of articulating a logic model could create opportunities to understand and improve awardees' projects, as well as the SciAct Program, while at the same time laying the groundwork for a comprehensive approach to program evaluation.

Value and Utility of a Portfolio-Level Evaluation

Currently, each SciAct project includes an evaluation team that can support learning and improvement within that individual project. While these individual project evaluators are tasked with characterizing the linkages between project outputs and short-term outcomes, because the current SciAct objectives are so broad, it is nearly impossible for evaluators to draw a line between the awards and portfolio's objectives. Despite this challenge, the committee heard from evaluators who are eager to contribute to a more comprehensive understanding of the portfolio's collective impact. As a result, the committee believes it is important for SciAct to consider the value and utility of a cross-portfolio evaluation.

An ongoing portfolio-level evaluation and assessment team could address a range of goals, including but not limited to:

- deepening understanding of how individual projects are aligning with SciAct goals;
- improving portfolio-level coherence throughout all stages of project planning, implementation, and assessment;

- surfacing unique and promising trends within the portfolio;
- identifying areas for improvement on a continual basis;
- representing one mechanism for feedback between SciAct network members and SciAct leadership;
- developing potential models for understanding SciAct's impact;
- directly facilitating participation routines across the network that support participatory knowledge building, problem and goal identification, and impact assessment approaches.

The independent evaluators that are part of the current portfolio mean that substantial cross-disciplinary expertise is present in the portfolio. The presence of NASA scientists, educational designers, community-based education organizations, and education experts in the form of program evaluators also represents a significant opportunity for coordinated learning and improvement across projects. Capitalizing on these existing resources offers one pathway into ossifying connections across individual projects as well as quantifying portfolio impact.

A Pathway Forward for a Logic Model and Evaluation

As mentioned in Chapter 2, the committee believes that the current four SciAct objectives are more appropriate for informing a vision for the program. A vision is "an aspirational description of what the organization would like to achieve in the mid- or long-term" (Business Dictionary, 2019). Thus, if SciAct's current objectives became the vision, and another set of overarching goals and objectives that are more specific to SciAct's logic model were developed, the program would have a touchpoint that could support collective progress (i.e., providing a basis for understanding progress and for sharing advances throughout the network). In their present form, one advantage of the current objectives is that they are sufficiently high level, such that all of the projects can address them in some way. Another advantage is that these objectives enjoy widespread support across multiple sectors and stakeholder groups, and these advantages would be retained even if the four objectives were to be elevated to the portfolio's vision.

A mid-level set of program goals and objectives that are actionable, measurable, and feasible given the scope of the SciAct resources, and are aligned with individual project goals will support better collaboration and program reporting. Currently, project evaluation plans try to align individual projects' desired outcomes with the four SciAct objectives. With this approach to evaluation, it is not possible for the program to synthesize actual impacts across the program, except to discuss numbers of people served. Establishing a mid-level set of overarching goals and objectives will provide a basis for discussing impacts as a whole.

Helping the network to adjust to new mid-level goals and an articulated logic model might benefit from the vantage point of a program-wide evaluator. A program evaluator would work across all of the projects to gather and synthesize data to inform the program, to suggest improvements, and to define impact. Awardees have articulated that an overall evaluation must be strategic in order to be useful rather than burdensome. The current project evaluators are working in a group to share practices and to understand the opportunities to move the whole program forward. Those who are doing this work are providing a valuable service to the program, but they are also constrained by the extent to which this program-level effort is supported within their individual projects.

The committee also acknowledges that a robust portfolio-level evaluation would require a substantial allocation of new resources, and for that reason, the committee stops short of explicitly recommending that SciAct pursue that investment in full. However, because of the potential benefits described, the committee believes that SciAct needs to weigh its utility against its associated financial and personnel-based costs. In Recommendation 7 below, the committee offers suggestions for how the SciAct portfolio could pursue immediate, real-time feedback.

RECOMMENDATIONS

The committee offers the following recommendations to Science Activation. Where appropriate, the committee follows these recommendations with additional critical considerations that SciAct leadership should attend to as it plans for the future.

> **RECOMMENDATION 1: Science Activation (SciAct) should go through a visioning process that brings the portfolio up to date with current research on learning and design, the new federal science, technology, engineering, and mathematics (STEM) plan, and evidence-based approaches to broadening participation. This process should also consider how SciAct fits within and contributes to the larger STEM education ecosystem and should provide the foundation for developing actionable and measureable portfolio goals.**

As described earlier in this report, the committee finds that NASA, and SciAct in particular, have a unique role to play in the STEM education landscape in the United States, especially given the tremendous value of NASA's assets. However, because the four overarching objectives of SciAct in their current form are broad, it is difficult to know exactly what part of this STEM education landscape SciAct hopes to represent and impact. Evidence presented to the committee suggests that SciAct also hopes to pursue ancillary goals that are not formally captured in its current high-level objectives, such as broadening participation in STEM, which is also a priority area in the current national agenda for STEM education (National Science and Technology Council, 2018). If these are goals of the portfolio, they need to be stated explicitly.

The visioning process we propose would allow the SciAct Program to clarify its role in the STEM education landscape; articulate the specific contributions the program can make in the larger STEM ecosystem; and identify a set of actionable, measurable goals for the portfolio.

RECOMMENDATION 2: Science Activation should articulate how it expects the portfolio will leverage National Aeronautics and Space Administration assets, how partnerships and networks will be built, and how these actions will lead to desired, measurable outcomes.

A clearly defined vision and accompanying objectives are not sufficient conditions for knowing whether or not the work of the SciAct portfolio is progressing toward specific aims. To make claims about progress, SciAct needs to thoroughly describe how it expects the work of its awardees to aggregate toward its objectives for the portfolio. As noted earlier in this chapter, developing a well-articulated logic model is a common approach for specifying how program activities lead to specific outcomes and objectives. To this end, it is necessary to think carefully about what mechanisms need to be in place to help ensure that NASA's assets are accessed and utilized by awardees effectively, as well as what tools and scaffolds are available to support awardees' attempts to build partnerships both in their communities and across awards. What, exactly, does SciAct expect to happen in the interactions between NASA assets and awardees, and how can the program's design and implementation achieve specific targets? Upon completion of a logic model, it should be clear how SciAct expects the work of its portfolio (both collectively and through individual projects) to make measurable progress toward the program's desired outcomes and objectives.

Critical Considerations for Recommendations 1 and 2. In the process of clarifying its vision, objectives, and portfolio logic, SciAct can make use of contemporary frameworks for the development of STEM learning ecosystems, as described in Chapter 4. Because SciAct awards are already integrated into the national STEM education landscape, it may be worthwhile to consider how to foreground strategies that connect learning across formal and informal education settings. These strategies are particularly valuable when they are successful in connecting in-school and out-of-school STEM learning experiences for youth in grades K–12. To the extent that SciAct can learn from practices being used by others to connect informal and formal learning, the program may find itself better positioned to leverage its work in ways that are more broadly impactful.

Additionally, in the process of clarifying its vision, objectives, and portfolio logic, SciAct may want to consider consistency of language across all portfolio materials, including its Cooperative Agreement Notice, evaluation guidance documents, and project plans. As discussed in Chapter 5, clarity on what constitutes a goal of the portfolio versus a specific, measurable objective toward that goal will help awardees focus both the design and implementation of their awards.

RECOMMENDATION 3: Science Activation (SciAct) must consider whether the development of a coordinated learning network of awardees across its portfolio is a program priority. If it is a priority, then the program must provide the necessary infrastructure to support a more active network of projects. At the very least, SciAct needs to develop more systematic mechanisms for projects to share best practices and learn from successes and failures.

Throughout this study, the committee heard testimony that a strength of the SciAct portfolio is that it has created an opportunity for awardees to learn from and share with one another. Though this opportunity has the potential to enhance the impact of SciAct, the portfolio of awards cannot be expected to function as a network unless specific scaffolds are built into the supporting structure of the portfolio. For example, offering a space to collaborate is not enough to ensure that collaboration occurs.

In its review of the evidence, the committee was struck by how important it is for awardees to be able to learn from one another's work, and we believe that the efficacy of both the overall portfolio and individual projects could be improved if awardees were offered incentives to and structures within which to collaborate. As described in Chapter 5, different kinds of networks function in different ways and require different kinds of supports. As part of delineating a more highly specified logic model (see Recommendations 1 and 2), SciAct should consider what kind of network would be most effective for helping to achieve the program's objectives, and then take steps to build in the appropriate supports.

RECOMMENDATION 4: Science Activation should use the opportunity provided by Phase 2 to reflect on the current portfolio within the context of the new vision, goals, and logic model. This process should critically review and guide existing projects, be explicit about the rationale and criteria for including new projects, and consider how best to integrate them into the existing portfolio. One important area for consideration is how to ensure that underserved communities receive more focused attention in the next phase of the program.

As stated in Conclusion 15 in Chapter 5, "while continuing existing awards may allow for continuity and support an environment of collaboration and partnership among existing awardees, lack of competition or opportunities to fund new projects may stifle the evolution of the portfolio." Indeed, SciAct is at a critical moment in its history: having made a tremendous shift from the 1 percent model to its current program design, it has succeeded in implementing a first phase of funding that supports a broad diversity of exciting projects. While the committee understands the impulse to continue the current state of funding as is, we believe that continuing these awards without any level of scrutiny could stifle innovation and stagnate progress for both individual awards and the portfolio as a whole. Awardees should be offered an opportunity to engage with clear, updated expectations for their success, and SciAct should consider places where current funding fails to address the needs of specific audiences and should identify a set of consistent selection criteria for new awardee applicants. This process could be undertaken as a community rather than as a top-down assessment process, with project leaders working collectively with SciAct leadership to align project-level design and goals with SciAct's current or re-envisioned overall objectives and logic model.

RECOMMENDATION 5: Science Activation (SciAct) should deepen its commitment to broadening participation by using evaluation measures that go beyond counting numbers of individuals who represent specific groups. In order to do this, SciAct must identify ways that the portfolio as a whole could draw upon and implement evidence-based strategies for broadening participation.

If broadening participation in STEM is indeed one of SciAct's primary objectives, the portfolio needs to specifically consider how it is reaching and engaging underserved communities. As described in Chapter 4, research has demonstrated the value of intentionally attending to the specific learning needs identified by participant communities, so that project participants feel both welcomed and represented. SciAct awardees should be encouraged to identify ways of leveraging the assets their participant communities bring to their participation, and carefully consider issues of representation in the design and implementation of their projects.

Critical Considerations for Recommendation 5. The issue of extending SciAct funding opportunities should be considered in light of the program's priorities around broadening participation. SciAct needs to understand clearly and comprehensively what communities it hopes to reach, why, and how; exactly whom its awardees are already reaching; and how those communities understand their STEM learning and engagement needs. Based on this understanding, SciAct should evaluate the extent to which its portfolio is poised to meet the needs of these communities, and assess whether and how new funding opportunities should be opened to fill specific gaps. The committee notes in particular that despite the considerable reach and resources of minority-serving institutions—and historically black colleges and universities in particular—SciAct has no formal relationships with these institutions.

Specific to supporting the efforts of individual awards in their pursuit of broadening participation, the committee notes that there is a substantial body of literature devoted to providing evidence-based strategies for program designers invested in supporting diversity, inclusion, equity, and accessibility in their projects. Across literatures, several key points emerge that will be important for SciAct to foreground as it supports awardees in these efforts. First, in the design and implementation of their projects, awardees should carefully consider their assumptions about the communities with which they are working, and endeavor to avoid "deficit" thinking when making decisions about engaging with participants, especially as those decisions apply to the work of underrepresented populations (Burgstahler, 2009). SciAct should encourage awardees to actively consider issues of power—and how power differentials may impact participants' experiences and learning—in the design and implementation of their projects, and support projects as they try to minimize power differentials as much as possible (Elmesky and Tobin, 2005). In effect, SciAct should expect that awardees will actively consider the various assets that their target participant populations bring to the table, and attempt to leverage those assets in the design and implementation of their projects (National Academies of Sciences, Engineering, and Medicine, 2018b).

RECOMMENDATION 6: Science Activation should build ongoing opportunities for dialogue with the National Aeronautics and Space Administration Science Mission Directorate's missions and scientists.

There is no doubt that NASA's missions and scientists represent one of its most promising assets for sparking interest in STEM and ensuring that the most current, exciting science makes its way to the American public. However, while it is important that SciAct optimize use of NASA resources, it is also critical to ensure that the appropriate scientific themes are drawn from the missions' work, and that those themes directly support SciAct's science education and learning objectives. The committee finds that SciAct is uniquely poised to capitalize on the opportunities presented by the missions and their scientists, and the transition to Phase 2 of the program provides an opportunity to consider mechanisms for engaging them more effectively.

Because NASA missions occur in real time with cutting-edge technologies and exciting phenomena, they hold the potential to build public enthusiasm for science in tangible, immediate ways. SciAct awardees could benefit from having a mechanism by which to take advantage of these discrete, important moments in time to engage their participant communities. While some of these moments can be planned for in advance, some occur without substantial forewarning. This would likely require that SciAct build into its portfolio flexible funding opportunities that leverage the real-time nature of certain missions.

Additionally, if opportunities to interact with missions in an ongoing way were built into the portfolio, it could help missions understand the science education and learning objectives of SciAct, and scientists could become aware of opportunities to be involved with the program. Because SciAct is committed to meeting the needs of learners, it is critical that NASA scientists understand not only what those needs are, but also how they can and should aim to support those needs.

Critical Considerations for Recommendation 6. If the involvement of mission scientists as subject matter experts (SMEs) continues to be a SciAct priority, SciAct needs to better understand how SMEs are involved in this work. To the extent that SciAct is committed to helping SMEs engage with the public, it needs to ensure that SMEs are engaging in evidence-based practices for communication and education when working directly with participants in SciAct activities. To this end, SciAct leadership and awardees need to fully understand strategies and issues associated with communicating science to the public, and ensure that SMEs who have direct contact with public audiences are effectively trained and supported. SciAct may want to consider how to coordinate its efforts strategically to support SMEs across its entire portfolio.

In order to effectively build an ongoing dialogue between SciAct and SMD missions, it is important to first determine who the appropriate stakeholders are—both at the mission level and within SciAct—who could capitalize on more consistent communication. Once those individuals (or types of individuals) have been identified, these stakeholders will need to determine what type of dialogue would meet everyone's needs most effectively. Several questions will need to be resolved: What should be accomplished through regular communication, and how will SciAct and mission stakeholders know if these things have been achieved? How often and through what channels should stakeholders be in communication? What are strategies that will enable SciAct to leverage exciting, unplanned discoveries or events to support the ongoing work of awardees? The committee suggests one mechanism for helping SciAct address these questions in Recommendation 7 below.

As the committee synthesized the evidence for this study, it became clear that one challenge facing SciAct is the potential friction between its twin ambitions of (1) optimizing NASA's assets and (2) meeting the learning needs of local communities. While it is certainly possible that NASA's existing assets may map perfectly to what communities need to support learning, this is by no means guaranteed. Indeed, it is the job of awardees to translate these assets into resources and experiences that address the needs of their participants. In doing so, however, awardees will likely need to make choices as to what to prioritize as they design and implement their projects. The committee believes that by building ongoing opportunities for dialogue with NASA's missions and scientists, SciAct will be better positioned to balance the potential tension of pursuing these two aims.

> **RECOMMENDATION 7: Science Activation should create an independent mechanism to obtain ongoing, real-time advice from individuals with expertise in learning and design, the larger policy context of science, technology, engineering, and mathematics (STEM) education, partnering with local communities, broadening participation in STEM, and science content relevant to the missions of the National Aeronautics and Space Administration Science Mission Directorate. Among other responsibilities, these experts should inform the new visioning and planning process.**

The committee recognizes the considerable effort that has gone into transforming SciAct into the impressive portfolio of awards that it is today. To sustain and expand this progress, SciAct should create a mechanism to obtain ongoing, expert input so that portfolio strategy can be informed by trustworthy, real-time feedback. Such a group would be able to assist SciAct leadership as it plans for the next phase of funding, but would also be available to advise around more immediate design and implementation issues.

Critical Considerations for Recommendation 7. The committee is sympathetic to the fact that the SciAct team is accomplishing a tremendous amount with a small staff. Drawing on outside expertise is an important strategy for supplementing, enhancing, and clarifying the goals and objectives of the SciAct portfolio. Independent advisors bring expertise that can help with the visioning process proposed in Recommendation 1 and the development of the logic model proposed in Recommendation 2, and help situate the distinctive work of SciAct within the larger STEM education ecosystem, which should include federal and state STEM education policy. Further, individuals with specific expertise in the science content relevant to SMD's missions should be able to help SciAct be strategic in its approach to building a mutually beneficial dialogue between SciAct stakeholders and SMD's missions and scientists. The committee notes that there are multiple strategies for how to facilitate obtaining expert feedback of this type, such as the procuring of individual consultants with specialized expertise, engaging a set of active awardees and project-level evaluators, or forming an independent group of relevant experts.

RECOMMENDATION 7a: With input from these experts, Science Activation (SciAct) should consider whether and how a portfolio-level evaluation could strengthen the focus of the program and ensure that projects in the portfolio are effectively meeting overarching SciAct Program goals and objectives.

On the issue of a portfolio-level evaluation, ultimate decisions around the SciAct vision and objectives, as well as its logic model, are likely to inform whether or not a portfolio-level evaluation has utility. The committee sees the potential for multiple outcomes here. Based on the vision and objectives identified for SciAct, it is possible that the individual project evaluators could be mobilized to better inform SciAct leadership about the progress of the portfolio. It is also possible that an outside entity could offer clearer insight into whether the portfolio's awards are truly aggregating toward achievement of the portfolio's objectives. In either case, experts that have been engaged in the process of informing the development of SciAct's vision and objectives would be well positioned to determine whether a portfolio-level evaluator would be a valuable investment.

This report represents the committee's best efforts to describe the current state of and best pathways forward for the SciAct portfolio. Based on our understanding of the evidence, we believe that with effort directed at clarifying its vision, objectives, and logic model, the SciAct portfolio can be an invaluable resource in the national effort to support STEM education and engagement. SciAct is uniquely positioned to leverage NASA's considerable assets, and it is our belief that the SciAct portfolio holds tremendous potential for supporting the needs of diverse learners nationwide.

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Appendix A

Science Activation Portfolio

	Project Title	Description	Lead Institution
1	AEROKATS and ROVER Educational Network (AREN)	This project seeks to train the next generation of science and engineering professionals through authentic, experiential learning experiences utilizing NASA technologies and data. Low-cost instrumentation systems (i.e., kite-based AEROKATS and remotely controlled aquatic and land-based ROVERS) will be used for both in-situ and remote sensing measurement activities. The overarching objective of this project is to bring NASA remote sensing and in-situ observation concepts, technology, and data into formal and informal educational settings for learners of all ages and socioeconomic backgrounds.	Wayne County Regional Educational Service Agency (MI)
2	Airborne Astronomy Ambassadors (AAA)	The project seeks to measurably enhance student science learning and STEM engagement in selected school districts via professional development for high school science teachers consisting of: (1) STEM training in astrophysics & planetary science content and pedagogy delivered via Webinars and in-person workshops; (2) a week-long STEM immersion experience at NASA's science research aircraft facility in Palmdale, CA, including participation in research flights on the Stratospheric Observatory for Infrared Astronomy (SOFIA); and (3) follow-through involving Webinars fostering connections with astrophysics and planetary science subject matter experts (SMEs).	SETI Institute (Mountain View, CA)
3	CodeRed: My STEM Mission (Challenger Center)	This project seeks to create and implement a comprehensive educational program focusing on planetary science. It will include five major components: (1) enhancements and implementation of a Mars simulation for students to learn planetary science in a hands-on and project-based environment; (2) planetary science videos and activities in a flipped classroom model; (3) Community Engagement Days to be run at Challenger Learning Centers; (4) creation and implementation of a lunar simulation for students to learn planetary science in a hands-on and project-based environment; and (5) creation and implementation of a Comet simulation for students to learn planetary science in a hands-on and project-based environment. This project is a partnership between NASA, Challenger Learning Centers in 27 states, Science Buddies, STEM Jobs, and the National Institute of Aerospace (NIA).	Challenger Center for Space Science Education (Washington, DC)

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Earth Science	Youth in grades 6–12, undergraduate students, adults (life-long learners)	Digital and experiential science and engineering learning: formal and informal settings	National	6000+ learners participated in the AREN Project STEM experiences; 50+ activities and events were held to promote professional development and AREN training; 5 potential partnerships in development
Cross-Discipline (Astrophysics and Planetary Science)	High school teachers (physics, physical science, earth and space science) and their respective students	Science professional learning: formal settings; science learning (students): formal settings	14 districts in 8 states (California, Georgia, Kentucky, Massachusetts, Nevada, Oklahoma, South Carolina, Texas)	NASA AAA Electromagnetic Spectrum & Multi-wavelength Astronomy High School curriculum reached 3,800 students, 39 teachers, and 7 districts
Space Science	K–12 teachers, and students, parents, and communities	Experiential, problem-based learning: formal, informal, and community settings	National	1,560 Expedition Mars simulations conducted; 39,722 student participants in Expedition Mars simulations; 5 episodes of Let's Launch produced; 15 hands-on classroom lessons to accompany videos; 30 Challenger Learning Centers involved in Community Engagement Days

	Project Title	Description	Lead Institution
4	Demonstration of the Feasibility of Improving Scientific Literacy and Lifelong Learning Through a Just-in-Time Dissemination Process (Scientific Literacy)	This project seeks to build on previous national surveys of civic scientific literacy and information acquisition to provide a set of national baseline measures that will document the current state of public interest in and understanding of science and technology and that will provide programmatic guidance to other projects in SMD. Through a series of annual reports, articles and papers, results will be shared with the other members of the cooperative (Science Activation) and with the broader scientific and educational communities.	University of Michigan, Ann Arbor
5	Enhancements of Astronomy and Earth Science Teaching Using High-Resolution Immersive Environments (Fiske Planetarium)	This project seeks to produce short video features that inform and excite audiences while highlighting NASA missions, and to distribute these to planetariums all over the U.S. in 360-degree (full-dome, surround) format. Additionally, the goals of this project include supporting a large and diverse audience in increasing their knowledge of how space and NASA affect their lives, inspiring students from a variety of backgrounds to recognize opportunities to pursue science as an interest or a career, and inspiring audiences to appreciate the beauty and wonder of space and the discoveries presented.	University of Colorado Boulder
6	Heliophysics Education Consortium: Through the Eyes of NASA to the Hearts and Minds of the Nation	This project seeks to address all areas of space science exploration and discovery for diverse populations in the U.S., specifically through (1) developing and promoting world-class national impact science education programs that engage the nation in meaningful discussions of space science discovery; (2) developing and promoting cutting edge educational technologies and assisting communities in developing new STEM applications using education technology in novel ways—central to this approach is a STEM Innovation Lab; (3) developing and incubating new capabilities and capacity in space science education; (4) sharing extensive resources with the larger NASA science education community to enable and improve existing NASA science education programs; and (5) enabling communication with diverse populations through an extensive network of community special-interest organizations.	NASA Goddard Space Flight Center/NASA Space Science Education Consortium (NSSEC) (Greenbelt, MD)

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Cross-Discipline (Astrophysics, Heliophysics, Earth, and Space Science)	Broader scientific and educational communities; members of Science Activation	Dissemination: formal and informal settings	National	National data were collected in 2016, creating a new baseline measure of civic scientific literacy; data were collected in 2017, with a baseline survey in February and March, a special follow-up survey was conducted immediately after the 2017 solar eclipse, and a third wave of data collection was conducted in October and November
Cross-Discipline (Astrophysics, Heliophysics, Earth, and Space Science)	General public and students of all ages	Digital learning: informal settings	National	Produced and distributed five short videos that highlight NASA missions in 360-degree (full-dome, surround) format for use at planetariums all over the U.S.
Space Science	K–12 and undergraduate students (emphasis on underrepresented groups), citizen scientists, informal educators, general public and NASA SMEs	Digital learning: informal settings	National	20 partnerships established, 263 space science activities developed and deployed; 8,447,314 total participants engaged (8,366,416 of the general public, 25,379 formal and informal educators, 16,818 K–12 students, 198 undergraduate students, 91 graduate students)

	Project Title	Description	Lead Institution
7	Imagine Mars/ NASA Active & Blended Learning Ecosystem (N-ABLE)	This hands-on, STEM-based project seeks to enable students to work with NASA scientists and engineers to imagine and design a community on Mars, and then express their ideas through the arts and humanities, integrating 21st century skills. Students explore their own community and decide which arts, scientific, and cultural elements will be important on Mars. Then, they develop their concepts relating to a future Mars community from an interdisciplinary perspective of arts, sciences, and technology. This project-based, active and blended learning experience challenges and inspires primarily at-risk, low-income students with one of NASA's real-world STEM problems: "How can you create a sustainable human habitat on the planet Mars?"	NASA Jet Propulsion Laboratory (Pasadena, CA)
8	Impacts and Feedbacks of a Warming Arctic: Engaging Learners in STEM Using NASA and GLOBE Assets (Arctic and Earth SIGNs)	This project seeks to provide rich experiences for youth, educators, and community members from rural and indigenous communities in Alaska and beyond to learn about, observe, and act upon locally important climate change issues. Specifically, this project aims to use GLOBE (Global Learning and Observations to Benefit the Environment) citizen science protocols, corresponding NASA satellite data, direct engagement with NASA subject matter experts and NASA Earth Science content, and culturally responsive curriculum to foster STEM learning environments where youth and adults underrepresented in STEM play an active role in understanding climate change and stewardship of climate change influenced by resources in their own community.	University of Alaska, Fairbanks
9	Mission Earth: Fusing GLOBE with NASA Assets to Build Systemic Innovation in STEM Education (GLOBE Mission EARTH)	This project is a systematic embedding of NASA assets into the GLOBE—Global Learning and Observations to Benefit the Environment—program and integrating it into the curricula of schools along the K–12 continuum. It seeks to bring together scientists and science educators to develop a K–12 "Earth as a system" curriculum progression. The curriculum will incorporate design principles that will make it appropriate for all student populations, especially those currently underrepresented in STEM careers. This project also involves working closely with schools to ensure that the innovations take hold, using participant input to improve the products. Finally, working with districts, state educational agencies, and key networks, components of this project will be incorporated into existing professional development infrastructure as a mechanism for replication and dissemination of best practices in STEM education.	The University of Toledo (Toledo, OH)

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Space Science	K–12 students (emphasis on underserved groups) and teachers, communities	Problem-based, active, and blended learning: formal and informal settings	Urban-Los Angeles, CA; Rural-East Texas; Native American Schools: Arizona, Hawaii, New Mexico, and Washington	1,956 youth participants in high-need settings; 26 teachers involved; and 11 SMEs engaged
Earth Science	Pre- and in-service K–12 teachers, informal STEM educators (4-H and others), community members, K–12 youth (with emphasis on rural, indigenous, and underrepresented in STEM youth)	Experiential learning and citizen science: formal and informal settings	Alaska (mainly), Hawaii, Montana, North Dakota, Oregon	415 formal and informal science educators and community members trained; 1,394 students engaged in climate change learning using Arctic and earth SIGNS activities; 6 NASA SMEs connected to 15 classrooms across urban and rural Alaska; 228 students engaged with NASA SMEs
Earth Science	K–12 pre- and in-service teachers, and K–12 students (emphasis on groups under-represented in STEM)	Experiential learning and citizen science: formal settings	California, Michigan, New Jersey, New Mexico, New York, Ohio, Rhode Island, Tennessee	32 partnerships established, 83 SMEs involved; 56 teachers reached through professional development and curricular materials; 130 undergraduate students involved in GLOBE projects (67 are pre-service teachers); 4,308 K–12 students engaged

	Project Title	Description	Lead Institution
10	NASA and WGBH: Bringing the Universe to America's Classrooms	This project seeks to design, develop, and produce dynamic instructional media-based materials infused with NASA SMD content for distribution to millions of educators and students across the U.S. via PBSLearning Media, a free online K–12 digital media library, assuring widespread access, appeal, and impact. In addition to digital resources, this project offers support and engagement opportunities for teachers and students nationally across the K–12 continuum, and seeks to build capacity for NASA SMD to deliver scalable and sustained K–12 STEM education on a national scale. In addition to instructional content, this project seeks to produce professional learning opportunities that meet teachers "where they are," with on-demand, real-time, and interactive products and services to support their instruction and learning.	WGBH Educational Foundation (Boston, MA)
11	NASA Earth Science Education Collaborative (NESEC)	This project seeks to enhance K–12 STEM teaching and learning by creating engaging, meaningful, and authentic STEM experiences and resources that (1) are based on NASA earth science; (2) are tailored to specific audiences based on their needs; (3) as a whole reach diverse learners throughout their lifetimes; and (4) are delivered broadly through strategic partnerships. For instance, participants can collect and use science data to conduct research projects and collaborate with other GLOBE schools and can participate in NASA science by making and submitting environmental observations to GLOBE through an easy to use app. NESEC is a partnership between the Institute for Global Environmental Strategies (IGES) and NASA earth science divisions at three NASA centers: Goddard Space Flight Center, Jet Propulsion Laboratory, and Langley Research Center.	Institute for Global Environmental Strategies (Arlington, VA)

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Cross-Discipline (Astrophysics, Heliophysics, Earth, and Space Science)	K–12 science teachers and students	Digital learning: formal settings; professional learning: formal settings	All 50 states and the District of Columbia	58,453 unique users of resources; 12 resource collections produced and deployed; 7,789 teachers engaged through professional learning opportunities
Earth Science	K–12 teachers and students, citizen scientists	Experiential and digital learning: formal and informal settings	National and international	114,197 created GLOBE Observer accounts; 29,236 citizen scientists have submitted one or more observations; 253,152 total observations submitted; in 2018, 179 U.S. student research projects created based on NESEC offerings: 38 GLOBE student research projects, 136 Girl Scout troops projects, and 5 GLOBE Clouds Junior Research Teams; 77 NASA-funded scientists contributed to NESEC activities

	Project Title	Description	Lead Institution
12	NASA eClips 4D Multi-Dimensional Strategies to Promote Understanding of NASA Science: Design, Develop, Disseminate and Discover	This project involves a multidimensional approach to inspire the next generation of scientists and engineers and to improve student science literacy through evidence-based interventions to confront common misconceptions that students have about science. Project components include research-based peer-to-peer approaches to teaching and learning; student-produced multimedia content; STEM career connections; field-testing within an underserved population; bilingual content development; and a broad dissemination network. NASA eClips is a widely utilized, Web-based STEM literacy and content knowledge provider of multimedia STEM educational products. The suite currently contains 257 videos and 50 resources (educator guides, Guide Lites, and Engineering Design packets).	National Institute of Aerospace Associates (Hampton, VA)
13	NASA SMD Exploration Connection/ Infiniscope	This project seeks to develop next-generation, digital, adaptive learning experiences that are compelling to learners of all ages and use NASA science, visualizations, and SMEs. Infiniscope provides a virtual space to connect learners with cutting-edge exploration experiences that incorporate active, minds-on learning that is motivated by the rational exploration of big questions. Additionally, this project seeks to train a community of educators to create their own adaptive learning experiences that provide feedback and pathways to meet the needs of their individual learners and communities as part of the Infiniscope Teaching Network.	Arizona State University/ Infiniscope (Tempe)
14	NASA Space and Earth Informal Science Education Network (SEISE-Net)	This project leverages an existing network of hundreds of museums to engage audiences across the U.S. in informal and lifelong learning about space and earth sciences. The project is developing and distributing validated STEM educational resources across the Network, including hands-on activity toolkits, small-footprint exhibitions, and professional development resources (including online workshops). Strategic national and local partnerships ensure broad reach to public audiences across the U.S., including geographic areas that are traditionally underserved by STEM learning organizations and populations underrepresented in STEM fields. This project utilizes NASA SMEs, SMD assets and data, and existing educational products and online portals to create compelling learning experiences where various audiences can experience earth and space phenomena and explore scientific discoveries.	Arizona State University/ SEISE Net (St. Paul, MN)

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Cross-Discipline (Astrophysics, Heliophysics, Earth, and Space Science)	K–12 teachers and students	Digital learning: formal and informal settings	National (with global access)	53 Spotlite videos created with 228 students and 7 teachers participating; 7 Spotlite interactive lessons developed with 14 teachers trained and 945 students reached; 4,450 students, teachers and public reached through 8 regional and national conferences and 18 local outreach events; 2 sites created (eClips Website and YouTube Channel), 19 new resources added, 966,643 total Web views
Space Science	General public; K–12 teachers, students in grades 5–12, undergraduate students	Digital learning: formal and informal settings	National	12 Infiniscope digital learning experiences developed, 1,301 educators (located in 48 states) participated in Infiniscope Digital Teaching Network, 14,765 total lessons used
Cross-Discipline (Astrophysics, Heliophysics, Earth, and Space Science)	General public (ages 4–adults) and STEM educators	Experiential and digital learning: informal settings	All 50 states and the District of Columbia, Puerto Rico	500 toolkits distributed to institutions (museums, planetariums, NASA visitor centers, colleges), 12,300 event volunteers used toolkits, 1.7M members of the public interacted with toolkits

	Project Title	Description	Lead Institution
15	NASA's Universe of Learning: An Integrated Astrophysics STEM Learning and Literacy Program	This project seeks to engage learners of all ages and backgrounds in exploring the universe for themselves. It utilizes scientists and educators from partner institutions and the broader NASA SMD community to create products, programs, and professional learning experiences that advance STEM learning and literacy on a national scale. The program spans the full spectrum of astrophysics mission science and technology, from cosmic origins, to physics of the cosmos, to exoplanet exploration and seeks to enable educational use of astrophysics mission data; provide participatory experiences; create multimedia and immersive experiences; design exhibits and community programs; provide professional learning experiences for pre-service educators, undergraduate instructors, and informal educators; and produce resources for diverse audiences and needs.	Space Telescope Science Institute (Baltimore, MD)
16	Navigating the Path of Totality	This project seeks to leverage total solar eclipses as platforms for sparking public engagement and learning about the sun, heliophysics, and the STEM content related to both. This public engagement process began with a live Webcast of the 2016 eclipse from Micronesia, followed up with online and video resources, activities, and outreach during the 17 months between the 2016 and 2017 eclipses, and deeper engagement during the 2017 eclipse through live Webcasts, broadcast and social media. To maintain momentum toward the 2024 Mexico/US eclipse, this project also seeks to explore the potential use of the South American eclipses in 2019 and 2020.	Exploratorium (San Francisco, CA)
17	Northwest Earth and Space Sciences Pipeline (NESSP)	This project seeks to create a model network that can serve as a physical NASA educational presence in states without NASA centers, acting as bridge to NASA experiences for middle and high school teachers and students in these regions. Additionally, this project seeks to use NASA-inspired activities and materials to excite and engage students in STEM, and thereby support the movement of these students into careers in STEM fields, specifically those traditionally underrepresented in STEM. Specific project activities include: creating a series of outreach events, extended camps for middle and high schools, and professional development workshops for middle and high school teachers all in the service of providing immersive events based on NASA earth and space science missions that increase the skill level and enthusiasm of teachers and students for STEM.	University of Washington, Seattle

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Astrophysics	Pre-service educators, undergraduate instructors, informal educators, general public, museums, libraries, groups underserved in STEM, program and product developers, planetarium, and communities	Experiential and digital learning: formal and informal settings	National	Over 700,000 views of video products on YouTube; products disseminated by 50+ venues; 40 projects involve SMEs
Space Science	General public, K–12 teachers and students	Digital learning: formal and informal settings	National	7 live eclipse streams, 34 informational videos, 14 distribution platforms, 63M viewers
Cross-Discipline (Earth and Space Science)	Middle and high school students and teachers	Experiential learning: formal and informal settings	Pacific Northwest (Idaho, Montana, Oregon, Washington)	34,400 middle school (MS) and high school students (HS) reached through Outreach Programs; 3,300 students participated in MS and HS camps/academies; 2,400 teachers participated in professional development workshops. At least 50% involvement in underserved or underrepresented communities and at least 50% female participation

	Project Title	Description	Lead Institution
18	OpenSpace: An Engine for Dynamic Visualization of Earth and Space Science for Informal Science and Beyond	This project seeks to develop an open source software, called OpenSpace, for visualizing NASA mission engineering activities and science results for use in informal science institutions (ISIs), along with associated programming and exhibitions for learners of all ages and the general public. This project also seeks to produce digital educational resources for middle and high school teachers and students.	American Museum of Natural History (AMNH) (New York City, NY)
19	PLANETS (Planetary Learning that Advances the Nexus of Engineering, Technology, and Science)	This project is an innovative, collaborative partnership (The Center for Science Teaching and Learning at Northern Arizona University, the U.S. Geological Survey Astrogeology Science Center, and the Museum of Boston) that seeks to develop and disseminate out-of-school time curricular and professional development modules that integrate planetary science, technology, and engineering. Additionally, this project seeks to understand the impact of out-of-school curriculum on student attitudes toward science and engineering and the impact of professional development modules in supporting educators to engage youth in STEM.	Northern Arizona University, Flagstaff
20	Reaching for the Stars: NASA Science for Girl Scouts	This project seeks to inspire and engage girls, ages 5–18, in NASA space science and to enhance STEM experiences for Girl Scouts in grades K–12 though the national Girl Scout Leadership Experience. This includes creating a new sequence of Girl Scout Space Science badges for all program levels; engaging girls and volunteers with the fundamental STEM concepts that underpin our human quest to explore the universe; early and sustained exposure to NASA scientists, NASA assets, and the excitement of NASA's missions; supporting in-depth experiences at astronomy and space camp activities; developing an online Volunteer Tool Kit to provide just-in-time materials and asynchronous learning opportunities for volunteers and leaders; providing authentic train-the-trainer experiences for Girl Scout leaders at NASA centers and observatory; enabling a network of NASA SMEs and astronomy and space science volunteers to connect with and support Girl Scouts; providing interactive learning experiences with NASA SMEs; and developing a long-term relationship with NASA to sustain connections to NASA's STEM professionals and achievements beyond the duration of the project.	SETI Institute/Girl Scouts USA (Mountain View, CA)

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Cross-Discipline (Astrophysics, Heliophysics, Earth, and Space Science)	Informal science institutions (ISI), middle and high school teachers and students, informal educators, general public, citizen scientists, scientific visualization community	Digital learning: formal and informal settings	Global	13 scenes visualizing NASA mission activities in OpenSpace developed, 16 informal science institutions using OpenSpace, 363,854 users of OpenSpace visualizations (236 educators, 33,698 youth, 329,620 museum visitors)
Space Science	Out-of-school educators; out-of-school students in elementary and middle grades	Experiential learning: informal settings	National	2 out-of-school planetary science and engineering modules for middle school students completed, 2,287 downloads in all 50 states + DC, 1,041 youth direct participation (52% underserved), 1,072 educators direct participation
Space Science	Girl Scouts (ages 5–18), Girl Scout USA leaders and volunteers	Experiential and online learning: informal settings	National	Daisy, Brownie and Junior (grades K–5) and Cadette, Senior and Ambassador (grades 6–12) badges and Volunteer Training Kits developed and tested, engaged 194 girls across 24 troops in Phase 1, 657 girls across 75 troops in Phase 2 and 2,472 Daisy, Brownie, and Junior Girl Scouts across 276 troops from 10 Girl Scout councils in Phase 3; Girl Scout Astronomy Destination Camp attended by 10+ girls per year; Girl Scout (GS) Astronomy Club Training at Goddard Space Flight Center attended by 10 teams per year from different Girl Scout Councils

	Project Title	Description	Lead Institution
21	Real World, Real Science: Using NASA Data to Explore Weather and Climate	This project aims to build middle school students' climate and data literacy by allowing them to work with NASA's rich array of earth system data assets in highly engaging ways that are deeply local. As part of a partnership with the Education Development Center, the AAA Lab at Stanford and a group of science centers throughout the Northeast, this project seeks to produce a suite of flexible interactive technology modules that translate NASA's atmosphere and ocean datasets into highly engaging science and mathematics learning experiences for middle school student that bridge informal and formal education settings. This project is also piloting a new program that affords opportunities for students and educators in science institutions and formal learning environments to customize and localize educational materials developed at GMRI such that they are relevant to the participants' regional experiences of weather and climate.	Gulf of Maine Research Institute (GMRI) (Portland)
22	Smoky Mountains STEM Collaborative: Bridging the Gaps in the K–12 to Post-Secondary Education Pathway	This project seeks to expand STEM education opportunities for native Appalachian students in western North Carolina who remain underrepresented in STEM fields as well as in college. Specifically, this project seeks to engage the region's public schools, the Eastern Band of the Cherokee Indians tribal schools, a community college, and a university in a cohesive partnership that leverages NASA SMEs and science centers. Project activities include: undergraduate research opportunities with scientists at the university, the community college, and the Pisgah Astronomical Research Institute; professional development workshops for middle and high school teachers, focusing on incorporating NASA science and aspects of the GLOBE program into science classrooms; orientations sessions on NASA and related STEM educational opportunities and career choices for middle and high school guidance counselors; and community events to provide local opportunities for members of the general community to increase their understanding of scientific principles (e.g., Starry Nights).	Southwestern Community College (Sylva, NC)

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Earth Science	Middle school teachers and students; informal science institution staff	Digital and experiential learning: formal and informal settings	Northeast (New England and New York), but resources available nationally	Developed LabVenture experience for middle school students that uses NASA data; expect 9,000+ Maine students per year to participate at Cohen Center for Interactive Learning
Space Science	Appalachian middle school, high school, and undergraduate students, and the local Appalachian communities	Experiential learning: formal and informal settings	Western North Carolina	Progress made toward integrating NASA content in the grades 6–12 North Carolina STEM curriculum (www.southwesterncc.edu/stem-repository); continued growth of calculus and calculus-based physics courses at Southwestern Community College; 6 teachers from 3 NC counties participated in GLOBE training; 6 community college students participated in summer research projects at Appalachian State University over 3 summers; 370 middle grade students from 4 geographic regions participated in 2018 summer STEM camp

	Project Title	Description	Lead Institution
23	NASA@ My Library: A National Earth and Space Science Initiative that Connects NASA, Public Libraries and their Communities	The overarching goal of this project is to develop effective STEM programs in public libraries using NASA/SMD resources and subject matter experts (SMEs) that reach underserved populations (e.g. rural communities) and underrepresented groups. The project will establish systemic collaborations between the public library community (individual libraries, state libraries, and library associations), informal education organizations, and NASA/SMD people and programs. Components include: STEM program activities, NASA STEM kits, digital learning tools, Patron Experience Pilot development, library/SME training program, community of practice development, and internal evaluation.	National Center for Interactive Learning/ Space Science Institute (Boulder, CO)
24	STEM Enhancement in Earth Science (SEES)	This project seeks to attract and retain students, particularly underrepresented minorities and those from underserved areas, in STEM disciplines by: 1) using NASA's earth-observing satellites as a catalyst for developing an earth science high school course to be offered online; 2) utilizing NASA resources that align with the Framework for K–12 Science Education to support STEM educators and leaders in delivering quality STEM instruction; 3) engaging high school students and teachers in authentic mission-based research that connects to NASA-unique resources in earth science; and 4) enabling NASA scientists and engineers to engage more effectively and efficiently with learners through the implementation of a high school internship program.	University of Texas, Austin

*Reach data were derived mostly from the annual awardee quad charts, and occasionally from the awardee annual reports, which are not necessarily consistent among awardees. In cases where a project had either no quad chart or very incomplete data, the respective annual program plan was used to determine the potential reach of the program's activities.

SMD Discipline	Primary Audiences	Learning: Mode and Setting	Geographic Regions Served	Reach*
Cross-Discipline (Astrophysics, Heliophysics, Earth, and Space Science)	Underserved populations and underserved groups, public library staff, state library agency staff and consultants, library patrons, NASA SMEs	Digital Learning: informal settings	All 50 states and the District of Columbia	Year 1 (2017): 75 libraries (representing all 50 states, 39% from rural communities) participated, 467 total programs occurred at libraries, 85,413 patrons attended programs; Year 2 (2018): 75 libraries, 662 programs, 40,046 patrons attended programs
Earth Science	High school students and their teachers	Experiential and online learning: formal settings	National	116 high school students engaged in NASA-related activities via GLOBE Mosquito Mapper project and SEES

Appendix B

Biographical Sketches of Committee Members and Staff

MARGARET A. HONEY (*Chair*) is the chief executive officer and president of the New York Hall of Science (NYSCI). Among her current interests at NYSCI is the role of design-based learning in promoting student interest and achievement in science, technology, engineering, and mathematics (STEM) subjects. She is widely recognized for her work using digital technologies to support children's learning across the disciplines of STEM. Prior to joining NYSCI, she spent 15 years as vice president of the Education Development Center (EDC) and director of EDC's Center for Children and Technology. While at EDC, she was the architect and overseer of numerous large-scale projects funded by organizations including the National Science Foundation (NSF), the Institute for Education Sciences, the Carnegie Corporation, the Library of Congress, the U.S. Department of Education, and the U.S. Department of Energy. She also co-directed the Northeast and Islands Regional Education Laboratory, which enabled educators, policy makers, and communities to improve schools by helping them leverage the most current research about learning and K–12 education. Dr. Honey has shared what she has learned before Congress, state legislatures, and federal panels, and through numerous articles, chapters, and books. She formerly served as a board member of the National Academies Board on Science Education and currently serves as a member of the Division of Behavioral and Social Sciences and Education's advisory committee. Her book *Design, Make, Play—Growing the Next Generation of STEM Innovators* explores the potential of these strategies for supporting student engagement and deeper learning. She received her Ph.D. in developmental psychology from Columbia University.

NETA A. BAHCALL is the Eugene Higgins professor of astrophysics at Princeton University. She is director of the Undergraduate Program in Astrophysics and past director of the Council on Science and Technology of Princeton University. Her work focuses on galaxies, clusters of galaxies, superclusters, and quasars. She combines observational data from large-scale surveys (such as the Sloan Digital Sky Survey and others) and other observations to determine the structure in the universe and its properties and compares it with those expected from cosmological simulations. Along with her colleagues, the determination of properties such as the cluster correlation function, the cluster mass function and its evolution, the mass-to-light function from galaxies to superclusters, the geometrical shape of clusters and of large-scale structures have provided powerful constraints on cosmology including one of the first determinations of the mass-density of the universe and the amplitude of mass-fluctuations. Dr. Bahcall works closely with students and postdoctoral fellows; their work is summarized in over 300 scientific publications. She is a member of the National Academy of Sciences. She received her Ph.D. from Tel-Aviv University, working in nuclear astrophysics.

BRONWYN BEVAN is senior research scientist at the University of Washington. Her research examines how science learning can be organized to empower individuals and communities. She is the principal investigator (PI) of the NSF-funded Research + Practice Collaboratory, the One Sky Institute, and several other federally and privately funded projects. For over two decades, she worked at the Exploratorium in San Francisco, where she led the teaching and learning, and research on learning programs. She served on the National Academies' Committee on Out-of-School Time STEM Learning and is on the editorial board of the journal *Science Education*. She holds her B.A. in history from Barnard College, Columbia University and received her Ph.D. in urban education from the City University of New York's Graduate Center.

JESSICA COVINGTON is a senior program assistant with the Board on Science Education (BOSE) and is currently supporting the Committee on Assessing the NASA Science Activation Program and the Developmental Math proceedings. Along with assisting on BOSE projects, she also maintains the BOSE Webpage with all the upcoming events and reports. Before joining the DBASSE team, she was the administrative assistant to an architectural and interior design firm in the DC metro area. In 2015, she received her B.S. in psychology from Frostburg State University.

KENNE A. DIBNER (*Study Director*) is a senior program officer with the Board on Science Education. She served as the study director for the

National Academies of Sciences, Engineering, and Medicine's consensus studies *Learning Through Citizen Science: Enhancing Opportunities by Design* and *Science Literacy: Concepts, Contexts, and Consequences,* as well as the deputy director for *Indicators for Monitoring Undergraduate STEM Education.* Prior to this position, she worked as a research associate at Policy Studies Associates, Inc., where she conducted evaluations of education policies and programs for government agencies, foundations, and school districts, including an evaluation of a partnership with the U.S. Department of Education, the National Park Service, and the Bureau of Indian Education to provide citizen science programming to tribal youth. She has also served as a research consultant with the Center on Education Policy and served as a legal intern for the U.S. House of Representatives' Committee on Education and the Workforce. She has a B.A in English literature from Skidmore College and a Ph.D. in education policy from Michigan State University.

WENDY GRAM has worked at the interface of science and education for more than 25 years, publishing in both the scientific research and science learning literature. She is passionate about science, data, and learning, and is committed to engaging diverse audiences in "doing science." As part of the Senior Leadership Team for COMET, a UCAR (University Corporation for Atmospheric Research) education and training program, she leads program management, a team of scientists and instructional designers, and supports business development and proposal management. Prior to joining COMET, she was the lead for Science Engagement and Education for the NSF-funded National Ecological Observatory Network (NEON) for 10 years. Dr. Gram led development, implementation, and evaluation of education and engagement programs and tools to enable the scientific community to effectively discover, access, and use NEON data and resources. As director of science and education at NEON, she also led a team of 60 scientists, technicians, educators, graphic designers, and outreach specialists that executed NEON Science and Engagement activities. Before joining NEON in 2008, she spent 9 years as head of education at the Sam Noble Oklahoma Museum of Natural History at the University of Oklahoma. There, she was a member of the Senior Leadership Team for the museum and led programs that integrated science with educational programming, such as innovative teacher professional development workshops, field courses, K–12 classes, and exhibit development. She holds a B.A. in biology from the University of Pennsylvania and a Ph.D. in ecology and evolution from the University of Missouri.

ROGERS HALL is Wachtmeister professor of mathematics education in the Department of Teaching and Learning, Vanderbilt University. His research concerns learning and teaching in STEM conceptual practices, comparative studies of embodied action in these practices, and the organization and development of representational practices more generally. Before joining the Vanderbilt faculty, where he served as chair of the Department of Teaching and Learning between 2011 and 2017, he taught for 10 years at the University of California (UC), Berkeley. Dr. Hall is a fellow of the American Educational Research Association and has been a residential fellow at the Center for Advanced Study in Behavioral Sciences (Stanford University, 2007–2008), the UC Humanities Research Institute (2001), and the Max Planck Institute for the History of Science (1999). He has also been a NAE/Spencer Foundation and McDonnell Foundation postdoctoral fellow (1996–1997). Dr. Hall completed his Ph.D. in information and computer science at the University of California, Irvine.

ABIGAIL JURIST LEVY is the co-director of EDC's STEM portfolio and a science researcher whose work seeks to understand the conditions, policies, and programs that enable STEM teachers to do their best work preparing all students for continued STEM learning and careers. Her work often focuses on the costs and cost- effectiveness of programs and policies relating to science teaching, and she has contributed to the knowledge base about teacher turnover and its cost, the professional development of science teachers, and the impact of an inquiry-based approach to science teaching. During her tenure at EDC, she has studied science fair participation and impact, the cost and cost-effectiveness of different models of elementary science instruction, and how teachers adapt to large-scale curriculum reform. She is a widely published author and has managed several multiyear research and evaluation studies funded by the National Science Foundation. She holds a Ph.D. in family and children policy from the Heller School for Social Policy and Management, Brandeis University.

CATHRYN A. MANDUCA has nearly two decades of experience leading national programs to improve geoscience education and undergraduate STEM education. She is the director of the Science Education Resource Center (SERC) at Carleton College and the executive director of the National Association of Geoscience Teachers. This work supports communities of educators in learning together and collaborating to create resources supporting widespread improvement. The 30,000+ pages comprising the SERC Websites are seen by more than 5 million visitors per year. Her research focuses on understanding faculty learning and the impact of professional networks on educational practice. She serves on the Board on Science Education and the LabX Advisory Board for the National Academies of Sciences, Engineering, and Medicine and has served on the elected leadership for the American Geophysical Union and AAAS Education Section in the past. She is a fellow of the American Association for the Advancement of Science (AAAS) and Geological Society of America, and past recipient of the American Geophysical Union award for Excellence in Earth and Space Education. She received her B.A. in geology from Williams College and her Ph.D. in geology from the California Institute of Technology.

RAFI SANTO is a learning scientist focused on the intersection of technology, education, equity, and institutional change. He is the principal researcher at Telos Learning and a research associate at CSforALL (Computer Science for ALL Students). Centering his work within research-practice partnerships, he has studied, collaborated with, and facilitated a range of organizational networks related to digital learning and computing education. Within informal education, he has focused on design of innovation networks, working with both regional networks including the Mozilla Hive NYC Learning Network, a collective of 70 informal education organizations, as well as national networks, including the Digital Learning Challenge community supported by the Susan Crown Exchange. His K–12 work with CSforALL looks at how school districts develop equitable, values-driven computer science initiatives. His research on Hacker Literacies has appeared in journals including *International Journal of Learning and Media* and *Digital Culture & Education*, and he is coauthor of a four-volume collection on digital making from MIT Press titled *Interconnections: Understanding Systems through Digital Design*. His scholarship spans multiple levels of activity—from understanding youth trajectories across multiple settings to investigating policy implementation and organizational design—in order to develop practical insights that come from a holistic perspective. He has received support from the National Science Foundation, the Spencer Foundation, the MacArthur Foundation, the Mozilla Foundation, the Susan Crown Exchange, and Google. He received his B.A from New York University and his Ph.D. in learning sciences from Indiana University.

DENNIS SCHATZ is senior advisor at Pacific Science Center in Seattle, Washington, and also senior fellow at the Institute for Learning Innovation. He was the inaugural field editor of *Connected Science Learning*, a journal that highlights links between in-school and out-of-school learning. The journal is a joint effort of NSTA (National Science Teaching Association) and ASTC (Association of Science-Technology Centers). He was recently elected to be president of NSTA, which involves a 3-year commitment—president-elect in 2018–2019, president in 2019–2020, retiring president in 2020–2021. In addition, he is on the board of BSCS Science Learning and a technical advisor to the Smithsonian Science Education Center (SSEC). A research solar astronomer prior to his career in science education, he worked at the Lawrence Hall of Science at the UC, Berkeley, prior to moving to Seattle in 1977. At Pacific Science Center, he has held a broad range of positions from director of the astronomy education in his early years to vice president for exhibits and vice president for education to senior vice president in more recent years. At Pacific Science Center, he served as PI for a number of NSF projects, including the Science Center's innovative Community Leadership project that develops science advocates in community-based organizations, and the nationally touring exhibit, Aliens: Worlds of Possibilities, which explores the nature of the solar system and the search for extraterrestrial life in the galaxy. He was the founding director of Portal to the Public, a nationwide effort to assist science-based professionals to engage with public audiences. He earned a B.S. in physics and astronomy from the University of Wisconsin–Madison and an M.S. in astronomy from the UC, Berkeley.

HEIDI SCHWEINGRUBER (*Board Director*) is the director of the Board on Science Education at the National Academies of Sciences, Engineering, and Medicine. She has served as study director or costudy director for a wide range of studies, including those on revising national standards for K–12 science education, learning and teaching science in grades K–8, and mathematics learning in early childhood. She also coauthored two award-winning books for practitioners that translate findings of the National Academies reports for a broader audience, on using research in K–8 science classrooms and on information science education. Prior to joining the National Academies, she worked as a senior research associate at the Institute of Education Sciences in the U.S. Department of Education. She also served on the faculty of Rice University and as the director of research for the Rice University School Mathematics Project, an outreach program in K–12 mathematics education. She has a Ph.D. in psychology (developmental) and anthropology and a certificate in culture and cognition, both from the University of Michigan.

MARK SHOWALTER is a senior research scientist and fellow at the SETI Institute. His research focuses on the dynamics of rings and small moons in the solar system. Known for his persistence in planetary image analysis, Dr. Showalter's early work with Voyager data led to the discoveries of Jupiter's faint, outer "gossamer" rings and Saturn's tiny ring-moon, Pan. Starting in 2003, his work with the Hubble Space Telescope led to the discoveries of "Mab" and "Cupid," small moons of Uranus now named after characters from Shakespeare's plays. His work also revealed two faint outer rings of dust encircling the planet. In 2011, he initiated a Hubble observing program focused on Pluto, which led to the discoveries of two tiny moons. Their names, "Kerberos" and "Styx," were selected through an international naming campaign. Dr. Showalter also discovered the 14th known moon of Neptune, Hippocamp. He is a co-investigator on NASA's Cassini mission to Saturn and its New Horizons mission to Pluto and beyond. In addition to his research, Dr. Showalter manages the Ring-Moon Systems Node of NASA's Planetary Data System. The site provides public access to images and other data from NASA's Voyager, Galileo, Cassini, and New Horizons missions, from the Hubble Space Telescope, and from a variety of earth-based telescopes. He received his Ph.D. in astronomy from Cornell University.

SUSAN SULLIVAN is the director of diversity and inclusion for Cooperative Institute for Research in Environmental Sciences and focused on bringing awareness to the need for science to serve society, to attract diverse talent, and to develop a culture where all involved can thrive. Her formal training is in atmospheric chemistry, while her primary foci as an educator has been in climate change and climate communications. She was previously the president of the National Association of Geoscience Teachers (NAGT) and has served as PI for multiple NASA grants and has been the education lead for two mission-based project teams in earth and space science. Through her work with NAGT, she has helped build the capacity for the Next Generation Science Standards along with her work through the Digital Library for Earth Systems Education. She received her B.S. in chemistry from California Polytechnic State University and her Ph.D. in analytical chemistry from University of Colorado Boulder.

TIFFANY E. TAYLOR is currently an associate program officer for the Board on Science Education at the National Academies of Sciences, Engineering, and Medicine. In this role, she provides research and planning support for several ongoing projects including the Roundtable on Systemic Change in Undergraduate STEM Education, an expert study to assess the NASA Science Activation Program, and a consensus study on Minority Serving Institutions: America's Underutilized Resource for Strengthening the STEM workforce, in collaboration with the Board on Higher Education and Workforce. She is currently the study director for the Workshop on the Increasing Student Success in Developmental Mathematics, which brought together a variety of stakeholders who have developed and/or implemented new initiatives to improve the mathematics education experience for all students. Taylor came to the National Academies as a Christine Mirzayan Science and Technology Policy Fellow in 2017, where she also worked with the Board on Science Education. She received her bachelor's degree in biology from Howard University and her Ph.D. in biomedical sciences from the University of California, San Diego (UCSD). She is extremely passionate about the inclusion of persons of diverse backgrounds in science, and aspires to leverage her Ph.D. training and science policy experience to address education equity within society in both domestic and global settings.

BRYAN KENT WALLACE serves as a physics faculty member and is the director of physics laboratories at Fisk University. In that capacity, he assumed responsibility for the modernization and instruction in all physics undergraduate laboratories, as well as laboratory curriculum. Under his supervision, the physics laboratories have advanced from partial to full computerization of data collection and received numerous improvements by way of renovation, organization, and utilization of more efficient equipment. He is currently primary investigator for Fisk University's Rocket Science Program, titled Altitude Achievement Missile Team (F.A.A.M.T). This program was built from scratch to compete in a NASA competition known as University Student Launch Initiative, wherein the students design, build, launch, and recover a sounding rocket carrying a scientific payload, which must achieve an altitude of exactly 1 mile. Wallace studies effective mentorship models for university students in science technology engineering and mathematics (STEM) careers as well as engaging in mentoring programs aimed at building self-efficacy in underrepresented populations in K–12. The goal of these efforts is to encouraging them to become full participants in their STEM curriculum and eventually go into STEM-related careers. He holds an Ed.D. in learning organizations and strategic change.

MING-YING WEI retired in 2016 from NASA Headquarters after serving more than 20 years as a program manager in the Earth Science Division of the Science Mission Directorate. Her portfolio included supporting graduate and early-career research in Earth system science with emphasis on the utilization of space-borne observations and resources, as well as promoting the teaching, learning, and public understanding of earth and environmental sciences. She has conducted research at the University of Wisconsin–Madison, and served as a rotator in the Atmospheric Sciences Division at the National Science Foundation. Wei received her Ph.D. in meteorology from the University of Oklahoma.

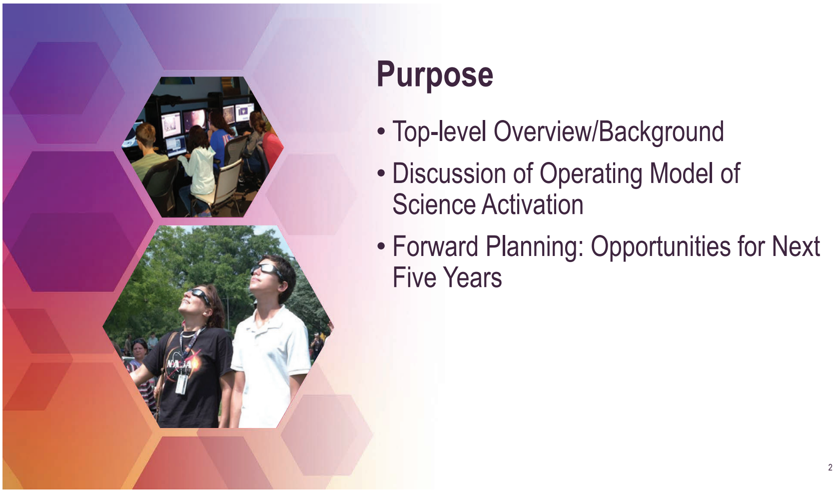
JULIE YU is a senior scientist at the Exploratorium, San Francisco's museum of science, art, and human perception. She provides science content support throughout the museum and works with teachers to bring inquiry-based science learning to their classrooms as part of the Exploratorium's Teacher Institute, a nationally recognized teacher professional learning center. With a broad interest in all sciences, her work and research have spanned from viruses and stem cells to teacher learning and inquiry to concrete and cement. This has led to a myriad of opportunities, including teaching science to Tibetan monks and nuns, launching an explosion of 2,000 ping pong balls, and acquiring a U.S. patent. Yu holds a B.S. in chemical engineering from Brown University and a Ph.D. in chemical engineering with a minor in molecular and cell biology from the University of California, Berkeley.

Appendix C

Kristen Erickson's Presentation to the Committee

NOTE: This appendix is available on The National Academies Press Webpage at http://www.nap.edu/25569.


NASA Science Activation
Presentation to National Academies Assessment Committee
National Aeronautics and Space Administration
NASA
Kristen J. Erickson
Science Engagement & Partnerships Division
Science Mission Directorate, NASA
April 8, 2019
https://science.nasa.gov/learners


Purpose
• Top-level Overview/Background
• Discussion of Operating Model of Science Activation
• Forward Planning: Opportunities for Next Five Years
2

Science Activation Summary

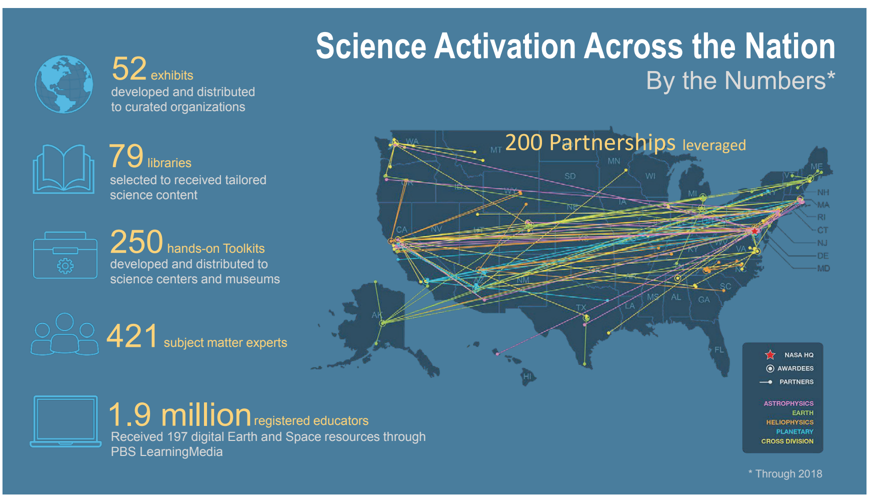
- Baselined in November 2016, a collaborative model leveraging over 200 partnerships through a network of science and community-based institutions using a "multiplier effect" across the U.S. to achieve objectives
- Currently, 24 competitively-selected cooperative agreement awardees enable NASA science experts and content to engage more effectively and efficiently with learners of all ages
- Each agreement uses independent evaluators to validate performance. New community of practice established
- Volunteer networks, such as Solar System Ambassadors and Night Sky Network, mobilized across the U.S.
- Annual SMD funding $45M for Science Activation activities balanced across NASA science disciplines
- In Year 4 of five-year Baseline period. One five-year Option to be exercised beginning 2021

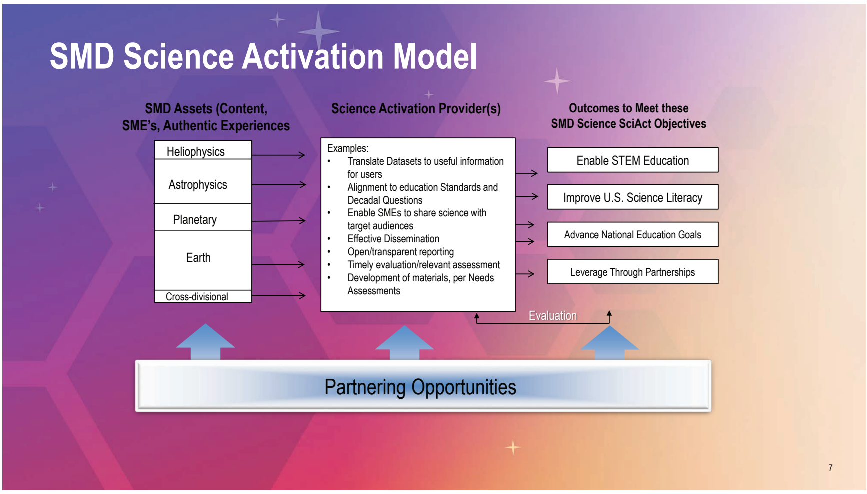
4

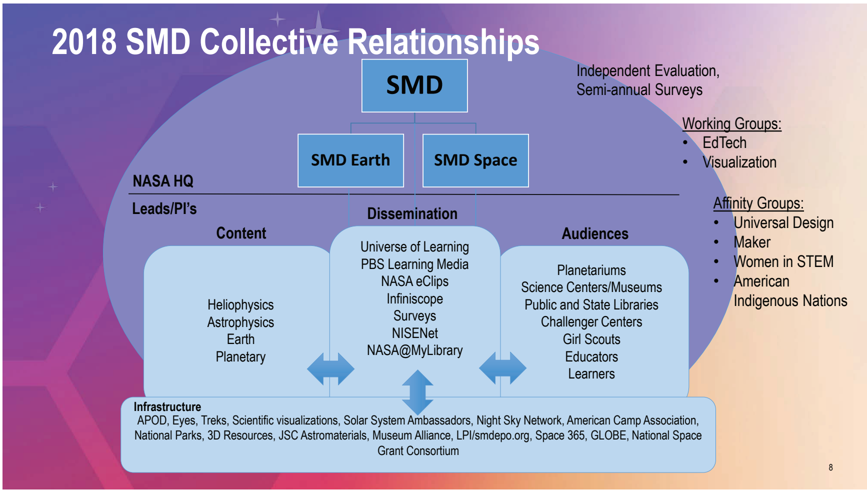
References

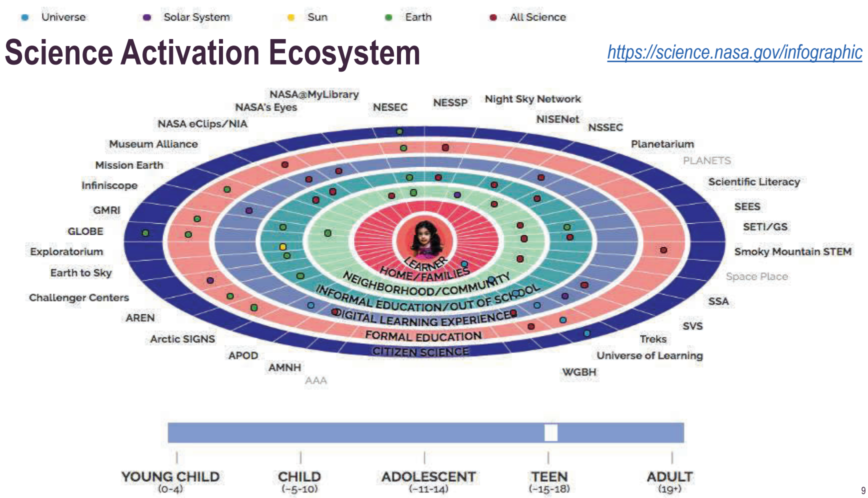
- SMD Decadal Surveys (2010-18)
- A Framework for K–12 Science Education
- Next-Generation Science Standards 2013
- 2013 and 2018 Co-STEM Federal Strategies
- National Science Foundation Science & Engineering Indicators 2014, 2016
- NRC 1996 Scientific Literacy report
- NASA Strategic Plans 2013-2018
- Paperwork Reduction Act (IRBs)
- 2017 American Innovation and Competitiveness Act (P.L. 114-329)

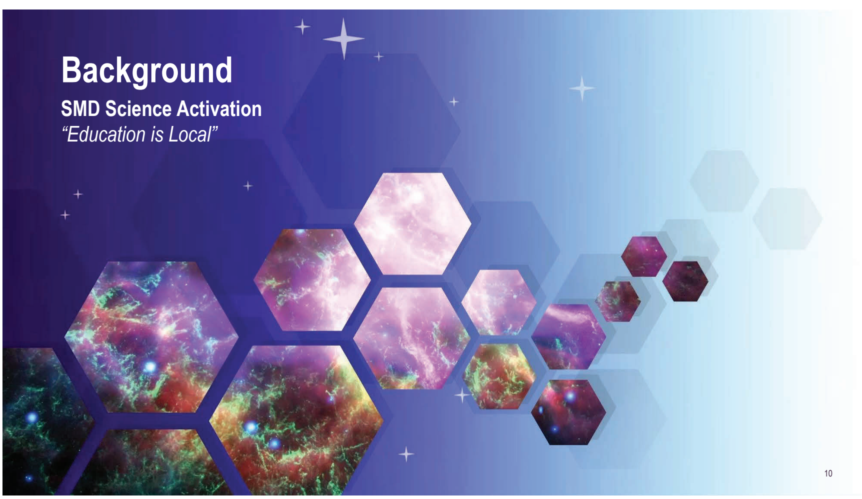
5




SMD Science Activation Model
SMD Assets (Content, SME's, Authentic Experiences
Heliophysics
Astrophysics
Planetary
Earth
Cross-divisional
Science Activation Provider(s)
Examples:
Translate Datasets to useful information for users
Alignment to education Standards and Decadal Questions
Enable SMEs to share science with target audiences
Effective Dissemination
Open/transparent reporting
Timely evaluation/relevant assessment
Development of materials, per Needs Assessments
Outcomes to Meet these SMD Science SciAct Objectives
Enable STEM Education
Improve U.S. Science Literacy
Advance National Education Goals
Leverage Through Partnerships
Evaluation
Partnering Opportunities
7

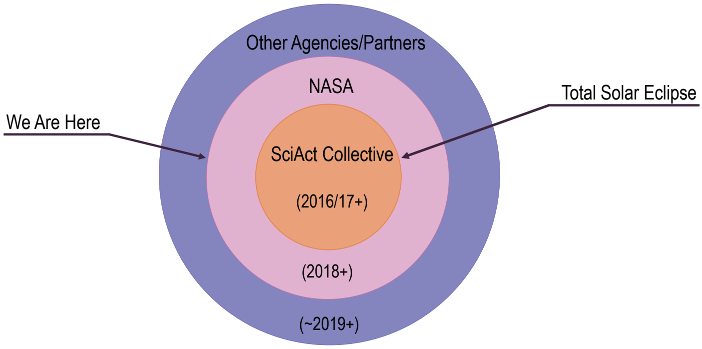

2018 SMD Collective Relationships
SMD
Independent Evaluation, Semi-annual Surveys
SMD Earth
SMD Space
Working Groups:
EdTech
Visualization
NASA HQ
Leads/PI's
Dissemination
Affinity Groups:
Universal Design
Maker
Women in STEM
American Indigenous Nations
Content
Audiences
Universe of Learning
PBS Learning Media
NASA eClips
Infiniscope
Surveys
NISENet
NASA@MyLibrary
Heliophysics
Astrophysics
Earth
Planetary
Planetariums
Science Centers/Museums
Public and State Libraries
Challenger Centers
Girl Scouts
Educators
Learners
Infrastructure
APOD, Eyes, Treks, Scientific visualizations, Solar System Ambassadors, Night Sky Network, American Camp Association, National Parks, 3D Resources, JSC Astromaterials, Museum Alliance, LPI/smdepo.org, Space 365, GLOBE, National Space Grant Consortium
8

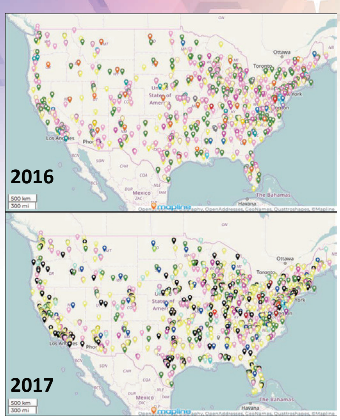

Universe
Solar System
Sun
Earth
All Science
Science Activation Ecosystem
https://science.nasa.gov/infographic
NASA@MyLibrary
NASA's Eyes
NESEC
NESSP
Night Sky Network
NISENet
NSSEC
NASA eClips/NIA
Museum Alliance
Planetarium
PLANETS
Mission Earth
Infiniscope
Scientific Literacy
SEES
GMRI
SETI/GS
GLOBE
Exploratorium
Smoky Mountain STEM
Earth to Sky
Space Place
Challenger Centers
SSA
AREN
SVS
Arctic SIGNS
Treks
APOD
Universe of Learning
AMNH
WGBH
AAA
LEARNER
HOME/FAMILIES
NEIGHBORHOOD/COMMUNITY
INFORMAL EDUCATION/OUT OF SCHOOL
DIGITAL LEARNING EXPERIENCE
FORMAL EDUCATION
CITIZEN SCIENCE
YOUNG CHILD (0-4)
CHILD (~5-10)
ADOLESCENT (~11-14)
TEEN (~15-18)
ADULT (19+)
9


Background
SMD Science Activation
"Education is Local"
10

History and Perspectives

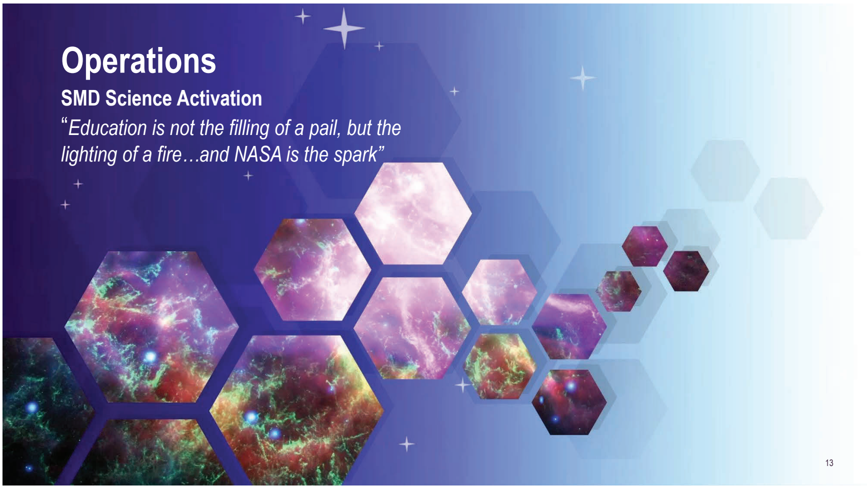
- Baselined in November 2016, this collaborative model enables over 200 partnerships through a network of science and community-based institutions using a “multiplier effect” across the U.S. to achieve Objectives
- Includes a number of digital learning approaches maximizing SMD’s unique capabilities
- Each agreement uses independent evaluators to validate performance





Comparisons

- 27 original awardees, now 24 due to efforts
  - Completed
  - Inconsistent with new SMD policies
  - Non-performance
- Several awards have been augmented
  - Partial selection to full award
  - Expansion
- “Reach” expanded due to Eclipse relationships, building of trust, partnering
- Metrics: 2018 devoted to finalizing agreements’ measures of success, but also cross-mapping to Top-level Objectives



Operations and Management Tools

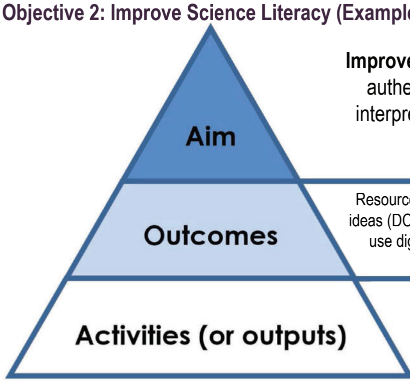
- For Science Activation, our experts, content, and authentic experiences are what we uniquely contribute into the education ecosystem. For stronger connections:
  - New Hotline and mapping tools posted on http://science.nasa.gov/learners
- Tools include Statements of Collaboration between Institutions and SMD Program Officer in each agreement
- Logic Models
- Evaluation Plans, monitored by Independent Evaluators
- Monthly and Annual reporting
- Quarterly Scorecard to PIs
- Working Groups and Affinity Groups
- Face-to-Face sessions. At least one annually
- Internal community site: https://smdepo.org
- Mapping Metrics to Top-Level Objectives
- Examples:
  - Statements of Cross-Collaboration
  - "Triangle" Impact Formats

14

Updated: As of February 2018	182 Agreements	CROSS COLLABORATION MATRIX	SCIENCE ACTIVATION AWARDS																									INFRASTRUCTURE												
Institution	PI	Title	AMNH	AREN	ASU	Challenger Center	Exploratorium	GSFC/NSSEC	IGES	JPL/Mars	Maine/Gulf of Maine Research Institute	NIA	Northern Arizona University	ASU NISE Net	SETI Institute /AAA	SETI Institute /GS	ASP	SCC	Space Science Institute	STScI	U Alaska, Fairbanks	U Colorado, Boulder	U Michigan, Ann Arbor	UTexas Austin	UToledo	U Washington, Seattle	WGBH	Eyes/JPL	Trek/JPL	Night Sky Network	GSFC/Education	Planetary Thematic	SVS	Wave-length	Museum Alliance	Solar System Ambassadors	JSC/Astro materials	Earth to Sky/NPS	GLOBE	TOTALS
American Museum Of Natural History	Kinzler	OpenSpace: An Engine for Dynamic Visualization of Earth and Space Science for Informal Education and Beyond						x			x			x			x			x		x					x	x	x						x					10
AREN/Wayne County Intermediate School District	Bydlowski	AEROKATS and ROVER Education Network (AREN)							x									x			x	x		x	x	x	x				x								x	10
Arizona State University/Infiniscope	Anbar	NASA SMD Exploration Connection						x		x		x	x	x		x		x	x	x	x		x	x		x	x	x	x	x	x		x		x	x		x		22
Challenger Center for Space Science Education	Bush	CodeRed:My STEM Mission								x	x	x	x											x					x					x						7
Exploratorium	Semper	Navigating the Path of Totality												x	x				x								x			x					x					6
Goddard Space Flight Center/NSSEC	Young	Heliophysics Education Consortium: Through the Eyes of NASA to the Hearts and Minds of the Nation	x		x					x	x	x		x		x			x								x	x	x	x	x	x	x		x	x		x	x	19
Institute For Global Environmental Strategies/NESSC	Schwerin	NASA Earth Science Education Collaborative		x								x		x			x		x		x			x	x			x							x			x		11
Jet Propulsion Laboratory/ImagineMars	Viotti	Imagine Mars			x	x		x					x							x							x	x	x						x	x		x		11
Maine/Gulf of Maine Research Institute	Peake	Real World, Real Science: Using NASA Data to Explore Weather and Climate	x			x		x				x		x					x						x		x						x		x					10
National Institute Of Aerospace Associates/NASA eClips	Spears	NASA eClips 4D Multi-Dimensional Strategies to Promote Understanding of NASA Science: Design, Develop, Disseminate and Discover			x	x		x	x		x		x	x	x		x					x				x	x	x	x		x	x			x	x	x	x		20
Northern Arizona University/PLANETS	Clark	PLANETS (Planetary Learning that Advances the Nexus of Engineering, Technology, and Science)			x	x				x		x									x					x	x		x						x			x		10
-ASU/NISENet	Martin	NASA Space and Earth Informal Science Education Network (NISE-Net)	x		x		x	x	x		x	x				x			x	x								x	x	x			x	x	x	x		x		18
SETI Institute/AAA	Backman	Airborne Astronomy Ambassadors (AAA)					x					x								x																x				4
SETI Institute/GS	Harman	Reaching for the Stars: NASA Science for Girl Scouts			x			x						x			x		x	x										x	x				x	x				10
-Astronomical Society of the Pacific (ASP)	Gay	CosmoQuest: Engaging Students & the Public through a Virtual Research Facility	x						x			x				x			x			x					x								x				x	9
Southwestern Community College	Cass	TE: Smoky Mountains STEM Collaborative: Bridging the Gaps in the K-12 to Post-Secondary Education Pathway		x															x									x	x										x	5
Space Science Institute/NASA@My Library	Dusenbery	NASA@ My Library: A National Earth and Space Science Initiative that Connects NASA, Public Libraries and their Communities			x		x	x	x		x			x	x	x	x			x	x	x					x	x	x	x	x	x			x	x	x		x	22
Space Telescope Science Institute/Universe of Learning	Smith	NASA's Universe of Learning: An Integrated Astrophysics STEM Learning and Literacy Program	x		x					x				x	x	x			x				x	x		x	x	x	x	x	x		x	x	x					18
University Of Alaska, Fairbanks	Sparrow	Impacts and feedbacks of a warming Arctic: Engaging learners in STEM using NASA and GLOBE assets		x	x				x				x						x						x			x										x		8
University Of Colorado, Boulder	Duncan	Enhancement of Astronomy and Earth Science Teaching Using High Resolution Immersive Environments	x		x							x					x		x				x						x				x							8
University Of Michigan, Ann Arbor	Miller	Demonstration of the feasibility of improving scientific literacy and lifelong learning through a just-in-time dissemination process			x														x	x		x																		4
University Of Texas, Austin/SEES	Baguio	STEM Enhancement in Earth Science		x	x	x			x											x							x	x	x										x	9
University Of Toledo	Czajkowski	Mission Earth: Fusing GLOBE with NASA Assets to Build Systemic Innovation in STEM Education		x					x		x										x																			4
University Of Washington, Seattle	Winglee	Northwest Earth and Space Sciences Pipeline (NESSP)		x	x							x	x							x																				5
WGBH Educational Foundation	Connolly	NASA and WGBH: Bringing the Universe to America's Classrooms	x	x	x		x	x		x	x	x	x				x		x	x				x				x							x			x		16
TOTALS:			7	7	14	5	4	9	8	6	8	12	7	10	4	6	7	2	14	11	6	6	3	6	4	5	13	13	13	7	7	3	6	3	15	8		9	6	

15

Objective 2: Improve Science Literacy (Example) *https://pbslearningmedia.org/universe*



Improve science literacy by engaging students with authentic scientific practices (i.e., analyzing and interpreting data) in the context of disciplinary core ideas.

Resources address 67% of the 18 "NASA-applicable" science disciplinary core ideas (DCIs) in the national education standards (NGSS). Twenty (20) resources use digital tools developed specifically to enable student engagement with science practices

BUAC resources address NASA-relevant national education standards (NGSS) across two-dimensions; disciplinary core ideas (DCIs) and scientific practices:

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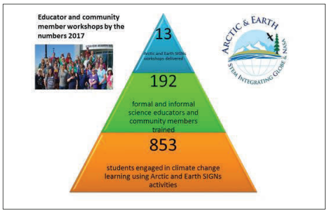
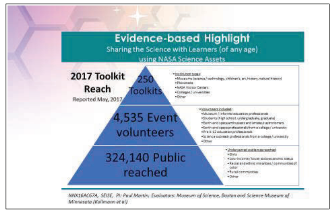
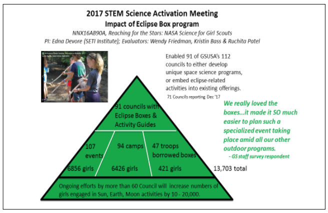
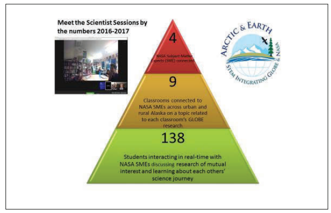
Impact Examples









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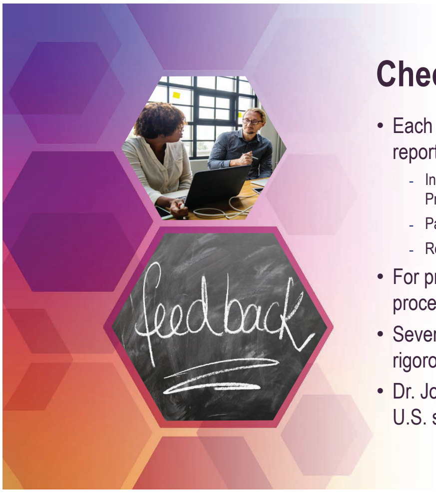
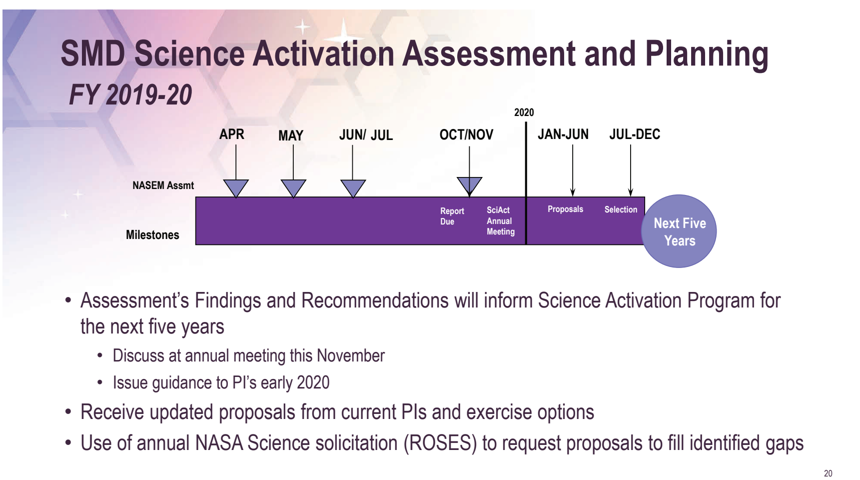


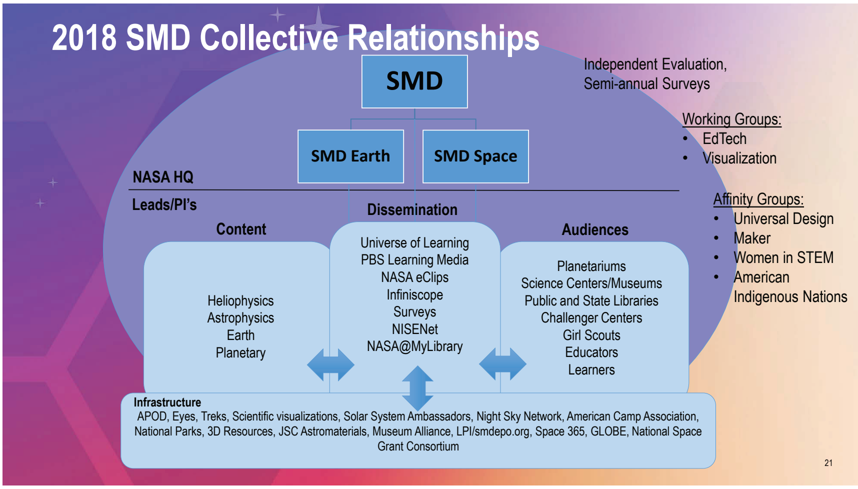
Checks and Balances

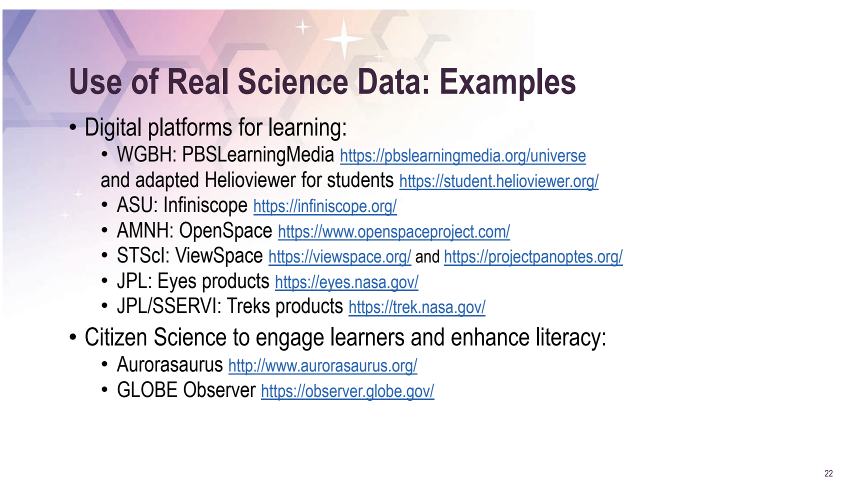
- Each agreement has an Independent Evaluator, reporting to the PI
  - Independent evaluators have developed their own Community of Practice
  - Participate in affinity conferences and SciAct annual meeting
  - Rely on their advice for collective impact across top-line Objectives
- For products, there is a separate independent review process
- Several of the agreements have additional internal, rigorous review processes e.g. NISENet, WGBH
- Dr. Jon Miller/University of Michigan, performs two U.S. surveys annually

18


Forward Planning
SMD Science Activation
"…solving pressing societal issues will require both a scientifically informed citizenry and a robust scientific and technical workforce."
Learning Science Through Computer Games and Simulations, p.22
19


SMD Science Activation Assessment and Planning
FY 2019-20
2020
APR
MAY
JUN/ JUL
OCT/NOV
JAN-JUN
JUL-DEC
NASEM Assmt
Milestones
Report Due
SciAct Annual Meeting
Proposals
Selection
Next Five Years
• Assessment's Findings and Recommendations will inform Science Activation Program for the next five years
• Discuss at annual meeting this November
• Issue guidance to PI's early 2020
• Receive updated proposals from current PIs and exercise options
• Use of annual NASA Science solicitation (ROSES) to request proposals to fill identified gaps
20


2018 SMD Collective Relationships
SMD
SMD Earth
SMD Space
Independent Evaluation, Semi-annual Surveys
Working Groups:
• EdTech
• Visualization
Affinity Groups:
• Universal Design
• Maker
• Women in STEM
• American Indigenous Nations
NASA HQ
Leads/PI's
Content
Heliophysics
Astrophysics
Earth
Planetary
Dissemination
Universe of Learning
PBS Learning Media
NASA eClips
Infiniscope
Surveys
NISENet
NASA@MyLibrary
Audiences
Planetariums
Science Centers/Museums
Public and State Libraries
Challenger Centers
Girl Scouts
Educators
Learners
Infrastructure
APOD, Eyes, Treks, Scientific visualizations, Solar System Ambassadors, Night Sky Network, American Camp Association, National Parks, 3D Resources, JSC Astromaterials, Museum Alliance, LPI/smdepo.org, Space 365, GLOBE, National Space Grant Consortium
21


Use of Real Science Data: Examples
• Digital platforms for learning:
• WGBH: PBSLearningMedia https://pbslearningmedia.org/universe and adapted Helioviewer for students https://student.helioviewer.org/
• ASU: Infiniscope https://infiniscope.org/
• AMNH: OpenSpace https://www.openspaceproject.com/
• STScI: ViewSpace https://viewspace.org/ and https://projectpanoptes.org/
• JPL: Eyes products https://eyes.nasa.gov/
• JPL/SSERVI: Treks products https://trek.nasa.gov/
• Citizen Science to engage learners and enhance literacy:
• Aurorasaurus http://www.aurorasaurus.org/
• GLOBE Observer https://observer.globe.gov/
22

Risks

- Turnover of personnel at all interfaces
- Lack of resources (time, capacity) to work with new interfaces/expand while balancing priority agreement commitments
- Leadership single point failure, flat organization
- Adaptability

Opportunities

- Collective Impact measures across the ecosystem and Nation to include: Rigor (evidence-based, logic model), Scalability, Underserved learners, Evidence of activity in all 50 States (GPRAMA measure), Enhanced SME Connections (GPRAMA measure)
- Total Solar Eclipse in 2024 (U.S.)
- Build upon current relationships for Long-term impact
- Fill gaps in Ecosystem

23

Questions?

- Balancing local needs with a National program, is this model scalable?
- If so, how can we better serve communities and the Nation given our unique assets?
- Further, how can SciAct optimize for the next five years?
- Is a balanced program for Learners of All Ages still optimal or is a more targeted approach recommended?
- Should we invest further in:
  - Homeschoolers
  - EdTech
  - STEM Equity
  - Universal Design for Learning
- Partnering at the Macro/Program level or continue organically at the agreement level?

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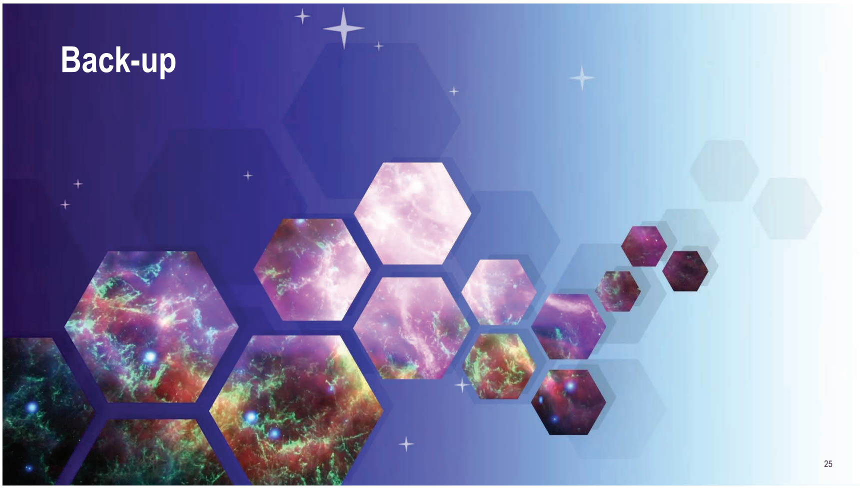

SMD Science Activation Program - Summary

External Assessment

National Academy of Science: Board of Science Education and Space Studies Board

Opportunities

- Enabling of SMD content and experts into additional areas and venues
- Improved coordination across SMD science education
- Reduction in fragmentation and duplication of efforts
- Increased support of targeted audiences based on needs assessments
- Improvement in the understanding of science literacy

Risks/Areas of Concern

- More dynamic education environment post ESSA
- Budget uncertainty until restructuring progress is demonstrated. Need $42M/year to successfully restructure
- Stakeholders disconnecting Science and combining with Education
- Identification of milestones to fill gaps in Formal and Underserved areas

Measurable Achievement

- Progress towards CoSTEM goals by 2020
- Statistical Improvement in applicable S&E Indicators by 2020
- Statistical improvement in scientific literacy surveys by 2020
- Budgets increase reflect progress towards Desired Outcome (Goal is $50M/year by 2020)

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SMD Science Activation Awardees: Cross- Discipline

Space Science Institute – Boulder, CA. Paul Dusenbery, Principal Investigator for "NASA@ My Library: A National Earth and Space Science Initiative that Connects NASA, Public Libraries and their Communities"

University Of Washington, Seattle –Seattle, WA. Robert Winglee, Principal Investigator for "Northwest Earth and Space Sciences Pipeline (NESSP)"

Arizona State University– Saint Paul, MN. Paul Martin, Principal Investigator for "NASA Space and Earth Informal Science Education Network (SEISE-Net)"

University of Michigan, Ann Arbor –Ann Arbor, MI. Jon Miller, Principal Investigator for "Demonstration of the Feasibility of Improving Scientific Literacy and Lifelong Learning through a Just-in-Time Dissemination Process"

University Of Colorado, Boulder – Boulder, CO. Douglas Duncan, Principal Investigator for "Enhancement of Astronomy and Earth Science Teaching Using High Resolution Immersive Environments"

WGBH Educational Foundation – Boston, MA. Rachel Connolly, Principal Investigator for "NASA and WGBH: Bringing the Universe to America's Classrooms"

American Museum of Natural History - New York City, NY. Rosamond Kinzler, Principal Investigator for "OpenSpace: An Engine for Dynamic Visualization of Earth and Space Science for Informal Education and Beyond"

National Institute of Aerospace Associates – Hampton, VA. Shelley Spears, Principal Investigator for "NASA eClips 4D Multi-Dimensional Strategies to Promote Understanding of NASA Science: Design, Develop, Disseminate and Discover"

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Astrophysics – Lead: Hashima Hasan

SETI Institute - Mountain View, CA. Pamela Harman, Principal Investigator for "Reaching for the Stars: NASA Science for Girl Scouts"

SETI Institute –Mountain View, CA. Dana Backman, Principal Investigator for "Airborne Astronomy Ambassadors (AAA)"

Space Telescope Science Institute - Baltimore, MD. Denise Smith, Principal Investigator for "NASA's Universe of Learning: An Integrated Astrophysics STEM Learning and Literacy Program"

Earth Science – Lead: Lin Chambers

Gulf of Maine Research Institute- Portland, ME. Leigh Peake, Principal Investigator for "Real World, Real Science: Using NASA Data to Explore Weather and Climate"

Institute for Global Environmental Strategies –Arlington, VA. Theresa Schwerin, Principal Investigator for "NASA Earth Science Education Collaborative"

University of Alaska, Fairbanks –Fairbanks, AK. Elena Sparrow, Principal Investigator for "Impacts and Feedbacks of a Warming Arctic: Engaging Learners in STEM using NASA and GLOBE Assets"

University of Texas, Austin –Austin, TX. Margaret Baguio, Principal Investigator for "STEM Enhancement in Earth Science"

University of Toledo –Toledo, OH. Kevin Czajkowski, Principal Investigator for "Mission Earth: Fusing GLOBE with NASA Assets to Build Systemic Innovation in STEM Education"

Wayne County Intermediate School District –Wayne, MI. David Bydlowski, Principal Investigator for "AEROKATS and ROVER Education Network (AREN)"

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Space Science – Lead: Hakeem Oluseyi

Arizona State University –Tempe, AZ. Ariel Anbar, Principal Investigator for "NASA SMD Exploration Connection"

Challenger Center for Space Science Education--Washington, DC Denise Kopecky, Principal Investigator for "CodeRed: My STEM Mission"

Jet Propulsion Laboratory –Pasadena, CA. Michelle Viotti, Principal Investigator for "NASA Active and Blended Learning Ecosystem (N-ABLE)"

Northern Arizona University—Flagstaff, AZ. Joelle Clark, Principal Investigator for "PLANETS (Planetary Learning that Advances the Nexus of Engineering, Technology, and Science)"

Exploratorium – San Francisco, CA. Robert Semper, Principal Investigator for "Navigating the Path of Totality"

NASA Goddard Space Flight Center - Greenbelt, MD. C. Alex Young, Principal Investigator for "Heliophysics Education Consortium: Through the Eyes of NASA to the Hearts and Minds of the Nation"

Southwestern Community College –Sylva, NC. Matt Cass, Principal Investigator for "Smoky Mountains STEM Collaborative: Bridging the Gaps in the K-12 to Post-Secondary Education Pathway"

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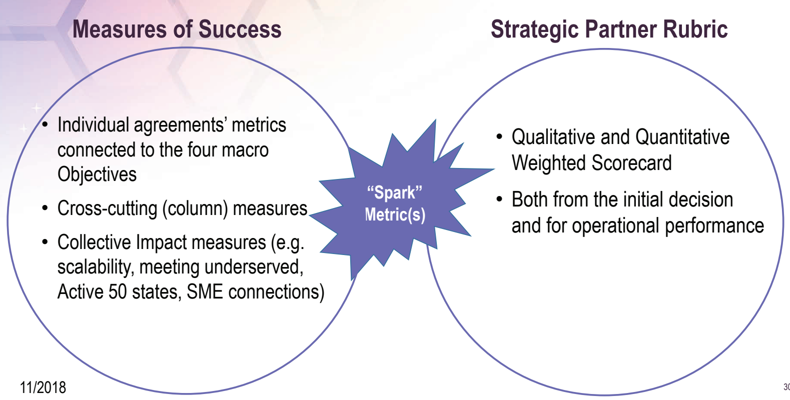
SciAct 2.0 Concept for Discussion



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