PROGRAM EVALUATION AND MONITORING INFORMATION

Evaluations at NSF are currently performed at the discretion of the individual directorate, office, or program being evaluated. This section provides information for each program directorate and office on three principal types of evaluation activities:

- Major external evaluations completed in FY 2021,
- Advisory Committees and Committees of Visitors, and
- Significant workshops related to NSF programs in these areas.

For more information about program evaluation and collection and management of NSF programmatic data, see the Office of Integrative Activities chapter's section on NSF's Evaluation and Assessment Capability.

Major External Evaluations Completed in FY 2021

CISE

Evaluation is a key part of all CISE's education programs. For example, K-12 computer science education projects managed by CISE include rigorous research and evaluation plans designed to guide project progress and measure project impacts. CISE has also funded a third-party evaluation across individual teacher professional development projects at the high school level. The evaluators for these activities meet regularly, discuss evaluation issues, and contribute statistics to a common dataset to track program-level progress. CISE expects to continue these evaluation activities in FY 2023.

EDU

- An evaluation contract for NSF INCLUDES was awarded in September 2021 to assess progress toward leveraging collaborative change strategies to increase diversity and inclusion and broaden participation in STEM fields. The evaluation will identify evidence of successful and promising programmatic efforts and generate recommendations to the program for enhancing measurement and reporting to demonstrate progress. NSF INCLUDES learning agenda questions provided the framework for the evaluation. This evaluation will be extensive and will include specific metrics for assessment of program impacts. While interim deliverables will provide NSF INCLUDES with formative evaluation findings in the base year - and option years, if exercised, final results are expected by end date of FY 2026.
- In FY 2022, the Louis Stokes Alliances for Minority Participation program (LSAMP) will initiate a program evaluation. Evaluation questions will (1) investigate the impact of LSAMP strategies to strengthen STEM pathways and increase undergraduate and graduate STEM degrees from African-Americans, Hispanic-Americans, American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders, students historically underrepresented in STEM, at all educational levels; (2) identify and characterize the organizational structure, governance, and institutional transformation of LSAMP alliances; and, (3) examine the strength of the knowledge base of evidence-based practices and models implemented by LSAMP grantees. Results are expected to be used to assess program impacts and equity gaps at the undergraduate and graduate STEM pathways to contribute to the diversity of the nation's STEM workforce. Final results from this study are expected in FY 2026.
- The LSAMP program conducted a descriptive study (or analytical study) using data collected from the LSAMP monitoring system. The study focused on student participants in the Bridge to the Baccalaureate activity of the LSAMP program and their transfer rate to 4-year institutions and

completion rate of baccalaureate degrees were compared with non-LSAMP students in the same institutions. Final results from this study are expected in FY 2022.

- In FY 2022, the Robert Noyce Teacher Scholarship Program is developing a comprehensive external evaluation plan to assess the efficacy of the program as it relates to the short-term, medium-term, and long-term programmatic outcomes consistent with the Congressional legislation that undergirds the Robert Noyce Teacher Scholarship program. The evaluation will be launched in FY 2023. Results from the study are expected in FY 2025 and will be used to inform solicitation revisions and new track development (as needed).
- In FY 2022, the Improving Undergraduate STEM Education: EDU program is developing a comprehensive external evaluation plan to assess the efficacy of the program as it relates to the short-term, medium-term, and long-term programmatic outcomes. The evaluation will be launched in FY 2023. Results from the study are expected in FY 2025 and will be used to inform solicitation revisions and new track development (as needed).
- In FY 2023 or FY 2024, the National Science Foundation Research Traineeship program plans to initiate a program evaluation. Findings will be used to inform NSF leadership and other stakeholders of progress towards achievement of the program's long-term goals and to inform decision-making related to program development and management.
- In FY 2023, the Innovations in Graduate Education Program plans to initiate a formative and/or developmental evaluation. Results are expected to be used to inform program planning and development.
- An evaluation of the ADVANCE: Organizational Change for Gender Equity in STEM Academic Professions program was performed to investigate the sustainability of ADVANCE grants beyond NSF funding and the diffusion of ADVANCE generated ideas. The report was delivered to the ADVANCE program in FY 2022. The evaluation found that former ADVANCE grantees have had success in sustaining policy changes and institutional structural changes to make the institution more equitable. This report will help determine the next steps that will be taken by the Division.

ENG

- In FY 2019, the Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET) co-funded a three-year study on "New Directions for Chemical Engineering" by the National Academies of Sciences, Engineering, and Medicine (the National Academies). With the goal of identifying opportunities for the profession over the next 10-30 years, the study examines the role chemical engineering will play in the decarbonization of the chemical industries, development of personalized medicines, and creation of a circular economy for plastics and other materials. The final report[1], issued in 2022, will inform investment in chemical engineering research and education.
- In July 2019, NSF initiated an assessment of the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs as required by Congress. An ad hoc committee of the National Academies is conducting the study of the economic and non-economic impacts of the NSF SBIR and STTR programs, drawing on published research and existing data.[2] The committee is also providing guidance to NSF on its outreach strategy to potential SBIR and STTR applicants. The committee's report is anticipated by the end of FY 2022.

[1] https://doi.org/10.17226/26342, National Academies of Sciences, Engineering, and Medicine. 2022. *New Directions for Chemical Engineering*. Washington, DC: The National Academies Press.

[2] www.nationalacademies.org/our-work/review-of-the-small-business-innovation-research-and-small-business-technology-transfer-programs-at-the-national-science-foundation

- In March 2019, NSF made a significant change to the SBIR/STTR proposal submission process, requiring that small businesses or entrepreneurs submit a three-page Project Pitch prior to submitting a full proposal. Pitch submitters learn within a month if their idea aligns with program objectives and receive program guidance. NSF has taken steps to assess the Project Pitch approach relative to the original goals, i.e., to offer real-time assistance to startups, advance the funding process, and accelerate the development of new ventures.
- In FY 2022, the Division of Civil, Mechanical, and Manufacturing Innovation (CMMI) has begun planning for an external study of future needs for the NSF Natural Hazards Engineering Research Infrastructure (NHERI) program after the current round of NHERI facility awards end. The study is intended to be completed in FY 2023 and will inform CMMI decisions on future directions for natural hazards engineering.
- In FY 2023, the Division of Engineering Education and Centers (EEC) is planning to initiate an external evaluation to examine aspects of the Engineering Research Centers program, such as the effectiveness of ERC graduates in industry and the benefits of ERC membership to industry. Findings are expected to help EEC understand the effectiveness of the ERC model in academic environments. Results from this study are expected in FY 2024.

MPS

MPS is leveraging several National Academies surveys and studies in support of program evaluations and studies, including:

- Division of Astronomical Sciences: In late October 2021, "Astro2020" the decadal survey on astronomy and astrophysics was published. The National Academies report "Pathways to Discovery in Astronomy and Astrophysics for the 2020s"[3], spells out the key scientific challenges for the next decade and proposes an ambitious program of ground-based and space-based activities for future investment. It also recommends near-term actions to support the foundations of the profession as well as technologies and tools to carry out the science.

The Division of Physics has two evaluations underway:

- Sponsored by NSF, the "Biological Physics/Physics of Living Systems: A Decadal Survey" is the first National Academies decadal survey of this field. It will survey developments in the field and identify new opportunities to use the tools and techniques of physics to address fundamental questions in living systems. The report[4] is expected to be completed in FY 2022.
- The "Elementary Particle Physics: Progress and Promise" decadal survey[5] will identify the fundamental scientific questions in particle physics that are expected to motivate research in the next decade along with potential new tools and techniques to address them. Jointly sponsored by the NSF and DOE, the survey is expected to be completed in FY 2024.

The Division of Materials Research (DMR) has three evaluations underway:

- In FY 2021, MPS/DMR commissioned a National Academies study[6] of the Designing Materials to Revolutionize and Engineer our Future (DMREF) program to examine its impact on the national Materials Genome Initiative. The study will evaluate the goals, progress, and scientific achievements of the DMREF program within the context of similar efforts both within the United

[3] www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020
[4] www.nationalacademies.org/our-work/biological-physicsphysics-of-living-systems-a-decadal-survey
[5] www.nationalacademies.org/our-work/elementary-particle-physics-progress-and-promise
[6] www8.nationalacademies.org/pa/projectview.aspx?key=52250

States and abroad, and it will provide high-level strategic recommendations for DMREF to take full advantage of opportunities for accelerating the progression of materials research.
- In FY 2022, MPS/DMR plans to commission a National Academies study of ultra-high-field magnet technology and the associated science drivers of the future. The study will be carried out jointly by the Board on Physics and Astronomy and National Materials and Manufacturing Board.
- In FY 2023, MPS/DMR plans to commission a National Academies study of the Materials Research Science and Engineering Centers (MRSEC) Program. Results are expected to inform future directions and the format of the program.

SBE
- In FY 2022, the National Center for Science and Engineering Statistics (NCSES) sponsored a consensus study[7] with the National Academy of Sciences Committee on National Statistics (CNSTAT) related to transparency and reproducibility. NCSES intends to use the recommendations of this study to help shape the Federal Statistical System's approach to transparency and to ultimately strengthen public trust in federal statistics.
- Over FY 2022, NCSES is sponsoring and leading a project[8] to inform the development of a virtual Research Data Center (RDC) for the Federal Statistical RDC system that can be used to inform the decision making of the Interagency Council on Statistical Policy. This study brings together various participants from different federal agencies and academia to NSF to link different data sets, provide training on those linked data sets—while building capacity for researchers and analysts inside and outside the Federal Statistical System.
- Over FY 2022, NCSES is continuing to develop and refine its data governance efforts as outlined in the Evidence Act, the President's Management Agenda, the Federal Data Strategy, and recent OMB guidance.

OIA

In FY 2021 and FY 2022, the following studies and statistics reports were completed:
- *A Comparative Analysis of the International Research Experiences for Undergraduates (IRES) and the Research Experiences for Undergraduates (REU) Programs.* The analysis indicates that both programs contribute to building and diversifying the scientific workforce, varying in the types of activities in which students engage and the types of institutions they attend. The study provided several considerations for strategic decisions to build efficiencies, capitalize knowledge, and further increase the participation of underrepresented groups in STEM.[9]
- *Merit Review Process: Fiscal Year 2020 Digest.*[10] The report's summary statistics are used as indicators of the performance of the merit review process. In FY 2020, NSF saw an increase in proposals, awards, and funding rate, likely driven by the response to the COVID-19 pandemic. When adjusted for inflation, research award sizes across NSF have largely been flat since FY 2011.
- NSF's Evaluation and Assessment Capability group is pursuing evaluations of the Convergence Accelerator (CA) as well as NSF's direct partnerships with the private sector. In the case of the CA evaluation, the goal is to establish and operationalize a thorough set of metrics for grantee selection, training, progress, and outcomes for the full three-year lifecycle of a team progressing through the two phases of the CA. This effort will provide a set of instruments and infrastructure

[7] www.nationalacademies.org/our-work/transparency-and-reproducibility-of-federal-statistics-for-the-national-center-for-science-and-engineering-statistics

[8] https://github.com/Coleridge-Initiative/ada-2021-ncses

[9] This study is expected to be released to the public in March 2022.

[10] www.nsf.gov/nsb/publications/2021/merit_review/FY-2020/nsb202145.pdf

to facilitate detailed and customized evaluation on a consistent basis going forward.

In FY 2022, the following studies are underway and are expected to be influential for decision making:

- *Education and Training Application.*[11] NSF is scaling up testing and adoption of this application that collects robust, high-quality data on applicants and participants in NSF programs. These data are vital for use in monitoring, research, and evaluation, and to promote equity and effectiveness in achieving NSF's mission. Findings are expected in FY 2022.
- *No deadlines literature review and descriptive analyses.* This study will enable NSF to assess the feasibility of conducting a rigorous evaluation of programs that removed proposal submission deadlines and inform decisions regarding next steps in removing deadlines more widely. Findings are expected in FY 2022.
- *Anti-harassment policies.* NSF designed and supported the implementation of an evaluation of its anti-harassment policies to inform learning about their efficacy and consider next steps in expanding the reach of these policies. Preliminary findings were included in NSF's Agency Equity Action Plan (January 2022). Final findings are expected in FY 2022.

OISE

- In FY 2022, OISE will initiate an assessment of the MULTIPLIER program.[12] Results are expected to determine the effectiveness of the MULTIPLIERs as a permanent mechanism for international engagement.
- An evaluation of the IRES was performed by Mathematica to assess participant demographic and background characteristics, program experiences, perceptions of the programs' impact on their professional careers and educational and employment outcomes. The final analysis, delivered to OISE in FY 2021, suggested the IRES program is well aligned with OISE's mission of leveraging international collaborations to advance science. The evaluation concluded with recommendations to encourage participation among underrepresented groups, stimulate participation from institutions with limited research opportunities, and to create a community of practice to promote best practices. The results from this evaluation will inform the next IRES solicitation for release in FY 2022.

OPP

In FY 2022 the National Academies released a Mid-Term Assessment of Progress on the *2015 Strategic Vision for Antarctic and Southern Ocean Research*. The report highlights progress in each of the three priority research areas: changing Antarctic ice sheets, biota evolution and adaption through genomic studies, and the origins of the universe. Opportunities identified in the next five years include greater progress in studying past ice sheet fluctuations, fostering community development to advance understanding of biological adaptations, and strive for improved communication between NSF and the scientific community.

Advisory Committees and Committees of Visitors

Each directorate and office has an external advisory committee that typically meets twice a year to review and provide advice on program management, discuss current issues, and review and provide advice on the impact of policies, programs, and activities in the disciplines and fields encompassed by

[11] nsfetap.org

[12] More information on NSF's Multiplier Program available at www.nsf.gov/od/oise/multiplier.jsp

the directorate or office. In addition to directorate and office advisory committees, NSF is also advised by external committees on specific topics. Recent examples include: biological infrastructure; human resource development; earth sciences; geosciences education programs; and social and economic sciences.

Committees of Visitors (COVs) are subcommittees of NSF directorate advisory committees. COV reviews provide NSF with external expert judgments in two areas: (1) assessments of the quality and integrity of program operations and program-level technical and managerial matters pertaining to proposal decisions; and (2) comments on how the outputs and outcomes generated by awardees have contributed to the attainment of NSF's mission and strategic outcome goals. COV reviews are conducted at regular intervals of approximately four years for programs and offices that recommend or award grants, cooperative agreements, and/or contracts and whose main focus is the conduct or support of NSF research and education in science and engineering. Approximately one-fourth of NSF's divisions are assessed each year.

A COV typically consists of up to 20 external experts, selected to ensure independence, programmatic coverage, and geographic balance. COV members come from academia, industry, government, and the public sector. They meet for two or three days to review and assess program priorities, program management, and award accomplishments or outcomes. Each COV prepares a report and the division or program that is being reviewed must prepare a response to the COV recommendations. These reports and responses are submitted to the parent advisory committee and to the Director of NSF. All reports and responses are public and posted on NSF's website.[13]

In FY 2021, four directorates convened five COVs, covering five divisions. A table of the COVs performed in recent years and planned through FY 2023 is provided on the next page. This chapter also contains information on these COVs, as well as information on *ad hoc* reports.

[13] www.nsf.gov/od/oia/activities/cov/covs.jsp

Table 1 of 2, List of Committees of Visitors Meetings, FY 2016-FY 2023

All: all programs within the division were covered. Some COVs cover only some of a division's programs; these are noted under the FY.

Proj: projected to be completed in the designated FY.

DIR	DIV	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
BIO	Biological Infrastructure					All		
	Environmental Biology			All				Proj
	Integrative Organismal Systems		All				Proj	
	Molecular and Cellular Biosciences		All				Proj	
CISE	Advanced Cyberinfrastructure		All				Proj	
	Computing and Communication Foundations				All			
	Computer and Network Systems				All			
	Information and Intelligent Systems				All			
EDU	EDU Core Research	All						
	Graduate Education						Proj	
	Human Resource Development					All		
	Research on Learning in Formal and Informal Settings				All			
	Undergraduate Education	TUES STEP WIDER IUSE					Proj	
ENG	Chemical, Bioengineering, Environmental and Transport Systems			All				Proj
	Civil, Mechanical and Manufacturing Innovations			All				Proj
	Electrical, Communications and Cyber Systems		All					Proj
	Emerging Frontiers and Multidisciplinary Activities		All				Proj	
	Engineering, Education and Centers				All			
	Industrial Innovation and Partnerships				All			

Table 2 of 2, List of Committees of Visitors Meetings, FY 2016-FY 2023

All: all programs within the division were covered. Some COVs cover only some of a division's programs; these are noted under the FY.

Proj: projected to be completed in the designated FY.

DIR	DIV	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
GEO	Atmospheric and Geospace Sciences		Geospace Section		All			
	Earth Sciences	All				All		
	Ocean Sciences: Integrative		All	All			Proj	
	Ocean Sciences: Research							
	Education and Diversity Programs	All				All		
MPS	Astronomy			All				Proj
	Chemistry				All			
	Materials Research			All	All			Proj
	Mathematical Sciences							
	Physics			All				Proj
SBE	Behavioral and Cognitive Sciences			All				
	Office of Multidisciplinary Activities				All			
	Social and Economic Sciences					All		
OIA	Major Research Infrastructure						Proj	
	Established Program to Stimulate Competitive Research				All			
	STC						Proj	
OISE			All (2)				Proj	
OPP	Antarctic Sciences (ANT)				All			
	Arctic Sciences (ARC)				All			

Committees of Visitors (COV)[14]

BIO: In FY 2021, the Division of Biological Infrastructure COV convened December 15-17 and reviewed division operations and the programmatic portfolio for the five-year period spanning FY 2016 – FY 2020. BIO is evaluating all the COV recommendations and working to include them in future planning activities.

EDU: In November 2020, a COV reviewed the Division of Human Resource Development, (to be renamed the Division of Equity for Excellence in STEM, EES, in FY 2023). The chair of the COV presented the report to the EDU Advisory Committee, which met virtually in May 2021. The COV commended the division for many aspects of its merit review process and program management, including its diverse reviewer pool; high standards regarding the selection of reviewers, conflict-of-interest considerations, confidentiality, and procedures; generally thorough review analyses and panel summaries; and well-balanced award portfolio across disciplines and geography. The COV recommended that the division increase the number of reviewers with experience in evaluation, educational psychology, and related areas; expand efforts to recruit early-career investigators and reviewers; provide additional guidance to reviewers to promote consistency in format and quality throughout reviews and panel summaries; support mentoring and outreach to prospective and active investigators to foster more transformative research and education projects; support research to clearly articulate the role of, and intersectionality between, multiple identities (including race, ethnicity, gender, and disability) in students' STEM success; develop rigorous evidentiary bases and analytic frameworks for evaluation across all division programs; align logic models across programs; and clearly communicate how individual division programs align with the division's strategic plan. The division is addressing the recommendations as it plans future revisions of solicitations and future reviews of proposals in the programs.

GEO: On May 12-13, 2021, a COV reviewed GEO-wide education programs and on June 21-24 a COV reviewed programs in EAR. The COVs presented their reports to the GEO Advisory Committee, which convened in October of 2021. The COVs made a number of observations about the positive impact of the programs under review and made suggestions to improve the utility of program documentation for future committees as well as to broaden the impact of the programs.

SBE: In 2021, a COV assessed the Division of Social and Economic Sciences division's merit review process and presented their report to the SBE Advisory Committee in December 2021. Based on recommendations from the COV regarding the proposal success rate of underrepresented investigator coupled with addressing NSF's goals of diversity, equity, and inclusion; the directorate is evaluating best practices for helping researchers improve their proposals. In addition, the directorate will continue to support SBE's Build and Broaden (B2) program. B2 is designed to increase proposal submissions, advance research collaborations and networks involving Minority Serving Institutions (MSI) scholars, and support research activities at MSIs. Future updates to the solicitation will further target greater MSI participation in research proposals submitted to B2.

OPP: In FY 2020, COVs reviewed the Antarctic and the Arctic programs. The COVs presented their reports to the Office of Polar Programs Advisory Committee (OPP AC), which convened in fall of 2020. The COVs made several recommendations including that OPP, in both polar regions, expand efforts

[14] www.nsf.gov/od/oia/activities/cov/covs.jsp, NSF Committee of Visitors (COV) Reports.

to broaden participation of under-represented individuals (PIs, students, and reviewers) and institutions. OPP provided responses to both 2020 COV reports during the spring 2021 OPP AC. In FY 2022 the OPP AC sub-committee on diversity and inclusion will deliver its report on broadening participation in polar research.

Workshops and Reports

BIO

BIO supported various workshops in FY 2021 that inform planning of the directorate's research programs.

- A workshop entitled "Trans-U.S. Government expert meeting to examine synthetic biology roadmap" was held in October 2019. The workshop, which included attendees across academia, industry, and U.S. government agencies, was convened to examine use cases in the field of synthetic biology and the most pressing basic research, technology, infrastructure, and workforce needs to advance the field. The results of the workshop helped inform the development of the work plan for the Interagency Synthetic Biology Working group as well as agency priorities in this area. An ongoing Dear Colleague Letter in plant synthetic biology, released in FY 2020 and supported by BIO and ENG at NSF, is one early outcome of this activity. In FY 2021, a follow up retreat was held, involving government employees only, to refresh and reprioritize the science needs that will enable the rapid advance of synthetic biology to address societal problems. Priorities included artificial intelligence, infrastructure and sequencing as well as microbial consortia as tools to advance synthetic biology or the products of synthetic biology. In FY 2022, a new partnership between NSF and DOE was launched (Accelerating Innovations in Biomanufacturing Approaches through Collaboration Between NSF and the DOE BETO funded Agile BioFoundry (NSF-DOE/ABF Collaboration), NSF 22-549) to enable access to infrastructure for synthetic biology more broadly in the science community.
- A series of virtual workshops are being held in the spring of 2022 to bring together diverse members of the research community to discuss creative strategies and build new research collaborations aimed at exploring how rules governing genotype-environment-phenotype relationships might be used to address grand challenges facing our society. Expected outcomes are to identify concrete ideas to inform the FY 2023 URoL solicitation based on Using the Rules of Life to Address Societal Challenges; the formation of interdisciplinary teams poised to advance these scientific questions; and insight into the readiness of the broader research community to engage in use-inspired research.

DBI supported multiple workshops in FY 2021 to inform the planning of the division's promotion of open data platforms for the BIO community and to inform future program management.

- As part of award #2027654 ("iDigBio: Sustaining the digitization, mobilization, accessibility, and use of biodiversity specimen data in U.S. museum and academic collections"; PI: Nelson), a workshop was conducted to address issues related to diversity, equity, and inclusion amongst the collections-based research community. The meeting was held on November 30, 2021 and was arranged as a listening session primarily to identify bottlenecks and barriers to participation by MSIs. The workshop was attended by several DBI POs to better engage with attendees and increase understanding of the impediments to their full participation in BIO programs.
- DBI supported a workshop in 2021 entitled "2020 Hackseq RNA Workshop" (award # 2024136). The goal of this workshop was to organize a coding intensive workshop where graduate students, post-docs, and researchers work together to uncover the role of uncharacterized ("dark") regions

of genomes and transcriptomes. In response to COVID pandemic, the workshop was held in a virtual format, with emphasis on supporting activities related to Bioinformatics Grand Challenges.[15] The funds were used in supporting 407 U.S. participants for the online RNA Society Meeting May 25-June 4, 2021.[16] 299 NSF-supported participants presented a talk or poster during the meeting. The recruitment of women scientists and underrepresented minorities in science to the 2020 and 2021 meetings was prioritized. The efforts of this workshop will help program officers align programs that support research leading to a better understanding of uncharacterized genome regions research with other high-priority NSF initiatives.

- DBI will be supporting a conference in 2022 entitled "The National Postdoctoral Association Pre-Conference Session to Promote IMPACT Fellowship Success." This will be a pre-conference day of workshops held before the 20th Annual National Postdoctoral Association (NPA) Conference held on March 31-April 2. The day of conferences will provide PRFB fellows within the Broadening Participation Area an opportunity to meet and network with each other, and with the National Postdoctoral Association IMPACT Fellows, a group of early career researchers from under-represented populations. IMPACT fellows receive training and professional development through the NPA for a 6-month period. The pre-conference workshops will provide multiple sessions for the professional development of the PRFB and IMPACT fellows, including peer learning, networking strategies, and workshops that will focus on mentoring and career training. In addition to gains for the fellows, NSF program officers attending the workshop will keep current in issues that are important to these early career scientists and best practices to maximize the postdoctoral period.
- A 2021 travel award entitled "NSF Student Travel Grant for the 2021 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)" (award #2131662) was provided to support a diverse group of 23 undergraduate and graduate students in their participation of the core conference programs and workshops on December 9-12, 2021. One of the workshops was focused on Long Non-coding RNAs: Mechanism, Function, and Computational (BIBM-lncRNA) which reflects NSF's recent effort on Dark Dimensions of the RNA Regulome (D2R2) (NSF 22-510). The workshop will help NSF POs better be aware of research challenges and best endeavor in the field, which will eventually lead to the support of right and cutting-edge science.

The Division of Environmental Biology (DEB) supported multiple workshops in FY 2021 to inform planning of research programs.

- A virtual workshop on pre-emergence and predictions of rare events in multiscale, complex, dynamical systems was funded with the goal to formulate new science on pandemic preparedness and construct integrative and multidisciplinary frameworks to enable insights into fundamental processes of pandemic emergence. Participants have delivered a final workshop report and an additional one to five white papers are being developed. Results from this are relevant to the DEB-led Ecology and Evolution of Infectious Diseases program, as well as the cross-directorate Pandemic Intelligence for Pandemic Prevention Program.
- A virtual workshop series titled "EVO-LTER: Building collaborations to investigate the effects of urbanization on eco-evolutionary dynamics across the LTER network" was supported to integrate LTER approaches and the eco-evolutionary dynamics framework. The workshop series will inform efforts to develop new research collaborations between evolutionary biologists and LTER Scientists.

[15] www.hackseq.com/projects

[16] www2.rnasociety.org/conferences/rna-2021/

- A virtual workshop entitled "The Moving Mountains Summit: Collaboratively Redefining the Future of Mountain Environments and Society" was funded and will allow for themes of agriculture, energy, and tourism to be addressed to explore cross-sector issues for rebuilding in a post-COVID mountain world. This workshop will include a broad set of stakeholders, including Indigenous communities from mountainous regions. This workshop will also help inform broadening participation efforts.
- A virtual workshop series titled "International Scientific Community Workshop Series on the Access and Benefit Sharing of Digital Sequence Information" was funded, to increase activity and engagement of U.S. stakeholders across science and industry in public comment on Nagoya Protocol issues. The aim is the co-development among scientific societies of practical, ethical, and collective solutions to catalyze fair and equitable benefits from biodiversity sequencing without slowing the pace of sequencing, publication efforts, and benefits. This effort held 3 (of 6) planned workshops, discussing Nagoya Protocol issues around bioethics of studying humans, using museum collections, and agricultural pathogens. Several white papers are in preparation and will inform efforts to prepare the DEB scientific community for navigating Nagoya Protocol issues in the context of their research data collection.

The Division of Integrative Organismal Systems (IOS) supported multiple workshops and meetings in FY 2021 that informed planning for research programs.

- The report from the IOS-commissioned National Academies workshop held February 10-12, 2020, entitled "Next Steps for Functional Genomics," continues to guide investments in plant and animal genomics across IOS and BIO.
- Both the report "Interagency Strategic Plan for Microbiome Research FY 2018-2022," released in April 2018, and the outcomes from community visioning workshop entitled "Deciphering the Microbiome," held in December 2019, continue to guide IOS investment into microbiomes, including energy production, microbial interactions with plants and animals in the warming world, and soil stability, fertility, and sustainability.
- The report from the NSF-sponsored National Academies 2018 workshop entitled "Science Breakthroughs to Advance Food and Agricultural Research by 2030" and the 2021 report from the NSF workshop series Innovation in the Bioeconomy on "Feeding the Planet Sustainably" continue to inform our investments in basic research to enable agriculture, including biotechnology, plant physiology, transformation and genomics, clean energy, and synthetic biology.
- During 2020 and 2021, IOS held a series of community visioning workshops with CAREER awardees, investigators receiving COVID RAPIDs, researchers developing novel neurotechnologies, and investigators working in plant and animal genomics to discuss gaps and future directions. These discussions informed subsequent development of Dear Colleague Letters, Solicitations, and investments in basic research, biotechnologies, climate impacts and their mitigation, and diversity in STEM.

The Division of Molecular and Cellular Biosciences (MCB) supported multiple workshops in FY 2021 that inform the planning of research programs.

- An Organization for Economic Cooperation and Development (OECD) Workshop, titled "Collaborative Platforms for Engineering Biology: Biofoundries and Distributed Biofoundries" was supported in FY 2020 as one in a series of activities to catalyze the development of a global network of biofoundries capable of addressing societal needs, including rapid response to pandemics. The workshop was part of the U.S. voluntary contribution to OECD work in the circular bioeconomy space and helped inform the development of a new MCB solicitation in collaboration

with DOE titled "Accelerating Innovations in Biomanufacturing Approaches through Collaboration Between NSF and the DOE BETO funded Agile BioFoundry" (NSF 22-549). The first round of submissions to this solicitation will occur in FY 2022.

- A workshop on "The Plant Cell Atlas Initiative" was held in January 2020. The workshop aimed to bring together a plant cell biology community to develop an atlas of imaging resources for plant biology. This workshop led to the development and funding in FY 2021 of a Research Coordination Network, RCN: Creating and Fostering a Plant Cell Atlas Community, a five-year effort to develop a community of practitioners as well as develop data standards and best practices for this field (MCB-2052590).
- MCB funded a series of workshops from 2017 – 2019 titled "Finding Your Inner Modeler" that led to the development of a Research Coordination Network, funded in 2021, that aims to catalyze collaborations between mathematical modelers and cell biologists and grow a community of practice of cell biologists working across disciplines to solve complex biological problems using computational approaches (MCB-2003415).
- A workshop entitled "Workshop: Biology, Information, Communication and Coding Theory" was funded in FY 2019 and was held in January 2020. The workshop and report helped frame the newest Semiconductor synthetic biology solicitation, released in FY 2022, Semiconductor Synthetic Biology Circuits and Communication for Information Storage (SemiSynBio III), (NSF 22-557).
- Two workshops were funded in FY 2021 to convene parts of the MCB community together to explore how best enable data reuse, data synthesis, and integration, and to consider inclusive models of shared computational resources and training to foster collaboration on large scale problems in the molecular and cellular biosciences. The workshop proposals were received in response to a Dear Colleague Letter for Conferences to prepare for the transformation of Molecular and Cellular Biosciences Research through Information Synthesis and Integration (MoCeIS-DCL) in 2021 (NSF 21-017). The two workshops (MCB-2129768 and MCB-2133405) were held in late FY 2021 or early FY 2022 and represent distinct perspectives from different subdisciplines supported by MCB on opportunities for synthesis.
- MCB supported a series of five workshops facilitated by University Industry Demonstration Partnerships (UIDP) that brought together stakeholders and experts from different industries, including small businesses, government (e.g., NIH, NSF, DoD), and academia, to better understand how to catalyze the community to prepare for a society that will increasingly leverage the capabilities of biotechnology. Topics covered by these workshops have centered around areas of research that are of high priority, including the circular bioeconomy, feeding the planet sustainably, and biotechnological solutions to mitigating climate change. The workshops have also brought together social scientists and economists to address public engagement, consumer behavior, the intersection of regulation, policy, and economic models, and equitable distribution of the benefits of biotechnology. The results of these workshops will inform planning for new investments in biotechnology either through the new Technology, Innovation and Partnerships Directorate or in MCB and BIO (MCB-2137471).
- MCB supported two workshops to address the state of the art of the synthetic cell community. A grantee meeting was held in FY 2021 (MCB-2024029) to convene the awardees of the 8 projects funded through the NSF Understanding the Rules of Life: Building a Synthetic Cell, An Ideas Lab Activity (NSF 18-599). In addition, a workshop entitled "Reconstituting Biology – a chart to minimal cells" was funded in FY 2021 that will take place in 2022 (postponed because of COVID) that will examine the state of the field of synthetic and artificial cells after the investments in the area by the NSF Understanding the Rules of Life: Building a Synthetic Cell, An Ideas Lab Activity and the

Designing Synthetic Cells Beyond the Bounds of Evolution solicitation (NSF 21-531), released in FY 2021 that resulted in the funding of 9 projects in FY 2021.

- A two-day workshop titled "Broadening access to research opportunities at PUIs and HBCs in the Memphis region" was funded in FY 2020. The workshop was designed to increase awareness of funding opportunities and increase funding success in obtaining NSF funding for predominately undergraduate institutions including the host institution, Rhodes College, and three historically Black Colleges (HBCs) in the Memphis, TN, region, and led to the development of a grant writing bootcamp for faculty and staff from partnering institutions. The outcomes of this workshop and the subsequent bootcamp are informing discussions on how to build solicitations that will attract and benefit a broader PI base (MCB-2016838).

CISE

CISE has funded several studies led by the Computer Science and Telecommunications Board (CSTB) within the National Academies that resonate with the directorate's FY 2023 investments.

- In FY 2021, the CSTB published a report, *Information Technology Innovation: Resurgence, Confluence, and Continuing Impact*,[17] that analyzes the IT innovation ecosystem and assesses the long-term economic impact of CISE investments. Earlier reports in 2009 and 2012 had provided an in-depth articulation of the nature and successes of U.S. research partnerships among government, industry, and universities, and how these partnerships led to the creation of a significant number of IT industries since 1965 that are valued at a minimum of $1 billion each. The most recent report identifies new products and industries, illustrates the interconnections across research areas and industry sectors, and underscores the rich economic payoffs of these research investments. For example, the report provides a comprehensive overview of the evolution of the field of AI, including the role that NSF and other federal agencies have had in driving seminal advances.
- Another CSTB study examined strategies to improve representation of women of color in technology and issued a report in 2021: *Transforming Trajectories for Women of Color in Tech*.[18] This report uses current research as well as information obtained through four public information-gathering workshops to provide recommendations to a broad set of stakeholders within the tech ecosystem for increasing recruitment, retention, and advancement of women of color. It identifies gaps in existing research that obscure the nature of challenges faced by women of color in tech, addresses systemic issues that negatively affect outcomes for women of color in tech, and provides guidance for transforming existing systems and implementing evidence-based policies and practices to increase the success of women of color in tech.
- An ongoing study on *Responsible Computing Research: Ethics and Governance of Computing Research and its Applications*[19] will identify ethical principles and practices that research funders, research-performing institutions, and individual researchers can use to formulate, conduct, and evaluate research and associated activities in the CISE topic spaces responsibly. It will also address how these principles and practices can be promulgated and adopted by the broader computing research community. The report is expected to be completed by Summer 2022.

The Computing Community Consortium (CCC) has led several community visioning efforts that resonate with the directorate's FY 2023 investments:

[17] www.nap.edu/catalog/25961/information-technology-innovation-resurgence-confluence-and-continuing-impact

[18] www.nationalacademies.org/our-work/addressing-the-underrepresentation-of-women-of-color-in-tech

[19] www.nationalacademies.org/our-work/responsible-computing-research-ethics-and-governance-of-computing-research-and-its-applications

- "Computing Research for the Climate Crisis 2021" brought together researchers from multiple disciplines to explore the role of computing in mitigating, adapting, and enhancing resiliency to climate change-induced challenges; the white paper identifies key areas in which these challenges will arise—energy, environmental justice, transportation, infrastructure, agriculture, and environmental monitoring and forecasting—and describes the- specific ways in which computing research can help address the associated problems.[20]
- "5G Security and Privacy: A Research Roadmap" identifies several research directions to identify and mitigate vulnerabilities that not only jeopardize the security of the 5G wireless networking ecosystem but also impact user privacy.[21]
- "A National Discovery Cloud: Preparing the U.S. for Global Competitiveness in the New Era of 21st Century Digital Transformation" outlines how to effectively harness cloud computing to advance data-driven discovery and computational modeling and simulation throughout the U.S. research and education enterprise.[22]
- "Assured Autonomy: Path Toward Living with Autonomous Systems We Can Trust" led a series of three workshops exploring assured autonomy, with the aim to create a unified understanding of the challenges of assuring the safety and security of autonomous systems, and the research needed to support these goals both economically and at scale.[23]
- "The Role of Robotics in Infectious Disease Crises" jointly with the National Academies, convened a virtual workshop with representation from the robotics community, clinicians, critical care workers, public health and safety experts, and emergency responders, to study the role of robotic systems in increasing national preparedness in infectious disease emergencies.[24]
- "A National Research Agenda for Intelligent Infrastructure: 2021" updated the 2017 research agenda for intelligent infrastructure, with a new focus on pandemics and worldwide natural disasters, sustainability and energy efficiency, job recovery and employment opportunities, and the advancement of social justice.[25]
- "A 20-Year Community Roadmap for Artificial Intelligence Research in the U.S." developed a roadmap for AI research over the next 20 years, including research priorities, challenges, and recommendations.[26]

CISE-funded community workshops and focus group studies also inform the directorate's FY 2023 investments.

- In FY 2021, CISE joined with other NSF directorates to support a series of interdisciplinary workshops on Pandemic Prediction and Prevention[27] which informed the development of the "Predictive Intelligence for Pandemic Prevention (PIPP)" program. These workshops spanned the underlying molecular, cellular, and physiological interactions giving rise to global behaviors of organisms; advanced biosensing, surveillance, and population risk modeling; identification of pre-

[20] cra.org/ccc/wp-content/uploads/sites/2/2021/08/Computing-Research-and-Climate-Change-—-August-2021.pdf
[21] cra.org/ccc/wp-content/uploads/sites/2/2020/03/5G-Security-and-Privacy-A-Research-Roadmap.pdf
[22] cra.org/ccc/wp-content/uploads/sites/2/2021/04/CCC-Whitepaper-National-Discovery-Cloud-2021.pdf
[23] cra.org/ccc/wp-content/uploads/sites/2/2020/10/Assured-Autonomy-Workshop-Report-Final.pdf
[24] cra.org/ccc/wp-content/uploads/sites/2/2020/10/Workshop-Final-Report-The-Role-of-Robotics-in-Infectious-Disease-Crises.pdf
[25] cra.org/ccc/wp-content/uploads/sites/2/2021/01/A-National-Research-Agenda-for-Intelligent-Infrastructure_-2021-Update-FINAL.pdf
[26] cra.org/ccc/wp-content/uploads/sites/2/2019/08/Community-Roadmap-for-AI-Research.pdf
[27] www.nsf.gov/events/event_summ.jsp?cntn_id=302023&org=NSF

emergence and prediction of rare events in multiscale, complex, dynamical systems; and human attitudes, social behaviors, and the drivers underlying infectious-disease transmission, control, and eradication.

- In FY 2020, CISE supported a series of workshops to initiate a national dialogue on envisioning the future of the role of computing in undergraduate education.[28] Computing educators and computer science departments, as well as colleagues and academic units representing other stakeholder disciplines, worked together to understand the challenges associated with the growing demand and increasingly diverse student body seeking to learn more about computing, computer science, and the role of computation in their own disciplines, and to develop a research and teaching agenda for both computer science and other stakeholder disciplines.
- In FY 2020, CISE funded several studies to measure the utilization of the Internet given the significant increase in the population working from home in response to the COVID-19 pandemic. These studies helped to identify gaps in Internet measurement, such as measurement research being conducted in a piecemeal and uncoordinated manner, and limited by network access, as well as measurement techniques failing to provide a comprehensive portrait of Internet performance, connectivity, and cybersecurity threats. In January and April 2021, CISE sponsored two workshops on *"Overcoming Measurement Barriers to Internet Research"*[29,30] with the goal of understanding the challenges in network and security data collection and sharing. The final report from these workshops[31] was published in July 2021 and helped inform the development of a program on Internet Measurement Research that CISE recently launched.
- In FY 2020, CISE supported a workshop on "Next Generation (NextG) Security"[32] that brought together researchers with expertise in wireless communications, networked systems, and security to generate a research agenda that would lead to new knowledge on securing NextG mobile networking. The workshop focused on physical-layer security, infrastructure security, validation and verification for securing the NextG mobile platforms, and data privacy. In August 2020, NSF also supported a workshop on "Wireless, Spectrum & Innovation"[33] to collect community input and create a roadmap of transformative technologies related to wireless communications, networking, and spectrum use that that could serve as a strategic guide for future research investments. The outputs from these workshops informed the eventual Resilient & Intelligent NextG Systems (RINGS) program that CISE launched in collaboration with two other federal agencies and nine industry partners.
- In FY 2021, in collaboration with the National Institute of Information and Communications Technology (NICT) of Japan, CISE supported a workshop on "Programmable Networking"[34]. This workshop brought together researchers from the U.S. and Japan networking communities to assess current collaborative research projects, share future research goals, and identify new joint research opportunities. The resultant workshop report[35] informed the development of a joint program between CISE and NICT, Japan-U.S. Network Opportunity 3 (JUNO3): R&D for Programmable Networking for Next-Generation Core and Beyond 5G/6G Networks, launched later in the year.

[28] cra.org/crn/2020/08/cue-next-envisioning-the-future-of-computing-in-undergraduate-education/
[29] www.caida.org/workshops/wombir/2101/
[30] www.caida.org/workshops/wombir/2104/
[31] www.caida.org/catalog/papers/2021_wombir2021_report/wombir2021_report.pdf
[32] nsf-nextg-security.cs.ucsb.edu/
[33] sites.google.com/view/nsf-workshop
[34] sites.google.com/view/us-japan-workshop/home
[35] https://drive.google.com/file/d/1wQBKYnh5KILfHxx3IkhY3mJTe8YFvOfL/view

- In FY 2021, CISE supported a focus group study on democratizing the use of advanced computational resources. The study involved a total of 15 focus groups, and six additional individual interviews were conducted with 88 key stakeholders of research cyberinfrastructure (CI) investments to more fully identify opportunities to democratize computation and bridge digital divides in ways that would better reach underrepresented groups in the field. The report from this study, *The Missing Millions: Democratizing Computation and Data to Bridge Digital Divides and Increase Access to Science for Underrepresented Communities*,[36] is helping to inform CISE efforts to enhance accessibility, equity, and diversity among users of NSF-funded CI resources.
- In FY 2020, CISE supported a workshop on the development of the CI workforce.[37] The report from this workshop, *Building the Research Innovation Workforce*,[38] identified the need for a coherent, collective, and coordinated national strategy and action plan to address the factors that inhibit the expansion and sustainment of a healthy CI and research computing workforce ecosystem. The findings in turn informed the recent Training-based Workforce Development for Advanced Cyberinfrastructure and Research Coordination Networks: Fostering and Nurturing a Diverse Community of CI Professionals programs.

EDU

- In FY 2021 the Science and Technology Policy Institute (STPI) completed a report titled *Broadening Participation Research Thematic Portfolio Review* focused on the activities of the Division of Human Resource Development, (to be renamed the Division of Equity for Excellence in STEM, EES, in FY 2023).
- EDU funded the "Roundtable on Systemic Change and the Future of Undergraduate STEM Education," an initiative to coordinate and catalyze national efforts to improve undergraduate STEM education so that learners are better prepared to be scientifically informed members of society and participate in the future STEM workforce. The National Academies' Board on Science Education and Board on Higher Education and Workforce will utilize the Roundtable to harness and accelerate on-going, evidence-based efforts to improve undergraduate STEM education while at the same time developing strategies for responding to the major transformations that face higher education in the coming decades. Through a series of interconnected projects and convenings engaging experts with diverse roles in higher education (e.g., classroom teaching laboratory instruction, research on education, professional development for faculty and instructors, department chairs, deans, provosts, and presidents) as well as experts from different sectors within and around higher education, the Roundtable will help the field anticipate STEM teaching and learning needs in light of the rapidly changing social and economic environments.
- In FY 2021, EDU Core Research provided funding to support a three-year initiative, Equity in PreK-12 STEM Education. Using the consensus study process of the National Academies, the National Academies' Board on Science Education (BOSE) convened an expert committee to investigate the specific ways that educational inequity manifests in STEM education and make actionable recommendations for how education stakeholders at all levels can take steps to address these inequities. The committee will write a consensus report that discussed how systemic inequity in STEM education can be addressed at all levels of the PREK-12 system to promote success in STEM for all students, regardless of background, demographic status, and community.[39]

[36] www.rti.org/publication/missing-millions
[37] www.rcac.purdue.edu/ciworkforce2020
[38] www.rcac.purdue.edu/ciworkforce2020/report
[39] www.nationalacademies.org/our-work/equity-in-prek-12-stem-education

ENG

- Science and Technology Policy Institute (STPI) Reports: In FY 2022, ENG/EFMA expects to receive STPI's final report on its evaluation of NSF ENG's Research Experience and Mentoring (REM) program. REM supports hands-on research and ongoing mentorship in STEM fields for high school students, STEM teachers, undergraduate STEM students, faculty, and veterans through supplements to EFMA, ERC, and IUCRC awards.
- CBET, MPS's Division of Chemistry, and the Department of Energy's Basic Energy Sciences program co-funded a 2020 workshop in Washington, DC led by Iowa State University "The Changing Landscape of Feedstocks for Chemical Production--Implications for Catalysis." The workshop explored opportunities to manufacture organic chemicals by renewable electricity and biomass feedstocks, as alternatives to conventional thermal catalysis and fossil feedstocks. A final report documenting opportunities for greenhouse gas reduction related to climate change is expected in FY 2022.
- In December 2020 and June-July 2021, two CMMI-funded workshops, co-sponsored with NIST, were held on "Strategy for Resilient Manufacturing Ecosystems Through Artificial Intelligence" by the University of California, Los Angeles. The first workshop identified key areas of artificial intelligence (AI) adoption that are synergistic with and build on a growing foundation of manufacturing digitalization.[40] The second workshop identified the most important research, development, and workforce education and training priorities for industry-wide adoption of AI, with the goal of dramatically improving the competitiveness, efficiency, and resilience of U.S. manufacturing.[41] The workshops informed NSF programs for advanced manufacturing and AI, as well as the Subcommittee on Advanced Manufacturing and the Subcommittee on Machine Learning and Artificial Intelligence of the National Science and Technology Council.
- In January 2021, the Division of Electrical, Communications, and Cyber Systems (ECCS) funded a workshop on "Addressing Wireless Communication Needs in Underwater Technologies" held by Lehigh University. The workshop explored the most important applications, performance requirements, and environmental impacts of underwater wireless communications for the research community to focus on in the next five to ten years and the research needed to achieve the desired technology advances. The workshop report[42] is informing ECCS investment in wireless communication technologies.
- In February 2021, an ECCS-supported workshop on "Pandemic Readiness for Emerging Pathogens" was held by the University of California, Los Angeles; this workshop was part of the four-part series supported by ENG, BIO, CISE, and SBE for Predictive Intelligence for Pandemic Prevention. The workshop outcomes[43] informed the development of NSF's Predictive Intelligence for Pandemic Prevention program.
- In February 2021, an EEC-supported workshop on quantum engineering undergraduate education[44] was held by the Colorado School of Mines. The workshop focused on determining the

[40] https://oarc.ucla.edu/sites/default/files/Workshop%201_%20Report_v9_03172021.pdf, Strategy for Resilient Manufacturing Ecosystems Through Artificial Intelligence, first workshop report.

[41] https://oarc.ucla.edu/sites/default/files/Workshop2ReportFinal11102021.pdf, Strategy for Resilient Manufacturing Ecosystems Through Artificial Intelligence, second workshop report.

[42] www.blue-uci2021.org/report.pdf, Workshop report on Advancing Underwater Cyber Infrastructure for Blue Science

[43] https://thepipp.org/workshop-summary, Workshop Summary on Pandemic Readiness for Emerging Pathogens

[44] https://quantum.mines.edu/nsf-qe-ed/, Workshop on Quantum Engineering Education, February 26-27, 2021

best way to introduce undergraduate quantum engineering education into universities and colleges nationwide. The workshop report[45] was delivered in August 2021.

- In April 2021, the Office of Emerging Frontiers and Multidisciplinary Activities (EFMA) established the Engineering Research Visioning Alliance (ERVA)[46] to convene the engineering community to identify important engineering research challenges and opportunities. ERVA held its first visioning event in December 2021, "The Role of Engineering in Addressing Climate Change." The second visioning event is scheduled for March 2022, "Leveraging Biology to Power Engineering Impact." These events will lead to reports in 2022 on future research visions that may have programmatic impacts.
- In June 2021, a workshop co-funded by CBET, CMMI, and MPS/DMR on "Emerging Opportunities at the Intersection of Quantum and Thermal Sciences"[47] identified potential roles for thermal engineering in advancing quantum information science and technology. The workshop informed the CBET Thermal Transport Processes program and the November 2021 CBET-CMMI-DMR DCL on "Cryogenics below 1K - Systems, Cycles, and Materials" (NSF 22-018)[48], which seeks new approaches to refrigeration at ultra-low temperatures without using the rare ^{3}He isotope.
- In August 2021, a CBET-supported workshop on resilient supply of critical minerals, including critical minerals research and workforce development, was hosted by the Missouri University of Science and Technology; the workshop was co-funded by GEO/EAR and other Federal agencies. The workshop and report[49] informed CBET programs and the work of the NSTC Critical Minerals Subcommittee, on which CBET participates. A second workshop is planned for August 2022.
- In 2022, an EEC-funded two-part workshop series on "Defining and Building the Engineering Workforce of the Future"[50] will be held by the American Society for Engineering Education. The workshops will identify the key competencies required for a future-ready engineering workforce and the elements of an education action plan to equip this workforce, which will inform directorate investment in engineering education.
- In 2021, NSF submitted its second biennial report[51] to Congress about the I-Corps program, in response to the American Innovation and Competitiveness Act (AICA) (P.L. 114-329), which requires NSF to develop program metrics and summarize progress.
- NSF held a workshop May 12-13, 2021, to enable a wide range of stakeholders, including academia, industry, government, philanthropy, investors, civil society, and communities of practice, to come together and explore the concept of a national network of research institutes. The recommendations of this workshop[52] informed the development of the Regional Innovation Engines program.
- NSF continued to fund workshops and other community engagements to better understand the role of federal investment in advancing the Nation's innovation and entrepreneurship ecosystem.

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[45] https://doi.org/10.48550/arXiv.2108.01311, Building a Quantum Engineering Undergraduate Program report

[46] www.nsf.gov/news/news_summ.jsp?cntn_id=302437&org=ENG, "NSF funds the Engineering Research Visioning Alliance," April 7, 2021

[47] https://cvent.utexas.edu/2021NSF-QTSW, NSF Workshop on Emerging Opportunities at the Intersection of Quantum and Thermal Sciences

[48] https://www.nsf.gov/pubs/2022/nsf22018/nsf22018.jsp, DCL: Cryogenics below 1K - Systems, Cycles, and Materials (NSF 22-018)

[49] https://criticalminerals.mst.edu/wp-content/uploads/sites/7/2021/10/Findings-Report_Workshop-on-Resilient-Supply-of-Critical-Minerals_Locmelis-et-al.-2021.pdf, Workshop on Resilient Supply of Critical Minerals report

[50] https://nsf.gov/awardsearch/showAward?AWD_ID=2042343, EEC award for engineering education workshops

[51] www.nsf.gov/news/special_reports/i-corps/pdf/NSFI-Corps2021BiennialReport.pdf

[52] https://gaia.cs.umass.edu/NNRI/NSF_NNRI_Workshop%20_Report_Final.pdf

For example, on February 26, 2020, the first NSF-funded "Engineering Innovation Leadership Council (EILC)" workshop was held in Alexandria, Virginia, with more than 40 attendees from academia and government agencies. The workshop explored the role that university leadership plays in academic innovation and entrepreneurship ecosystems, and the broader impacts across communities, regions, and the Nation.

- From September 2020 through April 2021, NSF funded a series of monthly virtual seminars, "The Deep Dive Into Deep Tech Incubation," to better understand relationships among incubators, accelerators, universities, governments, investors, and industrial partners; explore how to most effectively engage with incubators and other venture development organizations that provide deep tech incubation; study how to advance the deep tech incubation ecosystem and grow more and stronger early-stage deep-tech companies in the United States; and share best practices among stakeholders.

GEO

- In FY 2020, GEO divisions made an award to the National Academies to conduct a workshop to identify new priorities and themes for paleoclimate research at NSF, "Identifying New Community-Driven Science Themes for National Science Foundation (NSF)'s Support of Paleo Perspectives on Climate Change (P2C2): A Workshop". The workshop was held in June 2021 and a report was delivered in November 2021. The report recommendations are being used to develop a new paleoclimate solicitation that will involve all GEO divisions.[53]
- In early FY 2022, the Division of Atmospheric and Geospace Sciences made an award to the National Academies to support a Decadal Survey for Solar and Space Physics (2024-2033). The survey is also supported by NASA and NOAA. Over the next two years, the process will solicit community input and create detailed recommendations for science and research infrastructure priorities for the next decade, as well as evaluated needs for training a scientifically- and technically skilled workforce in solar and space physics.
- In FY 2020, the National Academies released *Earth in Time, a vision for NSF Earth Sciences, 2020-2030*. The study identified high-priority challenges for the Division of Earth Sciences (EAR). The Report identified 12 compelling, high-priority research questions that underscore the intertwined nature of Earth's processes as an active, dynamic, open system in which all components interact to shape the state of the planet. The Report concludes that to predict how present-day natural and anthropogenic changes are likely to influence human society, over the coming decade it is critical to generate a clear understanding of how the Earth works today as an integrated system and how it has worked in the past. The Report includes 14 recommendations to achieve these goals. EAR has established Working Groups that are prioritizing them and planning their implementation.[54]
- In FY 2020 the Instrumental Portfolio Review Committee (IPRC), a sub-committee of the Advisory Committee for Geosciences (AC/GEO), released its review of EAR's geophysical instrumentation. Its primary goal was to review the portfolio of capabilities provided by Seismological Facility for the Advancement of Geoscience (SAGE) and Geodetic Facility for the Advancement of Geoscience (GAGE) with special reference to the recommendations in the National Academies Earth in Time Report. In addition, it evaluated recent advances in seismic and geodetic instrumentation that are not currently provided by SAGE and GAGE. It recommended a prioritized set of capabilities that

[53] www.nap.edu/catalog/26377/identifying-new-community-driven-science-themes-for-nsfs-support-of-paleoclimate-research

[54] www.nap.edu/catalog/25761/a-vision-for-nsf-earth-sciences-2020-2030-earth-in

should be provided by the geophysical facility that will be formed by the coming merger of SAGE and GAGE to maximize progress on compelling science over the next decade.[55]

- In September 2021 AC/GEO released a report *Imperative Science for the 21st Century: Why a Vibrant Geoscience Research and Educational Enterprise Is Essential to American Society and How the National Science Foundation Can Ensure Its Vitality*. This report highlights the importance of geoscience to the nation, the necessity of utilizing a systems approach in understanding the interconnected and dynamic Earth system, and the importance of broadening diversity and inclusivity in the geosciences.[56]
- In 2021 the National Academies released a report *Next Generation Earth Systems Science at the National Science Foundation*. This report presents a vision for a robust, integrated approach for studying the Earth's systems and identifies NSF facilities, infrastructure, coordinating mechanisms, computing, and workforce development to support this vision.[57]

MPS

In July 2021, MPS/AST received the *Final Report[58] of the Extreme Precision Radial Velocity Working Group*. This community working group was formed to follow up on the 2018 *Exoplanet Science Strategy* consensus study report[59] by the National Academies. Their intensive 2-year study presents a range of program architectures and identifies opportunities for NSF and NASA cooperation in the quest to discover other Earth-like planets

The Division of Chemistry (CHE) supported multiple workshops in FY 2021 that inform the planning of research programs.

- MPS/CHE, DOE/Basic Energy Sciences (BES)/Chemical Sciences, Geosciences and Biosciences (CSGB), the National Institutes of Standards and Technology (NIST) and the American Chemical Society (ACS) continued a consensus study through the National Academies Board on Chemical Sciences and Technologies (BCST) on *Enhancing the U.S. Chemical Economy through Investments in Fundamental Research in the Chemical Sciences*. This study is expected to examine and define the roles of the chemical industry in the U.S. economy, assess how investments in long-term fundamental research in the chemical sciences contribute to the division, agency, and administration's goals of national security, environmental sustainability, manufacturing industries, and energy-technology development while exploring strategies for targeted research and chemical workforce investments. Results, expected in calendar year (CY) 2022, will help inform the scope of core funding activities in the chemical sciences.
- MPS/CHE and DOE/Basic Energy Sciences (BES)/Chemical Sciences, Geosciences and Biosciences (CSGB) co-sponsored a consensus study through the National Academies Board on Chemical Sciences and Technologies (BCST) on *Identifying Opportunities at the Interface of Chemistry and Quantum Information Science (QIS)*. This study is expected to identify the opportunities and research priorities that exist at the boundaries of chemistry and quantum information science (QIS). The expected outcome is a report with recommendations on how chemistry can move forward and expand the field of QIS while also identifying ways that QIS can impact the field of chemistry. Final results from this study are expected in CY 2023.

[55] www.nsf.gov/geo/adgeo/ear-instrumentation-review/AC-GEO-EAR-Instrumentation-Portfolio-Review-April-2021%20Report.pdf
[56] www.nsf.gov/geo/acgeo/geovision/acgeo-imperative-science-report-sept2021.pdf
[57] http://nap.edu/26042
[58] https://exoplanets.nasa.gov/exep/NNExplore/EPRV/
[59] www.nationalacademies.org/our-work/exoplanet-science-strategy

- MPS/CHE sponsored a "NSF ChemData/AI Researcher Meeting: Evaluate Progress and Think About What the Future Brings" in August 2021. The workshop aimed to assess the current landscape of data-driven chemical research and its impact; identify challenges that have hindered stronger engagement of the research community, and research opportunities that may lead to more impactful utilization of data-driven chemical research; identify needs for infrastructure and resources, ranging from laboratory scale to mid-scale, from tool development to community building, to maximize the impacts of data science on chemistry and advance chemistry through data science and vice versa; and identify needs and opportunities for workforce development that integrate data science, automation, and modern chemical education to explore solution landscapes. The workshop report is expected to become available in CY 2022.
- MPS/CHE (co)sponsored several educational and outreach activities, including the 2021 Chemistry Early Career Workshop attended by around 50 new faculty members from across the United States. The National Institutes of Health (NIH), DOE, and other federal agencies participated. CHE also organized community meetings at the American Chemical Society National Meeting (ACS Spring 2021, with representatives from DOE BES, NIH-NIGMS, and AFOSR; April 2021), the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE, September 2021), and the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS, October. 2021). Together, these outreach activities serve an important role in promoting high priority research initiatives and broadening participation of underrepresented and underserved populations in chemically-related sciences and engineering.

DMR supported multiple workshops in FY 2021 that inform the planning of research programs.

- MPS/DMR supported the Sustainable Polymers Square Table, which resulted in a workshop report[60] and an editorial[61] in the Macromolecules scientific journal.
- MPS/DMR held a joint workshop, intended to provide guidance on community needs and opportunities in experiment, theory, computation, and data-intensive research spanning the responsibilities of two programs in the areas of metals and metallic nanostructures. A report is forthcoming.
- MPS/DMR MRSEC program held a panel on "Emerging Frontiers in Materials Research – Beyond NSF's 10 Big Ideas." A report from the panel discussion was used to inform the current MRSEC Program Solicitation (NSF 21-625).
- MPS/DMR co-funded the Workshop on "Soft Matter Far from Equilibrium"[62] held at the Cornell High Energy Synchrotron Source. This highly interdisciplinary workshop aimed at identifying important fundamental questions related to soft matter far from equilibrium, highlighting the critical role x-ray-based tools play in answering these questions, and increasing the user community of synchrotrons.
- MPS/DMR co-sponsored the "US MUON Workshop 2021"[63] in a joint effort with DOE. The workshop aimed at assessing the science case for a future muon spectrometer. A report is forthcoming.
- MPS/DMR MRSEC program held a PI meeting on MRSEC umbrella activities (education, broadening participation, communication, facilities, industry). Discussion outcomes and planned next steps will be used to realign these activities with the mission of the MRSEC Program, so that it can grow its impacts and visibility.

[60] https://chemrxiv.org/engage/chemrxiv/article-details/60fed3e78804437c0ee3a401
[61] https://pubs.acs.org/doi/10.1021/acs.macromol.1c01751
[62] www.chess.cornell.edu/soft-matter-far-equilibrium-chess-2030-workshop-june-10-11-2021
[63] https://mrs.org/muon-2021

- MPS/DMR organized the "2D Interfacial and Layered Materials Forum," led by two Materials Innovation Platforms (MIP), which addressed teaching, training, and trusting data science for materials; democratization of data and data-tools access and archiving; interconnection between data and knowledge; AI-enabled digital twins; inorganic synthesis science; translation of materials and data from discovery to technology and to industry. A forthcoming report will be used to inform MIP activities, as well as to create opportunities to strengthen the connections between the MIPs and the scientific ecosystem that they interact with.
- In FY 2022, MPS/DMR will organize a workshop for faculty from PUIs, HBCUs, and MSIs motivating and leading faculty in ceramic and glass materials science and engineering to develop and expand vigorous undergraduate research programs. Its aim is to enhance the educational experiences of college students across a variety of institution types by increasing their exposure and experience with rigorous and up-to-date scientific activity.
- MPS/DMR-led DMREF program will sponsor a joint Materials Genome Initiative (MGI) PI meeting with DOE to discuss the new NSTC MGI Strategic Plan[64] and support a MGI Workforce workshop to respond to the *2019 TMS Creating the Next-Generation Materials Genome Initiative Workforce* study[65] and the new NSTC MGI Strategic Plan.[66]
- In FY 2023, MPS/DMR plans to hold a workshop on out-of-equilibrium soft matter, which besides materials research and physics connects to both the biological and the geological sciences. The purpose of the workshop is to bridge communities, and to identify opportunities as well as grand challenges.
- In FY 2023, MPS/DMR plans to hold a workshop on opportunities intended to provide guidance on community needs and opportunities in theory, simulation, and data-intensive research in soft-matter and polymeric materials. This is part of a foundational workshop series for the CMMT community to strengthen and bring together the diverse CMMT community.

The Division of Mathematical Sciences (DMS) supported multiple workshops in FY 2021 that inform the planning of research programs.

- In FY 2021, MPS/DMS and SBE supported a strategic study through a workshop on "Research on Enhancing Socially and Behaviorally Modulated Mathematical Models for Human Epidemiology," with a focus on the COVID-19 virus spreading. The report[67] informed the Foundation that current epidemiological models have proved inadequate in large part due to human behavioral and social processes that are missing from the existing models but that have appeared to be key to understanding the course of the pandemic. This report has guided the development of a partnership program/DCL (IHBEM) among MPS/DMS, SBE/SES, SBE/Division of Behavioral and Cognitive Sciences (BCS), and BIO/DEB to support convergent research that shall provide more reliable modeling tools to inform decision making and to evaluate public health policies during pandemics and other public health crises, with the premise that important advances will be made by incorporating human behavioral and social processes into mathematical epidemiological models.

[64] www.mgi.gov/sites/default/files/documents/MGI-2021-Strategic-Plan.pdf
[65] www.tms.org/portal/Publications/Studies/MGIworkforce/MGIworkforce.aspx
[66] www.mgi.gov/sites/default/files/documents/MGI-2021-Strategic-Plan.pdf
[67] Research on Enhancing Socially and Behaviorally Modulated Mathematical Models for Human Epidemiology (2021). https://giesbusiness.illinois.edu/bridging-disciplinary-divides-conference

- The SIAM Report[68] on *Research and Education Priorities to Address Climate Change, Boost Environmental Resilience, and Advance Clean Energy* recommended that NSF math-specific programs such as the Research Training Groups in the Mathematical Sciences (RTG) should prioritize training efforts that give student convergent research experiences and skills. The report recommends that NSF incentivize mathematicians and computational scientists to learn a completely new discipline or to explore new synergies and advance climate innovation, and that NSF should use their post-doctoral support to encourage interdisciplinary training, acquisition of computational and data science skills, and time spent with mentors in other disciplines or in practicums with other agencies.
- In FY 2021, the National Academies Report[69] on *The Future of Electric Power in the United States* supported the continuation of the joint MPS/DMS and DOE/OE program on "The Algorithms for Modern Power Systems (AMPS).[70]"

SBE

- In FY 2022, NCSES is sponsoring a workshop[71] with the National Academies to address measurement needs and related gaps in the theory on globalization of R&D and publish a proceedings volume summarizing the workshop discussions. NCSES hopes to use the outcome of this study to help shape the Federal Statistical System's approach to these topics in the future.
- In FY 2022, NCSES released *Doctorate Recipients from U.S. Universities*.[72] This annual report provides the major trends in doctoral education, organized into themes highlighting important questions about doctorate recipients. The report shows that doctorate recipients begin careers in large and small organizations, teach in universities, and start new businesses; that doctoral education develops human resources that are critical to a nation's progress—scientists, engineers, researchers, and scholars who create and share new knowledge and new ways of thinking that lead, directly and indirectly, to innovative products and services; and that in doing so, doctorate recipients contribute to the nation's economic growth, cultural development, and rising standard of living.
- In FY 2022, NCSES released *The State of U.S. Science and Engineering 2022*.[73] This biennial, congressionally mandated report provides information on the state of the U.S. science and engineering (S&E) enterprise over time and within a global context. NCSES also released nine other "thematic" reports that are part of the *Science and Engineering Indicators* suite of products providing in-depth data and information on science, technology, engineering, and mathematics (STEM) education at all levels; the STEM workforce; U.S. and international research and development performance; U.S. competitiveness in high-technology industries; invention, knowledge transfer, and innovation; and public perceptions and awareness of science and technology.
- In FY 2022, NCSES released *National Patterns of R&D Resources*.[74] This annual report provides current data on the levels and key trends of the performance and funding of research and experimental development in the United States

[68]www.siam.org/Portals/0/Publications/Reports/SIAM_Climate_Task_Force_Report_with_Appendix.pdf?ver=2021-08-12-091101-927

[69] www.nap.edu/catalog/25968/the-future-of-electric-power-in-the-united-states

[70] www.nsf.gov/pubs/2022/nsf22569/nsf22569.htm

[71] www.nationalacademies.org/our-work/understanding-the-impact-of-global-value-chains-a-workshop

[72] https://ncses.nsf.gov/pubs/nsf22300

[73] https://ncses.nsf.gov/pubs/nsb20221

[74] https://ncses.nsf.gov/pubs/nsf22320

- In FY 2020, SBE supported, in partnership with NIH, a National Academies ad hoc committee that will gather, review, and discuss the literature on the development of ontologies in scientific disciplines with a focus on developing the same in the behavioral sciences. The committee will provide recommendations for improving behavioral ontology advancement including: best practices and parameters for ontology development; resource, infrastructure and training needs; governance principles; identification of high priority research areas; recommendations for enhancing uptake and use in behavioral research; and recommendations for sustainability of the ontologies. The National Academies committee meetings and recommendation development continue to occur in FY 2022.
- In FY 2021, SBE funded a workshop to provide input for "Developing a Vision for a 21st Century National Data Infrastructure for Federal Statistics and Social and Economic Research." This project will convene a series of workshops, to develop a vision for a new national data infrastructure for the social and behavioral sciences.

OIA

- In FY 2020, the National Academies released a report titled *Promising Practices for Addressing the Underrepresentation of Women in Science, Engineering, and Medicine.*[75] The study and report production and dissemination was, in part, sponsored by federal funding from NSF and the National Institutes of Health (NIH). The report includes recommendations of evidence-based practices for increasing the participation, retention, and advancement of women in science, engineering, and medicine. NSF contributed to a wider dissemination of this report through funding provided in FY 2021.
- In FY 2020, NSF was one of several sponsors of a National Academies consensus study on *Advancing Anti-Racism, Diversity, Equity, and Inclusion in STEM Organizations*. The study report is anticipated in FY 2023.
- In FY 2021, building on the National Academies study and report on *Promising Practices for Addressing Underrepresentation of Women in Science, Engineering, and Medicine*, NSF and other federal and private partners sponsored a National Academies report to investigate the impact of the COVID-19 pandemic on academic careers of women in S&E fields. The report was published in FY 2021.[76]
- In FY 2021, the Committee on Equal Opportunity in Science and Engineering (CEOSE) transmitted to Congress its biennial report for 2019-2020, which is the first of a series of three reports focused on increasing the presence of underrepresented groups within the Nation's STEM enterprise.[77] The 2019-2020 report emphasized bold leadership actions. The next biennial report is anticipated in FY 2023.
- In FY 2021, NSF sponsored a workshop on leadership focused on increasing STEM leaders from historically underrepresented groups.[78] The three-day workshop concluded in January 2022, and provided an opportunity for participants to learn and document the characteristics of leaders from underrepresented groups, efforts to increase representation in STEM leadership, perspectives on STEM diversity and inclusion, strategies to develop the next generation of leaders, and approaches to integrate STEM and social science processes.

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[75] www.nap.edu/catalog/25585/promising-practices-for-addressing-the-underrepresentation-of-women-in-science-engineering-and-medicine#toc

[76]www.nap.edu/catalog/26061/the-impact-of-covid-19-on-the-careers-of-women-in-academic-sciences-engineering-and-medicine

[77] www.nsf.gov/od/oia/activities/ceose/reports/2019-2020-ceose-biennial-report-508.pdf

[78] https://leadershipinstem.psu.edu/schedule/

- In FY 2021, the NSF Advisory Committee for Environmental Research and Education provided NSF with two reports, *Environmental and Human Health: Research Priorities*[79] and *Environmental Change and Human Security: Research Directions*.[80] The first report articulates key priorities for future research into the ways in which human and environmental health intersect, as well as how to respond to these impacts as a scientific community. The report identifies new collaborations and scientific advances that are needed to anticipate and respond to future events that are meant to inform researchers and funders focused on the health-environment nexus. The second report describes opportunities to promote research at the intersection of environmental science and security and identifies near-term opportunities to promote important research through existing disciplinary approaches; more diverse and robust interdisciplinary/convergent research; and novel mechanisms to overcome barriers between academic groups and the national security community.

OPP

- In FY 2021, OPP and CISE's Office of Advanced Cyberinfrastructure jointly funded a workshop assembling a diverse mix of Antarctic domain science investigators to assess the science merits and benefits of a subsea telecommunications cable between New Zealand's South Island and McMurdo Station. It addressed how high speed/low latency telecommunications could transform scientific discovery in Antarctica as well as the potential to use the cable itself as a scientific instrument for such purposes as climate change research, ocean monitoring, seismic monitoring, and tsunami early warning. The general conclusion of the workshop report was that the cable concept was meritorious for further investigation.[81]
- In FY 2022 OPP is sponsoring the National Academies to conduct a workshop on technology developments to advance Antarctic research. A workshop report will be released in FY 2022. The workshop goal is to solicit community ideas and input on how technological innovation can:
  - Advance, facilitate, and transform Antarctic research and facilitate improvements to science support logistics;
  - Increase the reach of scientific investigations in Antarctica while reducing the logistics and environmental footprint of these operations; and
  - Facilitate broader, more diverse participation in Antarctic research.

[79] www.nsf.gov/ere/ereweb/reports/AC-ERE-Environmental-and-Human-Health-Report_June7-508.pdf
[80] www.nsf.gov/ere/ereweb/reports/AC-ERE-Environmental-Security-Report-508.pdf
[81] www.pgc.umn.edu/workshops/antarctic-cable/