

NSF BIG IDEAS

Since 2017, NSF began building a foundation for the Big Ideas through pioneering research and pilot activities. Over time those investments have matured. In 2023, NSF will continue to identify and support emerging opportunities for U.S. leadership in Big Ideas that serve the Nation's future.

NSF Big Ideas Funding¹ (Dollars in Millions)

	FY 2021 Actual	FY 2022 (TBD)	FY 2023 Request
Research Ideas²:			
Harnessing the Data Revolution for 21 st Century S&E (HDR)	\$191.79	-	\$182.11
Navigating the New Arctic (NNA)	40.11	-	35.20
The Future of Work at the Human-Technology Frontier (FW-HTF)	172.89	-	175.80
Understanding the Rules of Life: Predicting Phenotype (URoL)	113.92	-	93.50
Windows on the Universe (WoU)	74.80	-	61.85
Enabling Big Ideas:			
Growing Convergence Research (GCR)	15.99	-	16.00
NSF INCLUDES	20.75	-	50.50
Mid-Scale Research Infrastructure (Mid-Scale RI) ³	106.49	-	126.25

¹ NSF's Big Ideas may have funding overlap and thus should not be summed. The funding displayed may also have overlap with other topics and programs.

² Each of the Research Big Ideas include \$30.0 million in stewardship funding in the FY 2023 Request.

³ Funding for Mid-Scale RI is split between the R&RA and MREFC accounts. For the FY 2021 Actual, the split is \$32.45 million R&RA and \$74.04 million MREFC. For the FY 2023 Request the split is \$50.0 million R&RA and \$76.25 million MREFC.

About the Big Ideas

Five of the Big Ideas are research ideas, which build on the foundation of NSF-funded research over the last 70 years. The Research Big Ideas are complemented by Enabling Big Ideas, which are areas in which projects endeavor to improve the way in which science is done, from impacting the workforce to developing the infrastructure that will drive the discoveries and aid the discoverers of tomorrow's science.

Research Big Ideas

Harnessing the Data Revolution for 21st-Century Science and Engineering (HDR)

HDR engages NSF's research community in the pursuit of fundamental research in data science and engineering; the development of a cohesive, federated, national-scale approach to research data infrastructure; and the development of a 21st-century data-capable workforce.

- FY 2022 stewardship investments are focused in three areas:
 1. *Fundamental research in data science and engineering.* HDR primarily supports this area through the Transdisciplinary Research In Principles Of Data Science (HDR TRIPODS) program. In FY 2019, Phase I HDR TRIPODS awards were made to 15 projects, supporting the development of small, collaborative "data science research projects." In FY 2022, Phase II awards will enable a subset of the most successful of these smaller projects to expand with new partners into

larger data science efforts of increased scope and impact.

2. *A cohesive, federated, national-scale network of data-intensive science and engineering research institutes.* In FY 2019, NSF issued more than 100 conceptualization awards spanning 28 projects that supported interdisciplinary teams to conceptualize and pilot new modalities for collaboration and convergence beyond traditional disciplinary and organizational boundaries. These projects paved the way for funding five major interdisciplinary HDR Institutes for Data-Intensive Research in Science and Engineering in FY 2021. In FY 2022 and FY 2023 these HDR Institutes will continue to support convergence between science and engineering research communities as well as expertise in data science foundations, systems, applications, and cyberinfrastructure. By creating a portfolio of interrelated institutes, NSF aims to accelerate discovery and innovation in all areas of data-intensive science and engineering and formulate innovative data-intensive approaches to address critical national challenges.
 3. *Development of a 21st-century data-capable workforce.* NSF supports data science education and workforce development through the Data Science Corps (DSC) program. A second round of DSC awards in FY 2021 resulted in eight awards that will continue through FY 2023. A focal point of the education and workforce development portfolio is to enable the participation of individuals with diverse backgrounds and perspectives in building a diverse workforce trained in data management, data analytics, and data-driven decision-making.
- In FY 2023, HDR funds will be used to continue the projects launched in FY 2021 and FY 2022 in each of the three areas noted above, and to encourage activities enhancing communication and convergence among these institutes and projects, bringing together expertise in data science foundations, systems, applications, and cyberinfrastructure. Together, the NSF-funded teams will stimulate advances in multiple areas of science and engineering through data-intensive research that harnesses diverse data sources and applies new methodologies, technologies, and infrastructure for data generation, collection, modeling, and analysis.

Navigating the New Arctic (NNA)

NNA is establishing an observing network of mobile and fixed platforms and tools, including cyber tools, across the Arctic to document and understand the Arctic's rapid biological, physical, chemical, and social changes, in partnership with other agencies, countries, and native populations.

- In FY 2021, NSF made 77 NNA awards, including 56 new projects, half of which were collaborations. Several of these projects are studying how the changing environment will affect rivers, lakes, watersheds, and adjacent communities. In FY 2022, NSF issued a revised NNA solicitation with a focus on larger-scale convergent social, built, and natural environment systems science projects; advancing observation networks including knowledge co-production; communication and education projects; computation and data systems; and community-coordination activities.
- In FY 2023, the NNA program will focus on enabling advances and building on outcomes of prior supported activities. The solicitation published in FY 2022 will remain active for proposals in FY 2023. NSF will continue to coordinate and leverage NNA-related activities with external stakeholders, including other federal agencies through the Interagency Arctic Research Policy Committee (IARPC) chaired by the NSF Director; the NSF-funded, Navigating the New Arctic Community Office; local residents and Indigenous peoples through state and local governance structures of Alaska; and international partners through fora such as the biannual International Arctic Science Ministerial.

The Future of Work at the Human-Technology Frontier (FW-HTF)

FW-HTF catalyzes interdisciplinary science and engineering research to understand and build the

human-technology relationship; design new technologies to augment human performance; illuminate the emerging socio-technological landscape; and foster lifelong and ubiquitous learning to enhance the use of technology.

- In FY 2022, the Future of Work Big Idea supported (1) a set of forward-looking, convergent awards across industries, geography, and institutions as well as (2) the building of a new interdisciplinary research community. Awards represent a wide range of workers and future of work domains including construction and infrastructure, precision and digital agriculture, medicine and healthcare, intelligent and co-robotic manufacturing, and inclusive work for neurodiversity and disabilities. Several projects examine how workers and robots could collaborate intelligently and effectively on construction sites, in infrastructure inspection, nursing profession, seafood process, and recycling. New transition-to-scale awards emphasized research that would adapt and escalate the foundational basis for implementation and deployment in future workplaces and work contexts across industries and/or geographical locations. The Future of Work effort was also responsive to emerging problems and priorities, funding a set of supplements and NSF's Rapid Response Research awards in response to COVID-19.
- FY 2023 activities will leverage previous investments made through the Future of Work to support convergent research that is use-inspired, driven by challenges in improving work and the workforce through development of innovative technologies along with new structures and cultures of work that support and empower a diverse and inclusive workforce. Through the development of larger teams and partnerships, this research will improve ways to engage workers as co-contributors in the process of technological development and impel greater productivity, innovation in work practices, and the design and development of new industries and services. Special emphasis will be placed on ways in which the human-technology partnership can result in work solutions that are environmentally supportive and sustainable. The program promises to support the growth of U.S. businesses and entrepreneurs and STEM workforce development through research to improve reskilling, upskilling, and lifelong learning for future jobs and workplaces.

Understanding the Rules of Life (URoL): Predicting Phenotype

URoL is developing a predictive understanding of how key properties of living systems emerge from complex biological interactions. Advances in understanding life at fundamental levels will enable re-engineering of cells, organisms, and ecosystems, and the discovery of innovative biochemicals and biomaterials to sustain a vibrant bioeconomy, strengthen society, predict the behavior of living systems, and modify them to benefit humankind.

- Beginning in FY 2018, NSF's URoL Big Idea has supported 99 proposals in a series of new interdisciplinary research programs designed to elucidate rules at different hierarchical scales: Building a Synthetic Cell, for "minimal rules"; Epigenetics, for "rules of complexity"; Microbiomes: Theory and Microbiomes: Interactions, for "rules of interaction"; and Emergent Networks for "rules of emergence." Projects supported by URoL share a number of common features: they address a fundamental question in the life sciences; they focus on science at different scales (e.g., spatial, temporal, levels of biological organization, or complexity); they produce results designed to be broadly generalizable beyond the system under investigation, so that a rule can be formulated; and they enable the forecasting or prediction of change in a biological system in the context of others, including Earth, human, natural, and/or human-engineered systems. In FY 2022, a revised solicitation on emergent networks was released, and a series of meetings and workshops was sponsored to gain community input on how knowledge of the Rules of Life can be leveraged for future uses.

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- URoL activities in FY 2023 will build upon previous investments by seeking ways to Use the Rules of Life to address societal challenges, including those identified as Administration priorities. These activities will exploit lessons learned at all levels of biological organization, including the role of complex environmental inputs on genotype-to-phenotype relationships, and will support networks of researchers, technology developers, and educators across convergent URoL domains.

Windows on the Universe (WoU)

WoU uses powerful new syntheses of different messengers and different observational approaches to provide unique insights into the nature and behavior of matter and energy and to answer some of the most profound questions before humankind.

- The WoU Big Idea continues to be implemented through a dedicated program, NSF PD 18-5115: “Windows on the Universe: The Era of Multi-Messenger Astrophysics (WoU-MMA).” In FY2021, the WoU-MMA program made 73 awards through WoU-MMA stewardship and foundational funding. The awards spanned the full range of WoU investment areas: accelerating the theoretical, computational, and observational activities within the scientific community; building dedicated mid-scale experiments and instrumentation; and exploiting current facilities and developing the next generation of observatories. WoU also partnered with CISE’s Office of Advanced Cyberinfrastructure and the HDR Big Idea to invest in awards to enhance cyberinfrastructure for multi-messenger astrophysics. WoU awards have included investments in workforce development as well as diversity, equity, and inclusion activities.
- To continue advancing the WoU science goals, the successful meta-program approach will continue in FY 2023. New targeted solicitations are also being explored to address specific scientific needs and opportunities. In this era of the Vera C. Rubin Observatory, IceCube Neutrino Observatory, and the Large Interferometer Gravitational-Wave Observatory, the electromagnetic follow-up of multi-messenger events will require a concert of facilities and space missions which through WoU, NSF will invest by continuing to build partnerships within and outside of NSF, extending existing partnerships with DOE, and exploring new partnerships with other federal agencies and private organizations.

Enabling Big Ideas

NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES)

NSF INCLUDES is transforming education and career pathways to help broaden participation in science and engineering and build a diverse, highly skilled American workforce.

- NSF INCLUDES is a comprehensive, national initiative to advance equity and inclusion and broaden participation in STEM at scale by providing infrastructure for effective, collaborative change. NSF INCLUDES is continuing efforts to develop, strengthen, and sustain the National Network and communicate progress. Five new NSF INCLUDES Alliances were awarded in FY 2021. A total of thirteen Alliances have been funded since FY 2018. Each Alliance engages a range of strategic partners to address broadening participation challenges for specific groups of people, specific disciplines, and specific components of the STEM education system. NSF INCLUDES supports projects that advance the contributions of African Americans, Alaska Natives, Hispanics, Native Americans, Native Hawaiians, Native Pacific Islanders, persons with disabilities, persons from economically disadvantaged backgrounds, and women and girls from many academic and professional disciplines across the STEM education continuum. The NSF INCLUDES National Network has grown from just over 1,000 members in FY 2019 to nearly 4,000 members in FY 2021.

Research briefs, podcasts, webinars, publications, and convenings have been developed and shared broadly to build capacity for the work of broadening participation and raise the visibility of the National Network and its impact. Federal agency partners meet quarterly to share information and coordinate synergistic efforts.

- Planned investments for FY 2023 include: a) continuing to expand and strengthen the National Network through connections to networks with similar goals and by funding pilot projects, planning grants, and alliances; b) supporting the expansion of the NSF INCLUDES Coordination Hub, which leads and serves the National Network; c) supporting sustainability and scale of innovative, systemic strategies developed by currently funded projects; and d) advancing evidence-based approaches to broadening participation through shared measures and evaluation. An annual National Network survey and new evaluation contract were launched in FY 2021, along with the NSF INCLUDES Shared Measures platform. These activities will facilitate rigorous, formative evaluation of NSF INCLUDES' progress toward leveraging collaborative change strategies to increase diversity and inclusion and broaden participation in STEM fields and will provide an inventory of outcomes and broadening participation, collaborative change, institutional transformation, and system change indicators to measure progress and advance the adoption and adaptation of proven and promising approaches to realizing an inclusive STEM workforce.

Growing Convergence Research (GCR)

GCR deeply integrates ideas, approaches, tools, and technologies from widely diverse fields of science and engineering to advance fundamental understanding and the Nation's ability to meet pressing societal challenges.

- GCR supports five-year, complex convergence research projects, reviewing the progress made in the first two years to determine which will continue for three more years. In FY 2021, GCR funded eight new projects spanning 18 institutions and involving over 50 researchers, bridging two dozen disciplines. Projects included: fundamental science for the next generation of medical devices, such as ultra-miniature diagnostic devices, neuroprosthetics aimed at delaying the effects of degenerative diseases, and novel approaches to providing respiratory support in cases of lung failure; research to advance sustainability, including the sustainability of food systems, understanding and managing complex physical-biological systems, creating innovative ecological forecasts, and approaches for restoring degraded landscapes that deal with water cycling and supply, ecosystem nutrition, and carbon sequestration; and novel computing paradigms based on cultured biological neural networks to propel machine learning and artificial intelligence to the next level. In FY 2021, GCR also continued four projects that began in FY 2019. These included creating new scientific paradigms to enable sustainable bio-based materials generation, establishing an emerging field of Biomolecular Systems Engineering, developing science-based solutions to mitigating the impact of micro- and nano-plastics on aquatic environments, and developing transformative technologies that can rapidly capture, sense, and identify viruses and predict new strains.
- In FY 2023, GCR will incubate the capacity of research teams to address emerging research challenges that are large in scope, innovative in character, originate outside of any particular NSF directorate, and require the application of ideas, approaches and perspectives from multiple science and engineering fields. GCR investments will support three to seven new research collaborations and the continuation of three to six projects begun in FY 2021.

Mid-scale Research Infrastructure (Mid-scale RI)

Mid-scale RI is developing an agile process for funding experimental research capabilities in the mid-scale range, spanning the midscale gap in research infrastructure. This is a “sweet spot” for science and engineering that has been challenging to fund through traditional NSF programs.

- NSF made ten awards from the second Mid-scale RI-1 solicitation (NSF 21-505) on September 27, 2021¹, including construction of ocean-bottom seismographs; development of an observatory for on-line human and platform behavior; deployment of a network of sensors for measurement of atmospheric gases and aerosols; construction of a national silicon carbide fabrication facility; and support for the design of a new superconducting magnet and next generation astronomical radars. NSF made two additional awards from the first Mid-scale RI-2 solicitation (NSF 19-542): a network for advanced Nuclear Magnetic Resonance studies, in June 2021², and data infrastructure to enable transformative research by leveraging complex data about human behavior, society and the economy, in February 2022³.
- In FY 2023, NSF will invest \$126.25 million in Mid-scale RI, split between Mid-scale RI-1 (\$50.0 million), funded through R&RA, and Mid-scale RI-2 (\$76.25 million), funded through MREFC. NSF anticipates that Mid-scale RI-2 funding will provide continuing support to projects resulting from the first Mid-scale RI-2 competition that concluded in FY 2021 and will enable new awards to be made from proposals submitted to the second Mid-scale RI-2 solicitation (NSF 21-537). NSF plans to issue a new solicitation for Mid-scale RI-1 in FY 2023.

For more information on Mid-scale Research Infrastructure Track 1, see the IA narrative in the R&RA chapter. See the Mid-scale Research Infrastructure Track 2 narrative in the Research Infrastructure Theme chapter of NSF-wide Investments for more information on Track 2.

¹ www.nsf.gov/news/special_reports/announcements/092721.jsp

² www.nsf.gov/news/special_reports/announcements/061621.jsp

³ www.nsf.gov/news/special_reports/announcements/020422.jsp