DIRECTORATE FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE) **$1,067,580,000**

CISE Funding

(Dollars in Millions)

	FY 2023 Base Plan[1]	FY 2024 (TBD)	FY 2025 Request	Change over FY 2023 Base Plan[1] Amount	Percent
Computing and Communication Foundations (CCF)	$200.10	-	$200.66	$0.56	0.3%
Computer and Network Systems (CNS)	245.62	-	246.18	0.56	0.2%
Information and Intelligent Systems (IIS)	217.69	-	218.25	0.56	0.3%
Information Technology Research (ITR)	123.30	-	123.30	-	-
Office of Advanced Cyberinfrastructure (OAC)	249.19	-	279.19	30.00	12.0%
Total	**$1,035.90**	**-**	**$1,067.58**	**$31.68**	**3.1%**

[1] For comparability with FY 2025, the FY 2023 levels do not include this organization's share of Mission Support Services that were funded through the R&RA and EDU directorates and offices.

About CISE

CISE's mission is to promote the progress of computer and information science and engineering research and education, and advance the development and use of cyberinfrastructure (CI) across the science and engineering research enterprise; to promote understanding of the principles and uses of advanced computer, communication, and information systems in advancing science and engineering and in service to society; and to contribute to universal, transparent, and affordable participation in a knowledge-based society. CISE supports ambitious research and research infrastructure projects within and across the many subfields of computing, as well as advanced research CI for all areas of science and engineering; contributes to the education and training of computing and information professionals; and more broadly, informs the preparation of a U.S. workforce with computing, computational, and information competencies essential for success in an increasingly competitive global and digital market. Essentially all practical applications of today's IT are based on ideas and concepts that emerged from investments in fundamental computing and information research, many of them funded by CISE.[1]

In FY 2025, CISE will continue to play a leadership role in Advancing Emerging Industries for National and Economic Security through seminal investments in AI, advanced computing systems and services, quantum information science (QIS), advanced communications technologies, advanced manufacturing, semiconductors and microelectronics, biotechnology, and cybersecurity. CISE will also continue its investment in the SaTC program that supports research to advance the fields of cybersecurity and privacy, including through information integrity.

The National AI Initiative Act of 2020 called on NSF, in coordination with OSTP, to form a National AI Research Resource (NAIRR) Task Force to investigate the feasibility of establishing a NAIRR and develop a roadmap detailing how such a resource could be established and sustained. Comprising

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

members from government, academia, and the private sector, the NAIRR Task Force submitted its final report to the President and Congress, *Strengthening and Democratizing the U.S. Artificial Intelligence Innovation Ecosystem: An Implementation Plan for a NAIRR* in January 2023. In FY 2025, as directed in the President's *Executive Order on the Safe, Secure and Trustworthy Development and Use of AI*, NSF will continue to work with other federal agencies, the private sector, academia, civil society, and others to build on the NAIRR pilot initiated in FY 2024[2]. The NAIRR pilot will demonstrate the value and impact of the NAIRR concept and facilitate access to large-scale computing resources, data infrastructure, AI-ready datasets, pre-trained models, software and tools, and related skill training resources required to advance AI research and the use of AI in research and education.

In FY 2025, CISE will continue its investments in Building a Resilient Planet through the development of a National Discovery Cloud for Climate (NDC-C). This resource will federate advanced compute, data, software and networking resources, democratizing access to a CI ecosystem that is increasingly necessary to further climate-related S&E. CISE will also support investments in designing the next generation of computing systems that explore novel ways to not only dramatically increase energy efficiency but also incorporate clean energy technologies in the entire computing lifecycle.

CISE investments foster and support research and teaching environments that promote opportunities for everyone. In alignment with an agency-wide emphasis on Creating Opportunities Everywhere, CISE will continue to invest in a broad suite of activities to support broadening participation in research and education in CISE fields and STEM more generally. For example, in alignment with the INCLUDES Initiative, the Broadening Participation in Computing Alliances (BPC-A) will serve as broad coalitions of institutions of higher education, K-12 schools, government, industry, professional societies, and other not-for-profit organizations that design and carry out comprehensive programs addressing underrepresentation in the computing and information science disciplines. CISE will also broaden participation in computing by increasing engagement in CISE-funded research projects from MSIs through the CISE-MSI program and will emphasize education and training of more U.S. based students from diverse backgrounds through CISE Graduate Fellowships (CSGrad4US).

In FY 2025, CISE, through OAC, will continue to provide NSF's co-leadership of the Future Advanced Computing Ecosystem (FACE).[3] CISE investments support the full breadth of NSF-funded S&E by enabling shared resources and improved capabilities across a range of disciplines, a diverse set of users within many academic institutions, and a wide range of science and engineering advances. CISE will also continue to provide leadership for the Federal Government's Networking and Information Technology Research and Development (NITRD) program. The NITRD Subcommittee of the National Science and Technology Council (NSTC), which coordinates investments in networking and information technology research and development across more than 20 federal departments, agencies, and offices, is co-chaired by the NSF assistant director for CISE. All research, education, and research infrastructure projects supported by CISE contribute to NSF's NITRD portfolio.

Finally, CISE will build, strengthen, and expand strategic, multisector partnerships, including those with other NSF units, other federal agencies, private industry and foundations, and international funders, as an increasingly important means to maximize the scientific, economic, and societal impacts of the directorate's investments.

[2] https://new.nsf.gov/focus-areas/artificial-intelligence/nairr

[3] www.nitrd.gov/pubs/Future-Advanced-Computing-Ecosystem-Strategic-Plan-Nov-2020.pdf

Major Investments

CISE Major Investments

(Dollars in Millions)

Area of Investment[1,2]	FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request	Change over FY 2023 Base Plan Amount	Change over FY 2023 Base Plan Percent
Advanced Manufacturing	$44.30	-	$44.30	-	-
Advanced Wireless Research	88.76	-	93.61	4.85	5.5%
Artificial Intelligence	344.00	-	369.18	25.18	7.3%
Biotechnology	6.92	-	8.55	1.63	23.6%
BaRP: Clean Energy Technology	39.50	-	42.63	3.13	7.9%
BaRP: USGCRP	30.00	-	30.00	-	-
CSGrad4US	8.50	-	10.50	2.00	23.5%
Microelectronics/Semiconductors	40.00	-	41.80	1.80	4.5%
National Artificial Intelligence Research Resource (NAIRR)	-	-	30.00	30.00	N/A
Quantum Information Science	20.70	-	27.05	6.35	30.7%
Secure & Trustworthy Cyberspace	75.00	-	75.00	-	-

[1] Major investments may have funding overlap and thus should not be summed.

[2] This table reflects this directorate's support for selected topics. Investment priorities and presentation may differ by organization and so should not be summed across narratives.

To learn more about cross-agency themes and initiatives supported by CISE, including Advanced Manufacturing, Advanced Wireless Research, Artificial Intelligence, Biotechnology, Climate, Microelectronics/Semiconductors, Quantum Information Science, and Secure and Trustworthy Cyberspace, see individual narratives in the NSF-Wide Investments chapter.

- Advanced Wireless Research: CISE will continue to invest in research in advanced wireless networks, building on its track record of enabling early-stage successes in 5G through ground-breaking millimeter-wave research. CISE will accelerate research in areas with potential significant impact on emerging Next-Generation (NextG) wireless and mobile communications, networking, sensing, and computing systems, with a focus on greatly improving the resiliency and intelligence of such networked systems.
- Artificial Intelligence (AI): CISE, together with other NSF directorates/offices, other federal agencies, and the private sector, will increase support for AI research and development, which CISE leads at NSF. A key focal point will be continued support for the National AI Research Institutes. Through this program CISE, in partnership with other NSF directorates, will significantly broaden participation in AI research, education, and workforce development through capacity development projects such as ExpandAI, through CISE core investments, and through partnerships within the National AI Research Institutes ecosystem. CISE will also provide support for the NAIRR pilot to democratize access to advanced computing and data resources, thereby engaging a broad and diverse population.
- CSGrad4US Graduate Fellowships: CISE will support early-career individuals with the demonstrated potential to be high-achieving CISE researchers and innovators, with the goal of developing the national workforce necessary to ensure the Nation’s continued leadership in advancing CISE research and innovation. Through this investment, CISE aims to increase the

number and diversity of domestic graduate students pursuing graduate degrees and research and innovation careers in CISE fields and broaden participation among groups underrepresented in these areas.

- National Artificial Intelligence Research Resource (NAIRR): In FY 2025, CISE will continue to focus on the pilot implementation of the NAIRR to amplify efforts across the federal government to cultivate AI innovation and advance trustworthy AI. The NAIRR is envisioned as a widely accessible, national CI that will advance and accelerate the U.S. AI R&D environment and fuel AI discovery and innovation in the United States. Specifically, CISE will continue to work with other federal agencies and the broader community on the NAIRR pilot launched in 2024 to demonstrate the potential impact and value of the NAIRR concept.
- Secure and Trustworthy Cyberspace (SaTC): CISE will continue to lead SaTC in partnership with other NSF directorates, investing in current and emerging areas of importance for security and privacy. These areas include the application of AI to security, security and resilience of AI systems, security implications of quantum computation and communication, information integrity, and critical infrastructure security. CISE will fund programs that strengthen the national cybersecurity workforce pipeline through education, K-12 programs, and funding to universities and colleges.

Centers Programs

CISE Funding for Centers Programs

(Dollars in Millions)

	FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request	Change over FY 2023 Base Plan Amount	Change over FY 2023 Base Plan Percent
Artificial Intelligence Research Institutes (All units)	$19.95	-	$29.09	$9.14	45.8%

For detailed information on individual centers programs, please see the Cross Theme Topics section of the NSF-Wide Investments chapter.

CISE Divisions

CISE Division Funding by Category[1]

(Dollars in Millions)

	FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request	Change over FY 2023 Base Plan Amount	Change over FY 2023 Base Plan Percent
CCF	**$200.10**	**-**	**$200.66**	**$0.56**	**0.3%**
Research	185.80	-	188.36	2.56	1.4%
Education	12.70	-	10.70	-2.00	-15.7%
Infrastructure	1.60	-	1.60	-	-
CNS	**$245.62**	**-**	**$246.18**	**$0.56**	**0.2%**
Research	204.12	-	204.08	-0.04	-0.0%
Education	16.70	-	12.70	-4.00	-24.0%
Infrastructure	24.80	-	29.40	4.60	18.5%
IIS	**$217.69**	**-**	**$218.25**	**$0.56**	**0.3%**
Research	202.59	-	205.15	2.56	1.3%
Education	13.10	-	11.10	-2.00	-15.3%
Infrastructure	2.00	-	2.00	-	-
ITR	**$123.30**	**-**	**$123.30**	**-**	**-**
Research	111.40	-	108.85	-2.55	-2.3%
Education	1.00	-	1.50	0.50	50.0%
Infrastructure	10.90	-	12.95	2.05	18.8%
OAC	**$249.19**	**-**	**$279.19**	**$30.00**	**12.0%**
Research	75.09	-	95.77	20.68	27.5%
Education	22.30	-	22.30	-	-
Infrastructure	151.80	-	161.12	9.32	6.1%

[1] For comparability with FY 2025, the FY 2023 levels do not include this organization's share of Mission Support Services that were funded through the R&RA and EDU directorates and offices.

Division of Computing and Communication Foundations (CCF) supports research and education activities that advance the foundations of computing, communication, hardware, software, and emerging technologies such as quantum information science and bio-inspired systems. CCF's investments enable advances in the design and analysis of algorithms, computational complexity, and mathematical modeling of systems, with attention to the efficiency, fairness, correctness, and robustness of systems including AI systems. CCF also invests in foundational research on the theoretical underpinnings of information acquisition, transmission, and processing in communication and information networks, such as sensor, advanced wireless, biological, and quantum devices networks. In addition, CCF provides support for advancing the design, validation, verification and evaluation of computing hardware and software through new theories, programming languages, testing approaches, and formal methods for improving system performance, safety, usability, reliability, and scalability.

Division of Computer and Network Systems (CNS) supports research and education activities that develop new computing and networking technologies and that explore new ways to make use of existing technologies. CNS seeks to develop a better understanding of the fundamental properties of computer and network systems, cybersecurity, and cyber-physical systems and to create better abstractions and tools for designing, building, analyzing, and measuring future systems. CNS also supports the computing infrastructure that is required for experimental computing.

Division of Information and Intelligent Systems (IIS) supports research and education activities that advance our knowledge in the interrelated roles of people, computers, and information. The range of research topics within these areas is broad and encompasses several significant subareas of computing: trustworthy artificial Intelligence, which includes work on knowledge representation and reasoning, deep learning, machine learning, human language technologies, robotics and computer vision, and computational approaches to neuroscience; data science, which includes data collection and management, data integration, data mining and analytics, smart health and biomedical research, and informatics; and human centered computing, which includes usability, interfaces, assistive technology, virtual reality, and the social impacts of computing.

Division of Information Technology Research (ITR) provides support for transformative explorations in computer and information science and engineering research, infrastructure, and education, which are foundational for a wide range of emerging industries. These investments support emerging and urgent high-priority areas that cut across traditional disciplinary boundaries and promise to accelerate discovery at the frontiers of the field. This includes support for foundational research on AI, semiconductors, and advanced wireless as well as the development of world-class research infrastructure. ITR further catalyzes research through innovative partnerships and collaborations between academia and industry.

Office of Advanced Cyberinfrastructure (OAC) supports the conceptualization, design, and implementation of the advanced research CI ecosystem that is critical to advances in all areas of science and engineering research and education by enabling data science, artificial intelligence and machine learning, and predictive and high-end computational modeling and simulation. OAC investments also support training and workforce development and nurture the computational and data skills and expertise needed for next-generation science and engineering research. OAC enables researchers to address complex and multidisciplinary discovery, prediction, and innovation challenges by providing access to CI resources and services, along with secure connectivity to major facilities and scientific instruments.

APPENDIX A – ADVANCED COMPUTING SYSTEMS AND SERVICES PORTFOLIO

Advanced Computing Systems and Services Funding

(Dollars in Millions)

	FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request
Leadership Class Computing	$12.00	-	$12.00
Advanced/Innovative Computing Systems and Services	50.00	-	125.00
Coordination and Support Services	37.50	-	38.00
Total	**$99.50**	**-**	**$175.00**

Advanced Computing Systems and Services Overview

For nearly four decades, NSF has been a recognized leader in enabling the innovative use and broad availability of a cohesive, powerful, and advanced computing ecosystem to accelerate fundamental science and engineering (S&E) research. Going forward, NSF aims to sustain the Nation's leadership in the research, development, and broad deployment of existing as well as new advanced computing and data systems, services, and expertise, in part through its co-leadership of the all-of-government National Science and Technology Council (NSTC) Future Advanced Computing Ecosystem (FACE) Subcommittee efforts. Within the broad goals set for the FACE[4,5] and as further elaborated by the NSTC FACE Subcommittee, key NSF foci include fundamental and translational research to support future generations of the advanced computing ecosystem; research CI including software and data services to promote cohesive platforms and interoperability for large-scale data analytics as well as modeling and simulation applications across all of S&E; the expertise necessary for advancing the frontiers of CI, as well as communities of experts that enable S&E discovery and innovation using CI. These foci include an emphasis on a holistic approach to the Nation's computational and data infrastructure for S&E research, spanning both human and technical dimensions, and involve forging and expanding partnerships that ensure the Nation's leadership in science, technology, and innovation. For example, during the novel coronavirus disease 2019 (COVID-19) pandemic, NSF's suite of complementary advanced computing systems and coordination services were mobilized as key contributors to the COVID-19 High-Performance Computing (HPC) Consortium, a public-private partnership that NSF helped co-found and which is being used as an exemplar model for the rapid launch of the NAIRR pilot.

The overall NSF advanced computing strategy and program portfolio receives guidance and input from the Advisory Committee on Cyberinfrastructure (ACCI); NSF leadership; the Cyberinfrastructure Strategy Committee, which includes senior leadership from the NSF research and education directorates and offices; and directly from the research community through multiple sources including principal investigator meetings, workshops, sessions at professional conferences,[6] community blue-ribbon studies, and Requests for Information (RFIs). A Cyberinfrastructure Center of Excellence, funded in 2021, also conducted a series of stakeholder workshops that yielded numerous

[4] www.nitrd.gov/news/2020/Future-Advanced-Computing-Ecosystem-Strategic-Plan-Nov-2020.aspx
[5] www.nsf.gov/cise/nsci/
[6] See, for example, https://sc20.supercomputing.org/proceedings/bof/bof_pages/bof143.html

best practices and workforce capabilities essential to research computing and data.

In response to rapid advances in technology, changes in the capabilities and services offered by commercial interests (e.g., cloud services), and the rapid evolution of S&E research requirements, between FY 2019 and 2021, NSF released five forward-looking computational ecosystem blueprints, "Transforming Science Through Cyberinfrastructure". [7]

NSF continues to invest in three broad and complementary advanced computing areas that enable it to meet continually evolving needs in an agile yet predictable way. These investment areas complement each other as well as augment discipline-specific investments by NSF's directorates, mission-specific investments by other agencies, and cumulatively extensive, but individually smaller, investments by academic institutions at the regional and campus levels. Specifically, these areas are:

- **Leadership-Class Computing**, which aims to provide unique services and resources to advance the largest and most computationally intensive S&E research frontiers not otherwise possible;
- **Advanced/Innovative Computing Systems and Services**, which aims to provide a technically diverse, connected, and potentially future-looking advanced computing portfolio, reflecting the growing and changing use of computation and data in both the research and education processes, and capable of supporting hundreds to thousands of investigators conducting cutting-edge S&E research; and
- **Coordination and Support Services**, which aims to coordinate and evolve the provisioning, allocation, and integrated operation of NSF's advanced computing resources, providing advanced assistance to the user community, supporting aggregation and federation capabilities, translating CI research advances into operational technologies, measuring computing systems performance, and broadening participation by underrepresented communities nationwide.

In FY 2025, NSF-funded advanced computing systems and services will support the full breadth of NSF-funded S&E, including research furthering our understanding of environmental systems and advanced energy technologies, notably (i) AI and data-driven approaches to assimilate heterogeneous data sets about climatology; (ii) large-scale modeling of Earth systems; and (iii) high-end simulations of renewable and alternative energy approaches, and novel materials supporting energy efficiency and sustainability.

Leadership-Class Computing

Description

Leadership-class computing systems have represented a key component of NSF's computational portfolio for decades. NSF's current leadership-class computing system is Frontera, which is deployed at the Texas Advanced Computing Center (TACC) at the University of Texas at Austin (UT Austin). Frontera is one of the most powerful supercomputers in the world and is the most powerful supercomputer ever deployed on a U.S. academic campus. The system began accepting early S&E research users in May 2019 and became fully operational in October 2019. Using Frontera, researchers are tackling much larger and more complex S&E applications than ever before, within and across disciplines as diverse as biology, astronomy, engineering, materials science, and geosciences. The Frontera system offers the highest scale, throughput, and data analysis capabilities ever deployed on a U.S. university campus. In addition, Frontera's graphics processing unit (GPU) accelerates

[7] www.nsf.gov/cise/oac/vision/blueprint-2019/nsf-aci-blueprint-v10-508.pdf

discoveries in important research areas such as AI and molecular dynamics.

Current Status

At its July 2018 meeting, NSB authorized the Director to make a $60.0 million award to TACC for the acquisition of the Frontera system over a period of five years, the first acquisition in a two-phased process. NSB, at its May 2019 meeting, also authorized the Director to make a $60.0 million award to TACC for the operations and maintenance (O&M) of Frontera over a period of five years. Frontera has been in operation since September 2019 and is actively used by the S&E research and education community across NSF and other agencies.

The July 2018 NSB resolution also authorized, pending appropriate approval associated with MREFC policies, supplemental funding to advance the design of a Phase 2 leadership-class computing facility (LCCF). In July 2019, TACC started the design and planning process for the LCCF (refer to the MREFC narrative on the LCCF for more information). After extensive external and internal reviews, the NSF Director authorized the advancement of the LCCF project to the construction stage in December 2023.

S&E Research and Education Activities Enabled by Leadership-Class Computing

Leadership-class computing systems enable investigators across the Nation to conduct innovative research that is not otherwise possible due to demanding computing requirements. In FY 2020, NSF issued a Dear Colleague Letter[8] describing a new innovative pilot mechanism for the Nation's researchers to request access to Frontera to enable scientific and engineering research that would not otherwise be possible without access to a leadership-class computing resource. To date, this effort has resulted in over 250 allocation awards to research teams across the country. Examples of research that was enabled by the Frontera allocation awards include the full-scale modeling of the entire hippocampus in the brain to understand neurological disorders; simulations of supermassive black hole mergers to enable future gravitational wave detection; some of the largest simulations in the world to understand the physics and conditions that cause the formation of severe tornados; and high-resolution seismic hazard modeling to improve the health and safety of the Nation's earthquake prone regions. Using AI, a Frontera research team published a study that was able to, for the first time, pinpoint the genes that shape human skeletons. The study was published as the cover article for *Science* in July 2023[9].

NSF-funded leadership-class computing education and outreach activities consist of projects targeting students at pre-college, undergraduate, graduate, and post-graduate levels; workshops, conferences, summer schools, and seminars; as well as industry partnership activities. These activities have enabled more than 200 education, outreach, and training projects at over 160 institutions, including institutions in the Established Program to Stimulate Competitive Research (EPSCoR) jurisdictions. An example of one of these activities is the Frontera Computational Science Fellowship program,[10] which provides a year-long opportunity for talented graduate students to compute on Frontera and collaborate with experts at TACC; this program awarded four fellowships in FY 2023. Additionally, Frontera hosts numerous educational programs that are impacting hundreds of students from K-12 to mid-career professionals annually.

[8] www.nsf.gov/pubs/2020/nsf20018/nsf20018.jsp

[9] www.science.org/doi/10.1126/science.adf8009

[10] www.frontera-portal.tacc.utexas.edu/fellowship/

Management and Oversight
The Frontera project is overseen by OAC's program directors and BFA's Division of Grants and Agreements staff, who receive strategic advice from NSF leadership. Advice from the NSF Office of General Counsel is also sought, as necessary. NSB receives updates on any major changes in risk assessments, which are reviewed annually by an external panel. Risks monitored during the operational phase of a project include system security, performance, reliability, usability, project management, and other factors that could reduce the overall scientific impact.

Advanced/Innovative Computing Systems and Services

Description
NSF funds the acquisition and operation of nationally available Advanced/Innovative Computing Systems and Services that, in aggregate, are forward-looking, connected, and technically diverse, and reflect changing and growing use of data-intensive computation in both the research and education processes. At the same time, they are intended to enable discoveries at a computational scale beyond the reach of an individual or regional academic institution.

Deployed systems currently serve as a cohesive set of resource providers allocable within the Coordination and Support Services described in the following section. Awards are made as two parts: an acquisition and deployment award, which may be the result of a competitive or a renewal proposal; and a separate award for O&M following deployment. When an award is made, the awardee institution issues subawards to vendors and/or other organizations for acquisitions and services, as necessary. Expenditures are contingent on successful completion of deployment milestones. These resources are also accessible via the Partnership to Advance Throughput Computing (PATh) project and includes PATh's national scale federated data sharing fabric called the Open Science Data Federation.[11]

Current Status
In FY 2016, NSF awarded *Stampede 2: The Next Generation of Petascale Computing for Science and Engineering* to TACC, enabling the acquisition and deployment of Stampede 2. Stampede 2 serves as the primary national resource for approximately 7,000 academic researchers, complements other national advanced computing systems and services, and provides capabilities beyond the reach of individual campuses and regional resources. Stampede 2 was fully deployed as a production resource by the end of 2018 and is expected to continue operations through February 2024. This includes technical upgrades awarded in FY 2021 and FY 2023 to extend operations, partially upgrade the processor architecture, reconfigure the deployed filesystem, and explore pilot high-throughput computing allocations via the PATh project.[11]

Beginning in FY 2019, NSF made a series of investments in advanced/innovative computing systems and services to foster an integrated CI ecosystem that addresses the growing scale and diversity of the S&E community, the changing nature of S&E research requirements, and the rapidly evolving technology and services landscape, with the overarching goal of supporting the full range of computational- and data-intensive research across all S&E domains. Specifically, NSF issued the *Advanced Computing Systems and Services (ACSS): Adapting to the Rapid Evolution of Science and*

[11] www.nsf.gov/awardsearch/showAward?AWD_ID=2030508

Engineering Research solicitation[12] in FY 2019, with the first cohort of three awards running from FY 2019 to FY 2025,[13] followed by a second cohort of five awards running from FY 2020 to FY 2026,[14] and a third cohort of 2 awards running from FY 2021 to FY 2026.[15]

The ACSS solicitation called for investments in two categories:

- Category I, Capacity Systems: production computational resources maximizing the capacity provided to support the broad range of computation and data analytics needs in S&E research; and
- Category II, Innovative Prototypes/Testbeds: innovative forward-looking capabilities deploying novel technologies, architectures, usage modes, etc., and exploring new target applications, methods, and paradigms for S&E discoveries.

The current active ACSS solicitation includes support for Category I investments in FY 2023 and FY 2025, and Category II investments in FY 2024 and FY 2026.[16]

The current suite of Category I systems includes:

- *Expanse*: Located at the San Diego Supercomputer Center (SDSC), this system is a large-capacity, data-focused system supporting increasingly diverse, complex, and expanding research across multiple S&E disciplines within the "long tail" of science. Expanse is expected to be operational through FY 2025.
- *Bridges 2*: Located at the Pittsburgh Supercomputing Center (PSC), this system integrates AI-based analytics capabilities with the technical capacity to execute data- and computationally intensive research in a broad, cross-cutting manner, enabling advances across a range of S&E research and education. Bridges 2 is currently expected to be operational through FY 2025.
- *Anvil*: Located at Purdue University, Anvil is a composable system with an expansive portfolio of S&E-focused interfaces, programming environments, and advanced capabilities to support research and education. Anvil is currently expected to be operational through FY 2026.
- *Delta*: Located at the University of Illinois Urbana-Champaign (UIUC), Delta is a large-capacity, balanced computational resource supporting traditional computational methods combined with rapidly evolving and expanding AI-based techniques and advanced data science methods to advance S&E research and education. Delta is expected to be operational through FY 2026.
- *Jetstream 2*: Located at Indiana University, Jetstream 2 provides a nationally distributed, large-capacity, cloud-enabled computational resource supporting diverse S&E-focused "on-demand" access modes and utilization models to be available across research and education. Jetstream 2 is currently expected to be operational through FY 2026.

In FY 2023, NSF awarded "Category I: Stampede3 - Modernizing and Evolving the Largest ACCESS Compute Resource" to TACC, enabling the acquisition and deployment of Stampede3 a highly performant successor to Stampede 2 as the primary national resource for approximately 7,000 academic researchers, complementing other national advanced computing systems and services, and providing capabilities beyond the reach of individual campuses and regional resources. Additionally, in FY 2023, NSF awarded "Category I: Bridging the Gap Between AI/ML Computing Demands and

[12] www.nsf.gov/funding/pgm_summ.jsp?pims_id=503148
[13] www.nsf.gov/pubs/2019/nsf19534/nsf19534.htm
[14] www.nsf.gov/pubs/2019/nsf19587/nsf19587.htm
[15] www.nsf.gov/pubs/2020/nsf20606/nsf20606.htm
[16] www.nsf.gov/pubs/2023/nsf23518/nsf23518.htm

Today's Capabilities" to the University of Illinois Urbana-Champaign (UIUC) enabling acquisition of DeltaAI, a large-capacity computational resource supporting rapidly evolving and expanding AI-based techniques and advanced data science focused methods to advance S&E research and education.

In addition, the Category II, or Testbed-Prototype Systems, include:

- *Ookami*: Located at SUNY at Stony Brook, this prototype incorporates ARM-based processors keeping a familiar programming environment for researchers for both simulation and data analysis workloads. Ookami is currently expected to be operational through FY 2025.
- *Neocortex*: Located at PSC, this prototype deploys a novel AI-focused processor architecture in a high-performing system design supporting very high-scale, complex analytics challenges across S&E research and education. Neocortex is currently expected to be operational through May 2026.
- *Voyager*: Located at SDSC, this prototype integrates AI/ML/deep learning-focused components to advance S&E research and education. Voyager is currently expected to be operational through May 2026.
- *National Research Platform (NRP):* Located at SDSC, with partners at University of Nebraska, Lincoln (UNL) and the Massachusetts Green High Performance Computing Center (MGHPCC), this prototype will deploy a distributed testbed architecture including high-performance subsystems supported by low-latency high-bandwidth research and education networking. The prototype NRP is currently expected to be operational through May 2026.
- *Accelerating Computing for Emerging Sciences (ACES)*: Located at Texas A&M University, this prototype system will deploy a novel composable system architecture with the flexibility to aggregate various components on an as-needed basis to solve problems previously not addressable by researchers. ACES is currently expected to be operational through September 2026.

During their respective operational periods, NSF will evaluate the utility of the above listed Category II, or Testbed-Prototype Systems and determine whether they can be integrated into the suite of production services.

S&E Research and Education Activities Enabled by Advanced/Innovative Computing Systems and Services

The ecosystem of advanced/innovative computing systems and services is enabling new, world-leading, and transformative advances across the breadth of S&E research, in the integration of research and education, and in broadening participation in S&E by underrepresented groups. It is enabling new collaborations across public and private sectors to advance the Nation's security and economic competitiveness. These advances are made possible by providing researchers and educators with access to world-leading computational systems and services beyond what is typically available on most campuses. Providing access includes providing the expertise, interfaces, consulting support, and training necessary to facilitate use of the systems and services. This activity is central to achieving the full potential of complementary investments by NSF, other federal agencies, and academic institutions in computing infrastructure across the Nation.

Management and Oversight

OAC's program directors provide direct oversight over all Advanced/Innovative Computing Systems and Services awards. Oversight is executed via the use of cooperative agreements that include management structures, milestones, spending authorization levels, and review schedules. Each awardee is responsible for the satisfactory completion of milestones prior to NSF authorization of

spending. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors. Progress is assessed with the aid of annual external reviews. In addition, each project is required to have a project execution plan.

Any activity of this nature and at this scale comes with a certain element of risk. The review process, conducted prior to award, analyzes the risks as presented in the proposal and identifies any additional risks that should be considered. During the award process, risks are identified and analyzed, and a mitigation plan is created and followed. One of the activities that are a part of the periodic NSF external reviews conducted by an external panel of experts, is to revisit and reassess the risk and make recommendations as deemed necessary. In the case of projects that involve an acquisition, project risks are generally substantially reduced after deployment. Thus, the pacing of the acquisitions and deployments for such projects provides balance in the overall risk portfolio for the program.

Milestone-driven reviews occur during the acquisition award, typically with an external review prior to deployment. Annual reviews, conducted by an external panel of expert reviewers and managed by OAC program directors, are performed during the operational phase of each project.

Coordination and Support Services

Description

NSF's investments in a fabric of coordination and support services add value to the NSF advanced/innovative computing systems and services by provisioning, allocation, and integrated operation of NSF's advanced computing resources, providing advanced assistance to the user community, supporting aggregation and federation capabilities, translating CI research advances into operational technologies, measuring computing systems performance, and broadening participation by underrepresented communities nationwide. Activities funded within coordination and support services include two major foci: the Advanced Computing Coordination Ecosystem: Services and Support (ACCESS) suite of awards, and the Partnership to Advanced Throughput Computing (PATh).

The ACCESS shared services model for coherently and efficiently providing researchers with both access to and expertise for diverse, dynamic, and distributed resources is a cornerstone of the National advanced computing ecosystem; enabling the connection between individual campuses and national resources is an essential aspect. ACCESS enables and supports leading-edge scientific discovery and promotes science and technology education. The program encourages innovation in the design and implementation of an effective, efficient approach to the provisioning of high-end computing and data services while ensuring that the infrastructure continues to deliver high-quality access for the many researchers and educators who use it in their work.

ACCESS program services consist of several interrelated parts: allocation of resources to computational and data research projects; advanced user assistance; training, education, and outreach; architecture and operation of a secure, integrated services infrastructure; system performance metrics services; and overall communications and coordination. These elements are designed and implemented in a way that is clearly tied to the requirements of the S&E research community, using a flexible methodology that permits the architecture to evolve in response to changing community needs and that presents individual users with a common environment regardless of where the resources or researchers are located.

For researchers requiring high-throughput computing, computing that can be characterized by executing large numbers of tasks over a long period of time, the PATh project makes Distributed High Throughput Computing (dHTC) capacity available to researchers through a fabric of services. These services enable the federation of resources into an effective source of computing capacity for a wide spectrum of science applications. PATh supports single-PIs and collaborative science groups across science and engineering disciplines to join the cohort of international physical science collaborators who have leveraged the dHTC paradigm for decades.

Current Status

NSF outlined plans for a fabric of national CI coordination services in a blueprint document released in FY 2020.[17] This blueprint was based on findings from the NSTC FACE Subcommittee, guidance from ACCI and advisors, responses to an RFI, and feedback from engagement with the community about the structure and composition of future coordination efforts. Following the blueprint, NSF issued the *Advanced Cyberinfrastructure Coordination Ecosystem: Services & Support (ACCESS)* and *ACCESS - Coordination Office (ACCESS-ACO)* solicitations[18-19] in early FY 2021. Awards for ACCESS services and the ACCESS-ACO were made during FY 2022, except for the Technology Translation track that will be awarded in FY 2024 under the Cyberinfrastructure Technology Acceleration Pathway (CITAP) solicitation.

The current ACCESS suite of awards includes:

- *Allocation Services (RAMPS)*: The ACCESS Resource Allocations Marketplace and Platform Services (RAMPS) project was awarded to Carnegie-Mellon University (CMU), with subawards to UIUC and the University Corporation for Atmospheric Research. RAMPS reviews and allocates the capacity of the resource providers supported by the Advanced/Innovative Computing Systems and Services.
- *End User Support Services (MATCH)*: The Multi-tier Assistance, Training, and Computational Help (MATCH) was awarded to the University of Colorado Boulder, with subawards to the MGHPCC and the Ohio State University. MATCH enables innovative research through equitable and scalable support services to end users.
- *Operations & Integration Services (CONECT)*: Core National Ecosystem for CyberinfrasTructure (CONECT) project was awarded to UIUC, with subawards to the University of Chicago and CMU. CONECT delivers innovative integrations across the suite of resource providers in the areas of operations, data and networking, and cybersecurity.
- *Monitoring & Measurement Services*: Awarded to SUNY at Buffalo, this award provides metrics services allowing measurement and monitoring of key operational data from the advanced computing/innovative systems and services portfolio.
- *ACCESS Coordination Office (OpenCI)*: Awarded to UIUC, with a subaward to the University of California San Diego, the OpenCI Coordination Office facilitates shared governance across the ACCESS awardees and communications to stakeholders.

PATh is a five-year award to the University of Wisconsin-Madison. Within the award, six partners are engaged through sub-awards: Indiana University, Information Sciences Institute (USC), Morgridge Institute for Research, University of California San Diego, University of Chicago, and University of

[17] www.nsf.gov/cise/oac/vision/blueprint-2019/nsf-aci-blueprint-services.pdf
[18] www.nsf.gov/pubs/2021/nsf21555/nsf21555.htm
[19] www.nsf.gov/pubs/2021/nsf21556/nsf21556.htm?org=NSF

Nebraska-Lincoln. The award is now in its 2nd year.

S&E Research and Education Activities Enabled by Coordination and Support Services

Coordination and support services, as exemplified by the ACCESS and PATh awardees, enable transformative advances in S&E research, in the integration of research and education, and in broadening the participation of underrepresented groups in S&E. These advances are accomplished by providing researchers and educators with coherent and highly usable access to digital resources beyond those typically available on most campuses, together with the interfaces, consulting, advanced user support, and training necessary to facilitate their use.

Coordinated access to advanced/innovative computing systems and services enables researchers to efficiently manipulate, analyze, visualize, and share extremely large amounts of distributed digital information from simulations, sensors, and experiments. The coordination and support services awarded will enable the CI ecosystem, including resources and CI professionals, to innovate and evolve in sync with S&E research and education needs and opportunities. External communication, outreach, and community-building efforts by the ACCESS awardees will broaden the participation of individuals and communities that have been underserved by the national CI ecosystem.

The fabric of coordination and support services for the advanced CI ecosystem delivers tools and democratized access for researchers seeking resources, such as self-serve knowledgebase ask.CI. In doing so, these services facilitate dynamic access to digital resources, experimental testbeds, and CI professionals within and across university campuses with tools to submit jobs such as Open OnDemand, and Pegasus for workflow management. These services also support the integration of research software and data with CI resources. Human-in-the-loop expert services and widely available training materials reduce barriers to the use of advanced digital systems by the research and education communities, thereby promoting enhanced productivity.

Monitoring and measurement services collect multi-dimensional data from NSF's advanced computing systems for CI ecosystem usage statistics, users, and the computing resources' performance. Ongoing investments in these tools will enable the exploration of novel usage modes for advanced/testbed computing systems, integration with data repositories, instrumentation, and network performance. The immediate users of these methods and tools are the providers of NSF-supported advanced computing systems and services. However, both the tools and the data are publicly available and used by researchers, academic research computing center administrators, federal agencies, and industry seeking to optimize performance and forecast capacity demand.

Management and Oversight

Two OAC program directors oversee the advanced CI ecosystem services and support projects. Project management is supported by guidance from an external advisory board, service provider councils, and ongoing formal and informal engagement with stakeholder communities. OAC's oversight of projects includes participation in regular teleconferences with senior personnel of awardee teams, quarterly briefings, collaborative presence at national conferences, and regularly scheduled planning sessions such as the allocation requests review meetings. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors. Progress is assessed with the aid of external merit-based reviews annually. Each award is managed under a cooperative agreement with tailored terms and conditions, including an approved Project Execution Plan detailing management structure, milestones, deliverables, risk management, reporting of spending levels over time, and a

review schedule. Each awardee is responsible for the satisfactory completion of milestones prior to NSF authorization of spending.