DIRECTORATE FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE) **$1,062,400,000 +$77,280,000 / 7.8%**

CISE Funding
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Change over FY 2019 Actual Percent
Office of Advanced Cyberinfrastructure (OAC)	$221.84	-	$232.72	$10.88	4.9%
Computing and Communication Foundations (CCF)	193.55	-	202.96	9.41	4.9%
Computer and Network Systems (CNS)	229.42	-	240.42	11.00	4.8%
Information and Intelligent Systems (IIS)	208.37	-	240.05	31.68	15.2%
Information Technology Research (ITR)	131.93	-	146.25	14.32	10.9%
Total	**$985.12**	**-**	**$1,062.40**	**$77.28**	**7.8%**

About CISE

Advances in information technology (IT) over the past two decades have proven to be key drivers of the American economy. Essentially all practical applications of today's IT are based on ideas and concepts that emerged from investments in fundamental computing research, many of them funded by CISE.[1] Fundamental ideas and concepts advanced through computing research have enabled innovative products and applications that now permeate many aspects of daily life, including personal communication, energy, transportation, health care, advanced manufacturing, national and homeland security, disaster preparedness and response, education and workforce development, public and private organizational effectiveness and efficiency, and discovery and innovation at the frontiers of all areas of scientific and engineering research.

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 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, long-term 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 professionals; and more broadly, informs the preparation of an American workforce with computing and computational competencies essential for success in an increasingly competitive global and digital market. CISE investments foster and support research and teaching environments that reflect American values. CISE executes its mission through its Divisions of Computing and Communication Foundations, Computer and Network Systems, Information and Intelligent Systems, and Information and Technology Research, and through the Office of Advanced Cyberinfrastructure, which has a Foundation-wide role supporting advanced research CI for all areas of science and engineering—and in close partnership with other NSF units, federal agencies, the private sector, and international funders.

In FY 2021, CISE will continue to play a leadership role in advancing the Nation's priorities, including the Administration's Industries of the Future (IotF) initiative, through seminal investments in Artificial Intelligence (AI), Quantum Information Science (QIS), Advanced Wireless (beyond fifth-generation, or "5G," wireless networks), Advanced Manufacturing, and Biotechnologies (including synthetic biology) that will drive the future bioeconomy. CISE will also continue to invest in strategic computing as well as microelectronics and semiconductor research. Investments in these areas are critically important for national security, economic competitiveness, and the broad advancement of all fields of science and

[1] www.nap.edu/catalog.php?record_id=13427

engineering. Advances in these areas will provide opportunities for major scientific breakthroughs and will positively transform American lives and industry for years to come. For example, investments in next-generation manufacturing technologies enabled by AI and machine learning (ML) will help keep jobs in America, ensure products are made in America, and strengthen our national manufacturing industrial base. Development of powerful quantum computers will help solve extreme-scale optimization and ML problems that are unsolvable today, maintaining American leadership in future advanced computing systems.

CISE's FY 2021 Budget Request is also shaped by the directorate's continued support for NSF's Big Ideas, including co-leadership of HDR, FW-HTF, and QL, and participation in NNA and URoL. Advances in AI and ML are essential to both HDR and FW-HTF, and will help to achieve the full potential of QL. Further, as part of HDR, and in partnership with the other research directorates and offices, CISE will invest funds in its ITR division to support convergent activities that transcend the traditional disciplinary boundaries of individual NSF units. CISE's FY 2021 Budget Request comprises support for other ongoing NSF-wide priorities as well, including IUSE; NSF I-Corps™; and SaTC.

CISE, through OAC, will provide NSF's co-leadership of the recently updated, whole-of-nation National Strategic Computing Initiative (NSCI).[2] As part of its support for NSCI, CISE investments will (i) advance future computing paradigms, devices, architectures, and platforms; and (ii) further the development and deployment of advanced computing systems and services, including maximizing the benefits of these systems and services through the deep integration of emerging computing paradigms with current science and engineering research drivers. Key foci will include sustainable and interoperable software that will exploit emerging highly multicore, heterogeneous, and energy-efficient architectures; data maintenance and curation; next-generation security capabilities; and workforce training and re-skilling. These investments will enable shared resources and improved capabilities across a range of disciplines, a broad set of users within a large number of academic institutions, and a diversity of science and engineering advances.

In addition, CISE will 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. CISE will also continue to co-chair the NSTC Machine Learning and Artificial Intelligence Subcommittee.

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. These external partnerships leverage resources, inform use-inspired research, accelerate the transition of research innovations to practice, and enhance workforce development.

CISE provides about 87 percent of the federal funding for fundamental computer science research at U.S. academic institutions.

[2] www.whitehouse.gov/wp-content/uploads/2019/11/National-Strategic-Computing-Initiative-Update-2019.pdf

Major Investments

CISE Major Investments
(Dollars in Millions)

Area of Investment[1,2]	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Change over FY 2019 Actual Percent
Advanced Manufacturing	$41.27	-	$39.41	-$1.86	-4.5%
Advanced Wireless Research	79.30	-	75.70	-3.60	-4.5%
Artificial Intelligence	297.00	-	525.44	228.44	76.9%
Bioeconomy	7.66	-	4.75	-2.91	-38.0%
IUSE	2.74	-	2.00	-0.74	-27.0%
Microelectronics and Semiconductors	17.20	-	16.43	-0.77	-4.5%
NSF I-Corps™	11.70	-	13.11	1.41	12.1%
Quantum Information Science	12.10	-	14.60	2.50	20.7%
SaTC	70.22	-	65.00	-5.22	-7.4%
NSF's Big Ideas					
HDR Stewardship	*30.00*	*-*	*45.00*	*15.00*	*50.0%*

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

[2] This table reflects this directorate's support for selected areas of investment. In other directorate narratives, areas of investment displayed in this table may differ and thus should not be summed across narratives.

- Advanced Manufacturing: CISE will invest in research that integrates ubiquitous sensors, computational tools, and highly connected cyber-physical systems in smart processing and "cyber-manufacturing" systems. This investment will enable new functionalities that will increase the efficiency and sustainability of the production of the next generation of products and services.
- Advanced Wireless Research (Beyond 5G): 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 investments will enable further exploration of additional spectrum bands, efficient spectrum sharing, spectrum monitoring, and development of novel applications that leverage advanced wireless communication networks. CISE investments in city-scale research testing platforms through the Platforms for Advanced Wireless Research program will speed up the lab-to-market translation of innovative research outcomes in academic and government labs to successful commercial products and services.
- AI: CISE, together with other NSF directorates and offices, other federal agencies, and the private sector, will increase support for AI research and development. A key focal point will be support for a set of National AI Research Institutes. These center-scale projects will advance foundational research; leverage use-inspired research; build the next-generation of talent; mobilize multidisciplinary groups of scientists, engineers, and educators; and serve as a nexus point for multisector collaborative efforts. The National AI Research Institutes will fill a critical gap in America's AI research and education portfolio by accelerating AI innovations, training AI researchers and innovators, and transitioning outcomes across a range of sectors. CISE investments in AI align with the *National Artificial Intelligence Research and Development Strategic Plan: 2019 Update*.[3]
- Bioeconomy: CISE, together with other NSF directorates/offices, will invest in fundamental research in synthetic biology, biotechnology, bioinformatics, and computational biology, as well as the

[3] www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf

infrastructure and education that will advance the foundational knowledge needed to understand and harness biological processes for societal benefit (e.g., economy, food, health, national security).

- IUSE: Given the increasing centrality of computing and information to innovation across a wide range of disciplines, undergraduate computer science (CS) programs are being called upon to prepare larger and more diverse student populations for careers in both CS and non-CS fields. This preparation includes providing the understandings and competencies needed to learn how to use computation collaboratively across different, challenging contexts and problems. Through IUSE: Computing in Undergraduate Education, CISE, together with EHR, will continue to support efforts to re-envision the role of computing in interdisciplinary collaboration within America's institutions of higher education.
- Microelectronics and Semiconductors: CISE, together with ENG and MPS, will support research to address fundamental science and engineering questions about the concepts, materials, devices, circuits, and platforms necessary to sustain progress in microelectronics and semiconductor technologies. Such progress is critical for emerging technologies such as AI and quantum computing, and will in turn contribute to advances across all sectors of the economy, including energy, transportation, health care, and advanced manufacturing. Investments in microelectronics and semiconductor research will enable whole-of-government access to trusted and assured systems for future storage and computing paradigms.
- NSF I-Corps™: CISE, in partnership with the other directorates, will continue to support the I-Corps™ program, which is establishing a National Innovation Network that connects NSF-funded science and engineering research with the technological, entrepreneurial, and business communities, linking scientific discovery with technology development, societal needs, and economic growth.
- QIS: CISE will continue to advance quantum computing, quantum communication, and other quantum-based approaches for processing, communicating, and using information. CISE investments will specifically support novel quantum algorithms, programming languages, architectures, and circuits; simulation of quantum algorithms and systems; and designing, programming, optimizing, and testing quantum computers and systems, including through cloud-based services. A particular focus of CISE's investments in QIS will be to continue growing capacity within academic computer and information science departments, including cross-disciplinary and multi-department collaborations, to support advances in quantum computing and/or communication over the long term.
- SaTC: CISE will continue to lead SaTC in partnership with EHR, ENG, MPS, and SBE, 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, and critical infrastructure security. These investments will also nurture the next generation of American cybersecurity and privacy researchers and practitioners.
- HDR Stewardship: CISE, as the steward for HDR, will support fundamental research in data science and engineering; development of a cohesive, federated approach to the research data infrastructure; and development of a 21st-century data-capable workforce. Increased investment in HDR stewardship funds in FY 2021 will allow NSF to fund critical new methods and advances in artificial intelligence (AI), notably in deep learning and ML.

CISE Funding for Centers Programs

CISE Funding for Centers Programs
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Change over FY 2019 Actual Percent
Total	**$8.70**	**-**	**$4.15**	**-$4.55**	**-52.3%**
STC: Center for the Science of Information (CCF)[1]	3.70	-	-	-3.70	-100.0%
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence (CCF, IIS, ITR)	5.00	-	4.15	-0.85	-17.0%

[1] The Center for the Science of Information is sunsetting as planned.

For additional information on NSF's centers programs, please see the NSF-Wide Investments chapter.

Funding Profile

CISE Funding Profile

	FY 2019 Actual Estimate	FY 2020 (TBD)	FY 2021 Estimate
Statistics for Competitive Awards:			
Number of Proposals	8,616	-	9,500
Number of New Awards	2,009	-	2,200
Funding Rate	23%	N/A	23%
Statistics for Research Grants:			
Number of Research Grant Proposals	8,240	-	9,100
Number of Research Grants	1,696	-	1,900
Funding Rate	21%	N/A	21%
Median Annualized Award Size	$166,559	-	$175,000
Average Annualized Award Size	$211,653	-	$220,000
Average Award Duration, in years	3.0	-	3.0

In FY 2021, the number of research grant proposals is expected to increase as compared to the FY 2019 Actual Estimate, and correspondingly the number of research grant awards is anticipated to increase to 1,900. The funding rate for research grants is expected to be 21 percent in FY 2021, the same as in FY 2019. Average annualized award size and average award duration are expected to increase slightly between the FY 2019 Actual Estimate and FY 2021 Estimate.

Program Monitoring and Evaluation

External Program Evaluations and Studies

- In FY 2012, the Science and Technology Policy Institute (STPI) conducted a program evaluation feasibility study for SaTC. This feasibility study provided methods for examining baseline portfolio investments and identifying metrics to measure progress toward program goals. The study was part of a broader effort to develop a plan for a future impact assessment. STPI identified baseline evaluation metrics in FY 2013-FY 2015 and completed the evaluation feasibility study in FY 2016. CISE, together

with the NSF Evaluation and Assessment Capability, funded a program evaluation of SaTC, and the results of that program evaluation are anticipated in FY 2020.

- Evaluation is a key part of all of CISE's education programs. 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 in order to track program-level progress. CISE expects to continue these evaluation activities in FY 2021.
- CISE is co-leading NSF's FY 2020-FY 2021 Agency Priority Goal (APG) to expand public and private partnerships agency-wide in order to enhance the impact of NSF's investments and contribute to American economic competitiveness and security. This APG builds on a prior APG on the same topic, which allowed NSF to develop an inventory of its public and private partnerships, along with a toolkit for aiding in partnership development. The new APG will focus on an agency-wide strategy for public and private partnerships, including identifying potential areas for partnership as well as prospective partners. Outputs of this APG will help in the evaluation of the impacts of NSF's partnerships across its portfolio of research, education, and research infrastructure investments.
- In FY 2020, CISE launched an impact analysis and evaluation of programs in which the directorate partners with the private sector to jointly support research at colleges and universities across the U.S. This study will identify the critical success factors and key performance indicators in both quantitative and qualitative form, to assess these in the context of specific partnership programs over the last five years, and to convey the outcomes in communications materials. The impact analysis and program evaluation are expected to conclude in FY 2021.

Workshops and Reports

- CISE has funded several studies led by the Computer Science and Telecommunications Board (CSTB) within the National Academies of Sciences, Engineering, and Medicine that resonate with the directorate's FY 2021 investments:
  - In FY 2017, CISE funded CSTB to update the so-called "tire-tracks" diagram[4] from the 2012 report, *Continuing Innovation in Information Technology*,[5] depicting the interconnections across research areas with the creation and evolution of billion-dollar IT industry sectors.[6]
  - *Information Technology and the U.S. Workforce: Where Are We and Where Do We Go from Here?*[7] a 2017 report on the interactions between technological, economic, and societal trends, notably how significant advances in IT and automation have profoundly impacted the way work is conducted, and identified open questions and promising research pathways.[8]
  - *Assessing and Responding to the Growth of Computer Science Undergraduate Enrollments*,[9] a 2018 report recommending responses to growing undergraduate computer science enrollments.
  - *Data Science for Undergraduates: Opportunities and Options*,[10] a 2018 report offering a vision for the emerging discipline of data science at the undergraduate level along with considerations and approaches for academic institutions and others to help guide the ongoing transformation of the field.
  - *Quantum Computing: Progress and Prospects*,[11] a 2019 report assessing the current progress and possible future pathways toward developing a general-purpose quantum computer as well as its potential implications.

[4] www.nap.edu/resource/23393/innovation-brochure-2017-forweb.pdf
[5] www.nap.edu/catalog.php?record_id=13427
[6] www.nsf.gov/awardsearch/showAward?AWD_ID=1748756&HistoricalAwards=false
[7] www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and
[8] www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and
[9] www.nap.edu/catalog/24926/assessing-and-responding-to-the-growth-of-computer-science-undergraduate-enrollments
[10] www.nap.edu/catalog/25104/data-science-for-undergraduates-opportunities-and-options
[11] www.nap.edu/catalog/25196/quantum-computing-progress-and-prospects

- The Computing Community Consortium has led several community visioning efforts that resonate with the directorate's FY 2021 investments:
  - *Computing Visions 2025.*[12] Two workshops were held under this activity: *Interacting with Computers All Around Us* (May 2014), and *The New Making Renaissance: Programmable Matter and Things* (June 2014).
  - *Intelligent Infrastructure*,[13] jointly with the Electrical and Computer Engineering Department Heads Association, presented a national research agenda for intelligent infrastructure, or the deep embedding of sensing, computation, and communication capabilities into traditional physical infrastructure such as roads, bridges, railways, and buildings, for enhancing efficiency, resiliency, and safety.
  - *Next Steps in Quantum Computing: Computer Science's Role*,[14] brought together researchers from quantum computing, computer architecture, electronic design automation, compiler construction, and classical programming languages to articulate the central role that various CISE subfields play to close the gap between the problems for which a quantum computer might be useful and what we can currently build, program, and run.
  - *Thermodynamic Computing*,[15] discussed the re-emergence of thermodynamics in a new role as an algorithmic technique in areas such as ML, annealing, quantum systems, and neuromorphic systems, with recent theoretical developments in non-equilibrium thermodynamics leading to computing systems that self-organize in response to external input.
  - *The Frontiers of Fairness in Machine Learning*,[16] convened a group of about 50 experts drawn from academia, industry, and government, to assess the state of understanding of the fundamentals of the nascent science of fairness in machine learning, and to identify the unanswered questions that seem the most pressing.
  - *Algorithmic and Economic Perspectives on Fairness*,[17] brought together computer science researchers with backgrounds in algorithmic decision making, machine learning, and data science with policy makers, legal experts, economists, and business leaders to discuss methods to ensure economic fairness in a data-driven world.
  - *Identifying Research Challenges in Post Quantum Cryptography Migration and Cryptographic Agility*,[18] identified academic research challenges in post quantum cryptography migration and cryptographic agility, identifying aspects of the complex and global migration to new public-key cryptography standards that could benefit from a more rigorous study and analysis.
  - *A 20-Year Community Roadmap for Artificial Intelligence Research in the US*,[19] developed a roadmap for AI research over the next 20 years, including research priorities, challenges, and recommendations.
- CISE-funded community workshops also resonate with the directorate's FY 2021 investments. For example, a May 2019 workshop on *Future Directions for Parallel and Distributed Computing*[20] brought together researchers from academia, industry, and government to discuss how the next generation of parallel and distributed computing systems will be domain-specific, and ways to combine a heterogeneous mix of computational patterns, algorithms, and hardware to achieve a set of goals that go beyond the aims of traditional systems to meet society's needs for more scalable, energy-efficient, reliable, verifiable, and secure computing systems. The outputs of this workshop align with CISE's co-leadership of the recently updated NSCI.

[12] https://cra.org/ccc/visioning/computing-visions-2025/
[13] https://cra.org/ccc/wp-content/uploads/sites/2/2017/03/A-National-Research-Agenda-for-Intelligent-Infrastructure.pdf
[14] https://cra.org/ccc/events/quantum-computing/
[15] https://cra.org/ccc/events/thermodynamic-computing/
[16] https://cra.org/ccc/events/fair-representations-fair-interactive-learning/
[17] https://cra.org/ccc/events/economics-and-fairness//
[18] https://cra.org/ccc/events/identifying-research-challenges-in-pqc-migration-and-cryptographic-agility/
[19] https://cra.org/ccc/wp-content/uploads/sites/2/2019/08/Community-Roadmap-for-AI-Research.pdf
[20] www.sigarch.org/nsf-workshop-report-on-future-directions-for-parallel-and-distributed-computing/

Committees of Visitors (COVs)[21]

- In early FY 2018, OAC convened a COV to examine and assess the quality of the merit review process across OAC. The report from that COV was accepted by the Advisory Committee for Cyberinfrastructure (ACCI) at its Spring 2018 meeting.
- In early FY 2020, CISE convened a COV to conduct a similar review of the FY 2014-FY 2018 programmatics within its CCF, CNS, and IIS divisions. The report from that COV was accepted by the CISE Advisory Committee at its Fall 2019 meeting.

The Performance and Management chapter provides details regarding the periodic reviews of programs and portfolios of programs by external COVs and directorate Advisory Committees. Please refer to this chapter for additional information.

People Involved in CISE Activities

Number of People Involved in CISE Activities

	FY 2019 Actual Estimate	FY 2020 (TBD)	FY 2021 Estimate
Senior Researchers	7,936	-	8,600
Other Professionals	1,229	-	1,400
Postdoctoral Associates	471	-	500
Graduate Students	6,495	-	6,700
Undergraduate Students	3,242	-	3,900
K-12 Teachers	-	-	-
K-12 Students	-	-	-
Total Number of People	**19,373**	**-**	**21,100**

[21] www.nsf.gov/od/oia/activities/cov/covs.jsp#cise

OFFICE OF ADVANCED CYBERINFRASTRUCTURE (OAC) **$232,720,000**
+$10,880,000 / 4.9%

OAC Funding
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Change over FY 2019 Actual Percent
Total	**$221.84**	**-**	**$232.72**	**$10.88**	**4.9%**
Research	**87.17**	**-**	**116.42**	**29.25**	**33.6%**
Education	**7.76**	**-**	**5.26**	**-2.50**	**-32.2%**
Infrastructure	**126.91**	**-**	**111.04**	**-15.87**	**-12.5%**
Networking and Computational Resources Infrastructure and Services	126.91	-	111.04	-15.87	-12.5%

About OAC

OAC supports the conceptualization, design, and implementation of the advanced research cyberinfrastructure (CI) ecosystem that is critical to advances in all areas of science and engineering research and education in the 21st century, including the Industries of the Future such as AI, QIS, and advanced wireless. In this way, OAC serves to sustain U.S. economic competitiveness and national security. Given its role across all of science and engineering, OAC works in partnership with all NSF directorates and offices as well as other CISE divisions, to provide support to academic institutions, and encourages a rich and vibrant ecosystem that blends translational computer and computational research and research-specific CI with innovations from the private sector. Specifically, OAC investments include acquisition, integration, coordination, and operations associated with shared data, secure networking, advanced computation, scientific software and data services, and the design and development of computational and data-enabled science and engineering tools. OAC also nurtures the computational and data skills and expertise needed for next-generation science and engineering research. Collectively, OAC enables more than 8,000 faculty and 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 national and international facilities and scientific instruments. OAC promotes innovative, robust, secure, and interoperable CI, as well as sharing and collaboration among academic research infrastructure groups, other federal agencies and international research funders, and the private sector.

OAC will continue to provide NSF's co-leadership of the recently updated NSCI. This activity will support research advances in new, advanced computing architectures, systems, and services to address 21st-century scientific and technological challenges and opportunities; develop and broaden the Nation's computational infrastructure ecosystem; and forge and expand partnerships for the future of computing.

In general, about 34 percent of the OAC portfolio is available to support new grants. The remaining 66 percent supports grants made in prior years.

DIVISION OF COMPUTING AND COMMUNICATION FOUNDATIONS (CCF) **$202,960,000**
+$9,410,000 / 4.9%

CCF Funding
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Percent
Total	**$193.55**	**-**	**$202.96**	**$9.41**	**4.9%**
Research	**182.11**	**-**	**193.80**	**11.69**	**6.4%**
Centers Funding (total)	6.70	-	2.49	-4.21	-62.8%
STC: Center for the Science of Information[1]	3.70	-	-	-3.70	-100.0%
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	3.00	-	2.49	-0.51	-17.0%
Education	**9.84**	**-**	**7.60**	**-2.24**	**-22.8%**
Infrastructure	**1.60**	**-**	**1.56**	**-0.04**	**-2.5%**
National Nanotechnology Coordinated Infrastructure (NNCI)	0.60	-	0.56	-0.04	-6.7%
Research Resources	1.00	-	1.00	-	-

[1] The Center for the Science of Information is sunsetting as planned.

About CCF

CCF supports research and educational activities involving the theoretical foundations of computing, communication, and information. CCF's investments enable advances in the design and analysis of algorithms, computational complexity, and mathematical modeling of systems, with attention to the fairness, correctness, and verification of 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, multimedia, and biological 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, correctness, usability, reliability, and scalability. CCF investments also explore the potential impact of emerging technologies, including quantum devices and systems, neuromorphic architectures, biocomputing, synthetic biology, and nanotechnology, on the various facets of computation, communication, and information that are of relevance to the IotF, notably advanced manufacturing and biotechnologies.

In general, about 69 percent of the CCF portfolio is available to support new grants. The remaining 31 percent supports grants made in prior years.

DIVISION OF COMPUTER AND NETWORK SYSTEMS (CNS) **$240,420,000**
+$11,000,000 / 4.8%

CNS Funding
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Percent
Total	**$229.42**	**-**	**$240.42**	**$11.00**	**4.8%**
Research	**185.72**	**-**	**207.77**	**22.05**	**11.9%**
Education	**18.64**	**-**	**10.65**	**-7.99**	**-42.9%**
Infrastructure	**25.06**	**-**	**22.00**	**-3.06**	**-12.2%**
Research Resources	25.06	-	22.00	-3.06	-12.2%

About CNS

CNS supports research and education activities that advance understanding of the fundamental properties of computer systems and networks. CNS investments produce new insights into the dynamics of complex hardware and software systems and explore new architectures for future-generation computing and communication infrastructures and services, thereby lowering barriers to innovation and enhancing economic competitiveness. These investments enable future AI, quantum computing and communication, and advanced wireless systems. CNS-enabled systems include, but are not limited to, cyber-physical, embedded, distributed, centralized, virtualized, cloud, wireless, and mobile systems. CNS also supports research and education activities in cybersecurity, including post-quantum cryptography, to ensure that society's ubiquitous computing and communication infrastructures deliver the quality of service they are designed to achieve without disruption, while enabling and preserving privacy, security, and trust. CNS also plays a leadership role in coordinating CISE investments in systems research infrastructure and in the development of the computing workforce of the future.

In general, about 70 percent of the CNS portfolio is available to support new grants. The remaining 30 percent supports grants made in prior years.

DIVISION OF INFORMATION AND INTELLIGENT SYSTEMS (IIS) **$240,050,000**
+$31,680,000 / 15.2%

IIS Funding
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Change over FY 2019 Actual Percent
Total	**$208.37**	**-**	**$240.05**	**$31.68**	**15.2%**
Research	**194.24**	**-**	**230.45**	**36.21**	**18.6%**
Centers Funding (total)	1.00	-	0.83	-0.17	-17.0%
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	1.00	-	0.83	-0.17	-17.0%
Education	**11.94**	**-**	**7.60**	**-4.34**	**-36.3%**
Infrastructure	**2.19**	**-**	**2.00**	**-0.19**	**-8.7%**
Research Resources	2.19	-	2.00	-0.19	-8.7%

About IIS

IIS supports research that studies the interrelated roles of people, computers, and information. Specifically, IIS supports research and education in AI, data science, and human-computer interaction. Research in AI includes machine learning, knowledge representation, computer vision, and natural language processing. Research in data science includes data management, data collection, data analytics, and data integration. Research in human-computer interaction includes work on computer system usability, new kinds of user interfaces, and computer systems to augment human capabilities. Research supported by IIS addresses fundamental questions about machine intelligence, helps us understand how data can improve our lives, and lays the foundation for innovations in a myriad of sectors including energy, transportation, healthcare, manufacturing, and defense.

In general, about 77 percent of the IIS portfolio is available to support new grants. The remaining 23 percent supports grants made in prior years.

DIVISION OF INFORMATION TECHNOLOGY RESEARCH (ITR) **$146,250,000**
+$14,320,000 / 10.9%

ITR Funding
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual Amount	Change over FY 2019 Actual Percent
Total	**$131.93**	**-**	**$146.25**	**$14.32**	**10.9%**
Research	**114.00**	**-**	**132.25**	**18.25**	**16.0%**
Centers Funding (total)	1.00	-	0.83	-0.17	-17.0%
STC: Center for Brains, Minds and Machines: The Science and the Technology of Intelligence	1.00	-	0.83	-0.17	-17.0%
Education	**1.47**	**-**	**-**	**-1.47**	**-100.0%**
Infrastructure	**16.46**	**-**	**14.00**	**-2.46**	**-14.9%**
Research Resources	16.46	-	14.00	-2.46	-14.9%

About ITR

ITR provides support for transformative explorations in computer and information science and engineering research, infrastructure, and education, which are foundational for the IotF. 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 fundamental research on AI, QIS, particularly quantum computation and communication, and advanced wireless; innovative partnerships and collaborations between academia and industry; as well as the development of world-class research infrastructure. This is done in partnership with all of the CISE divisions as well as through cross-NSF and interagency activities.

ITR, in partnership with all of the NSF directorates and research offices, will advance the HDR Big Idea by investing funds to support convergent activities that transcend the traditional disciplinary boundaries of individual NSF directorates and offices. These activities will enable 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. While budget management and reporting for this investment will be the responsibility of CISE, the convergent activities will be overseen and managed collaboratively by the multi-directorate/office HDR leadership team.

In general, about 44 percent of the ITR portfolio is available to support new grants. The remaining 56 percent supports grants made in prior years.

APPENDIX A – ADVANCED COMPUTING SYSTEMS AND SERVICES PORTFOLIO

Advanced Computing Systems and Services Funding
(Dollars in Millions)

	FY 2019 Actual	FY 2020 (TBD)	FY 2021 Request
Leadership Class Computing	$55.07	-	$12.00
Advanced/Innovative Computing	27.38	-	37.00
Coordination and Support Services	11.81	-	29.00
Total	**$94.26**	**-**	**$78.00**

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. NSF aims to sustain America's leadership in the research, development, and broad deployment of existing as well as new advanced computing technologies, services, and skills, in part through co-leadership of the recently updated NSCI.[22] Within the broad goals set for the updated NSCI, key NSF foci include fundamental research to support future generations of an advanced computing ecosystem and research CI including software and data services and CI expertise to promote cohesive platforms and interoperability for large-scale data analytics as well as modeling and simulation applications across all of science and engineering.[23] These foci include an emphasis on a holistic approach to America's computational infrastructure for science and engineering research, spanning both human and technical dimensions, including forging and expanding partnerships that ensure American leadership in science, technology, and innovation.

The overall NSF advanced computing strategy and program portfolio receives guidance and input from the ACCI; Assistant Directors (AD) Council, which includes ADs and office heads from the NSF research and education directorates and offices; Cyberinfrastructure Strategy Group, which includes division directors or deputy division directors from the NSF research and education directorates and offices; cross-directorate working group for strategic computing; and directly from the research community through principal investigators' meetings, workshops, and sessions at professional conferences.[24] In 2013, OAC supported a National Academies of Sciences, Engineering, and Medicine study to further inform the implementation of its advanced computing strategy in the 2017 to 2020 timeframe. The final report, *Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science and Engineering in 2017-2020*, was published in 2016.[25] In 2017, OAC launched an effort to refresh the vision, strategy, and investment approaches for CI, including advanced computing, to support the evolving needs of the science and engineering community,[26] and also funded a study seeking to identify and catalog best practices for collaborations between academic or federally-funded High-Performance Computing (HPC) centers and industry.[27] In 2018, NSF funded a workshop focused on "Future Cyberinfrastructure: Rethinking NSF's Computational Ecosystem for 21st-Century Science and Engineering."[28] In 2019, NSF funded a follow-on conference, the *National Cyberinfrastructure Coordination Service Conference*, which examined the configuration of services intrinsic to a national CI; the report is currently under development. Additionally, international

[22] www.whitehouse.gov/wp-content/uploads/2019/11/National-Strategic-Computing-Initiative-Update-2019.pdf
[23] www.nsf.gov/cise/nsci/
[24] See, for example, https://sc18.supercomputing.org/presentation/?id=bof154&sess=sess417
[25] www.nap.edu/catalog/21886/future-directions-for-nsf-advanced-computing-infrastructure-to-support-us-science-6
[26] www.nsf.gov/cise/oac/ci2030/
[27] www.ncsa.illinois.edu/assets/pdf/industry/Industry_Report_2017.pdf
[28] https://uiowa.edu/nsfcyberinfrastructure/article/workshop-report

activities to accelerate investments in leadership-class computing, particularly in Europe and Asia, are providing additional urgency and importance for this investment strategy to ensure the U.S. maintains its global leadership role in science and engineering.

Technological advances come rapidly, along with changes in the capabilities and services offered by commercial interests (e.g., cloud services). In addition, the requirements of the science and engineering research communities are heterogeneous and also rapidly evolving. As outlined in the forward-looking computational ecosystem blueprint released in FY 2019,[29] NSF currently invests in three broad and complementary advanced computing areas that enable it to meet these continually evolving needs in an agile yet predictable way. These investments complement each other as well as 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 science and engineering research frontiers not otherwise possible;
- **Advanced/Innovative Computing Systems and Services** which aims to provide a technically diverse 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 science and engineering research; and
- **Coordination and Support Services** which aims to coordinate the provisioning, allocation, and operations of NSF's advanced computing resources, providing advanced assistance to the user community, supporting aggregation and federation capabilities, enabling the translation of CI research advances, and broadening participation.

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 science and engineering research users in May 2019 and became fully operational in October 2019. Frontera is expected to allow researchers to tackle much larger and more complex science and engineering applications than ever before, within and across disciplines as diverse as biology, astronomy, engineering, materials science, and the geosciences.

Blue Waters, the NSF-funded leadership-class computing resource deployed at the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign (UIUC), became operational in FY 2013. Although Blue Waters was originally anticipated to complete its operational cycle in December 2019, the National Geospatial-Intelligence Agency has provided funding to NSF to maintain the system into FY 2021 to support automated, large-scale generation of digital elevation models. The continued operations of Blue Waters will produce geospatial products that will contribute significantly to the advancement of Earth science and provide critical benefits to Federal agencies needing to access unclassified geospatial data.[30]

Current Status

The acquisition of Frontera was the result of a year-long competition from FY 2017 to FY 2018. At its July

[29] www.nsf.gov/cise/oac/vision/blueprint-2019/nsf-aci-blueprint-v10-508.pdf
[30] www.congress.gov/116/crpt/hrpt101/CRPT-116hrpt101.pdf (pg. 97)

2018 meeting, the NSB authorized the Director at her discretion to make an award to TACC for the acquisition of the Frontera system in an amount not to exceed $60.0 million over a period of five years. The resolution also authorized, pending appropriate approval associated with NSF's MREFC policies, an additional amount not to exceed $8.0 million to be made available to TACC in the form of supplemental funding to advance the design of a Phase 2 leadership-class computing facility (LCCF).

At its May 2019 meeting, the NSB authorized the Director at her discretion to make an award to TACC for the O&M of Frontera in an amount not to exceed $60.0 million over a period of five years. It offers the highest scale, throughput, and data analysis capabilities ever deployed on a U.S. university campus. Through its primary central processing unit subsystem, Frontera offers more than five times greater capacity than Blue Waters. In addition, Frontera's graphics processing unit (GPU) accelerates discoveries in important research areas such as deep learning and molecular dynamics.

In July 2019, TACC started the design and planning process for a follow-on Phase 2 LCCF, which will enable a 10 times performance improvement over the existing Frontera system. The Phase 2 LCCF will be managed and overseen by the NSF MREFC process. This project is therefore subject to MREFC policies regarding entry and approval into the required design stages as laid out in the NSF Major Facilities Guide.[31] The Frontera system is providing science and engineering evaluation to inform the design of the future facility.

Science and Engineering 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 2019, NSF issued a Dear Colleague Letter[32] inviting supplemental funding requests to active NSF research awards for time on the Frontera and Blue Waters systems to enable scientific and engineering research that would not otherwise be possible without access to a leadership-class computing resource; this effort resulted in 48 awards to research teams across the country. Research topics supported through these awards include: a very large-scale simulation of the entire stellar universe to understand the first billion years of cosmic evolution; a never-before-done simulation of mammalian brain activity at varied behavioral time scales to better understand how the human brain works; a comprehensive climate model study to understand the role of atmospheric rivers in shaping recorded hydroclimates in the southwest region of North America; detailed calculations of seismic energy propagation to enable better earthquake prediction and its effects on buildings and other civil infrastructure; a massive computation effort to produce openly distributed, very high-resolution digital surface models covering a substantial portion of the Earth's land mass; simulations of the largest and most aggressive types of tornadoes common in the U.S. to enable better severe weather predictions; development of a new framework for cosmological simulations of galaxy formation, combining machine learning with cosmological codes; and the integration of deep learning methods with biophysics models in the application of understanding how brain cancer develops and progresses.

In FY 2020, NSF issued a Dear Colleague Letter[33] describing a new innovative pilot mechanism for the Nation's researchers to request access to Frontera. The pilot mechanism is expected to promote novel leadership-class applications, ensure appropriate prioritization of cutting-edge science and engineering, and enable maximal utilization of the computing resource. New awards for access to Frontera through this mechanism are anticipated to begin in April 2020.

Education and outreach activities supported by the program consist of projects targeting students at pre-college, undergraduate, graduate, and post-graduate levels; workshops, conferences, summer schools, and

[31] www.nsf.gov/pubs/2019/nsf19068/nsf19068.pdf
[32] www.nsf.gov/pubs/2019/nsf19030/nsf19030.jsp
[33] www.nsf.gov/pubs/2020/nsf20018/nsf20018.jsp

seminars; and industry partnership activities. To date, NSF-funded leadership-class computing 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 jurisdictions.

Management and Oversight
The Frontera and Blue Waters projects are overseen by OAC's program directors and BFA's Division of Grants and Agreements staff, who receive strategic advice from the AD Council. Advice from the NSF Office of General Counsel is also sought, as necessary. Planning for the Phase 2 system is coordinated through the Large Facilities Office, as well as the Division of Acquisition and Cooperative Support, and will be reviewed in accordance with NSF's major facilities policies and procedures.

The 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 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 allocable resources within the eXtreme Digital (XD) integrated services infrastructure, which is described in the following section. Awards are generally 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 operations and maintenance following deployment. When an award is made, the awardee institution issues sub-awards to vendors and/or other organizations for acquisitions and services as necessary. Expenditures are contingent on successful completion of deployment milestones.

Current Status
Four resources (Wrangler, Comet, Bridges, and Jetstream) commenced operations in FY 2015 and FY 2016. In FY 2018, the period of operation for these four systems was extended, as noted below, allowing for increased return on investment and ensuring continuity of operations for the research community. Stampede 2, the largest of the currently active HPC resources within this portfolio, commenced operation in FY 2017.

Deployed in FY 2015 at TACC, Wrangler is the most powerful data analysis system allocated in XD and provides flexible support for a wide range of scientific domains and will remain operational through December 2020.

Comet also came online in FY 2015 at the University of California, San Diego (UCSD). It supports research interests and priorities requiring large, high-throughput workloads, as well as massive amounts of computation but at moderate scale. Comet was augmented with GPUs in FY 2018 and is planned to remain operational through March 2021.

Bridges came online in FY 2016 at the Pittsburgh Supercomputing Center on the campus of Carnegie Mellon University (CMU). Bridges provides an innovative HPC and data analytics system integrating advanced memory technologies to empower new communities. It brings desktop convenience to HPC, potentially enabling new communities to access advanced computing resources. Bridges was augmented

with GPU nodes in FY 2018 and will remain operational through November 2020.

Jetstream also came online in FY 2016 at Indiana University. Jetstream is a cloud-based platform that incorporates the elements of commercial cloud computing resources with important scientific applications. Jetstream's system operation was augmented in FY 2017 to provide additional focused staff expertise to accelerate effective researcher utilizations of the programmable CI/virtual machine-enabled architecture. The system will continue operations through November 2020.

In FY 2016, NSF awarded *Stampede 2: The Next Generation of Petascale Computing for Science and Engineering* to TACC following a rigorous merit review, enabling the acquisition and deployment of Stampede 2 as a successor resource to the highly successful Stampede system. Stampede operated from 2013 through 2017 and was considered the "backbone" for the XD environment, annually supporting more than 5,000 researchers and more than 1,000 computationally-intensive projects across the Nation. Stampede 2 similarly serves as the primary national resource for thousands of 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 November 2022.

As noted above, Wrangler, Comet, Bridges, and Jetstream are all scheduled to ramp down operations during the FY 2020 to FY 2021 timeframe. During this period, Stampede 2 will continue full operations and the new leadership-class computing system, Frontera, will ramp up to full operations, ensuring continued support for the science and engineering research community. Moving forward, NSF envisions that investments in advanced/innovative computing systems and services will foster an integrated CI ecosystem that addresses the growing scale and diversity of the science and engineering community, the changing nature of science and engineering 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 science and engineering domains. To further this goal, NSF issued a solicitation for advanced computing systems and services in FY 2019 with anticipated awards spanning FY 2019 to FY 2024.[34] This solicitation calls 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 science and engineering research.
- 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 science and engineering discoveries.

The solicitation allowed for two competitions spanning FY 2019 and FY 2020. In the first competition, three awards were made: two in Category I, to the Pittsburgh Supercomputing Center at CMU and to the San Diego Supercomputer Center at UCSD; and one in Category II to the State University of New York at Stony Brook. The second competition is currently underway.

<u>Science and Engineering Research and Education Activities Enabled by Advanced/Innovative Computing Systems and Services</u>

The ecosystem of advanced/innovative computing systems and services is enabling new, world-leading, and transformative advances across the breadth of science and engineering research, in the integration of research and education, and in broadening participation in science and engineering by underrepresented groups. It is enabling new collaborations across public and private sectors to advance American 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 necessary expertise, interfaces, consulting support, and training necessary to facilitate use of the systems and services. This activity is central to America

[34] www.nsf.gov/pubs/2019/nsf19534/nsf19534.htm

achieving the full potential of complementary investments by NSF, other federal agencies, and academic institutions in computing infrastructure.

Management and Oversight
OAC's program directors provide direct oversight during both the acquisition, and O&M awards. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors.

Awards for advanced/innovative computing system and services are managed under cooperative agreements that include the 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. Progress is assessed with the aid of annual external reviews. In addition, each project is required to have a project management 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 of the periodic NSF external reviews, conducted by an external panel of experts, is to revisit and reassess the risk situation and make recommendations as deemed necessary. In the case of projects that involve an acquisition, project risks are generally substantially reduced subsequent to 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 coordination and support services, as exemplified by the XD integrated services infrastructure, add value to the NSF advanced/innovative computing systems and services by coordinating allocations and access to the systems and services, providing advanced assistance to the user community, and broadening participation. The XD program's shared services model for coherently and efficiently providing researchers with both access and expertise to diverse, dynamic, and distributed resources is a cornerstone of the American advanced computing ecosystem. Enabling the connection between individual campuses and national resources is an essential aspect of the advanced computing ecosystem.

XD 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, increasingly virtualized approach to the provision of high-end digital services, while ensuring that the infrastructure continues to deliver high-quality access for the many researchers and educators who use it in their work.

XD shared 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 an integrated digital services infrastructure; metrics services; and overall coordination. These elements are designed and implemented in a way that is clearly tied to the requirements of the science and engineering 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.

Current Status

Two awards are currently active within the XD program: XD Metrics Service (XMS) and the eXtreme Science and Engineering Discovery Environment (XSEDE). The XMS award was made in FY 2015 to The State University of New York at Buffalo. This award provides metrics services allowing measurement of key operational data for both resources and services. All other services are provided by XSEDE. The XSEDE award to UIUC was renewed in September 2016, continuing the prior XSEDE award for another five-year period. The award will conclude at the end of August 2021, and in anticipation of that date, NSF has initiated engagements with the community about the structure and composition of future coordination efforts.

Within the current XSEDE project, there are 18 partners engaged via subawards to the University of Tennessee at Knoxville (National Institute for Computational Sciences), CMU and University of Pittsburgh (Pittsburgh Supercomputing Center), UT Austin (TACC), UCSD (San Diego Supercomputing Center), University of Chicago, Indiana University, Purdue University, Shodor Education Foundation, Ohio Supercomputer Center, Southeastern Universities Research Association, Cornell University, National Center for Atmospheric Research, Georgia Institute of Technology, Oklahoma State University, University of Georgia, Oklahoma University, University of Southern California, and University of Arkansas.

The mid-project external site review of the XMS project took place in June 2018 and continued operations were authorized based on the successful outcome of that review. XSEDE has annual external reviews at NSF. The first external review of the renewed XSEDE project took place in June 2017; subsequent external milestone reviews have taken place in January and June, with the most recent review having occurred in June 2019. On the basis of these successful reviews, funds were authorized for continued operations. NSF has outlined its plans for national CI coordination services moving forward in a blueprint document released in Q1 of FY 2020.[35]

Science and Engineering Research and Education Activities Enabled by Coordination and Support Services

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

XD coordinates access to advanced/innovative computing systems and services and enables researchers to efficiently manipulate, analyze, visualize, and share extremely large amounts of distributed digital information from simulations, sensors, and experiments.

The XSEDE project delivers tools and services that not only link users to national facilities, but also enable scientific collaborations of geographically distributed teams. In doing so, it facilitates dynamic access to digital resources and experimental testbeds within and across university campuses, as well as government laboratories. XSEDE includes outreach and training critical to reducing barriers to the use of advanced digital systems by the research and education communities, thereby promoting enhanced productivity.

The XMS project develops analysis tools and collects operational data from XSEDE services and the advanced computing/innovative systems and services. The immediate users of these methods and tools are the providers of NSF-supported advanced computing systems and services. However, both tools and data are publicly available and used by other projects such as Blue Waters, Frontera, and individual universities.

[35] www.nsf.gov/cise/oac/vision/blueprint-2019/nsf-aci-blueprint-services.pdf

Management and Oversight

OAC's program directors oversee the XD projects. XSEDE has an external advisory board, a user board, and a service provider forum to ensure that all stakeholders can provide project input. OAC oversight of the XSEDE project includes participation in weekly teleconferences with senior XSEDE personnel and in quarterly project-wide staff meetings. Formal reporting consists of quarterly and annual reports, which are reviewed by the program directors.

Each XD award is managed under a cooperative agreement that includes requirements for a specific management structure, milestones, 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. In addition, each project is required to have a detailed management plan in place.

While XD is operational in nature, the virtual organizations of the XSEDE project and the services of all XD projects are innovative and thus bear inherent risks. The projects maintain risk registers that are reviewed periodically by external panels and by the cognizant program directors.

Annual reviews for XSEDE and mid-project reviews for XMS are conducted by external panels of expert reviewers and managed by OAC program directors.