DIRECTORATE FOR ENGINEERING (ENG) **$881,420,000**
-$96,480,000 / -9.9%

ENG Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Chemical, Bioengineering, Environmental and Transport Systems (CBET)	$187.19	-	$169.43	-$17.76	-9.5%
Civil, Mechanical, and Manufacturing Innovation (CMMI)	236.95	-	204.00	-32.95	-13.9%
Electrical, Communications, and Cyber Systems (ECCS)	116.05	-	105.04	-11.01	-9.5%
Engineering Education and Centers (EEC)	116.71	-	92.60	-24.11	-20.7%
Industrial Innovation and Partnerships (IIP)	271.71	-	245.25	-26.46	-9.7%
Emerging Frontiers and Multidisciplinary Activities (EFMA)	49.28	-	65.10	15.82	32.1%
Total	**$977.90**	-	**$881.42**	**-$96.48**	**-9.9%**

About ENG

In FY 2020, ENG will invest in fundamental engineering research and in Administration and NSF-wide research priorities that contribute to America's security, prosperity, health, and technological leadership. Substantial directorate investments—in the NSF Big Ideas and the new generation of NSF Engineering Research Centers (ERCs)—will emphasize convergence research approaches to help address grand challenges and societal needs. In addition, to advance U.S. global competitiveness, strategic ENG support will strengthen the engineering workforce and accelerate innovation by high-tech small businesses and industry.

To help protect the American people, ENG investments will drive advances in quantum technologies for secure communication systems, as well as sensing and information systems as part of the QL Big Idea. ENG will continue its long-term support of engineering research to improve resilience to hurricanes, earthquakes, and other disasters through the Natural Hazards Engineering Research Infrastructure (NHERI) and other programs. Other ENG-funded research will investigate methods and technologies for securing the electric grid, detecting biological threats, and disrupting illicit supply networks.

To enhance U.S. economic and technologic leadership, ENG will steward the FW-HTF Big Idea, while its convergence activities will be overseen and managed collaboratively by the multi-directorate/office FW-HTF leadership team. ENG will also make critical contributions to FW-HTF through foundational research on soft robotics, embodied intelligent cognitive assistants, and artificial intelligence.

ENG collaboration in the HDR Big Idea will intersect with support for advanced materials and devices, smart systems and connected communities, and disruptive technologies for energy-efficient computing and high-speed, high-capacity networks; ENG will work closely with OIA on the C-Accel planned for the area of HDR.

ENG's NNA Big Idea investments will help ensure sustainable and reliable infrastructure systems in the Arctic through research in, for example, sensor systems to understand soil dynamics, complex food-energy-water systems and models, water supply and treatment, resilient structure designs, and advanced materials.

To advance health technologies and systems, ENG will invest in fundamental research to observe nanoscale cellular processes and changes, in engineering biology to reverse disease and produce therapies, and in synthetic biology to support URoL, another NSF Big Idea. For more information about the Big Ideas, see the narratives in the NSF-Wide Investments chapter.

Along with its support for Big Ideas, ENG investments in artificial intelligence, quantum information sciences and technology, and microelectronics and semiconductor design and manufacturing will make essential contributions to U.S. competitiveness.

The directorate also will support neurotechnologies and imaging for UtB, including the BRAIN Initiative. Engineering investments will continue advances in prosthetic and assistive technologies for veterans and for aging and disabled people.

While fundamental engineering research fuels U.S. technological innovation and competitiveness, ENG support for workforce development and innovation speeds and strengthens the process. The directorate will invest in research on education, broadening participation, and inclusion in engineering, as well as in student experiences with industry. ENG will maintain its commitment to talented early-career faculty by making a sizable investment in CAREER and by allowing proposal submissions to core programs at any time to encourage creative, significant research contributions. ENG investments in academic partnerships with industry, entrepreneurial training through the I-Corps™ program, and small businesses through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs will help translate new ideas from lab to market and fortify the Nation's innovation ecosystem.

ENG provides 36 percent of the federal funding for basic research at academic institutions in the engineering disciplines.

Major Investments

ENG Major Investments
(Dollars in Millions)

Area of Investment	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Advanced Manufacturing	$110.89	-	$110.89	-	-
Artificial Intelligence (AI)	114.70	-	126.45	11.75	10.2%
CAREER	78.56	-	76.00	-2.56	-3.3%
INFEWS	6.73	-	5.00	-1.73	-25.7%
IUSE	0.05	-	4.75	4.70	9465.6%
Microelectronics and Semiconductors	37.50	-	37.50	-	-
I-Corps™	17.20	-	15.40	-1.80	-10.4%
Quantum Information Sciences (QIS)	26.77	-	29.30	2.53	9.5%
SaTC	3.25	-	3.25	-	-
UtB	28.08	-	16.75	-11.33	-40.3%
BRAIN Initiative	*28.08*	*-*	*16.75*	*-11.33*	*-40.3%*
NSF's Big Ideas	-	-	30.00	30.00	N/A
FW-HTF Stewardship	*-*	*-*	*30.00*	*30.00*	*N/A*

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

- Advanced Manufacturing ($110.89 million) ENG research accelerates advances in manufacturing technologies with emphasis on multidisciplinary research that fundamentally alters and transforms manufacturing capabilities, methods and practices. Investments in advanced manufacturing include research on highly connected cyber-physical systems in smart processing and cyber manufacturing systems, and activities that develop new methods, processes, analyses, tools, or equipment for new or existing manufacturing products, supply chain components, or materials. NSF's investments will enable new functionalities that will increase the efficiency and sustainability of the production of the next generation of products and services. These developments will yield advantages such as reduced time to market, new performance attributes, improved small-batch production, cost savings, energy savings, or reduced environmental impact from the manufacturing of products.

- AI ($126.45 million): ENG, together with other NSF directorates/offices, will increase support for AI research and development. A key focal point will be support for "AI Frontiers," a center-scale activity that will span (a) foundational areas of machine learning, computer vision, natural language processing, and autonomy, along with safety, security, robustness, and explainability of AI systems; (b) translational research at the intersection of AI and various science and engineering domains supported by NSF as well as sectors such as agriculture, advanced manufacturing, transportation, and personalized medicine; (c) workforce development, including growing human capital and institutional capacity to nurture a new generation of ethical AI researchers and practitioners; and (d) advanced computing infrastructure, including access to data and computing capabilities.

- Faculty Early Career Development (CAREER) ($76.0 million): CAREER awards support promising junior faculty to serve as role models for outstanding research and education, and to lead advances in their organizational mission. This funding level will support approximately 150 awards.

- INFEWS ($5.0 million): ENG will continue to co-lead this NSF-wide initiative with GEO in FY 2020. The goal is to catalyze well-integrated, interdisciplinary research efforts to transform understanding of the food-energy-water nexus to improve system function and management, address system stress, increase resilience, and ensure sustainability. ENG will focus on supporting fundamental engineering research to enable innovative system and technological solutions that address critical challenges in the food-energy-water nexus. INFEWS will leverage existing ENG programs in energy, water, and environmental technologies that support projects, for example, to reduce water consumption in power plants.

- IUSE ($4.75 million): ENG's investment in the NSF-wide IUSE initiative, which integrates the agency's investments in undergraduate education, will continue as support for the IUSE/Professional Formation of Engineers: Revolutionizing Engineering Departments (PFE:RED) solicitation moves to a biennial cycle. PFE:RED enables research and innovations leading to and propagating interventions that improve both the quality and quantity of engineering graduates.

- Microelectronics and Semiconductors ($37.50 million): ENG, together with other NSF directorates and offices, will support research to address fundamental science and engineering questions on the concepts, materials, devices, circuits, and platforms necessary to sustain progress in semiconductor and microelectronic technologies. Research in semiconductors and microelectronics is critical to future advances and security in information technology, communications, sensing, smart electric grid, transportation, health, advanced manufacturing, and other areas. The investment will strengthen America's capabilities and capacity for revolutionary microelectronics design, architecture, and fabrication, as well as high-performance computing. New discoveries will enable the nation to overcome crucial scientific barriers for emerging technologies such as artificial intelligence, quantum

technologies, and interconnected autonomous systems, and they will strengthen U.S. scientific leadership, economic prosperity, and national security.

- I-Corps™ ($15.40 million): ENG, in partnership with other directorates, will continue strong support for the NSF-wide I-Corps™ program that connects NSF-funded science and engineering research with the technological, entrepreneurial, and business communities, and fosters a national innovation ecosystem that links scientific discovery with technology development, societal needs, and economic opportunities.

- QIS ($29.30 million): ENG, together with other NSF directorates and offices, will increase support for quantum information science research and development, which strongly aligns with the Administration's National Quantum Initiative to consolidate and expand the U.S.' world-leading position in fundamental quantum research and deliver proof-of-concept devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts. Research in QIS examines uniquely quantum phenomena that can be harnessed to advance information processing, transmission, measurement, and fundamental understanding in ways that classical approaches can only do much less efficiently, or not at all. Current and future QIS applications differ from prior applications of quantum mechanics, such as the laser, transistor, and magnetic resonance imaging, by using distinct quantum phenomena—superposition and entanglement—that do not have classical counterparts. QIS research activities will also address education and workforce development needs, broadening research collaborations, promoting innovative team- building activities, and stimulating cross-disciplinary curriculum development and training to provide a quantum-smart workforce.

- SaTC ($3.25 million): ENG support for SaTC will focus on the engineering aspects of the NITRD Strategic Plan for the Federal Cybersecurity Research and Development Program.[1] NITRD's research thrusts cover a set of interrelated priorities for U.S. government agencies that conduct or sponsor research and development in cybersecurity.

- UtB ($16.75 million): ENG investments in neuroimaging and neurotechnology research are critical to success of the BRAIN Initiative. Research will drive integration across scales and disciplines; accelerate the development of novel experimental and analytical approaches, such as computational and data-enabled modeling; and enable neural technology innovation.

- FW-HTF ($30.0 million): ENG will steward the FW-HTF Big Idea. While financial stewardship for this Emerging Frontiers and Multidisciplinary Activities (EFMA) investment will be the responsibility of ENG, the convergence activities will be overseen and managed collaboratively by the multi-directorate/office FW-HTF leadership team. These activities will enable pursuit of fundamental research on advancing cognitive and physical capabilities in the context of human-technology interactions and the development of a 21st-century workforce capable of adapting to a changing employment landscape. ENG will work closely with OIA on the Convergence Accelerator (C-Accel) planned for the area of FW-HTF, building on collaborative design of the C-Accel model that draws on ENG experience in technology translation and partnerships.

[1] www.nitrd.gov/pubs/FY2019-Cybersecurity-RD-Roadmap.pdf

ENG Funding for Centers Programs and Facilities

ENG Funding for Centers Programs
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$83.42**	**-**	**$62.26**	**-$21.16**	**-25.4%**
Engineering Research Centers (EEC)	68.49	-	54.66	-13.83	-20.2%
STC: Emergent Behaviors for Integrated Cellular Systems (CBET)	5.00	-	1.30	-3.70	-74.0%
STC: Engineering Mechano-Biology (CMMI)	4.93	-	5.00	0.07	1.4%
STC: Energy Efficient Electronics Systems (ECCS)	5.00	-	1.30	-3.70	-74.0%

For detailed information about NSF Centers programs, please see the NSF-Wide Investments chapter.

ENG Funding for Major Multi-User Facilities
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$26.37**	**-**	**$12.75**	**-$13.62**	**-51.6%**
Cornell High Energy Synchrotron Source (CHESS)	4.00	-	1.00	-3.00	-75.0%
Natural Hazards Engineering Research Infrastructure (NHERI)[1]	22.37	-	11.75	-10.62	-47.5%

[1] FY 2018 Actual includes $11.50 million in additional FY 2018 one-time funding above the requested

For detailed information on individual facilities, please see the Facilities chapter.

Funding Profile

ENG Funding Profile

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Statistics for Competitive Awards:			
Number of Proposals	13,092	-	10,000
Number of New Awards	2,458	-	2,200
Funding Rate	19%	N/A	22%
Statistics for Research Grants:			
Number of Research Grant Proposals	9,899	-	7,500
Number of Research Grants	1,844	-	1,680
Funding Rate	19%	N/A	22%
Median Annualized Award Size	$113,059	-	$114,000
Average Annualized Award Size	$131,793	-	$134,000
Average Award Duration, in years	2.7	-	2.8

ENG investments support fundamental engineering research, engineering education, and innovation, as

well as research infrastructure such as facilities. In FY 2020, funding for centers accounts for over nine percent of ENG's non-SBIR/STTR Request. In FY 2020, funding for facilities is just under two percent of ENG's non-SBIR/STTR Request.

In FY 2020, the number of competitive proposals received, which includes SBIR/STTR proposals, is expected to be about 10,000, which includes about 7,500 research grant proposals. In FY 2019, ENG implemented the removal of all deadlines associated with unsolicited "core" programs across the directorate, which is expected to produce a reduction in the total number of proposals received and allow for increases in both award size and duration.

Program Monitoring and Evaluation

External Program Evaluations and Studies:

- In FY 2015, NSF funded the National Academies of Sciences, Engineering, and Medicine (the National Academies) to study the future of center-based, multidisciplinary engineering research. The study report,[2] delivered May 2017, articulates a vision for the future of NSF-supported center-scale, multidisciplinary engineering research. After careful consideration, in FY 2018 ENG sparked new convergence engineering research collaborations through planning grants, providing 60 awards to build capacity for a new generation of engineering research centers. In October 2018, ENG released a solicitation for the 4th generation of ERCs (NSF 19-503) and anticipates awards in 2020.
- Since 2016, the PFE:RED program has engaged a Participatory Action Research team (REDPAR) composed of two partners: the Center for Evaluation & Research in STEM Equity (CERSE) from the University of Washington and the Making Academic Change Happen (MACH) group from the Rose-Hulman Institute of Technology. REDPAR has collected data from a variety of sources for evaluation and assessment examining the partnerships that teams are creating along with the project results/outputs. The group has been providing feedback and briefings on a regular basis and will produce a summative report in the 2019–2020 timeframe. To date, ENG has used the data collected to change the language in RED solicitations to emphasize key areas that were not appropriately addressed in the proposals being received. For example, the FY 2019 solicitation includes a new track, the RED A&I (Adaptation and Implementation) track, that focuses on the use of evidence-based and evidence generating change strategy approaches and actions that are adapted to the local context of implementation.
- In FY 2016, NSF initiated a rigorous evaluation of the I-Corps™ Teams program. The evaluation seeks to assess the impact of the program on teams that completed the entrepreneurial training. In addition, NSF seeks to understand the impact of the program on academic culture, such as the kinds of networks and connections principal investigators develop with industry and investors and how their research and other activities are impacted by the I-Corps™ experience. The analysis relies on quantitative data from surveys and case studies developed from in-depth interviews and site visits. A report is expected to be available in FY 2019.
- In FY 2017, the American Innovation and Competitiveness Act (AICA) became law and required NSF to develop metrics to evaluate the I-Corps™ program and to deliver a report to Congress every two years. NSF has completed development of the metrics, prepared the first report, and plans to submit it to Congress in spring 2019.
- In FY 2018, the SBIR/STTR Baseline Monitoring Survey was cleared by the Office of Management and Budget. The survey consists of two parts: Company and Founder. The aim of the survey is to learn more about these small businesses shortly after they receive their first NSF SBIR/STTR Phase I awards. Some of the metrics collected in the survey include: technology readiness, R&D efforts, university affiliations, payroll and revenue, as well as NSF lineage. The survey allows ENG to create a performance baseline for these small businesses, benchmark internally across cohorts, understand what

[2] www.nap.edu/catalog/24767/a-new-vision-for-center-based-engineering-research

best-in-class small businesses do differently, and identify root causes for low performers so NSF can design tailored improvement initiatives for the SBIR and STTR programs. ENG is administering surveys to small businesses who received their Phase I award in 2018 and 2019.

- In FY 2019, the data collection and management process for the Industry-University Cooperative Research Center (IUCRC) program is migrating from North Carolina State University to NSF. One of the overarching goals of this migration process involves building an in-house data ecosystem for the IUCRC program that entails collecting, organizing, and managing internal and external data, including data from an annual survey. The combination of data sources will provide a holistic view of the IUCRC program and enable customized analyses and insights to be made on a center level.

Workshops and Reports:

- In FY 2016, CBET, EFMA and others co-funded a three-year study on Grand Challenges in Environmental Engineering by the National Academies.[3] The study aimed to identify high-priority challenges for environmental engineering and science for the next several decades. The three planned public workshops associated with the study were held May 2017; September 2017; and January 2018. The report,[4] delivered in December 2018 at a 500-person event, will shape the growth of university departments, inspire the next generation of engineers and scientists to address the most pressing global environmental challenges, and improve the training of environmental engineers and scientists to better meet these challenges. It will also help inform NSF program directors of emerging areas for research. In addition, the Association of Environmental Engineering and Science Professors (AEESP) will convene a special session during their 2019 biannual meeting on the Grand Challenges for Engineering.
- With ECCS support, a workshop on Microsystems for Bioelectronics Medicine organized by NSF and the Semiconductor Research Corp. (SRC) was held in April 2017. The organizing committee included extensive representation from other federal agencies (Defense Advanced Research Projects Agency, Department of the Army, Food and Drug Administration, the National Institutes of Health [NIH]) and pharmaceutical and other companies (such as Medtronic, Boston Scientific, Philips, Intel, GlaxoSmithKline, Pfizer, IBM, and Texas Instruments). The workshop helped identify scientific areas for future investment in ECCS core programs and led to an NSF-SRC-IARPA solicitation on Semiconductor Synthetic Biology for Information Processing and Storage Technologies (SemiSynBio) (NSF 17-557),[5] with awards in FY 2018.
- In FY 2017, ENG (CBET and EFMA) and BIO co-funded a workshop on "The Subterranean Macroscope: Sensor networks for understanding, modeling, and managing soil processes," held November 2017, at the University of Chicago. The workshop's goal was to create a vision and framework for how such a subterranean sensor network could be built across different geographical scales, with sensors that will generate dense, useful data that will inform soil science, plant science, and modeling efforts. These efforts, in turn, would lead to the next level of understanding of the physical, chemical, and biological nature of soil and its impact on plant science and food security. The workshop included diverse scientists and engineers and representatives from industry and the small business community. The workshop was expected to generate cross-directorate research opportunities advancing measurement system capabilities for soil biological, chemical, and physical components over space and time and to contribute to several of NSF's 10 Big Ideas. The workshop led to the multi-directorate NSF Dear Colleague Letter on Signals in the Soil (NSF 18-047)[6] in FY 2018 and the NSF solicitation on Signals in the Soil (NSF 19-556)[7] in FY 2019; collaborating with NSF in FY 2019 are the U.S. Department of Agriculture's National Institute of Food and Agriculture (USDA/NIFA) and several

[3] http://dels.nas.edu/Study-In-Progress/Grand-Challenges-Opportunities-Environmental/DELS-WSTB-15-01
[4] www.nap.edu/catalog/25121/environmental-engineering-for-the-21st-century-addressing-grand-challenges
[5] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505397
[6] www.nsf.gov/pubs/2018/nsf18047/nsf18047.jsp
[7] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505577&org=NSF

arms of the United Kingdom's Research and Innovation.

- In FY 2017, CMMI supported a workshop on "Disrupting Illicit Supply Networks: New Applications of Operations Research and Data Analytics to End Modern Slavery,"[8] in December 2017. The workshop brought together operations researchers, computer scientists, social scientists, business researchers, geographers, social service agency representatives, and federal agencies to increase understanding of both the nature, and the challenges to disruption, of illicit supply chains. This led to a dear colleague letter[9] from the CMMI Operations Engineering program for an initial round of awards[10] in FY 2018; a follow-up workshop is planned for March 2019.
- ECCS sponsored a workshop on Real-time Learning and Decision Making in Dynamical systems in February 2018.This workshop brought together a group of 130 leading experts in complementary backgrounds to bridge research areas and shape the research paradigm that arises from many real-time data-driven dynamical systems. This workshop looked at ways to integrate data science methods with domain knowledge from physical engineering systems to make critical decisions in real-time. The workshop led to the ENG Dear Colleague Letter: Real-Time Learning and Decision-Making in Engineered Systems (Real-D) (NSF18-063)[11] that funded about $5.0 million in NSF EArly Concepts for Exploratory Research (EAGER) grants in real-time learning and decision making applied to engineering systems. The outcomes of this workshop strongly impacted current funding activities under the HDR Big Idea.
- In FY 2018, CBET and National Aeronautics and Space Administration's (NASA) Ames Research Center and Centennial Challenges program co-funded a Bioengineering Road Map Summit[12] held March 2018. At the Summit, 110 academics, industry professionals, and government leaders came together to identify, characterize, and review specific scientific and technical hurdles toward creating bioengineered solutions to ending the organ shortage. The outcomes included a comprehensive version of the "Road Map to Ending the Organ Shortage" for use by the research community and public alike. 3D tissue and organ engineering has been identified as a high priority area of research by the federal government, and major initiatives are underway through NSF, NIH, Department of Defense, and the U.S. Department of Veterans Affairs (VA). This Summit has helped coordinate efforts between all active partners, including industry and academia, which is required to move science and engineering from academic laboratory to clinical translation in the most effective way possible.
- In FY 2019, an ECCS-supported workshop on Power Electronics in the Electrified Transportation Industry was held in October 2018. Power electronics play a critical role in efficient and reliable electric propulsion, fast and dynamic wireless charging, active suspension, energy harvesting, electrically assisted steering, and anti-lock-braking systems. The workshop brought together researchers and technical leaders from academia and industry to discuss scientific/technological breakthroughs that are needed in this emerging field. The report from this workshop, which will be available in fall 2019, will inform ECCS plans and priorities in the area of smart electric grid.
- With support from ECCS and MPS/Division of Materials Research, the Optical Society of America organized an incubator workshop on Quantum Nanophotonics in Emerging Materials[13] in October 2018, to help establish new directions for research with optically-active semiconductor defects that take advantage of the unique properties afforded by emerging materials. The workshop brought together three different related but often non-intersecting communities to discuss how to advance materials, theory, and instrumentation to realize new quantum-coherent systems with unprecedented functionality. The report will be available in 2019. The results will inform future activities under the

[8] http://ic2.utexas.edu/disn2017/
[9] www.nsf.gov/pubs/2018/nsf18059/nsf18059.jsp
[10] nsf.gov/news/news_summ.jsp?cntn_id=296258
[11] www.nsf.gov/pubs/2018/nsf18063/nsf18063.jsp
[12] www.neworgan.org/roadmap-summit.php
[13] www.osa.org/en-us/meetings/incubator_meetings/past_incubator_meetings/2018/osa_defects_by_design_incubator_quantum_nanophoto/

QL Big Idea.

- In FY 2019, CMMI supported an award for the planned "International Workshop on Bio-Inspired Geotechnics,"[14] to be held in May 2019. The emerging field of bio-inspired geotechnics is at a critical, formative stage where researchers are beginning to define how biological phenomena can inspire an engineering analog in geotechnical applications such as earthworks, foundations, or pavements to support built structures. This workshop, with 55 interdisciplinary individuals from across the world, will accelerate growth in this new field and inform the creation of a potential research initiative supporting bio-inspired engineering and design.

Committees of Visitors (COV):

- In 2018, COVs reviewed ECCS and EFMA for the period FY 2014–2017. The COVs presented their reports to the ENG Advisory Committee, which convened in April and October of 2018. The ECCS COV recommended that the division return to multiple submission windows, and ECCS, along with CBET, CMMI, and EEC, instituted a new policy beginning in FY 2019 that removes deadlines for submission of unsolicited proposals to all core programs. The EFMA COV recommended that EFMA encourage individuals performing proposal review to provide some level of detail for all review requirements, and in FY 2018, EFMA began providing templates for both reviews and panel summaries that list each criterion for specific comment.
- In 2019, COVs will review CBET and CMMI.
- In 2020, COVs will review EEC and IIP.

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

People Involved in ENG Activities

Number of People Involved in ENG Activities

	FY 2018 Actual Estimate	FY 2019 (TBD)	FY 2020 Estimate
Senior Researchers	9,299	-	8,900
Other Professionals	1,937	-	1,900
Postdoctoral Associates	484	-	500
Graduate Students	7,760	-	7,200
Undergraduate Students	4,217	-	4,200
Total Number of People	**23,697**	-	**22,700**

[14] sites.google.com/view/1st-bio-geotech-workshop

DIVISION OF CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, AND TRANSPORT SYSTEMS (CBET) **$169,430,000**
-$17,760,000 / -9.5%

CBET Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$187.19**	**-**	**$169.43**	**-$17.76**	**-9.5%**
Research	**181.57**	**-**	**163.64**	**-17.93**	**-9.9%**
CAREER	31.72	-	31.00	-0.72	-2.3%
Centers Funding (total)	5.00	-	1.30	-3.70	-74.0%
STC: Emergent Behaviors for Integrated Cellular Systems	5.00	-	1.30	-3.70	-74.0%
Education	**1.91**	**-**	**2.10**	**0.19**	**9.9%**
Infrastructure	**3.71**	**-**	**3.69**	**-0.02**	**-0.5%**
NNCI	3.68	-	3.69	0.01	0.3%

About CBET

CBET supports research to enhance and protect U.S. national health, energy, food, water, environment, process manufacturing, and security. Through CBET, the physical, chemical, life, and social sciences are integrated in engineering research and education, resulting in advances in the rapidly evolving fields of biotechnology, bioengineering, biomanufacturing, advanced materials, environmental engineering, and sustainable energy. CBET also invests in areas that involve the transformation and/or transport of matter and energy by chemical, thermal, or mechanical means. CBET investments contribute significantly to the knowledge base and to the workforce development of major U.S. economy components, such as chemicals, pharmaceuticals, medical devices, specialty chemicals, and materials for advanced manufacturing, natural gas and petroleum production, food, textiles, utilities, and microelectronics.

CBET supports the chemical, environmental, biomedical, mechanical (transport), and civil (environmental) engineering disciplines. To serve these communities and achieve its goals, CBET is organized into four thematic clusters: Chemical Process Systems; Engineering Biology and Health; Environmental Engineering and Sustainability; and Transport Phenomena.

In general, about 84 percent of the CBET portfolio is available to support new research grants. The remaining 16 percent supports research grants made in prior years and the research infrastructure needed by this community.

DIVISION OF CIVIL, MECHANICAL, AND MANUFACTURING INNOVATION (CMMI) **$204,000,000**
-$32,950,000 / -13.9%

CMMI Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$236.95**	**-**	**$204.00**	**-$32.95**	**-13.9%**
Research	**210.02**	**-**	**186.90**	**-23.12**	**-11.0%**
CAREER	32.24	-	30.00	-2.24	-6.9%
Centers Funding (total)	4.93	-	5.00	0.07	1.4%
STC: Engineering Mechano-Biology	4.93	-	5.00	0.07	1.4%
Education	**2.67**	**-**	**2.65**	**-0.02**	**-0.7%**
Infrastructure	**24.27**	**-**	**14.45**	**-9.82**	**-40.5%**
CHESS	-	-	0.80	0.80	N/A
NHERI[1]	22.37	-	11.75	-10.62	-47.5%
NNCI	1.90	-	1.90	-	-

[1] FY 2018 Actual includes $11.50 million in additional FY 2018 one-time funding above the requested amount.

About CMMI

CMMI funds fundamental research in support of the Foundation's strategic goals directed at advances in civil, mechanical, industrial, systems, manufacturing, and materials engineering. In addition, the division has a focus on the reduction of risks and damage resulting from earthquakes, wind, and other hazards. CMMI encourages discoveries enabled by cross-cutting technologies such as adaptive systems, artificial intelligence, nanotechnology, and high-performance computational modeling and simulation.

The division promotes cross-disciplinary research partnerships at the intersections of traditional research disciplines to achieve transformative research results that promote innovative manufacturing technology (such as semiconductor fabrication); enable the design and analysis of complex engineered systems; enhance the sustainability and resilience of U.S. infrastructure (for example, buildings, transportation, and communication networks); help protect the Nation from extreme natural and human-induced events; and apply engineering principles to improve the Nation's service and manufacturing enterprise systems, such as healthcare.

CMMI also provides funding and management of NHERI and contributes to the directorate's annual operations support of the CHESS facility.

In general, 81 percent of the CMMI portfolio is comprised of new research grants and 19 percent supports continuing grants.

DIVISION OF ELECTRICAL, COMMUNICATIONS, AND CYBER SYSTEMS (ECCS) **$105,040,000**
-$11,010,000 / -9.5%

ECCS Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$116.05**	**-**	**$105.04**	**-$11.01**	**-9.5%**
Research	**109.99**	**-**	**98.04**	**-11.95**	**-10.9%**
CAREER	13.55	-	15.00	1.45	10.7%
Centers Funding (total)	5.00	-	1.30	-3.70	-74.0%
STC: Energy Efficient Electronics	5.00	-	1.30	-3.70	-74.0%
Education	**0.68**	**-**	**1.66**	**0.98**	**143.4%**
Infrastructure	**5.37**	**-**	**5.34**	**-0.03**	**-0.6%**
CHESS	-	-	0.10	0.10	N/A
NNCI	5.37	-	5.24	-0.13	-2.5%

About ECCS

ECCS supports enabling and transformative research at the nano, micro, and macro scales that fuels progress in engineering system applications with high societal impacts. The division's programs encompass novel electronic, photonic, quantum, and magnetic devices (such as semiconductors integrated with biological structures), and the integration of these devices into circuit and system environments, intelligent systems, control, and networks. ECCS investments in artificial intelligence research for real-time learning and decision-making will lead to safe, reliable, and efficient data-enabled engineering systems. Breakthroughs in devices and systems advance applications spanning communications and cyber technologies, energy and power, healthcare, environment, transportation, robotics, manufacturing, and other systems-related areas. ECCS strongly emphasizes the integration of education into its research programs to ensure the preparation of a diverse and professionally skilled workforce. ECCS also strengthens its programs through links to other areas of engineering, science, industry, government, and international collaborations.

The division also provides funding, in partnership with other NSF directorates, and management of the National Nanotechnology Coordinated Infrastructure (NNCI).

In general, 81 percent of the ECCS portfolio is comprised of new research grants and 19 percent supports continuing grants.

DIVISION OF ENGINEERING EDUCATION AND CENTERS (EEC) **$92,600,000**
-$24,110,000 / -20.7%

EEC Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
Total	**$116.71**	**-**	**$92.60**	**-$24.11**	**-20.7%**
Research	**93.79**	**-**	**76.49**	**-17.30**	**-18.4%**
CAREER	0.77	-	-	-0.77	-100.0%
Centers Funding (total)	68.49	-	54.66	-13.83	-20.2%
Engineering Research Centers	68.49	-	54.66	-13.83	-20.2%
Education	**22.93**	**-**	**16.11**	**-6.82**	**-29.7%**

About EEC

EEC integrates disciplinary basic research and education conducted in other ENG divisions and across NSF into strategic frameworks that address societal grand challenges and promote innovation. Research included in the EEC portfolio spans both the physical/life sciences and engineering, from nanostructured materials to new device concepts, subsystems, and systems. Applications range across a wide spectrum, such as energy, medicine, telecommunications, nanoelectronics, manufacturing, civil infrastructure, the environment, computer networks, cybersecurity, and others. Also included are formal scholarly studies in the professional formation of engineers, which can lead to innovations in engineering education and career development.

The complex, integrative role of EEC requires a comprehensive infrastructure of people, equipment, and centers. Creative and effective approaches to developing the engineering workforce are vital, as a lack of properly prepared engineers is a critical barrier to a healthy U.S. economy. EEC invests in faculty, graduate and undergraduate students, post-doctoral scholars, and K–12 teachers. As nontraditional students—such as part-time, delayed enrollment, veteran, and others—comprise more than 70 percent of the general undergraduate population, EEC is also defining alternative pathways for these students, especially veterans, to successfully earn degrees in engineering.

The programs in EEC are administratively managed within four categories: (1) Major Centers and Facilities; (2) Engineering Education Research; (3) Engineering Workforce Development; and (4) Broadening Participation in Engineering. The Major Centers and Facilities category is comprised of the signature Engineering Research Centers (ERC) program.

The ERC program provides the framework for interdisciplinary research and education, development, and technology transfer in partnership with academia, industry, and government. The FY 2020 funding level supports 17 centers. The total includes initial funding for three 4th-generation ERCs that will advance convergence engineering research to tackle high-impact challenges and benefit U.S. security, prosperity, health and society. The new ERCs will implement new strategies for effective team formation and engagement with stakeholder communities to maximize their impacts. As referenced in the Program Monitoring and Evaluation section, in FY 2015, NSF funded the National Academies to study the future of center-based, multidisciplinary engineering research. The study report articulates a vision for the future of NSF-supported center-scale, multidisciplinary engineering research. After careful consideration, in FY 2018 ENG sparked new convergence engineering research collaborations through planning grants, providing 60 awards to build capacity for a new generation of engineering research centers. In October

2018, ENG released a solicitation (NSF 19-503) for the 4th generation of ERCs and anticipates awards in 2020.

Engineering Education Research advances new productive engineering pedagogy and learning strategies in traditional and non-traditional environments. This category also includes EEC's participation in the NSF-wide activity, IUSE, which integrates the agency's investments in undergraduate education. Engineering Workforce Development includes programs such as Research Experiences for Undergraduate (REU) and Research Experiences for Teachers. Broadening Participation in Engineering supports research and activities that enhance opportunities for underrepresented groups by addressing structural inequalities and biases within educational and workforce systems. This category also includes EEC's engagement with the NSF INCLUDES Big Idea, which integrates the agency's investments to build on and scale up what works in broadening participation programs.

In general, 26 percent of the EEC portfolio is comprised of new research grants. The remaining 74 percent funds continuing grants and cooperative agreements made in previous years. This high fraction of multi-year commitments is primarily a consequence of centers funding, which includes awards made as five-year cooperative agreements.

DIVISION OF INDUSTRIAL INNOVATION AND PARTNERSHIPS (IIP) **$245,250,000**
-$26,460,000 / -9.7%

IIP Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$271.71**	**-**	**$245.25**	**-$26.46**	**-9.7%**
Research	**271.52**	**-**	**244.86**	**-26.66**	**-9.8%**
SBIR/STTR, including Operations	209.98	-	195.15	-14.83	-7.1%
SBIR	182.39	-	166.71	-15.68	-8.6%
STTR	22.59	-	23.44	0.85	3.8%
SBIR/STTR Operations	5.00	-	5.00	-	-
Education	**0.20**	**-**	**0.39**	**0.19**	**97.2%**

About IIP

IIP contributes to the NSF innovation ecosystem by: (1) supporting innovation research that builds on fundamental research discoveries that exhibit potential for societal and economic impact; (2) encouraging research partnerships between academia and industry; and (3) offering hands-on experience in the innovation process to current and future hi-tech entrepreneurs and innovators.

IIP is home to two cross-agency small business research programs, the SBIR and STTR programs. These programs seek to transform scientific discovery into societal and economic benefit by catalyzing private sector commercialization of technological innovations. SBIR/STTR programs provide the opportunity for startups and small businesses to undertake cutting-edge, high-quality scientific research and development to determine the scientific and technical feasibility of a new concept or innovation that could be developed into new products, processes, or services. SBIR/STTR technology topics draw upon the breadth of NSF scientific and engineering research disciplines and are aligned with national and societal priorities.

IIP also supports academic research through three industry-university research programs: IUCRC, Partnerships for Innovation (PFI), and Grant Opportunities for Academic Liaison with Industry (GOALI)/Non-Academic Research Internships for Graduate Students (INTERN). These programs aim to stimulate academia–industry partnerships, leverage industrial support, accelerate technology commercialization, and empower future generations in science and engineering. University grantees in these programs collaborate with industry to create enabling technologies that meet national needs, such as managing the electrical power system, improving manufacturing and biological processing, and supporting new information and communications technologies.

IIP also leads the I-Corps™ program that connects NSF-funded science and engineering research with the technological, entrepreneurial, and business communities, and fosters a national innovation ecosystem that links scientific discovery with technology development, societal needs, and economic opportunities.

In general, 97 percent of the IIP portfolio is comprised of new research grants and three percent supports continuing grants.

OFFICE OF EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES (EFMA) **$65,100,000**
+$15,820,000 / 32.1%

EFMA Funding
(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Change over FY 2018 Actual Percent
Total	**$49.28**	**-**	**$65.10**	**$15.82**	**32.1%**
Research	**41.22**	**-**	**64.90**	**23.68**	**57.5%**
Big Idea: FW-HTF	-	-	30.00	30.00	N/A
Education	**4.07**	**-**	**0.10**	**-3.97**	**-97.5%**
Infrastructure	**4.00**	**-**	**0.10**	**-3.90**	**-97.5%**
CHESS	4.00	-	0.10	-3.90	-97.5%

About EFMA

EFMA strategically pursues and supports projects in important emerging areas. The office also provides support to high impact multidisciplinary education and learning platform programs such as Germination of Research Ideas for Large Opportunities and Critical Societal Needs (GERMINATION), Research Experience and Mentoring (REM), REU supplements, and contributes to the directorate's annual operations support of NSF facilities such as CHESS.

Funding for the FW-HTF Big Idea ($30.0 million) will support convergence activities that transcend the traditional disciplinary boundaries of individual NSF directorates and offices. While financial stewardship for this NSF investment will be the responsibility of ENG, the convergence activities will be overseen and managed collaboratively by the multi-directorate/office FW-HTF leadership team. These activities will enable pursuit of fundamental research on advancing cognitive and physical capabilities in the context of human-technology interactions, and the development of a 21st-century workforce capable of adapting to a changing employment landscape.

A major activity in EFMA is the Emerging Frontiers in Research and Innovation (EFRI) program. Each year EFRI funds interdisciplinary projects at the frontiers of engineering that have the potential for major impacts on national needs and/or grand challenges, particularly in areas that may lead to breakthrough technologies and strengthen the economy's technical underpinnings. Recent EFRI topics have included areas such as: integrated processes and systems designed to make U.S. infrastructures more resilient; highly secure communication using advanced quantum technologies; advances in soft robotics; flexible technologies and regenerative engineering for healthcare; and biomolecular engineering technologies that will lead to transformative strategies for the screening and treatment of pre-cancers, to solve persistent environmental problems, and uncover new plant traits for agriculture. EFRI is intended to have the necessary flexibility to target long-term challenges, while retaining the ability and agility to adapt as new challenges demand.

During FY 2016–2017, EFRI invested in Advancing Communication Quantum Information Research in Engineering (ACQUIRE) that aims to enhance secure, scalable, and efficient data communication. ACQUIRE researchers are investigating fundamental engineering challenges in quantum communication systems to enable lossless, room temperature, point-to-point links combining components, repeaters, networks, and architectures. In FY 2018 and FY 2019, EFRI is investing in two new topics: Chromatin and Epigenetic Engineering (CEE) and Continuum, Compliant, and Configurable Soft Robotics Engineering (C3 SoRo). EFRI is collaborating with BIO, CISE, and MPS and the Air Force Office of Scientific Research

(AFOSR) on these topics. A competition is currently underway for selection and prioritization of EFRI topic areas for FY 2020 and FY 2021 based on ideas submitted by the research community.

In general, about 76 percent of the EFMA portfolio is comprised of new research grants, and about 24 percent supports continuing increments for grants made in previous years.