



Let's Compute!

JOIN US
IN CREATING AND NURTURING
A WORLD-CLASS COMPUTING WORKFORCE

Directorate for Computer and Information
Science and Engineering (CISE)
National Science Foundation

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Foreword



The Directorate for Computer and Information Science and Engineering (CISE) at the National Science Foundation (NSF) plays a unique role in motivating and supporting the preparation of a world-class computing workforce. Established to ensure that the United States maintains a world leadership position in computer and information science and engineering, CISE supports ambitious research projects within and across the many sub-fields of computing, contributes to the education and training of computing professionals and, more broadly, informs the preparation of a U.S. workforce with the computing acumen essential to success in an increasingly competitive, global marketplace.

In *Let's Compute!*, we invite all members of the national computing community to join us in addressing a real national challenge – the imperative that we equip a larger and more diverse cadre of our Nation's youth with computing competencies, inspiring larger numbers of these youth to consider the pursuit of rewarding careers in the computing professions.

Just as important, we note that many of the activities described in this document provide stimulating food for thought about ways in which investigators might include strong Broader Impacts activities in the ~6,000 proposals submitted to CISE annually for funding consideration. We encourage our investigators to think creatively and ambitiously about the roles they can and should play in creating and nurturing the computing workforce of the future.

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The Computing Workforce - A National Imperative



The impact of advances in computing, communications, and associated information technologies (IT) cannot be overstated. In the last fifty years, computing has transformed our lives in both overt and unobtrusive ways. Information technologies now enable, control and maintain our civil and human infrastructure – our transportation systems, our national power grid, our communications and emergency response systems and services, our healthcare enterprise, and our banking and commerce systems. Over the past decade in particular, we have witnessed the creation of richly interconnected worlds where people and IT together demonstrate new forms of collaboration, communication, and emergent intelligence that were not previously achievable by people or IT alone. For example, large numbers of Internet-based volunteer communities now collaboratively write encyclopedia articles of significant scope and scale, craft successful open source software, and perform complex computations that exploit the unused power of millions of computers worldwide. Commerce has been revolutionized: online marketplaces harness the collective behaviors of their participants, create vast storehouses of consumer-supplied reviews, recommend products by matching a consumer's shopping behavior with those of other customers with similar behaviors, and set marketplace prices via computationally-mediated auctions. Search engines prioritize web pages based on the extent to which each page has been linked to by others across the entire World Wide Web. Political movements are creating new forms of engagement and collective action in political systems worldwide. Computing is also transforming entertainment, bringing millions of people together to develop and execute complex activities in online games and virtual worlds. In the future, individuals, groups and communities will continue to come together through computing and its technologies in powerful and imaginative new ways.

It's hardly surprising then, that computing is where many new jobs are. In 2009, the Bureau of Labor Statistics forecast that computing (and mathematical) occupations will grow more than twice as fast as the average for all occupations in the economy between 2008 and 2018. They project that new computing jobs will arise in almost every industry, but roughly half will be located in the computer systems design industry, which is expected to employ more than one in four computer specialists by 2018¹.

Astoundingly, despite the pervasive influence of computing in society, and the recognition that the number of jobs in computing is growing, the IT professions fail to attract significant numbers of our Nation's youth. In fact, despite the pervasive impact of IT, the number of

¹ *Occupational Employment Projections*, Lacey and Wright, Monthly Labor Review, 132, 11, November 2009, <http://www.bls.gov/opub/mlr/2009/11/art5full.pdf>.

students showing interest in computing has been level at best. Troubling trends are observed as early as high school: the number of high school students who took the Computer Science Advanced Placement exam has declined from over 23,000 in 2001 and 2002 to approximately 21,000 students in 2009². The comparison with the number of students taking other Advanced Placement tests is startling: in 2009, over 230,000 students took the Calculus AB exam and almost 160,000 students took the Biology AP exam. Perhaps not surprisingly, since so few students are exposed to the computing fundamentals in high school, only 1 percent of incoming college freshman in 2008 identified computer science as their probable major, down from a high of 3.6 percent in 1999.

Equally troubling are data that show that computer science not only fails to attract a sufficient number of students, the field also fails to attract a diverse population of US students. Despite the fact that it is projected that Hispanics will represent about one quarter of the US population by 2050³, in 2007-2008 Hispanics represented only 1-2 percent of students enrolled in Ph.D. programs in computer and information science and engineering⁴. Similarly African Americans, who represented approximately 11 percent of the civilian labor force in 2008⁵, accounted for less than 2 percent of Ph.D. students in computer and information science and engineering in the 2007-2008 academic year. Women, who make up approximately 46 percent of the US civilian labor force⁶, accounted for only 11.8 percent of bachelor's recipients in computer science and engineering in 2008, and 20.5 percent of Ph.D. recipients in the same period. Clearly, the significant underrepresentation of key sectors of the US population further exacerbates the challenges we face in developing a world-class computing workforce, and foreshadows a significant missed opportunity for technological innovation and economic growth in service to the Nation.

We believe the need for action is clear, and the time for action is now!

So Let's Compute!

² AP Data 2009, AP Examination Volume Change, <http://professionals.collegeboard.com/data-reports-research/ap/data>.

³ Hispanics in the United States, http://www.census.gov/population/www/socdemo/hispanic/files/Internet_Hispanic_in_US_2006.pdf

⁴ Upward Trend in Undergraduate CS Enrollment; Doctoral Production Continues at Peak Levels, Zweben, Computer Research News, May 2009, <http://archive.cra.org/statistics/survey/0708.pdf>.

⁵ Labor Force Characteristics by Race and Ethnicity, U.S. Bureau of Labor Statistics, November 2009, Report 1020, <http://www.bls.gov/cps/cpsrace2008.pdf>.

⁶ A New Look at Long-term Labor Force Projections to 2050, Toosie, Monthly Labor Review, November 2009, <http://www.bls.gov/opub/mlr/2006/11/art3full.pdf>.

Let's Compute! - A Strategic Approach

Recognizing the challenges before us as a Nation, we in CISE are recommitting ourselves to play a more prominent role in the preparation and nurturing of a world-class computing workforce. Our actions are motivated by a vision of ...

a workforce of computing professionals that exemplifies the great diversity, creativity, vitality, and entrepreneurial spirit of our Nation's citizens – a computing workforce that is poised to contribute to wealth creation and to enhancing the human condition.

We've identified three strategic goals to help us realize this vision:

- *Ensure that all learners in K-12 and higher education have the opportunity to develop core computational competencies;*
- *Inspire a larger and more diverse cadre of young Americans to pursue careers in computing; and*
- *Increase the participation of groups currently underrepresented in the computing workforce, including African Americans, Alaskan Natives, Hispanics, Native Americans, Native Hawaiians and other Pacific Islanders, Persons with Disabilities, and Women.*

We believe the following three core strategies will be critical to success:

- **Support High-Impact Workforce Preparation Interventions At All Stages in the Pipeline:** CISE provides a comprehensive set of funding opportunities to prepare and sustain a world-class computing workforce, with programs that are sufficiently flexible to accommodate new ideas and unusual approaches, and that reflect our commitment to increase and broaden participation in the computing professions.
- **Identify Mechanisms that Promote Partnerships and Share Promising Practices:** CISE establishes strategic partnerships and conducts targeted outreach to organizations, groups and individuals to ensure that all stakeholders are informed by and have the opportunity to contribute to the realization of our workforce vision and goals. We also encourage and support the identification and sharing of promising practices and lessons learned, through a variety of mechanisms that include workshops, on-line materials and resources, and monthly newsletters.
- **Practice What We Preach:** The CISE workplace and our business processes and practices demonstrate by example our commitment to increasing and broadening participation in computing, with transparent accountability measures built in to all our efforts.

We elaborate on these strategies in subsequent chapters of this document, in some cases providing *representative* examples of activities undertaken to realize our vision and goals. These examples are provided not to constrain your thinking, but rather to open your minds, and ours, to the many diverse approaches that will help us achieve our shared vision and goals.

Finally, demonstrating our commitment to transparency and accountability, we will report annually on our progress towards realizing the vision and goals described in this document. The report will be provided to the CISE Advisory Committee at its annual spring meeting and will be published on the CISE web site shortly thereafter.

If you have ***Let's Compute!*** ideas, or effective practices you'd like to share with us or with the broader community, please contact us at LetsCompute@nsf.gov - we'd love to hear from you!

I. Workforce Preparation Interventions At All Stages in the Pipeline

CISE programs are grouped in three major categories: those contributing to NSF's *Discovery* strategic goal; those focused on the *Infrastructure* strategic goal; and those focused on the agency's *Education* strategic goal. All of these programs are designed to contribute to the realization of a diverse, world-class computing workforce, albeit with slightly different emphases.

- Our *Discovery* programs (e.g. Algorithmic Foundations, Computer Systems Research, Robust Intelligence) traditionally support graduate student research training, as well as postdoctoral and faculty professional development. Further, these programs often support the participation of undergraduates and K-14 teachers and students in research activities that enrich their learning experiences and in some cases encourage participants to pursue research careers.
- Our *Infrastructure* programs (e.g. Computing Research Infrastructure) support the acquisition, enhancement, and operation of forefront computing infrastructure and experimental facilities, exposing individuals at all levels, from grade school through higher education, to state-of-the-art research and education activities in computing.
- Finally, our *Education* programs (e.g. Broadening Participation Alliances) support the development of a diverse and well-prepared workforce of professionals in the fields of computing and information science and engineering. Interventions are supported in the K-12 system, in community colleges and 4-year schools, and in research-intensive colleges and universities.

To provide a sense of the diversity of individuals, institutions and activities CISE programs support, we provide herein representative examples that we hope enrich your thinking about ways in which you, our CISE investigators, might integrate your research and education interests and responsibilities.

A. K-12 Education

CISE supports:

- ***Pre-service and in-service professional development for teachers***
Vignette: Researchers and educators at the University of California Los Angeles and in the Los Angeles Unified School District (LAUSD) ([CNS-0943507](#)) have developed a model pre-Advanced Placement computer science curriculum, Exploring Computer Science, which is being piloted in 20 Los Angeles high schools. Project leaders are providing computer science teachers in the LAUSD with access to continuous professional

development supported by a district-wide computer science coaching/peer-to-peer mentoring system, on-going professional development workshops throughout the school year, and access to an on-line learning community. Lessons learned in this project will be disseminated nationwide for use by other school districts and higher education institutions.

Vignette: Investigators in Operation Reboot at the Georgia Institute of Technology ([CNS-0940932](#)) are helping IT workers make a career switch into high school teaching and earn their teaching certification, and existing high school teachers develop competencies in computing principles and practices.

- ***Engagement of high school students in computing research***

Vignette: The Center for Embedded Network Sensing (CENS) ([CCF-0120778](#)) offers an eight-week summer internship program that engages high school students in hands-on computer science research, in collaboration with undergraduate interns and under the guidance of faculty, graduate, and undergraduate mentors. Recent summer interns developed and used distributed and wireless sensing technology to enable environmental, participatory, image, and urban sensing. One team of high school students led an effort to design and program a mobile-to-web system and used it to conduct beach water quality research.

- ***Creation of engaging and inspiring curricular materials focused on fundamental computing concepts***

Vignette: CISE investigators are working with the College Board to prepare a new Advanced Placement (AP) course - AP Computer Science: Principles ([CNS-0938336](#)) to identify the principles and practices of computing. Consistent with the 2002 National Research Council recommendation that AP courses *reflect what we know about how students learn, build students' transferable, conceptual understanding and inquiry skills, and convey the content and unifying concepts of a discipline*, we hope that the new course will foster wider appeal among students, teachers, and administrators and will enhance learning in computing.

Vignette: The Computer Science Teachers Association and the International Society for Technology in Education ([CNS-0964217](#)) are bringing thought leaders together to build a shared understanding of computational thinking and to prioritize the strategies and resources that need to be developed to implement computational thinking in K-12 education. At a follow-on workshop, participants will begin drafting the resources required to bring about real and sustained changes in K-12 education.

- ***Creation of communities that support mentoring and the identification of positive role models***

Vignette: Faculty and students at Loyola University, the University of Illinois at Chicago and the University of Illinois at Urbana-Champaign ([CNS-0837480](#)) are reaching out to high school students and teachers in Chicago high schools to expose them to a variety of career paths in computing and to different types of computing-enabled community-

building activities. The project leaders hope to cultivate a larger, stronger, and more diverse corps of computing professionals that is more outward-looking and service-oriented.

- ***Research experiences for teachers (RET)***

Vignette: Encouraging the active participation of teachers in on-going CISE research projects is an excellent way to strengthen the computing expertise of our nation's teachers. Further, RET awards help build collaborative relationships between grade school educators and the CISE research and education community, encouraging the articulation of students interested in pursuing careers in computing between high school and community college and baccalaureate education. More information about RET can be found at http://www.nsf.gov/cise/funding/2009_RED_supplement_DCL.jsp.

- ***Participation of graduate students in K-12 education to provide professional development opportunities for K-12 teachers, enriched learning for K-12 students, and strengthened and sustained partnerships in STEM between institutions of higher education and local school districts***

Vignette: Faculty and graduate students at the University of Maine ([DGE-0538457](#)) and teachers in several Maine middle and high schools are introducing sensors into secondary curricula to motivate students to follow computer science and engineering career paths. Secondary school teachers are awarded fellowships for an eight-week summer session, where they become involved in state-of-the-art sensor research. During the summer, GK-12 Fellows graduate students, are paired with the teachers and the Fellows become participating teachers in the program.

B. Two- and Four-Year Undergraduate Education

At the undergraduate level, CISE:

- ***Promotes the collaboration of faculty and students at community colleges and 4-year institutions***

Vignette: Faculty in the Los Rios Community College are working in partnership with colleagues at Sacramento State University ([CNS-0939168](#)) to develop: computational thinking skills and competencies critical at each point along the K-14 education continuum; assessment tools for accurately measuring acquisition of computational thinking skills; and, a small-scale pilot of infusion strategies to test the promise of the model. This project reaches a large and highly diverse student population, and has led to increased enrollment in computing programs in the participating institutions.

- ***Supports research experiences for undergraduate students***

Vignette: The University of Maryland, College Park supports a Research Experiences for Undergraduates (REU) site ([CNS-0647321](#)), focused on computer security and reliability

engineering. A nationwide recruitment process identifies cohorts of undergraduate students to participate in ten-week summer research programs. The students are mentored by experienced computer science faculty members, attend technical seminars and workshops, participate in team-building activities, develop and give research presentations, and participate in other professional development activities.

Vignette: The influence of Dr. Rajiv Gandhi, at Rutgers Camden (RU-C) has had enormous impact on the career aspirations of economically-disadvantaged undergraduate students from Camden, NJ ([CCF-0830569](#)). Matriculation of students into leading advanced degree programs is a normal occurrence at many colleges, but not at RU-C where typical students transfer from local community colleges, and are often admitted with modest academic backgrounds and financially disadvantaged circumstances. Many students arrive on campus with about two years of coursework remaining and simply plan to graduate and get a job. Teaching students advanced topics such as Approximation Algorithms, requiring them to prepare and deliver presentations for the department colloquia, and challenging them to investigate stimulating problems over the summer are just some of the tactics Gandhi employs with his students. As a result, several students have been accepted into prominent graduate programs. A growing cohort of Computer Science scholars is emerging at RU-C, establishing a new precedent of success and building an abundant supply of inspiration for students and faculty alike.

- ***Improves the undergraduate curriculum in computing***

Vignette: Faculty at Auburn University, Washington State University and the University of Hawaii are implementing a studio-based learning model to trigger a fundamental shift in computing education. In this collaborative project ([CNS-0939055](#), [CNS-0939017](#) and [CNS-0939157](#)), faculty development workshops train computing educators to teach up to twenty courses taken by a variety of computing and IT majors at up to fifteen community colleges and universities across the country, with each course taught once in a studio-based format and once in a traditional format. A rich set of data, including pre- and post-tests, pre- and post-surveys, student interviews, and instructor reports, is being collected and analyzed to evaluate the efficacy of studio-based learning.

- ***Supports the participation of undergraduate students in conferences, peer mentoring activities, networking and professional skill development***

Vignette: With CISE support, Brooklyn College faculty are targeting interventions at both high school and undergraduate levels ([CNS-0540549](#)): a computing preparatory class, offered both in summer and after school, gives inner-city high school students project-based opportunities to explore multiple contextualized computing concepts, acquire background for college-level classes and earn high school science elective credit; "flavored" sections of introductory computing classes for undergraduates provide focused, intra- and inter-disciplinary contexts for hands-on, applied learning of fundamental programming concepts; interdisciplinary courses in socially relevant applications of computing expand the interests of upper-level undergraduates, opening

opportunities for computing minors and masters degree conversion; and involvement in undergraduate research and mentoring shows computer science students the utility of the technical skills they are developing while improving students' communication and time management skills.

Vignette: A Systems Mentoring Workshop was held at the University of Delaware ([CCF-0829760](#)) to expand the pipeline and broaden participation of individuals from underrepresented groups in the systems areas of computer science. Interested in attracting undergraduate students or M.S. students from non-Ph.D.-granting institutions, the workshop organizers recruited 42 students from 25 institutions to attend. Topics covered at the workshop included exciting research opportunities in computer systems as well as career building topics such as how to successfully apply to graduate school and obtain a Ph.D. The students also had several opportunities to network with world-class researchers.

Vignette: Humboldt State University ([CNS-0634528](#)) is working in partnership with the Center for Indian Community Development, the Natural Resource, Science and Engineering Program, and the Indian Teacher and Educational Personnel Program to recruit American Indian students, meet their unique retention needs, and provide computer science programs geared toward employment opportunities in tribal communities. The project involves students' families, tribal communities, faculty advisors at 2- and 4-year schools, specialized student support services personnel, and tribal IT professionals in culturally appropriate mentoring and career development activities.

C. Graduate Education

CISE supports:

- ***Graduate fellowships and traineeships for a diverse cohort of graduate students.***

CISE supports NSF's Graduate Research Fellowships (GRF) program, supplementing agency-level investments in computing Fellows awardees with additional directorate resources. We strongly encourage computing faculty to mentor and coach promising undergraduate students in their junior and senior years, as well as first year graduate students, urging them to apply for GRF support, as the GRF program is undersubscribed in the computing fields.

Vignette: One of our most successful and entrepreneurial Graduate Research Fellows, Larry Page, met Sergey Brin in the computer science Ph.D. program at Stanford University – Sergey received NSF graduate assistant support - and together they established and now run Google, a multibillion dollar organization.

CISE also supports traineeships through the Integrative Graduate Education and Research Training (IGERT) program and the Graduate STEM Fellows in K-12 Education (GK-12) program.

Vignette: With CISE support, IGERT Trainees at Washington State University ([DGE-0900781](#)) are designing and studying health-assistive smart environments, receiving integrated training in the complementary disciplines of computer science, electrical

engineering, mechanical engineering, psychology, sociology, and health care. Trainees conduct research to determine whether technology can automatically monitor and analyze human health and behavior, whether it can simulate human behavior and activities, whether it can enhance human physical and cognitive abilities, and whether these technologies are likely to be accepted by society.

Vignette: With NSF support ([DGE-0338329](#)), eight GK-12 Fellows at Columbia University helped 30 teachers in local middle schools and high schools use technology effectively, and teachers helped the Fellows develop effective pedagogical techniques and classroom-management skills. The Fellows viewed these experiences as necessary and valuable for their future academic careers.

- ***Research assistantships through core and cross-cutting research programs***

Each year, CISE supports approximately 6,000 graduate assistants through awards made in our core and cross-cutting research and education programs. CISE strongly encourages Principal Investigators applying for core or cross-cutting program funding to engage graduate students from underrepresented groups in their projects.

Vignette: As a graduate student, Subhasish Mitra received CISE research assistantship support on a grant made to his advisor, Ed McCluskey. Now an Assistant Professor at Stanford University, Mitra's major honors include the 2008 Presidential Early Career Award for Scientists and Engineers (PECASE, the highest honor bestowed by the US government on early-career outstanding scientists and engineers), an NSF CAREER Award, Terman Fellowship, and an Association for Computing Machinery Special Interest Group on Design Automation (SIGDA) Outstanding New Faculty Award. Prof. Mitra has co-authored over 125 technical papers, and has invented design and test techniques that have seen widespread proliferation in the semiconductor industry.

Vignette: Irina Shklovski received CISE research assistantship support as a graduate student in the Human Computer Interaction Institute at Carnegie Mellon University, where her research focused on investigating how people use communication technologies in life. After receiving her Ph.D., Irina became a postdoctoral fellow at UC Irvine, where she worked with colleagues to study technology use in Southern California wildfires. She is now an Assistant Professor and she participated in the second Summer Institute for the Consortium for the Science of Socio-technical Systems at Syracuse University in June 2009, an institute that actively mentors top graduate students and young faculty doing research in social informatics.

- ***Conference travel grants and other enrichment activities***

Vignette: Travel grants are given to about twenty junior researchers (i.e., graduate students and young faculty) for each of the GENI Engineering Conferences (GEC). In this way, young scientists and engineers without research funds can attend the GEC and learn more about GENI. With this support and the insights and ideas he developed as a result of attending the meeting, Dr. Jiang Li, a computer science faculty member at Howard University, submitted a successful GENI development and prototyping proposal on pigeon networks – a special type of delay tolerant network, <http://www.networks.howard.edu/lij/>.

Vignette: A travel grant ([CNS-0936346](#)) supports the participation of approximately one hundred undergraduate and graduate students in the 2009 - 2011 Grace Hopper Celebration of Women in Computing, students who would otherwise not have been able to attend. The 2009 Grace Hopper Celebration conference meetings are designed to bring the research and career interests of women in computing to the forefront. Leading researchers present their current work and special sessions focus on the role of women in today's technology fields.

D. Post-Doctoral Development and Training

At the post-doctoral level, CISE provides support for:

- ***Postdoctoral appointments through grants in our core and cross-cutting programs***

Vignette: CISE supports an Expedition in Computing to understand, cope with, and benefit from intractability ([CCF-0832797](#)). In this project, fifteen postdoctoral researchers from Princeton University, Rutgers University, New York University and the Institute for Advanced Study are attacking some of the deepest and hardest problems in computer science, striving to bridge fundamental gaps in our understanding about the power and limits of efficient algorithms. Amir Yehudayoff and Pavel Hrubes joined the Expedition two years ago and have since collaborated with Expedition leader, Avi Wigderson on research dealing with computation by arithmetic circuits. The group has focused on models of computation in which the usual laws of commutativity and associativity are abandoned, and they have discovered that even without these laws a rich theory of computational complexity exists. In 2011, the group will part ways, Pavel will go on to do another postdoc while Amir will take a faculty position.

- ***Individuals preparing for careers in the professoriate***

Vignette: The Computing Innovation Fellows (CIFellows) Project, ([CNS-0937060](#)), was established to forestall the permanent loss of research talent likely to occur if new PhDs are forced to seek employment outside of the field due to the current economic crisis. The project, which is administered by the Computing Research Association, supports the placement of new PhD recipients for one to two years in colleges, universities, and other organizations that advance the field of computing and its positive impact on society. In 2009, the project funded a diverse group of 60 CIFellows with PhDs from 44 different universities at 49 different host institutions. Learn more about the Computing Innovation Fellows Project at: <http://cifellows.org/>.

E. Faculty Development

CISE provides support for:

- ***The early career development of junior faculty through NSF's flagship CAREER program and the Administration's PECASE program***

CAREER - The Faculty Early Career Development (CAREER) program supports junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research within the context of the missions of their organizations. CAREER grants allow the recipients to build a firm foundation for a lifetime of leadership in integrating education and research.

Vignette: Nikos Chrisochoides, a CISE CAREER awardee in 1998, ([CCF-9876179](#)), is now a Full Professor in the Computer Science Department of the College of William & Mary and a John Simon Guggenheim Fellow in Medicine and Health. In November 2005, Chrisochoides and his collaborators at Harvard Medical School were the first team of doctors and scientists to complete, in near real-time, the alignment of pre- and intra-operative MRI brain images using landmark tracking across the entire brain volume and present the results to neurosurgeons during a tumor resection procedure. He is now working on real-time mesh generation for biomedical applications such as non-rigid registration for Image Guided Neurosurgery. Chrisochoides has more than 120 technical publications in parallel scientific computing and has held visiting positions at Harvard Medical School, MIT, Brown University and NASA/Langley.

PECASE - Each year, NSF selects nominees for the Presidential Early Career Awards for Scientists and Engineers (PECASE) from among the most meritorious new CAREER awardees. Selection for this award is based on two important criteria: innovative research at the frontiers of science and technology; and, community service demonstrated through scientific leadership, education or community outreach. CISE makes approximately 100 new CAREER awards annually, from which two to four individuals are typically selected to receive PECASE awards.

Vignette: Sean Hallgren, a PECASE awardee, is leveraging his research in Quantum Algorithms and Classical Cryptography to ensure that undergraduates experience an integrated sequence of topics, and that courses are application driven. Quantum computation, which is inherently interdisciplinary, draws on ideas from computer science, mathematics and physics. Sean believes this new and exciting field can draw graduate students and advanced undergraduates and he is developing course materials to appeal to those cohorts of students. He will also develop a series of lectures in quantum computation, appropriate for undergraduates, to increase interest in graduate school. Hallgren is also advising undergraduates on senior theses in quantum computing.

- ***The development of systemic organizational approaches to transform institutions of higher education in ways that will increase the participation and advancement of groups underrepresented in academic careers***

Vignette: ([HRD-0620022](#)), The University of Michigan is improving its campus environment through the development of: equitable faculty recruiting practices; preemptive strategies to prevent the loss of valued faculty; an improved departmental climate for faculty, staff and students; and, skills that allow academic leaders to nurture positive departmental climates. Initially focused on institutional transformation important to women faculty in science and engineering fields, the project has expanded to effect institutional changes supportive of the needs of a diverse faculty in all fields.

II. Mechanisms To Promote Partnerships and Share Promising Practices

Using a variety of mechanisms, CISE supports the development and dissemination of information and resources that enhance the image of computing, increase the effectiveness of computing education; and promulgate best practices and tips for individuals and institutions committed to the development of a diverse, world-class computing workforce. We also promote awareness about issues surrounding the broader inclusion of persons with disabilities and underrepresented minorities in the computing enterprise through the support of workshops and other means by which to bring people together to explore common interests and goals.

CISE also establishes strategic partnerships with, and conducts targeted outreach to, a wide variety organizations, groups and individuals, to capitalize on common interests and to ensure our stakeholders are fully informed about our vision, goals, and strategies. We place emphasis on reaching out to those institutions and individuals currently underrepresented in CISE activities.

A. Our Commitment to Promote and Sustain Value-added Partnerships

Recognizing that partnerships are essential to realizing our workforce vision and goals, we:

- ***Pursue cooperative relationships with other government agencies, professional organizations, industry and other organizations similarly committed to enhancing the effectiveness of computing education and increasing and broadening participation in computing.***

Vignette: In a partnership led by the Association for Computing Machinery (ACM), CISE joined with the Computer Science Teachers Association, the Computing Research Association, the National Center for Women & Information Technology, the Anita Borg Institute, Google Inc., Intel, Microsoft, and the U.S. House of Representatives to establish and support [Computer Science Education Week](#) (CSEdWeek). CSEdWeek raises awareness of the critical role of computing in our global information society; promotes efforts to expose students to robust computer science education; highlight the challenges facing computer science education; and engages supporters to equip students with the knowledge and skills they need for the 21st century.

B. Our Commitment to Outreach

We conduct outreach to a range of organizations and individuals and we support the work of our grantees in doing so. We:

- ***Support efforts that create and market a new image for computing to inspire our Nation's youth and provide appealing professional role models***

Vignette: With support provided by CISE, Microsoft, Avaya, Phizer, and the Bank of America, the National Center for Women in IT (NCWIT) is working to improve both the public image of computing and the number of girls and women who choose to participate in computing, by broadening its appeal and by giving young people a chance to see that computing is valuable work and a great career choice. NCWIT develops and provides outreach resources and conducts national campaigns. Activities supported include Outreach-in-a-Box, the NCWIT Award for Aspirations in Computing, Gotta Have IT, NCWIT Heroes, By the Numbers, and Information Technology: how the power of IT and the power of women will power the future. You can learn more about NCWIT and access their resources at www.ncwit.org.

- ***Encourage computing researchers to attend workshops that focus on increasing and broadening participation in computing***

Vignette: CISE hosted a Broader Impacts Showcase to explore new ways to educate the CISE community about Broader Impacts and allow principal investigators to discuss and engage in a wide range of broadening activities that enrich CISE's award portfolio. More information on the Showcase is available at <http://toilers.mines.edu/BIRDS/index.html>.

- ***Reach out to investigators in minority-serving and other underrepresented institutions to encourage them to participate in CISE activities and build capacity***

Vignette: CISE personnel participate in at least eight outreach events sponsored each year to expose minority serving and other institutions underrepresented in the CISE portfolio to the full range of funding opportunities that we offer.

C. Our Commitment to Identifying and Sharing Promising Practices and Lessons Learned

CISE promotes the identification and sharing of promising practices and lessons learned by

- ***Supporting meetings and workshops where CISE and other investigators share relevant research experiences and best practices***

Vignette: In February 2010, CISE supported a Broadening Participation in Computing PI meeting to encourage the sharing of promising practices and lessons learned among

grantees; the theme for the meeting was Community College Involvement. The majority of the meeting time was spent in small, self-organizing break-out sessions with topics proposed by participants and dynamically scheduled. The break-outs were used to present results and best practices, discuss common issues and strategies, and kick off new collaborations and partnerships.

- **Establishing virtual venues for dialog and resource sharing**

Vignette: With NSF support, a network of organizations headed by the Center for Women and Information Technology (CWIT) at the University of Maryland Baltimore County (UMBC) ([HRD-0631796](#)) is building a web portal that centralizes access to thousands of widely scattered resources on the issue of and solutions to the global technology divide between men and women, and the under-utilization of women in the development of information technology. By creating a centralized web portal to open up lines of communication between international researchers and program implementation personnel, the investigators will identify promising practices based on sharing global knowledge. This project is supported by NSF's Program on Gender Equity. *Vignette:* Investigators in the CISE-supported AccessComputing project ([CNS-0540615](#)) are creating a nationwide resource to help students with disabilities participate in computing fields, and to help computing educators and employers, professional organizations, and other stakeholders develop more inclusive programs and share [promising practices nationwide](#).

- ***Emphasizing interventions that are scalable and replicable and lead to widespread systemic change***

Vignette: CISE is working with academic leaders in computing to develop "model" departmental plans that colleges and universities can consult for advice on increasing and broadening participation in computing. Learning from the successes of a similar initiative undertaken by the academic Chemistry community, CISE encourages department heads in computing in the Nation's colleges and universities to develop such plans that might be used as resources by investigators and others to develop proposals that are creatively and successfully responsive to NSF's "Broader Impacts" merit review criterion.

III. Practice What We Preach

Just as we ask our partners in academic institutions and other types of organizations to demonstrate a commitment to increasing and broadening participation in the computing workforce, so we in CISE seek to demonstrate our commitment to do so in all our business operations.

A. Our Commitment to Ensuring the CISE Workforce Represents the Diversity of Our Nation

We ensure that the CISE workforce represents the diversity of our Nation by designing and implementing recruitment policies and practices to encourage the broad participation of individuals who are members of underrepresented groups or representatives from underrepresented institutions. CISE advertises open positions in a variety of venues, including the NSF website, the Computing Research Association, the Hispanic Association of Colleges and Universities, the Chronicle of Higher Education, SACNAS and Black Issues in Higher Education. Advertisements specifically encourage applications from individuals from groups and institutions currently underrepresented in computing research and education activities.

B. Ensuring the CISE Workforce Fully Contributes to Realizing Our Workforce Vision and Goals

CISE effects a workplace environment that values diversity and creativity. Both formal and informal training opportunities are provided to all staff to ensure the CISE workforce understands and executes its responsibilities for supporting the development of a larger, more diverse computing workforce. At CISE all-hands and division meetings, staff regularly discusses education and broadening participation efforts and issues.

C. Ensuring Our Program Solicitation and Merit Review Processes Align With and Support Our Workforce Vision and Goals

- **Program Solicitations**

CISE solicitations:

- highlight the importance of increasing and broadening participation in computing, encouraging CISE investigators to partner with community colleges,

minority-serving institutions and other institutions underrepresented in CISE activities, to provide increased research opportunities and pathways for a broad range of students;

- link to resources that help investigators respond to NSF's Broader Impacts merit review criterion; and
- include an additional review criterion in the Expeditions program that requires that projects proposed include activities designed specifically to increase and broaden participation in computing.

- ***Merit Review Process***

CISE uses the agency's merit review process to identify the most promising proposals submitted for funding consideration. Reviewers are drawn from the national or international computing community, and are experts in the areas relevant to the proposals under review.

CISE staff are constantly refining and strengthening the effectiveness of the merit review process to sharpen the reviewer community's focus on the importance of developing and nurturing a diverse computing workforce. We:

- brief panelists about the unintended consequences of implicit bias and the importance of addressing the Broader Impacts criterion in all proposals and reviews;
- implement effective practices that ensure better representation on panels; and
- consistently expand the pool of potential panelists from underrepresented groups and institutions, developing a community of reviewers who are sensitive to national workforce needs and to issues of underrepresentation.