

# ENHANCING OUR LIVES THROUGH COMPUTING



Computer & Information Science & Engineering



National Science Foundation

# Transforming Our World Through Computing

Advances in computer, communication and information science and engineering (S&E) have profoundly transformed our lives. Research supported by the Directorate for Computer and Information Science and Engineering (CISE) at the National Science Foundation (NSF) has enabled innovations such as the Internet, Web browsers and smart devices including robotic and assistive technologies and driverless cars—just to name a few examples. Essentially all practical applications of information technology are based on ideas and concepts that emerged from investments in basic computing research.

Innovations in computing serve as key drivers of U.S. competitiveness and sustainable economic growth. Since 1995, networking and information technology industries accounted for 25 percent of U.S. economic development. In 2010 alone, information technology industries grew 16 percent and contributed 5 percent to the overall U.S. gross domestic product.

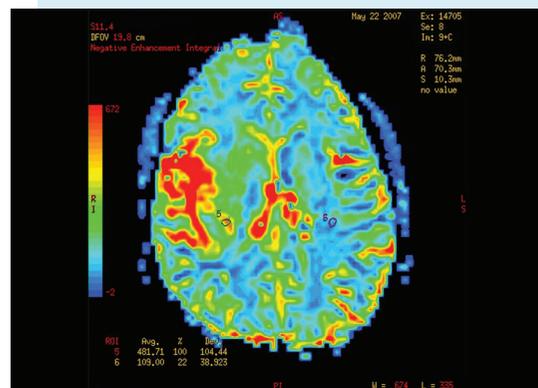
Beyond contributing to economic growth, computing accelerates the pace of discovery and innovation in nearly all fields of S&E inquiry, opening new windows into phenomena as vast as the universe and as small as nanoparticles. Further, computing provides solutions to some of society's most pressing challenges—from improving human health and well-being to mitigating natural disasters.

The support of fundamental computing research and infrastructure by NSF has returned exceptional dividends to the nation. Through investments in ambitious research and infrastructure by CISE, one of NSF's seven research funding arms, the agency continues to ensure that the U.S. remains at the forefront of cutting-edge computing.

## CISE's Impact

By employing NSF's gold standard merit review process, CISE distributes more than 1,600 awards annually to over 17,000 researchers, of which nearly half are undergraduate and graduate students. CISE supports all areas of computer and information S&E and fosters broad interdisciplinary collaborations. The directorate develops and maintains cutting-edge national computing and information infrastructure for furthering research and education. CISE also contributes to the development of a computer and information technology workforce with skills essential for success in the new era of computation and data. These efforts include a special emphasis on educating teachers as well as recruiting and retaining underrepresented groups in computing.

As our reliance on computationally enabled technologies and knowledge grows, computing will continue to have broad and significant implications for society and enhance our everyday lives.



Researchers are using advanced computing infrastructure to improve the quality of brain tumor imaging. Advanced tools allow doctors to make more informed decisions about treatment options and perform more successful surgeries.



CISE is committed to increasing the number and diversity of students in computing, including attracting and retaining females whose participation in computing is very low.

## Expanding the Frontiers of Computing

The mission of CISE is to promote the progress of computer and information S&E research and education and advance the development and use of cyberinfrastructure; promote understanding of the principles and uses of advanced computer, communication and information systems in support of societal priorities; and contribute to universal, transparent and affordable participation in a knowledge-based society. CISE accomplishes this through four divisions.



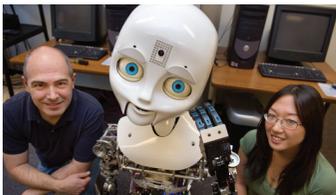
**Advanced Cyberinfrastructure** supports and coordinates the development, acquisition and provision of state-of-the-art cyberinfrastructure resources, tools and services essential to the advancement and transformation of S&E.



**Computing and Communication Foundations** advances computing and communication theory, algorithms for computer and computational sciences and architecture and the design of computers and software.



**Computer and Network Systems** invests new computing and networking technologies, while ensuring their security and privacy, and finds new ways to make use of current technologies.



**Information and Intelligent Systems** studies the interrelated roles of people, computers and information to increase the ability to understand data, as well as mimic the hallmarks of intelligence in computational systems.

### CISE by the Numbers (FY 2013)

**\$858 million**  
Total Appropriations

**7,821**  
Number of proposals

**1,616**  
Competitive awards funded

**21%**  
Success rate of proposals

**17,227**  
Total number of people directly supported

**8,313**  
Number of senior researchers, professionals and postdoctoral associates

**8,914**  
Number of graduate and undergraduate students

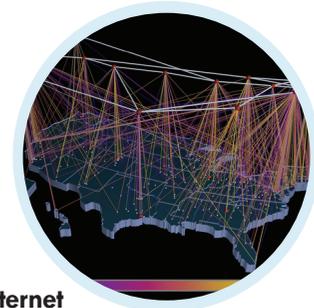
## Meeting National and Societal Needs

The CISE directorate supports fundamental research in all fields of computing and deploys cutting-edge infrastructure to support S&E across all disciplines. CISE investments lead to discoveries and services essential to achieving national and societal priorities—from human health, transportation and environmental sustainability to education and workforce development. These pages contain a few examples of the impact of CISE on these priorities.



### Just “Google” It

During the Internet’s infancy, NSF recognized the need for searchable interfaces for the growing collection of online information and supported the Stanford Integrated Digital Library Project. Two graduate students, Larry Page and Sergey Brin, working on this project developed a new way to search the Web by using page ranking. Today, this methodology is at the core of the search engine used by Google, which is worth more than \$300 billion and employs over 45,000 people.



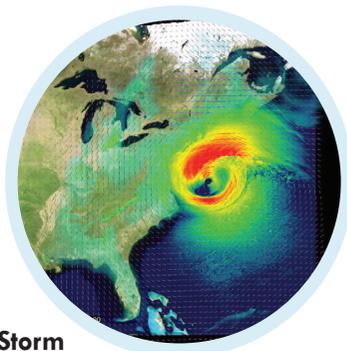
### Expanding the Internet

NSF helped make the Internet a reality and continues to make it safer, faster and more accessible. In 1985, NSF initiated NSFNET, the first large-scale use of Internet technologies, which linked researchers to the nation’s supercomputing centers. Since then, CISE has helped shape the growth and operation of the modern Internet, fostered international network connections and funded the development of the world’s first freely-available Web browser, Mosaic. Along the way, NSF helped transition the network into the self-governing and commercially viable Internet we know today.



### Combining Human and Computer Intelligence

Any time you are required to decipher a set of graphically distorted alphanumeric characters on a website, you are likely encountering a reCAPTCHA, a technology initially supported by CISE. One set of characters is used as a security measure to ensure user authenticity, while the other is an image that optical character recognition software could not decipher. By entering both, reCAPTCHA helped digitize 20 years of *The New York Times* in less than three months.



### Into the Eye of a Storm

Researchers used NSF-supported advanced computing resources to develop a new, high-resolution hurricane forecasting system that incorporates Doppler radar data from planes flying into storms. The forecasts improve storm intensity predictions by an average of 20 to 40 percent over standard official forecasts. This prediction system may become part of the operational forecasting system used by the National Hurricane Center in future emergencies.



### Powering Mobile Devices

With support from CISE, researchers developed a novel approach to power mobile devices that reduces battery usage by 20 percent. The technology optimizes how a battery powers the chips inside a phone, converting high-voltage current to a lower voltage at the exact location where it is consumed.

Credits: (left top to bottom) © Google; NSF; Alan Norton, Mel Shapiro, Tom Galarneau, Perry Domingo (National Center for Atmospheric Research), Peter Johnsen (Cray Inc.) and Mark Straka (NCSA, University of Illinois at Urbana-Champaign); (right top to bottom) Donna Cox and Robert Patterson, courtesy of NCSA and the Board of Trustees of the University of Illinois; Thinkstock



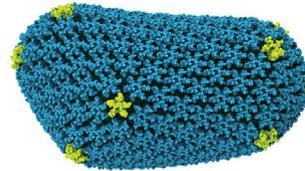
### Self-driving Cars

The development of real-time sensors, smart algorithms and verification tools, supported by CISE over the years, are enabling self-driving cars to effectively sense their surroundings and act in complex, dynamic environments. The deployment of autonomous vehicles could prevent thousands of automobile-related fatalities and injuries resulting from the almost 11 million traffic collisions occurring in the U.S. each year.



### The Sky's the Limit

Cloud computing provides on-demand access to data, storage, software and other computing utilities over the Internet. Applications that use this methodology include Gmail and Dropbox, which cumulatively have more than 600 million users. The virtualization software that enables cloud computing resulted from the work of a CISE-funded researcher, who also co-founded VMware, Inc. The company, which provides cloud software and services, is now worth more than \$35 billion.



### Computer Models Target HIV

More than 35 million people around the world live with HIV. Using state-of-the-art, NSF-funded supercomputers, researchers determined the precise atomic structure of the protein shell of the virus. The simulations revealed a new attractive target for drugs that suppress the HIV virus and stop the progression of AIDS.



### Search-and-rescue Robots

CISE-funded search-and-rescue robots were on-site at Ground Zero within 24 hours of the September 11 attacks to search for survivors. Since then, the robots have evolved to include caterpillar-like crawlers slinking through rubble, mini-helicopters hovering above wreckage and small boats inspecting structures in water. To date, rescue robots have been deployed in more than 30 disasters.



### Computing Education for the 21st Century

Sixty-two percent of all projected job growth in S&E over the next decade will be in information technology, yet there are only enough graduates to fill two-thirds of the job openings each year. To address this shortfall, NSF aims to train 10,000 teachers who will provide rigorous, academic computing courses in 10,000 high schools across the country.

# More Ways

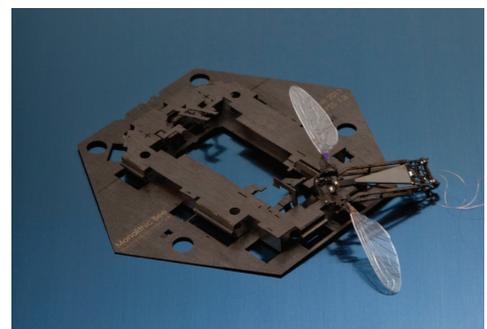
## CISE Impacts Our Lives

Discoveries and innovations supported by CISE enrich our lives and result in widespread economic benefit. As CISE continues to invest responsibly in cutting-edge research and infrastructure, the directorate will expand the possibilities in computing. Below are more ways CISE research is impacting our daily lives.

- Accelerating the pace of discovery**
- Advancing sustainable technologies**
- Augmenting human capabilities**
- Creating smart systems**
- Cultivating computer scientists and engineers**
- Designing the next-generation Internet**
- Driving the future of robotics**
- Expanding the limits of computation**
- Envisioning the future of learning**
- Extracting knowledge from large datasets**
- Forecasting and mitigating natural disasters**
- Harnessing the power of parallel processing**
- Improving energy and transportation systems**
- Innovating manufacturing methods**
- Optimizing wireless networks**
- Modeling the brain**
- Motivating well-being through technology**
- Protecting personal information**
- Recruiting women and minorities to computing**
- Safeguarding cyberspace**
- Securing critical infrastructure**
- Sensing the world around us**
- Simulating natural phenomenon**
- Transforming health care**



An NSF-supported graduate research fellow developed a multi-touch keyboard, which was acquired and incorporated by Apple Inc. into their touchscreen products, including iPhones and iPads.



CISE-funded researchers have revolutionized micro-manufacturing by printing delicate robotic bee bodies. The printed sheets “pop up” like children’s picture books, creating functional flying robots.



CISE-supported researchers are developing WIFIRE, an end-to-end cyberinfrastructure that uses real-time, data-driven assessment to predict a wildfire’s rate of spread.

# CISE:

## Leading the Nation

### National Initiatives



The **National Big Data Research and Development Initiative** coordinates efforts to manage, visualize and extract useful information from large, diverse, distributed and heterogeneous datasets.



**US Ignite** promotes U.S. leadership in the development and deployment of next-generation, end-user applications that leverage ultra-fast, programmable networks with the potential for significant societal impact.



The **National Robotics Initiative** is a federally coordinated cross-agency program to develop the next generation of collaborative robots, or co-robots, that work beside and cooperatively with people to increase their productivity and safety.



The **Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative** aims to revolutionize understanding of the brain by integrating research across multiple scales ranging from molecular to behavioral levels.

### Infrastructure for Discovery



The **Extreme Science and Engineering Discovery Environment (XSEDE)** is the most advanced, powerful and robust collection of advanced digital resources and services in the world. It is a single virtual system that scientists can use to interactively share computing resources, data and expertise.



**Blue Waters** is one of the world's most powerful supercomputers, accelerating the pace of scientific progress across multiple disciplines and enabling previously impossible discoveries.



The **Global Environment for Networking Innovations (GENI)** is a unique virtual laboratory for exploring future internets at scale and is transforming research at the frontiers of networking S&E. GENI serves as the technical foundation for US Ignite.



NSF 14-807



February 2014

[www.nsf.gov](http://www.nsf.gov)

4201 Wilson Boulevard | Arlington | Virginia 22230