Innovating for Society: Realizing the Transformative Impact of Computing and Communication

Farnam Jahanian
CISE Directorate
National Science Foundation

50 Years of Purdue Computer Science
April 2013
Pervasive Impact

• Computing community is at the center of an ongoing societal transformation and will be for decades to come.

• Advances in computing, communications and information technology:
  – Underpin our economic prosperity and national security;
  – Serve as a key driver of U.S. competitiveness and sustainable economic growth in an increasingly global market;
  – Accelerate the pace of discovery and innovation in nearly all other fields of inquiry;
  – Are crucial to achieving our major national and societal priorities.
Economic Impact of IT

• Growth of IT industry coupled with productivity gains across the entire economy have had enormous impact.

• IT industries accounted for 25% of US economic growth since 1995.
  – In 2010, IT industries grew 16% and contributed 5% to overall US GDP

• Use and production of IT accounted for ~2/3 of the post-1995 growth in labor productivity.

• IT sector generates jobs: IT jobs have grown 125x faster than employment as a whole between 2001 and 2011, and in 2011, IT workers earned 74% more than the average worker.

• IT diversifies regional economies to include idea-driven “creative” industries.

Innovations over the past thirty years...

The top innovations of the last thirty years, according to judges at the Wharton School of the University of Pennsylvania.

1. Internet, broadband
2. PC and laptop computers
3. Mobile phones
4. E-mail
5. DNA testing and sequencing
6. Magnetic resonance imaging
7. Microprocessors
8. Fiber optics
9. Office software
10. Laser/robotic surgery
11. Open-source software
12. Light-emitting diodes
13. Liquid crystal display
14. GPS devices
15. E-commerce and auctions
16. Media file compression
17. Microfinance
18. Photovoltaic solar energy
19. Large-scale wind turbines
20. Internet social networking

Life Changers

A panel of eight judges from the Wharton School of the University of Pennsylvania was required to go back only 30 years — not to the dawn of history — when asked a similar question. So its answers, of course, were very different.

In the survey, the Internet was voted the biggest innovation of the last three decades, followed by computers, mobile phones and e-mail. The survey was sponsored by Knowledge@Wharton, the school’s business publication, and PBS’s “Nightly Business Report.”

Good, important choices all, but for classic, long-lasting appeal, they still can’t beat the wheel. PHYLILLIS KORSKI
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THE NEW YORK TIMES

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The past thirty years …
The most recent ten years ...

- Search
- Scalability
- Digital media
- Mobility
- eCommerce
- The Cloud
- Social networking and crowd-sourcing
Technology Push

Transistor counts

Dynamic RAM Price
Bits per Dollar at Production
(Packaged Dollars)

Microprocessor Cost Per Transistor Cycle

Reduction in Watts per MIPS
50 years of Moore’s Law
Same for the Internet

Number of hosts


1,000,000,000 100,000,000 10,000,000 1,000,000 100,000 10,000 1,000 100 10 1
• Ditto the Internet

In just the past 20 years (1992-2012), the number of Internet hosts and the number of transistors on a die each have increased 2000x!
Social Networks

- Twitter, Upstream, Justin, Jaiku
- YouTube, Revver, Reddit, Digg, Ning
- Facebook, Orkut, Multiply
- Friendster
- Napster
- BitTorrent
- AOL, Six Degrees
- IRC
- GeoCities
- Instant Messaging
- Friendfeed, Tumbir, iRovr
- LinkedIn, MySpace, Delicious, Hi5, Photobucket
- Flickr, Google Wave, Authonomy, Posterous
- Google+, Faces.com, Tripl Wellwer
- USENET
- Compuserve, The WELL

Timeline:
- 1980
- 1985
- 1990
- 1999
- 2000
- 2005
- 2010
“Recent technological and societal trends place the further advancement and application of networking and information technology squarely at the center of our Nation’s ability to achieve essentially all of our priorities and to address essentially all of our challenges.”

CISE and National Priorities

- Broadband & Universal Connectivity
- Environment & Sustainability
- Emergency Response & Disaster Resiliency
- Health & Wellbeing
- Manufacturing, Robotics, & Smart Systems
- Secure Cyberspace
- Transportation & Energy
- Education and Workforce Development

Image Credits:
- MicroStrain, Inc.
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- Nicolle Rager Fuller, NSF
- ThinkStock
- Cisco, Inc.
- Georgia Computes! Georgia Tech
National Science Foundation’s Mission

“To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense...”
systems

- robotics
- data
- networks
- learning
Who is the CISE community?

PI and Co-PI Departments for FY 2011 Awards Funded by NSF
CISE

- Computer Science & Information Science, 24%
- Sciences & Humanities, 4.5%
- Engineering (excluding Computer Engineering), 11%
- Interdisciplinary Centers, 4.5%
- PI and Co-PI Departments for FY 2011 Awards Funded by NSF CISE, 61%
Who is the CISE community?

PI and Co-PI Departments for FY 2011 Awards Funded by NSF

CISE

- Computer Science & Information Science & Computer Engineering (CISE), 65%
- Sciences & Humanities, 21%
- Engineering (excluding Computer Engineering), 11%
- Interdisciplinary Centers, 3%
- PI and Co-PI Departments for FY 2011 Awards Funded by NSF

Who is the CISE community?
## Snapshot of CISE FY 2012 Activities

<table>
<thead>
<tr>
<th>Category</th>
<th>CISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Budget</td>
<td>$865M</td>
</tr>
<tr>
<td>Number of Proposals</td>
<td>7695</td>
</tr>
<tr>
<td>Number of Awards</td>
<td>1,741</td>
</tr>
<tr>
<td>Success Rate</td>
<td>~22%</td>
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<tr>
<td>Average Annualized Award Size</td>
<td>$200K</td>
</tr>
<tr>
<td>Number of Panels Held</td>
<td>316</td>
</tr>
<tr>
<td>Number of People Supported</td>
<td>18,460</td>
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</table>

### Number of People Supported

<table>
<thead>
<tr>
<th>Category</th>
<th>CISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior Researchers</td>
<td>8417</td>
</tr>
<tr>
<td>Other Professionals</td>
<td>943</td>
</tr>
<tr>
<td>Postdoctoral Associates</td>
<td>371</td>
</tr>
<tr>
<td>Graduate Students</td>
<td>6131</td>
</tr>
<tr>
<td>Undergraduate Students</td>
<td>2,513</td>
</tr>
</tbody>
</table>
Budget Process Brief Overview

**Community Input**
- Societies and Academies
- CCC and CRA visioning activities
  - CSTB Studies
- CISE Advisory Committee and Industry
- Workshops and direct engagement of PIs

**Internal Deliberation and Negotiation**
- within directorate
- cross-foundation
- cross-agency

**Administration Priorities**
- Office of Science and Technology Policy (OSTP)
- Office of Management and Budget (OMB)
**Budget Activity Timeline**

**FY 2012**
- Apr 12
- May 12
- Jun 12
- Jul 12
- Aug 12
- Sep 12
- Oct 12
- Nov 12
- Dec 12

**FY 2013**
- Jan 13
- Feb 13
- Mar 13

**Budget Formulation**
- Commit, Obligate and Spend
- Develop Interim Operating Plan
- Planning / Set Long-Term Priorities
- Budget Retreat
- NSB Meeting to discuss priorities

**Budget Execution**
- Develop / Submit FY14 Budget to OMB
- NSB Meeting to review and approve budget
- Submit FY14 Budget to OMB

**External Milestones**
- Develop FY14 Budget to OMB

**Internal Milestones**
- Submit FY14 Budget to OMB

**Congressional Action on FY 2013**
- Congress Action on FY 2013
- Publish FY12 Agency Financial Report
- Financial Audit
- Submit FY14 Budget to Congress

**Note:** Timing of internal deadlines and appropriations fluctuates from year-to-year.
Appropriations Drift

NSF Appropriations Dates* versus Start of Federal Fiscal Year (October 1)
*Date that Congress passes appropriation bill

FY 2013: 170 days and counting
Emerging Frontiers

- Data Explosion
- Smart Systems: Sensing, Analysis and Decision
- Expanding the Limits of Computation
- Secure Cyberspace
- Universal Connectivity
- Augmenting Human Capabilities
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FROM DATA TO KNOWLEDGE TO ACTION

Data represent a transformative new currency for science, engineering, education and commerce.
Seizing the Big Data Revolution

- **Data Tsunami: Explosive Growth in Size, Complexity, and Data Rates**
  - Enabled by experimental methods, observational studies, scientific instruments, simulations, email, videos, images, click streams, Internet transactions … and sensors everywhere!

- **The Age of Data: From Data to Knowledge to Action**
  - Widespread use of data to create actionable information leads to timely and more informed decisions and actions.

Image Credit: Chi Birmingham
Paradigm Shift: from Hypothesis-driven to Data-driven Discovery

Data are motivating a profound transformation in the culture and conduct of scientific research.
“By 2018 the United States alone faces a shortage of 140,000 to 190,000 people with analytical expertise and 1.5 million managers and analysts with the skills to understand and make decisions based on the analysis of big data.”

Federal Big Data R&D Initiative
(WH Launch on March 29, 2012)

- Cross-agency “Big Data” Senior Steering Group – chartered in spring 2011 by the White House OSTP:
  - Co-chaired by NSF and NIH
  - Significant research community input

- Major Announcements: NSF, NIH, USGS, DoD, DARPA, DOE

- NEW PROGRAM: Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIG DATA)
  - All NSF Directorates and 8 NIH Institutes
  - Research thrusts: Collection, Storage, and Management; Data Analytics; Research in Data Sharing and Collaboration

U.S. Federal “Big Data” R&D Initiative

• Big Data Senior Steering Group – chartered in spring 2011 under the Networking and Information Technology R&D (NITRD) Program
  – Members from DARPA, DOD OSD, DHS, DOE-Science, HHS, NARA, NASA, NIST, NOAA, NSA, OFR, and USGS
  – Co-chaired by NSF and NIH

• Initiative launched by White House OSTP on March 29, 2012
Framework for Investments

- Foundational research to develop new techniques and technologies to derive knowledge from data
- New cyberinfrastructure to manage, curate, and serve data to research communities
- New approaches for education and workforce development
- New types of interdisciplinary collaboration, community building

Policy
New Tool for Extracting Knowledge from Large Data Sets: A new statistical tool, part of a suite called MINE, can tease out multiple patterns hidden in health information from around the globe, statistics amassed from major league baseball, data on bacterial biodiversity, and much more. (Michael Mitzenmacher, Harvard with researchers from the Broad Institute)

Forecasting Tornadoes: Parallel computing, data mining, and meteorology are being used to determine tornado formation and more reliable tornado forecasting. (Amy McGovern and Kevin Droegemeier, University of Oklahoma)
Complex Policy Setting

- Researchers want data.
- Public policy requires access to data.
- Public policy also requires protection of privacy, intellectual property, and sensitive information.
- Policy and implementation plan for data sharing and open access are needed.
Public Access

• White House Memo on Feb. 22 directs United States federal agencies to develop a plan to support “increased public access” of results from federally funded research.

• Peer-reviewed publications should be stored for “long-term preservation and publicly accessible to search, retrieve, and analyze in ways that maximize the impact and accountability of the Federal research investment.”

• Implementation plans for public access could vary by discipline, and new business models for universities, libraries, publishers, and scholarly and professional societies could emerge.

• Digitally formatted scientific data resulting from unclassified research … “should be stored and publicly accessible to search, retrieve, and analyze.”
Principles for Public Access

- **Value to the Society.** Investing in fundamental STEM research and education is an essential pathway to the future prosperity.

Implementation plans for public access could vary by discipline, and new business models for universities, libraries, publishers, and scholarly and professional societies could emerge.

- **Community roles.** Future policy must acknowledge diverse communities of practice and varied roles and responsibilities, and the role of technology in information and knowledge sharing and dissemination.
A Complex Policy Setting

- Researchers want data.
- Public policy requires access to data and publications.
- Public policy also requires protection of privacy and intellectual property and other sensitive information.
- Business model challenges for publishers and societies.

*More to come*: Policy on data management and open access.

Opportunity for the CISE community to lead the nation.
Emerging Frontiers

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- Augmenting Human Capabilities
Ubiquitous deployment of sensors

The melding of the cyber and physical worlds enables smart systems all around us.
Smart Systems: Sensing, Reasoning, and Decision

Environment Sensing

People-Centric Sensing

Social

Emergency Response

Situation Awareness: Humans as sensors feed multi-modal data streams

Computing

Informatics

Smart Health Care

Personal Sensing

Public Sensing

Social Sensing

Credit: Image courtesy of University of Florida

Source: Sajal Das, Keith Marzullo
Cyber-Physical Systems (CPS)

• Deeply integrate computation, communication, and control into physical systems
• Aspects of CPS include pervasive computing, sensing and control; networking at multi- and extreme scales; dynamically reorganizing/reconfiguring systems; and high degrees of automation
• Dependable operation with high assurance of reliability, safety, security, and usability

National Robotics Initiative (NRI)

• Develop the next generation of collaborative robots, or co-robots, that work beside and cooperatively with people
• A nationally concerted cross-agency effort among NSF, NASA, USDA, and NIH
• Initiative includes aim to understand the long-term social, behavioral, and economic implications
• Potential to enhance personal safety, health, and productivity

Research to Enable Smart Systems

200+ total awards since 2009:
• $140M+ total investment
• 350+ PIs and Co-PIs
• 35 states
FY 12 commitment:
• 45 new awards (29 projects)
• $30M+ investment
Coming this Year:
• Frontiers in CPS

Over 700 proposals submitted & $1B in funding requested

NSF FY 12 commitment:
• ~$30M (~$50M across agencies)
• 31 projects
• 108 PIs and Co-PIs
• 22 states

Image Credit: Bristol Robotics Lab

Image Credit: MicroStrain, Inc.

Application sectors

Transportation

Energy and Industrial Automation

Health and Medical Care

Critical Infrastructure

NSF

ApplicaDon sectors

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Application sectors:
- Transportation
- Energy and Industrial Automation
- Health and Medical Care
- Critical Infrastructure
The National Robotics Initiative (NRI)

A **nationally coordinated** program across multiple government agencies to develop the **next generation of robotics**, to advance the **capability and usability** of such systems and artifacts, and to encourage existing and new communities to focus on **innovative application areas**.
“If you build it, they will come”

108 Researchers and 65 Institutions in 22 states funded
Broad Applications for Smart Systems

**Assistive Medical Technologies**: Programmable second skin senses and re-educates injured nervous systems. (Eugene Goldfield, Harvard Medical School)

**Towel-folding Robots**: Development of novel computer vision and algorithms enable robots to manipulate flexible objects that change shape. (Pieter Abbeel, UC Berkeley)

**Autonomous Vehicles**: Development of precision and real-time sensors, smart algorithms, and verification tools enabling self-driving cars. (Ragunathan “Raj” Rajkumar, CMU, et al.)
Emerging Frontiers

Data Explosion

Smart Systems: Sensing, Analysis and Decision

Expanding the Limits of Computation

Secure Cyberspace

Universal Connectivity

Augmenting Human Capabilities
Processor Performance Plateaued Around 2004

Microprocessor Performance “Expectation Gap” over Time (1985-2020 projected)

Credit: Graph reprinted with permission from The Future of Computing Performance: 
Impact of Single-Processor Performance

Accentuated by emergence of **massive data sets**, scientists have an increasing appetite and need for speed and performance.

Important new science questions in **physics, materials, biology, health and medicine, and climate change** require increased processing power.

**Support of national defense and intelligence community** will need increasingly more processing power.

Applications include training simulations, autonomous robotic vehicles, airport security, surveillance, video analytics, infrastructure defense against cyber attacks, and data analysis for intelligence.

Both **consumer and enterprise needs** are increasing.

Applications include search and data mining, real-time decision-making, web services, digital content creation, speech recognition, and simulation and modeling for product design.
Can we continue the exponential growth in computational power (Moore’s Law) in the coming decades?
Research to Expand the Limits of Computation

Happening now
- Architectural innovations with multi-core and many-core
- Domain-specific integrated circuits
- Energy-efficient computing and new processor architectures

Mid-term solutions
- Need to fully exploit broadly available concurrency and parallelism
- Algorithmic innovations exploiting parallelism
- Software systems leading to improved performance

Long-term solutions
- New materials (e.g., carbon nanotubes, graphene based devices)
- Non-charge transfer devices; (e.g., electron spin)
- Bio, nano, and quantum devices
Exploiting Parallelism and Scalability (XPS)

Support groundbreaking research that will lead to a new era of parallel computing.

- Goal is to establish *new* collaborations combining expertise cutting across abstraction, software, hardware layers.
- Each proposal must have two, or more, PIs providing different and distinct expertise.

**Foundational Principles**
- New models guiding parallel algorithm design on diverse platforms
- Optimization for resources (energy, bandwidth, memory hierarchy)

**Cross-layer Approaches**
- Re-thinking/re-designing the hardware and software stack
- Coordination across all layers

**Scalable Distributed Architectures**
- Highly scalable and parallel architectures for people and things connected everywhere
- Runtime platforms and virtualization tools

**Domain-specific Design**
- Exploiting domain knowledge to improve programmability and performance
Advanced Computational Infrastructure

• Anticipate and invest in diverse and innovative national scale shared resources, outreach and education complementing campus and other national investments

• Leverage and invest in collaborative flexible “fabrics” dynamically connecting scientific communities with computational resources and services at all scales (campus, regional, national, international)
Building Rome in a Day
Advanced Computing Infrastructure

- ACI prioritizes NSF investments in data analytics and management and in fundamental research in computer science and engineering above funding for the development and procurement of large-scale high performance computing systems.

- Including:
  1. Foundational research to fully exploit parallelism and concurrency
  2. Research and development in the use of high-end computing resources in partnerships with scientific domains
  3. Building, testing, and deploying sustainable and innovative resources into a collaborative ecosystem
  4. Development of comprehensive education and workforce programs
  5. Development and evaluation of transformational and grand challenge community programs that support contemporary complex problem solving

Advanced Computing Infrastructure

• NSF strategic plan for “Advanced Computing Infrastructure” announced in February 2012.

• “Agencies should give priority to investment in data analytics and management and in fundamental research in computer science and engineering above funding for the development and procurement of large-scale high performance computing systems.”


Emerging Frontiers

- Data Explosion
- Smart Systems: Sensing, Analysis and Decision
- Expanding the Limits of Computation
- Secure Cyberspace
- Universal Connectivity
- Augmenting Human Capabilities
Cyber Security Challenge

- **Attacks and defenses co-evolve**: a system that was secure yesterday might no longer be secure tomorrow.

- The technology base of our systems is frequently updated to improve functionality, availability, and/or performance. **New systems introduce new vulnerabilities** that need new defenses.

- The **environments** in which our computing systems are deployed and the functionality they provide are **dynamic**, e.g. cloud computing, mobile platforms.

- As **automation pervades new platforms**, vulnerabilities will be found in critical infrastructure, automotive systems, medical devices.

- The **sophistication** of attackers is increasing as well as their sheer **number** and the **specificity** of their targets.

- Cyber security is a **multi-dimensional** problem requiring expertise from CS, mathematics, economics, behavioral and social sciences.
Cyber-physical Security

- Law Enforcement Communications
- Embedded Medical Devices
- Control Systems
- Automobiles
THE BEST OF BOTH WORLDS:

Achieving Privacy & Utility

Reaping the benefits of a data-rich world without sacrificing our privacy
Secure and Trustworthy Cyberspace (SaTC)

Securing our Nation’s cyberspace

- Aims to support fundamental scientific advances and technologies to protect cyber-systems from malicious behavior, while preserving privacy and promoting usability.

- Program addresses three perspectives:
  - Trustworthy Computing Systems
  - Social, Behavioral and Economic Sciences
  - Transition to Practice

- Frontiers support center-scale activities

Cross-Directorate Effort: CISE, ENG, EHR, MPS, OCI, and SBE
Emerging Frontiers

Data Explosion

Smart Systems: Sensing, Analysis and Decision

Expanding the Limits of Computation

Secure Cyberspace

Universal Connectivity

Augmenting Human Capabilities
Explosive Growth in Volume & Traffic Diversity

**VoIP**
- 663M registered Skype users in September 2011.
- Represents 20% of long distance minutes world-wide.
- If Skype were a carrier, it would be the 3rd largest in the world (behind China Mobile and Vodaphone).
- Largest provider of cross-border communication.

**Video**
- Recent estimates as high as 60% of internet traffic is video and music sharing; 35 hours of new videos are uploaded every minute in 2011; 2 billion views per day.

**Twitter**
- Expected to reach 500M registered users in 2012.

**Broadband**
- 20% of global internet users have residential broadband; 68% in U.S. subscribe to broadband.

Remarkable Pace of Innovation

1988

Today
What Happens in an Internet Minute?

639,800 GB of global IP data transferred
204 million Emails sent
47,000 App downloads
135 Botnet infections
1,300 New mobile users
47,000 New victims of identity theft
583,000 New LinkedIn accounts
6,141 Hours of music
20 million Photo views
320+ New Twitter accounts
3,000 Photo uploads
100,000 New tweets

And Future Growth is Staggering

Today, the number of networked devices = the global population
By 2015, the number of networked devices = 2x the global population
In 2015, it would take you 5 years to view all video crossing IP networks each second

Credit: Intel Corporation
Cellular Networks, Mobile Devices and Pervasive Computing

- 5.3 billion mobile phone subscribers; 85% of new handsets will be able to access the mobile web; 1 in 5 has access to fast service, 3G or better; IM, MMS, SMS expected to exceed 10 trillion messages by 2013.
  - Only digital system accessible to the majority of the planet.

- Growing ecosystem of tools and applications:
  - Banking, commerce, healthcare, social networking:
    600K distinct active apps just in App Store.
  - Mobile browsers can now display much of the content available to their desktop counterparts.

- Mobile payment systems are now common in the developing world.

- Sensitive and private data stored & entered on devices.

Research Themes:

- Infrastructure scalability
- Spectrum management
- Security and privacy
- Energy consumption
- Leveraging and advancing new networking technologies
Global Environment for Networking Innovations (GENI)
- A virtual laboratory for exploring future internets at-scale, now taking shape in prototype form across the U.S.
- Key GENI concepts:
  - Slices & deep programmability
  - Federation and enabling “at scale” experiments

US Ignite
- Launched June 14, 2012 at the WH
- NSF leadership
  - Leveraging GENI investments
  - Stitching together testbeds and network resources across the country
  - Jumpstarting gigabit public sector application development
- Public Private Partnership
  - Bringing industry and foundations into the mix

NSF Cloud
- Virtualization beyond the network to resources located in the “cloud”
- Develop competing prototypes
- Allow for experimentation not possible elsewhere

Advancing networking, distributed systems, cloud computing and cybersecurity research through experimentation at scale
Emerging Frontiers

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Universal Connectivity

Augmenting Human Capabilities
Networked Society

Computing technologies and human societies co-evolve, transforming each other in the process
Networked Society

**Computing technologies and human societies co-evolve, transforming each other in the process**

- We are increasingly becoming a networked society.
- Access to technology and information is enhancing our cognitive and physical capabilities.
- This trend will be accelerated by advances in:
  - social informatics
  - assistive technologies
  - augmented reality
  - robotics
  - crowd sourcing
  - learning technologies
  - understanding
  - vision and perception
  - artificial intelligence
  - machine learning
  - information retrieval
- natural language
Social Networks Solving Complex Problems

Networks of human minds are taking citizen science to a new level

In 2011, players of Foldit helped to decipher the crystal structure of the Mason-Pfizer monkey virus (M-PMV) retroviral protease, an AIDS-causing monkey virus. Players produced an accurate 3D model of the enzyme in just ten days. The problem of how to configure the structure of the enzyme had stumped scientists for 15 years.

This is just the beginning of a new field of collective intelligence in which modern technology yields new understanding of collective human behavior and new methods for problem solving.
Augmenting Human Capabilities

Converging technologies for enhancing performance and quality of life

Synergistic combination of emerging technologies from information, cognition, nanotechnology, and materials will improve the quantity and quality of our labor and thought; it will sustain and enhance our function and quality of life diminished by age or injury; and it will improve personal performance with augmented cognition and strength.
CISE and National Priorities

Broadband & Universal Connectivity

Emergency Response & Disaster Resiliency

Environment & Sustainability

Health & Wellbeing

Manufacturing, Robotics, & Smart Systems

Secure Cyberspace

Transportation & Energy

Education and Workforce Development

Image Credit: MicroStrain, Inc.

Image Credit: Texas A&M University

Image Credit: Nicolle Rager Fuller, NSF

Image Credit: ThinkStock

Image Credit: Cisco, Inc.

Image Credit: Georgia Computes! Georgia Tech
The computing community faces three significant and interrelated challenges in workforce development:

- **Underproduction of degrees**
- **Under-representation**
- **Lack of a presence in K-12**
CS10K

Transforming high school computing

Get engaging, rigorous curricula into computing courses in 10,000 high schools, taught by 10,000 well-prepared teachers by 2016.

• New preAP course, Exploring Computer Science (ECS)
• New (proposed) AP Course, CS Principles
• Develops scalable models, curricula and materials for professional development for teachers
• Fosters the growth of national community and partnerships needed to scale to 10,000 teachers & schools
Cyberlearning

Improving learning by integrating emerging technologies with knowledge from research about how people learn

Computer science is both the enabling discipline for the development of technologies that enhance learning and a discipline with an immediate and critical need for cyberlearning technologies as it aims to scale K-16 educational transformations at the national scale.

Goals:

- Understand how people learn in technology rich environments
- Design and study ways in which innovative technologies and tools can promote learning and support assessment
- Prototype new technologies and integrate them into learning environments
CISE and National Priorities

- Broadband & Universal Connectivity
- Emergency Response & Disaster Resiliency
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- Health & Wellbeing
- Manufacturing, Robotics, & Smart Systems
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- MicroStrain, Inc.
- Texas A&M University
- Nicole Rager Fuller, NSF
- ThinkStock
- Cisco, Inc.
- Georgia Computes! Georgia Tech
Towards a Sustainable Human Future

Of all the challenges we face as a nation and as a planet, none is as pressing as the three-pronged challenge of climate change, sustainable development and the need to foster new and cleaner sources of energy.

(Office of Science and Technology Policy, Executive Office of the President)
Energy consumption growing

Coal – 40%
Natural gas – 20%
Renewables – 20%
Nuclear – 15%
Oil / Other Petroleum – 5%
Looking ahead to 2030 ... you can see sustained growth in global demand for electricity is inevitable. Demand is forecasted to more than double by 2030 (Energy Information Administration).
Cyber-Enabled Sustainability Science and Engineering (CyberSEES)

New program announced October 2012

Co-funding with Semiconductor Research Corporation (SRC) Energy Research Initiative in areas of smart infrastructure

CISE-led program aims to advance interdisciplinary research in which
• the science and engineering of sustainability are enabled by new advances in computing, and
• where computational innovation is grounded in the context of sustainability problems
Cyber-enabled Sustainability & “Green” Computing

Monitoring Aquatic Environments: Sensors in autonomous robotic fish monitor real-time movement and quality of water in lakes at the Kellogg Biological Station. (Xiabo Tan, Michigan State University)

New Approach to Power Distribution in Mobile Devices: Reduces battery usage by up to 20% and may revolutionize handset design. (David Brooks, Harvard)
CISE and National Priorities

Broadband & Universal Connectivity

Emergency Response & Disaster Resiliency

Environment & Sustainability

Health & Wellbeing

Manufacturing, Robotics, & Smart Systems

Secure Cyberspace

Transportation & Energy

Education and Workforce Development

Image Credit: MicroStrain, Inc.
Image Credit: Texas A&M University
Image Credit: Nicolle Rager Fuller, NSF
Image Credit: ThinkStock
Image Credit: Cisco, Inc.
Image Credit: Georgia Computes! Georgia Tech
Smart and Connected Health

Transforming healthcare from reactive and hospital-centered to preventive, proactive, evidence-based, person-centered and focused on wellbeing rather than disease.

Cross-Directorate Program: CISE, ENG, and SBE, also NIH
Expeditions-in-Computing

Exploring scientific frontiers that promise transformative innovations in computing

- $10M total per project
  - $2M/year per award for 5 years
- 14 awards to date

### Beyond Moore’s Law
- Variability-aware Software for Efficient Computing with Nanoscale Devices, UCSD, UCLA, UIUC, Stanford, Michigan, 2010
- Customizable Domain-Specific Computing, UCLA, UCSB, Rice, Ohio State, 2009

### Sustainability & Environment
- Understanding Climate Change: A Data Driven Approach – Minnesota, Northwestern, NC State, NC A&T State, 2010

### Wireless & Internet
- Open Programmable Mobile Internet 2020, Stanford, 2008

### Healthcare & Wellbeing
- Socially Assistive Robots, Yale, USC, MIT, Stanford, Willow Garage, 2011

### Robotics
- An Expedition in Computing for Compiling Printable Programmable Machines, MIT, U Penn, Harvard, 2011

### Limits of Computation
- Understanding, Coping with, and Benefiting from Intractability – Princeton, Rutgers, NYU, Institute for Advanced Study, 2008

### Formal Modeling and Verification
- Next-Generation Model Checking and Abstract Interpretation with a Focus on Embedded Control and Systems Biology, Carnegie Mellon, Stony Brook, NYU, UMD, Pitt, Lehman College, JPL, 2009
- Expeditions in Computer Augmented Program Engineering, U Penn, UC Berkeley, UMD, Rice, Cornell, U of Michigan, U of Illinois-UC, UCLA, MIT, 2011

### Big Data
- Algorithms, Machines, and People, UC Berkeley, UC San Francisco, 2011
- Understanding Climate Change: A Data Driven Approach – Minnesota, Northwestern, NC State, NC A&T State, 2010

Image Credit: Harvard University
**Expeditions-in-Computing**

**Programming with DNA:** Employing logic circuits using DNA and RNA has the potential to change the way we analyze, understand, and manipulate molecular systems. (Erik Winfree, Caltech, et al.)

![DNA Logic Circuit](image1)

**RoboBees:** Microrobots with real-time sensing and communication capabilities with the potential to impact assisted agriculture, search and rescue, and environmental monitoring. (Robert Wood, Harvard, et al.)

![RoboBees](image2)

*Image Credit: Harvard University*
Programmatic Innovation in Translational Research

1980
1985
1990
1995
2000
2005
2010

I/UCRC 1979
ERC 1985
GOALI 1993
PFI 2000
EFRI 2007
I-Corps 2011

SBIR 1982
NEES 2004

EFRI 2007

PFI 2000

GOALI 1993

ERC 1985
SBIR 1982

I/UCRC 1979
Discovery and Innovation Ecosystem

- Universities and research labs
- Public-private partnerships
- Venture capital
- Government investments
- Infrastructure
- Scientists and engineers
- Private sector
Discovery and Innovation Ecosystem

- Universities and research labs
- Public-private partnerships
- Scientists and engineers
- Venture capital
- Infrastructure
- Government investments
- Private sector
Innovation Corps (I-Corps)

**Accelerating innovations from the laboratory to the market**

- Aims to develop and nurture a national innovation ecosystem that builds upon fundamental research to guide the output of scientific discoveries to the development of technologies, products and processes that benefit society.
- Seeks to identify NSF-funded researchers to receive additional support - in the form of mentoring and funding.
- Two new subcomponents in FY 2013:
  - **Sites**: fund academic institutions with existing innovation units to enable them to nurture and support multiple, local teams to transition ideas, devices, processes or other intellectual activities into the marketplace.
  - **Nodes**: establish regional nodes to provide training to I-Corps teams; develop tools and resources that impact and expand benefits; identify and pursue longer-term research and development projects.

**Award Information:**
- 25 awards in FY11
- 100 awards in FY12

NSF-wide Initiative
CISE Startups

- Google
- Coverity
- VMware
- panasas
- Arbor Networks
- ReCAPTCHA
- Sana Security
- NexID Biometrics
- nicira
- Mushroom Networks
- VOCi
- algenta
- Conviva
- AVIRTEK
- Smarter Cyber Resilience
- CILK ARTS
- wombat™
- JASPER
- Power Fingerprinting, Inc.
- DayZero Systems
- usable security systems
- Private Machines
- Dependable Computing Incorporated
- Assure Technologies
-(zip)arno
- Private Machines
Innovation Corps (I-Corps)

Accelerating innovations from the laboratory to the market
Building the Nation’s I-Corps “Fabric”

I-Corps Nodes (NSF Program)

I-Corps Sites (NSF Program)

I-Corps Mentors (External Partners Activity)

I-Corps Teams (NSF Program)

I-Corps Mentors

National network of serial entrepreneurs who Mentor I-Corps Teams

I-Corps Sites

National network of universities that can enable their local teams

I-Corps Nodes

National Network of university collaborators – offer immersion curriculum and engage in research about commercialization

I-Corps Teams

National network of “Grass-Roots” activities by NSF PIs – individual teams pursue I-Corps Curriculum and commercialization
Some New CISE Solicitations

- BIGDATA (NSF 12-499)
- Campus Cyberinfrastructure – Network Infrastructure and Engineering Program (NSF 13-530) – 2\(^{nd}\) year
- Cyber Physical Systems (NSF 13-502)
- CyberSEES (NSF 13-500)
- Exploiting Parallelism and Scalability, XPS (NSF 13-507)
- Hazards SEES (NSF 12-610)
- NRI (NSF 12-607) – 2\(^{nd}\) year
- SaTC (NSF 12-596) – 2\(^{nd}\) year
- United States-Israel Collaboration in Computer Science, USICCS (NSF 12-603)
- CCF, CNS, IIS Core programs
Looking Forward
Advanced Cyberinfrastructure

- **Transformative Application** to enhance discovery & learning
- **Provisioning** to create, deploy, and operate advanced CI environments
- **R&D** to enhance technical and social effectiveness of future CI environments
Advanced Cyberinfrastructure

Transformative Application to enhance discovery & learning

Provisioning to create, deploy, and operate advanced CI

R&D to enhance technical and social effectiveness of future CI environments
Cyberinfrastructure Investments

- High Performance Computing
- Network Infrastructure
- Mid-scale Research Infrastructure (i.e., GENI and US Ignite)
Advanced Computational Infrastructure

- Anticipate and invest in diverse and innovative national scale shared resources, outreach and education complementing campus and other national investments.

- Leverage and invest in collaborative flexible “fabrics” dynamically connecting scientific communities with computational resources and services at all scales (campus, regional, national, international).

CIPRES – Cyberinfrastructure for Phylogenetic Research
Network Infrastructure

• Campus Cyberinfrastructure–Network Infrastructure and Engineering (CC-NIE)
  – Network infrastructure improvements at campus level (re-architecting for large data science flows, upgrades within campus and external connectivity)
  – Network integration and applied innovation (e.g., experimental deployment of SDN/openflow)
  – See Kevin Thompson’s Wed. afternoon talk

• International Research Network Connections (IRNC)
  – Continues NSF’s long commitment to directly supporting international network connectivity dedicated to research and education
  – Mid-way through 5-year awards supporting multi-gig connectivity to Europe, Asia, Americas, Australia
  – New approach under consideration for a globally coordinated International Research Network Backbone to meet science and education demands into 2020, stay tuned
Global Environment for Networking Innovations (GENI)

• A virtual laboratory for exploring future internets at-scale, now taking shape in prototype form across the U.S.

• Key GENI concepts:
  – Slices & deep programmability
  – Federation and enabling “at scale” experiments

US Ignite

• Launched June 14, 2012 at the White House
• NSF leadership
  – Leveraging GENI investments
  – Stitching together testbeds and network resources across the country
  – Jumpstarting gigabit public sector application development

• Public Private Partnership
  – Bringing industry and foundations into the mix

The future?
The Promise

• Our investments in **research and education** have returned exceptional dividends to our nation.

• A thriving discovery and innovation ecosystem is the foundation for sustained **economic prosperity** and **national security**.

• To keep those benefits flowing, we need to constantly **replenish** the wellspring of **new ideas** and train **new talent**.

• “Foster an environment that encourages students to imagine, think broadly, collaborate, and capture serendipity, as well as the freedom to take risks and create.” - *Grown up Digital* by Don Tapscott
New Era of Science and Engineering

New Era of Observation
(theory, experiment, computation, “citizen science”)

New Era of Data and Information
Key Trends of the New Era

- **Global Challenges need Global Solutions:** Pandemics, natural and man-made disasters, displaced populations, water shortages, rising sea levels, food security, etc.
  - NAE Grand Challenges

- **Borderless Knowledge Enterprise:** National borders no barrier to instant information access, talent recruitment

- **Shifting Demographics:** Rapidly increasing concentration of engineers and scientists in Asia

- **Shifting Economics:** Science and engineering research and education seen as ticket to economic prosperity in large and small developing countries
Moving ahead

Nurture and Support a Culture of Engagement and Service

• Help shape the future directions of the field, priorities for the nation, and formulate a research and education agenda to address societal challenges.

Embrace a Collaborative Culture Enabled by Foundational Research

• Advances in IT and CI are pushed by long-term investment in foundational research and cross- and inter-disciplinary research and pulled by expanding complexity, scope, and scale of global priorities.

Educate and Empower the Next Generation

• Lead a cyber- and technology-enabled transformation in education and learning to develop the next generation IT workforce and contribute to universal, transparent, and affordable participation in a knowledge-based society.
Long-Term Investment in Basic Research is Imperative

• There is often a long, unpredictable incubation period – requiring sustained investment – between initial exploration and impact.

• Interactions of research ideas multiply their impact and seed new ideas with the potential to lead to unanticipated advances.

• Unanticipated outcomes are often as important as the anticipated ones.
The Growing Imperative of Research and Education

- Our investments in **research, education** and **infrastructure** have returned exceptional dividends to our nation.

- A thriving basic research community is the foundation for long-term **discovery** and **innovation**, **economic prosperity**, and **national security**.

- As a field of inquiry, computer, communication and information science and engineering has a **rich intellectual agenda** – highly creative, highly interactive, with enormous possibilities for changing the world!

- To keep those benefits flowing, we need to constantly **replenish** the wellspring of **new ideas** and train **new talent**.
Thanks!

fjahania@nsf.gov
1. Nurture and Support a Culture of Engagement and Service

• Why Serve?
  – Opportunity to shape the future directions of the field and priorities for the nation
  – Formulate research and education agenda to address societal challenges

• How?
  – Community engagement at many levels

University and industry leadership: encourage and reward national service
Many Opportunities for Community Engagement

- **Come to NSF**
  - Proposal merit review
  - Program review - Committee of Visitors
  - CISE Advisory Committee (Subcommittees and Working Groups)
  - Community Visioning Activities
  - CCC, CRA, CSTB and ACM Interactions
  - Studies with the National Academies

- Program Webinars
- CAREER Proposal Writing Workshops
- CS Bits & Bytes
- CI Fellows Program
- PI Meetings & Conferences
- Broadening Participation in Computing Alliances (CRA-W, NCWIT, etc.)
- Public outreach
Recent Rotators from across the US

- Carnegie Mellon University
- Case Western Reserve University
- Catholic University of America
- Cornell University
- Duke University
- Florida Institute of Technology
- Florida State University
- George Mason University
- Georgetown University
- Georgia Institute of Technology
- Iowa State University
- Oak Ridge National Laboratory
- Old Dominion University
- Oregon Health and Science University
- Penn State University
- Purdue University
- Rensselaer Polytechnic Institute
- Rutgers University
- SRI International
- University of Arizona
- UC Davis
- UCLA
- UC San Diego
- University of Chicago
- University of Denver
- University of Kansas
- University of Maryland
- University of Massachusetts
- University of Michigan
- University of Minnesota
- University of Oklahoma
- University of Pennsylvania
- University of Southern California
- University of Texas at Arlington
- University of Texas at Austin
- University of Toledo
- University of Utah
- University of Vermont
- Virginia Tech
2. Embrace a Collaborative Culture Enabled by Foundational Research

• Long-term investment in foundational research is imperative
  – There is often a long, unpredictable incubation period – requiring sustained investment – between initial exploration and impact.
  – Interactions of research ideas multiply their impact and seed new ideas with the potential to lead to unanticipated advances.
  – Unanticipated outcomes are often as important as the anticipated ones.

• A strong foundation fuels cross- and inter-disciplinary research
  – Tremendous opportunity for the CISE community to work with other disciplines in true collaborations and to address challenges facing humanity.
2. Embrace a Collaborative Culture Enabled by Foundational Research

- Long-term investment in foundational research is imperative.
  - There is often a long, unpredictable incubation period – requiring sustained investment – between initial exploration and impact.
  - Interactions of research ideas multiply their impact and seed new ideas with the potential to lead to unanticipated advances.
  - Unanticipated outcomes are often as important as the anticipated ones.

- Advanced cyberinfrastructure will accelerate the pace of discovery and innovation in all areas of inquiry.

- Cross- and inter-disciplinary research is pushed by advances in IT and pulled by the expanding complexity, scope, and scale of global priorities.
3. Educate and Empower the Next Generation

• Develop the next generation of the computing and information technology workforce.

• Empower citizens by promoting understanding of the principles and uses of computation- and data-intensive techniques.

• Lead a cyber- and technology-enabled transformation in education and learning.

• Contribute to universal, transparent, and affordable participation in a knowledge-based society.