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

Farnam Jahanian
CISE Directorate
National Science Foundation

December 2012
Pervasive Impact

• Our 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.
The past thirty years …

**Life Changers**
The top innovations of the last 30 years, according to judges at the Wharton School of the University of Pennsylvania.

---

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 Its “Nightly Business Report.”

Good, important choices all, but for classic, long-lasting appeal, they still can’t beat the wheel. **PHYLLIS KORSKI**
Life Changers

The top innovations of the last 30 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

The New York Times

Internet, Mobile Phones Named Most Important Inventions

In response to the shouted-out question, “What are some of the greatest inventions of all time?”, nearly 60 percent of the 300 people surveyed gave the following answers: the wheel, the engine, the ballistic pendulum, and the cheese Danish.

The past thirty years …
The past thirty years ...
A National Imperative

“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.”


http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nitrd-report-2010.pdf
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:
- Image Credit: MicroStrain, Inc.
- Image Credit: Texas A&M University
- Image Credit: Nicolle Rager Fuller, NSF
- Image Credit: ThinkStock
- Image Credit: Georgia Computes! Georgia Tech
Strong Commitment to the Core

“NSF continues to **cast a wide net and let the best ideas surface**, rather than pursuing a prescriptive research agenda. It engages the [research] community in **developing new fundamental ideas**, which are then evaluated by the best researchers through the merit review process. This process, which supports the vast majority of unclassified [computing] research in the United States, has **led to innovative and transformative results.**”

-Testimony of Farnam Jahanian before the House Subcommittee on Technology and Innovation and the House Subcommittee on Research and Science Education, May 2011.
Who is the CISE community?

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

- Computer Science & Information Science (CISE), 65%
- Sciences & Humanities, 21%
- Engineering (excluding Computer Engineering), 11%
- Interdisciplinary Centers, 3%
Who is the CISE community?
More than Computer and Information Scientists and Engineers!
Includes other disciplines and increasingly entrepreneurs and industry partners.
### Snapshot of FY 2012 Activities

<table>
<thead>
<tr>
<th>Category</th>
<th>CISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Budget</td>
<td>$653M</td>
</tr>
<tr>
<td>Number of Proposals</td>
<td>6,838</td>
</tr>
<tr>
<td>Number of Awards</td>
<td>1,508</td>
</tr>
<tr>
<td>Success Rate</td>
<td>~20%</td>
</tr>
<tr>
<td>Average Award Size</td>
<td>$171K</td>
</tr>
<tr>
<td>Number of Panels Held</td>
<td>275</td>
</tr>
<tr>
<td>Number of People Supported</td>
<td>16,644</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>CISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior Researchers</td>
<td>7,553</td>
</tr>
<tr>
<td>Other Professionals</td>
<td>617</td>
</tr>
<tr>
<td>Postdoctoral Associates</td>
<td>366</td>
</tr>
<tr>
<td>Graduate Students</td>
<td>5,758</td>
</tr>
<tr>
<td>Undergraduate Students</td>
<td>2,350</td>
</tr>
</tbody>
</table>
### Budget from FY 2010 - 2013

<table>
<thead>
<tr>
<th></th>
<th>FY 2010 Actual ($M)</th>
<th>FY 2011 Actual ($M)</th>
<th>FY 2012 Estimate ($M)</th>
<th>FY 2013 Request ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CISE Total</td>
<td>$618.71</td>
<td>$636.06</td>
<td>$653.59</td>
<td>$709.72</td>
</tr>
<tr>
<td>NSF Research</td>
<td>$5,615.33</td>
<td>$5,608.38</td>
<td>$5,689.00</td>
<td>$5,983.28</td>
</tr>
</tbody>
</table>
Strategy

• Leverage the CISE community’s intellectual leadership in addressing national priorities.

• Promote research agenda led by our community to cross-NSF or cross-agency efforts.

• Sustain long-term commitment to emerging areas of exploration.

• Advance the research frontiers through the right science at the right scale.

• Build on broad bi-partisan support for science and engineering research to cultivate support.
Research Frontiers

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

- Data Explosion
- Smart Systems: Sensing, Analysis and Decision
- Expanding the Limits of Computation
- Secure Cyberspace
- Universal Connectivity
- Augmenting Human Capabilities
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.
Paradigm Shift: from Hypothesis-driven to Data-driven Discovery

Data are motivating a profound transformation in the culture and conduct of scientific research.

http://www.sciencemag.org/site/special/data/
http://www.economist.com/node/15579717
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

- Federal Big Data R&D Initiative launched by White House OSTP on March 29, 2012
- Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIG DATA)
  - Joint solicitation between NIH and NSF
  - 3 research thrusts
    1. Collection, Storage, and Management
    2. Data Analytics
    3. Research in Data Sharing and Collaboration

More information available at:
Federal Big Data R&D Initiative
(Launched 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

More information available at:
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)
Emerging Frontiers

Data Explosion

Secure Cyberspace

Smart Systems: Sensing, Analysis and Decision

Universal Connectivity

Expanding the Limits of Computation

Augmenting Human Capabilities
Smart Systems: Sensing, Reasoning, and Decision

Environment Sensing
- Percepts (sensors)
- Agent (Reasoning)
- Actions (controllers)
- Pervasive

People-Centric Sensing
- Personal Sensing
- Public Sensing
- Social Sensing

Social

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

Smart Health Care
- ECG
- Blood pressure
- SpO2
- GSR
- Accelerometer

Informatics
- Sense
- Evaluate
- Intervene
- Identify
- Assess

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 computation, 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

Application sectors

- Transportation
- Energy and Industrial Automation
- Health and Medical Care
- Critical Infrastructure
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.)

[Image Credit: Wyss Institute, Harvard University]

[Credit: Provided by NSF]

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: Game Over or Next Level? National Academy of Sciences (2011).
Impact of Single-Processor Performance Plateau

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.
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)

New program announced October 2012

- Computational models and programming languages to enable new ways of “thinking parallel” and expression of parallelism at every scale.
- **Algorithms and algorithmic paradigms** that allow reasoning about parallel performance and scalability.
- **Software systems** capable of handling both small and extreme-scale data systems and aware of communication and energy use.
- **Synthesis tools** that generate efficient parallel codes from high-level descriptions.
- **Scalable and energy-efficient architectures** ranging from sensors to clouds while addressing programmability, reliability, and security.
- **A new cross-layer approach** integrating both software and hardware through new programming languages, models, algorithms, compilers, runtime systems and architectures.

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.
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

Image Credit: ThinkStock
Implantable Medical Device Security:
Demonstrating the ability to gain wireless access to a combination heart defibrillator and pacemaker to turn it off and deliver jolts of electricity have resulted in a collaboration with physicians to secure these devices against extraneous signals and attacks. (Kevin Fu, UMass – Amherst)

Security Risks in Automobiles:
Demonstrating the ability to remotely take over automotive control systems has led to a collaboration with the automotive industry to develop new methods for assuring security and safety of automotive electronics. (Stefan Savage, UC San Diego and Tadayoshi Kohno, U Washington)
Research 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 Vodafone).
- 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.
What Happens in an **Internet Minute**?

- **639,800 GB of global IP data transferred**
- **20** New victims of identity theft
- **2,044 million** Emails sent
- **47,000** App downloads
- **$83,000** In sales
- **61,141** Hours of music
- **20 million** Photo views
- **320+** New Twitter accounts
- **3,000** Photo uploads
- **100,000** New tweets

6 New Wikipedia articles published

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 message 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.
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
Research Frontiers

- Data Explosion
- Smart Systems: Sensing, Analysis and Decision
- Expanding the Limits of Computation
- Secure Cyberspace
- Universal Connectivity
- Augmenting Human Capabilities
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
  - natural language understanding
  - vision and perception
  - artificial intelligence
  - machine learning
  - information retrieval
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.
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.
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 Credits:
- MicroStrain, Inc.
- Texas A&M University
- Nicolle Rager Fuller, NSF
- ThinkStock
- Cisco, Inc.
- 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**
Underproduction

- Women, African Americans, Hispanics, Native Americans and indigenous people, and persons with disabilities—together representing 70% of US population—participate in very low numbers in computing.

- While there are disciplines with lower numbers, computing is the only field where the gender gap has grown significantly over the last 20 years (mostly at the undergraduate level).

Underrepresentation

Computing Education for the 21st Century (CE21)

Enhancing computational competencies

- Increase number and diversity of K-14 students and teachers who develop and practice computational competencies
- Increase number of postsecondary students who have background necessary to pursue degrees in computing and computationally-intensive fields
- Build a research base for CS 10K Project
- Cross-Directorate Program: CISE, EHR, OCI
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
Advancing the Research Frontiers Requires the Right Science at the Right Scale
Programmatic Innovations

• **INSPIRE**: Integrated NSF Support Promoting Interdisciplinary Research and Education

• **Innovation Corps (I-Corps)**: Public-private partnership to catalyze a national innovation ecosystem

• **SAVI**: Science Across Virtual Institutes

• **CISE Center-Scale Research Efforts**:
  – Expedition-in-Computing
  – Frontiers in Cybersecurity
  – Frontiers in Cyber-Physical Systems
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 (4 awards in FY 2012)

**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, 2012

**Robotics**
- An Expedition in Computing for Compiling Printable Programmable Machines, MIT, U Penn, Harvard, 2012

**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, 2012

**Big Data**
- Algorithms, Machines, and People, UC Berkeley, UC San Francisco, 2012
- Understanding Climate Change: A Data Driven Approach – Minnesota, Northwestern, NC State, NC A&T State, 2010
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.)

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.)
Looking Forward

Sloan Digital Sky Survey telescope. Credit: Fermilab Photo
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.
The Growing Imperative of Research and Education in Computing

- Our investments in research and education 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