Perspectives on Broader Engagement in the Context of Advanced Computing

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National Science Foundation (NSF)
NSF funds about 11,000 new awards annually

- the only federal agency whose mission includes support for all fields of fundamental science and engineering, except for medical sciences.

- the funding source for approximately 20 percent of all federally supported basic research conducted by America's colleges and universities.
NSF Support of Academic Basic Research in Selected Fields – FY 2009
(as a percentage of total federal support)

- Mathematics and Computer Science: 76.49%
- Social Sciences: 63.88%
- Life Sciences*: 60.67%
- Environmental Sciences: 60.59%
- Physical Sciences: 48.64%
- Engineering: 39.11%
- All Science and Engineering Fields: 24.08%

*Excludes the National Institutes of Health
Source: NSF Survey of Federal Funds for Research and Development
National Science Foundation is organized by Discipline
Computer and Information Science and Engineering (CISE) Directorate

Office of the Assistant Director for CISE
Assistant Director: Dr. Farnam Jahanian
Deputy Assistant Director: Dr. C. Suzanne Iacono

Research Cyberinfrastructure
- Advanced Cyberinfrastructure

Foundational Research
- Computing and Communications Foundations
- Computer and Network Systems
- Information and Intelligent Systems
  - Networking & Security
  - Advanced Computing
  - Data
  - Software
  - Workforce Development
- Algorithmic Foundations
- Communication and Information
- Software and Hardware
- Computer Systems Research
- Networking Technology and Systems
- Education and Workforce
- Human-Centered Computing
- Information Integration and Informatics
- Robust Intelligence

Advanced Cyberinfrastructure
HPC ancestral origins are with Turing and von Neumann, a community populated by mathematicians and physicists.

“why would you want more than machine language?”
And ...not so long ago..... HPC benefitted from Branscomb and Moore

The Branscomb Report

TITLE: From Desktop to TeraFlop: Exploiting the U.S. Lead in High Performance Computing

AUTHORS: NSF Blue Ribbon Panel on High Performance Computing (Branscomb, Belytschko, Bridenbaugh, Chay, Dozier, Grest, Hays, Honig, Lane, Lester, McCrae, Sethian, Smith, Vernon)

DATE: August, 1993
Sustained intellectual and economic investment in simulation-based science and HPC yields transformational results
And....HPC contributes broadly to Computer Science

- **Parallel System Architectures**
  - Vectors, Massively Parallel Systems – SIMD & MIMD
  - High bandwidth interconnects
  - Hybrid multicore/accelerator systems

- **System Software**
  - Parallel File Systems
  - Open Source
  - Multiprocessors

- **Parallel Compilers, Libraries and Languages**
  - Automatic vectorization
  - MPI
  - UPC

- **Parallel, scalable applications**
  - Multi-scale mesh, adaptive mesh algorithms
  - Coupled multi-model software frameworks
  - Open source community models

- **International virtual organizations and communities, both formal and informal of all sizes, types and disciplines**
Personal History

• Education: Math -> Computer Science (Numerical Analysis, Turning Machine, Game Theory)
• Cray Research, Inc. -> autovectorization, parallel algorithms, MPP
• Research in Pharmaceutical Industry -> information science, genomics, molecular dynamics, data privacy/access/policy/mining
• Sabbaticals/visiting scientist: NASA, ETH, Électricité de France (EDF)

• Keys:
  – Deep understanding of Parallelism (HW, SW, Applications)
  – “Startup Opportunities” - failures and successes
  – Being part of a Community ...Connections, Mentors (all men)
  – Bridging Disciplinary Cultural Divides -> Importance of Experience Breadth
Being an “Underrepresented” Member of HPC Community

• Always a bit of an “outlier” but always felt welcomed and allowed lots of opportunity
• Cray Research, Inc. experience formative:
  – A midwest start-up with world-leading intellects
  – International, Industry, Academic connections and community
  – Career mentors hugely important
• People like Fran Allen (IBM), Laney Kulsrud (IDA) and Susan Graham were important models
• Deep disappointment to see that the proportions are the same as when I started
That was then
This is now....
Ubiquity in mobile devices, social networks, sensors and instruments have created a complex data-rich environment ripe for new scientific and engineering advances.

An artist's conception of the National Ecological Observatory Network (NEON) depicting its distributed sensor networks, experiments and aerial and satellite remote sensing capabilities, all linked via cyberinfrastructure into a single, scalable, integrated research platform for conducting continental-scale ecological research. NEON is one of several National Science Foundation Earth-observing systems.

*Credit: Nicolle Rager Fuller, National Science Foundation*
At the same time, long-term, basic research aimed at developing fundamentally new approaches in high-performance computing is needed.

- **Architecture and core technologies**
  - Power (processors, memory, storage)
  - Performance (efficiency, scale, generality)
  - Reliability (number of component parts, concurrent actions, complexity)

- **Software**
  - Portability (across architectures, across scales, over time)
  - Sustainable Complex Applications, Frameworks, Workflows (economical, agile, V&V, UQ)
  - Parallel Models, Methods and Algorithms
This century’s grand challenges require an expanded and collaborative role for large scale computation throughout the scientific process.
Progress in Advanced Computing for simulation and data analysis will require:

- Both “pure” basic research and Use-inspired basic research
- Interdisciplinary research
- Community building across scientific computing communities
- Computational science education and workforce development within S&E domains
- Broadening participation within computing and between computing and S&E disciplines
Learning and Workforce Development
Workforce as Cyberinfrastructure

CI-focused **Cyber Scientists**
to develop, pilot and deliver new capabilities

- Computational Scientists
- Data Scientists
- Design Engineers
- System Administrators

CI-enabled **Domain Scientists**
To explore and exploit new capabilities
How does computing compare across S&E as a whole?

Percent Women by Field and Degree Level
2007 Degree Conferrals

Parity Line: 50%

-Commission on Professionals in Science and Technology (CPST), 2008
How does computing compare on minorities?

Percent URM by Field and Degree Level
2007 Degree Conferrals

- Parity Line: 28%

-CPST, 2008
The computing community faces three significant and interrelated challenges in workforce development:

1. Underproduction of degrees
2. Under-representation
3. Lack of a presence in K-12

![Diagram showing number of degrees earned vs. projected job openings.](ncwit.org)
NSF Programs Supporting Broadening Participation/Education

- Research Experiences for Undergraduates (REU) 
- Computing Education for the 21st Century (CE21) 
- Expeditions in Training, Research, and Education for Mathematics and Statistics through Quantitative Explorations of Data (EXTREEMS-QED) 
- ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE) 
- Support of workshops
- Support undergraduate travel to conferences
NSF Directorate for Education and Human Resources (EHR)

- Undergraduate Education (DUE)

  Advanced Technological Education (ATE)

  Building Community and Capacity for Data-Intensive Research in the Social, Behavioral, and Economic Sciences and in Education and Human Resources (BCC-SBE/EHR)

  Climate Change Education Partnership Alliance Office (CCEPA Office)

  Cooperative Activity with Department of Energy Programs for Education and Human Resource Development (Request for Supplement)

  CyberCorps: Scholarship for Service (SFS)

  Math and Science Partnership (MSP)

  Nanotechnology Undergraduate Education (NUE) in Engineering

  National STEM Education Distributed Learning (NSDL)

  NSF Director's Award for Distinguished Teaching Scholars (DTS)

  NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)

  Robert Noyce Teacher Scholarship Program

  Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP)

  Science, Technology, Engineering, and Mathematics Talent Expansion Program Centers (STEP Centers)

  Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) (TUES)

  Widening Implementation & Demonstration of Evidence-Based Reforms (WIDER)
NSF/EHR/DUE Programs (Undergraduate)

- Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) has funded activities in this area, including:
  - Shoop & Brown, CCLI-Responding to manycore: A strategy for injecting parallel computing education throughout the computer science curriculum
  - Mache & Bunde: Responding to Manycore: Teaching parallel computing with higher-level languages and activity-based laboratories
- CyberCorps: Scholarship for Service (SFS): focused on cybersecurity education and workforce development
- Advanced Technological Education (ATE): education of technicians for high tech fields
Computing Education for the 21st Century (CE21)

Enhancing computational competencies

Goals:

- 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.
- For FY14, now in STEM-C Partnerships

Cross-Directorate Solicitation: CISE, EHR
Cyberlearning: Transforming Education

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

**Goals:**

- Design ways that innovative tools can be effectively integrated into learning,
- Understand how people learn with technology, and
- Implement new technologies into learning environments in ways so that their potential is fulfilled.

Cross-Directorate Solicitation: CISE, EHR, SBE
Curricula Resources – Parallel Programming

• Parallel
  – TCPP model curriculum
    • http://www.cs.gsu.edu/~tcpp/curriculum/
  – Others also exploring this space
    • E.g., new curriculum at CMU - http://hiperfit.dk/pdf/HIPERFIT-2-harper.pdf
  – Intel Academic Community
    • http://software.intel.com/en-us/academic

• Distributed

• Parallel and Distributed
  – ACM/IEEE-CS Computer Science Curricula 2013
Resources: Parallel/Distributed Computing Curriculum and Course Repositories
CSinParallel

- http://serc.carleton.edu/csinparallel
- Website and materials developed in conjunction with NSF awards DUE-0941962 and 0942190 CCLI-Responding to manycore: A strategy for injecting parallel computing education throughout the computer science curriculum
- Materials uploaded by Richard Brown (St. Olaf College), Elizabeth Shoop (Macalester College)
  - Modules (teaching materials and exercises), Parallel Platform Packages (PPPs, interface and library tools with which to implement modules), information about platform resources, and WebMapReduce (WMR, a web interface to Hadoop map-reduce computing that is simple enough for CS1 students to use yet powerful enough for data-intensive computing projects)
- Workshops at SIGCSE and SC
Distributed Computing Repository

• http://www.cs.appstate.edu/distributedComputing/
• Website and materials developed in conjunction with NSF award DUE-073735 Modern Distributed Computing Education
• Materials uploaded by Barry Kurtz (Appalachian State University), Barry Wilkinson (University of North Carolina – Charlotte), Yaohang Li (North Carolina Agricultural and Technical State University)
  – Includes presentation slides for lectures, lab activities in the form of MicroLabs (5-20 minute hands-on activities in midst of lectures), programming assignments, course projects, examinations
• Used for undergrad courses: Parallel Computing, Distributed Systems, Grid Computing, and regional workshops (1 – 1 ½ days)
• Papers, presentations, and demos at SIGCSE
HPC University (HPCU)

• A virtual organization
• Goal: to provide cohesive, persistent, and sustainable on-line environment to share educational and training materials for continuum of HPC environments from desktops to the highest-end facilities
• Resources to guide researchers, educators and students to
  – Choose successful paths for HPC learning and workforce development
  – Contribute high-quality and pedagogically effective materials that allow individuals at all levels and in all fields of study to advance scientific discovery
• Actively seeks participation from all parts of HPC community to:
  – Assess the learning and workforce development needs and requirements of the community
  – Catalog, disseminate and promote peer-reviewed and persistent HPC resources
  – Develop new content to fill the gaps to address community needs
  – Broaden access by a larger and more diverse community via a variety of delivery methods
  – Pursue other activities as needed to address community needs
• http://hpcuniversity.org/
National Science Digital Library

- [http://nsdl.org](http://nsdl.org/)
The National Science Foundation remains committed to broadening participation because it is essential for the nation’s scientific progress.

-Dr. Joan-Ferrini Mundy*
Assistant Director for Education and Human Resources

Thank you!

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