An Expanding and Expansive View of Computer and Information Science and Engineering

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Outline

CISE: the national imperative
CISE programatics
Looking Forward
National Science Foundation’s Mission

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

CISE’s Economic and Societal Context

- CISE is at the center of an ongoing, long-term societal transformation
- Advances in computing, communications, information technologies, cyberinfrastructure:
  - underpin economic prosperity, national security
  - drive U.S. competitiveness and sustainable economic growth
  - accelerate the pace of discovery and innovation
  - are crucial to achieving national and societal priorities, including education and workforce development
CISE programs to address national priorities

From federally-funded research to $B industries

Advances in computing, communications, information technologies, cyberinfrastructure:
- drive U.S. competitiveness, sustainable economic growth (IT: 25% of economic growth since 1995)
- underpin national security
- have profound impacts on our daily lives
This impact continues today ...

**Machine Learning**
- Big Data Analytics Market: $125B (Forbes)
- Eric Schmidt: (Google/Alphabet):
  - Google Pittsburgh: generated $30-40B in profit for Google
  - NSF: "where all interesting research gets started..."

**Software-Defined Networking (SDN)**
- $8B in 2018 (IDC)
... and this impact will continue

Top twelve economically disruptive technologies (by 2025)

![Disruptive technologies: Advances that will transform life, business, and the global economy]

Many STEM jobs are in computing

![Pie chart showing distribution of STEM job openings by discipline]

Job Openings 2014 – 2024 (growth and replacement)

US Bureau of Labor Statistics

Data from the spreadsheet linked at http://www.bls.gov/emp/ind-occ-matrix/occupation.xlsx
Scientists that were noted, but not considered in our analysis.

The number of positions being searched for using the three different values for "multiple positions." There are between 595 and 775 total positions for 2017 depending on the number of positions searched for.

Figure 1: Three-Year Numbers of Number of Institutions Searching and Total Number of Positions

Table 1 with 20 Dean and Chair searches as well as 85 faculty searches from 347 institutions (313 are U.S. based). 269 (78%) of these institutions indicate a specific number of positions being searched for.

Using this methodology our resulting dataset contains information for faculty searches from 347 institutions (249 U.S.-based) with 216 (81%) of these institutions.

Finally, in terms of institutions and positions we did encourage additional ads for Computer Science

Growth in CS Undergrad Majors

Source: 2015 CRA Taulbee Survey

Increase in CS tenure track openings

(# advertised opening, 2015-2017)

71% two-year increase in the number of TT positions being searched

Source: http://web.cs.wpi.edu/~cew/papers/CSareas17.pdf
It is an exciting, impactful and important time to be in computer and information science and engineering!!

Outline

CISE: the national imperative  
CISE programmatic

Looking Forward
NSF Support of Academic Basic Research
(as a percentage of total federal support)

<table>
<thead>
<tr>
<th>Field</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Science and Engineering Fields</td>
<td>24%</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>40%</td>
</tr>
<tr>
<td>Engineering</td>
<td>41%</td>
</tr>
<tr>
<td>Environmental Sciences</td>
<td>59%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>61%</td>
</tr>
<tr>
<td>Social Sciences</td>
<td>67%</td>
</tr>
<tr>
<td>Biology</td>
<td>68%</td>
</tr>
<tr>
<td>Computer Science</td>
<td>82%</td>
</tr>
</tbody>
</table>

An expanding, expansive view of computing

**CISE foundations**
- Theoretical foundations
- Algorithms
- Programming languages
- Learning
- Systems: networks, OS, DB
- Data to knowledge to action
- Societal impacts

**Computational science**

**Software**

**Security**

**Intelligence**

**Computational neuroscience**

**Information systems**

**Communication, control**

**An expanding, expansive view of computing**

**Human-centered computing**
- Assistive technologies, affective computing, social informatics, mind/machine interface, brain

**Science, societal applications**
- Science, engineering, humanities
- Health, security, environment
- Energy, transport, commerce, education

**Nano, quantum, molecular, optical**

**Smart vehicles & buildings, cyber-physical systems, swarms, mobile/cloud computing embedded around us**

**Changing “physicalness” of computing**

**Beyond**
- Electrical, CMOS
CISE’s Commitment to the Core
The heart of what we do

- Casting a broad net
- Letting the best ideas surface
- Engaging research community in developing new fundamental ideas
  - evaluated by research community via merit review process

This process, which supports the vast majority of unclassified computing research in the United States, has led to innovative and transformative scientific results with enormous economic impact and societal benefits.

CISE Research Programmatics

CISE Core Programs
- CCF
- CNS
- IIS
- OAC

NSF Cross-cutting
- NRT
- INFEWS
- I-Corps
- Risk & Resilience
- I/U CRC
- RED

NSF Cross-cutting
- BIGDATA
- Data Building Blocks
- Cyberlearning
- E2CDA
- TRIPODS
- Smart & Connected Communities
- Smart & Connected Heath

CISE Cross-cutting
- FutureCloud
- GENI
- Expeditions
- Smart & Autonomous Systems
- AITF
- Industry
- International
- PAWR
PAWR: Platforms for Advanced Wireless Research

- At-scale experimental exploration: robust new wireless devices, communication techniques, networks, systems
  - dynamic spectrum, mmWave, network architecture, wide-area wireless backhaul, metrology
- Public-private partnership: $50M NSF/CISE, $50M in industry consortium (7 years)
- Planning 4 city-scale wireless research platforms
- Program solicitation NSF 16-585: project office

Smart & Connected Communities (S&CC)

Improving quality of life, health, well-being and learning in communities

- Partnership among CISE, EHR, ENG, GEO, SBE
- Fundamental research: integrative, socio-technical, community engagement
  - Advanced networking; physical sensors/devices; large-scale data management, analysis, and decision making
- Builds on previous investments in Urban Science, US Ignite
- $24.5M solicitation (NSF 16-610) announced
NSF’s Big Data / Data Science Programs

- BIGDATA
  - CDS&E (Computational and Data Science and Engineering)
  - QuBBBD (Quantitative Approaches in Biomedical Big Data)
  - BDD (Big Data and Disaster Research)
  - FutureCloud (CISE/CNS)...

- CC*: Campus Cyberinfrastructure
- DIBBS: Data Infrastructure Building Blocks
- RIDIR: SBE resource building
- BCC: EHR resource building...

- NRT: NSF Research Traineeship (with emphasis on Data-Enabled Science & Engineering)

- BD Hubs/Spokes: Big Data Regional Innovation Hubs and Spokes

Big Data Regional Innovation Hubs

- Northeast: Columbia University
- West: UCSD, UC Berkeley, UW
- South: NC Capel Hill, Georgia Tech
- MidWest: UIUC

- Goal: ignite new Big Data public-private partnerships
- Hub:
  - Consortium from academia, industry, gov’t
  - focus on Big Data challenges, opportunities for region
  - Support breadth of local stakeholders, achieve common Big Data goals not be possible alone
Big Data Spokes of the BDHubs

Each Hub supports subcommitees on **topical areas of interest** ("Spokes")

BDSpokes solicitation aims to support **collaborative projects** surfaced or developed by the Hubs and Spokes

- Two award categories: **Planning Grants** (100K for 1 year) and **Spokes** ($1M total over 3 years)
- Total funding: ~$11M
- 10 Spokes, 10 Planning Grants
**Smart & Autonomous Systems (S&AS)**

*Fundamental research on intelligent physical systems that sense, perceive, and operate in dynamic, uncertain and unanticipated environments*

- Research in smart and autonomous systems at interstices of NRI, CPS
  - NRI: “co-robots” – robots that work alongside, or cooperatively with, people
  - CPS: deeply integrating computation, communication, control into physical systems, typically with provably correct behavior
- Exceeding today’s X-ilies: adaptability, autonomy, functionality, efficiency, reliability, safety, usability, recoverability, recyclability

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**Advanced CyberInfrastructure**

- National Strategy Computing Initiative: research, infrastructure
- ACI, Polar re-alignment reviews
- NSB long-form presentation* (May 2016)
- Numerous accomplishments: Stampede2, XSEDE2, DIBBS, Si2, cross-agency collaborations, ...

* NSB Presentations online at http://www.tvworldwide.com/events/nsf/160505/default.cfm
**Education: Computer Science for All**

- Enable all students to have access to high-quality CS education in K-12:
  - Knowledge base, capacity for rigorous, engaging CS education
  - Teacher PD
- Inter-agency WG
- Collaboration: industry, non-profits
- NSF: $120 million over five years

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**NSF “Big Ideas”**

NSF director unveils big ideas, with an eye on the next president and Congress
**NSF “Big Ideas”**

**RESEARCH IDEAS**
- Harnessing Data for 21st Century Science and Engineering
- Shaping the new Human – Technology Frontier
- Understanding the Rules of Life: Predicting Phenotype
- The Quantum Leap: Leading the Next Quantum Revolution
- Navigating the New Arctic
- Windows on the Universe: The Era of Multi-messenger Astrophysics

**PROCESS IDEAS**
- Growing Convergent Research at NSF
- Mid-scale Research Infrastructure
- NSF 2050
- INCLUDES

*Video of NSF presentation and discussion is at: [http://www.tvworldwide.com/events/nsf/160505/globe_show/default_go_archive.cfm?gsid=2957&type=flv&test=0&live=0](http://www.tvworldwide.com/events/nsf/160505/globe_show/default_go_archive.cfm?gsid=2957&type=flv&test=0&live=0)*

(the presentation/discussion starts about 20 minutes into this video)

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**Harnessing the Data Revolution**

**Research** across all NSF Directorates

*Theoretical foundations*
- mathematics, statistics, computer & computational science

*Systems foundations*
- data-centric algorithms, systems

*Data-intensive research*
- in all areas of science and engineering

**Educational pathways**
- Innovations grounded in an education-research-based framework

**Advanced cyberinfrastructure ecosystem**
- Accelerating data-intensive research
Foundations: Transdisciplinary Research in Principles of Data Science (TRIPODS) NSF 16-615

Workshop: CISE/MPS Theoretical Foundations of Data Science (April 2016)
- design, enable center-scale collaboration on theoretical research among mathematicians, statisticians, computer and computational scientists

Phase I: develop capacity, thematic directions for traditional center-like activities:
- research, education, workforce

A foundation for convergent research in data science

Work at The Human-Technology Frontier: Shaping the Future

Emerging technologies and human-technology interactions are transforming the world of work and the lives of workers

Understanding how constantly evolving technologies are actively shaping our lives and how we in turn can shape those technologies, especially in the world of work
- understand benefits, risks of new technologies: efficiency, quality, productivity, human dynamics
- science and engineering: creating technologies that promise to enhance work lives
- Education: changing workplace demands changing workforce
Work at The Human-Technology Frontier: Shaping the Future

Seamless collaboration between human, cyber-enabled systems:
- understanding of reciprocal human-technology interactions;
- Systems: tailored, optimized, continuously adapted for humans; and
- education and lifelong learning to create requisite workforce

Overview
- CISE: the national imperative
- NSF CISE: programmatic
- Future challenges and opportunities (CISE)
Partnerships: Many dimensions

Partnerships build capacity, leverage resources, increase the speed of translation from discovery to innovation

- PAWR: Platforms for Advanced Wireless Research
- NSF/SRC: E2CDA
- NSF/Intel: Information-Centric Networking
- NSF/VMware: SDI for Clean-Slate Computing Security
- BIGDATA, cloud providers
- Innovation Transition DCL
- Infrastructure collaborations

Prescription 3: Establishing a More Robust National Government-University-Industry Research Partnership

Partnerships: Many dimensions

Partnerships build capacity, leverage resources, increase the speed of translation from discovery to innovation

- Cyber Physical Systems (CPS): DHS, DOT, NASA, NIH
- National Robotics Initiative (NRI): DARPA, NASA, NIH, USDA
- Smart and Connected Health (SCH): NIH
- Collaborative Research in Computational Neuroscience (CRCNS): NIH

*all joint with other NSF directorates*
Partnerships: Many dimensions

Partnerships build capacity, leverage resources, increase the speed of translation from discovery to innovation

- NSF-BSF (Israel): CCF and CNS core, SATC
- US-Japan: interest in BIGDATA, ML
- NSF-Finland: WIFUS
- NSF-India: S&CC
- NSF-Netherlands: privacy
- NSF-Brazil: cybersecurity

Education

Explosion of interest seems different this time around
- broader interests
- minors, other disciplines
Education

- Increasing CISE footprint, program sizes imply increasing TT faculty sizes?
  - additional grant pressures
  - funding expectations based on history 10+ years ago
  - career pathways for PhD students?
- Interesting reading:
  - “Rescuing US Bio-medical Research from its systemic flaws,” Alberts, Kirschner, Tilgham, Varmus, PNAS
Education

- **second sea change (tsunami):** broadening interest in computing among incoming students
- success of K-12 activities
- CS+X

An **amazing** time to be in CISE!

- **Ubiquity**
  Computing is everywhere – across all of science and engineering, and all of society

- **Engagement**
  Computing intertwines with many communities

- **Urgency**
  Computing is rapidly expanding and evolving. There is tremendous opportunity … now!