Transforming Science in the 21st Century: NSF Big Ideas, Advanced Cyberinfrastructure, and the CISE Research Agenda

Manish Parashar
Director, Office of Advanced Cyberinfrastructure,
Directorate for Computer & Information Science & Engineering
National Science Foundation

SCJ Symposium, Tokyo, Japan
January 09, 2020
Outline

NSF Mission & Priorities

CISE, OAC Overview & Priorities

Towards a National CI Ecosystem

Conclusion
NSF Champions Research & Education Across All Fields of Science & Engineering

- Biological Sciences
- Engineering
- Mathematical & Physical Sciences
- Computer & Information Science & Engineering
- Geosciences (including Polar Programs)
- Integrative Activities
- Education & Human Resources
- Social, Behavioral & Economic Sciences
- International Science & Engineering

M. Parashar CISE/OAC
Most numbers based on FY 2018 activities

- 94% funds research, education and related activities
- $8.1B FY 2019 enacted
- 48,000 proposals evaluated
- 1,800 NSF-funded institutions
- 12,000 awards funded
- 386K people NSF supported
- $1.2B STEM education
- $100M Seeds public-private partnerships
- 236 NSF-funded Nobel Laureates
NSF’s 10 Big Ideas

"... bold questions that will drive NSF's long-term research agenda -- questions that will ensure future generations continue to reap the benefits of fundamental S&E research."
NSF Supports Fundamental Research Across All Areas

NSF support as a percentage of total federal support for basic academic research

<table>
<thead>
<tr>
<th>Field</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Science and Engineering Fields</td>
<td>25%</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>45%</td>
</tr>
<tr>
<td>Engineering</td>
<td>46%</td>
</tr>
<tr>
<td>Environmental Sciences</td>
<td>64%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>67%</td>
</tr>
<tr>
<td>Social and Psychological Sciences</td>
<td>67%</td>
</tr>
<tr>
<td>Biology</td>
<td>67%</td>
</tr>
<tr>
<td>Computer Science</td>
<td>87%</td>
</tr>
</tbody>
</table>

Outline

- NSF Mission & Priorities
- CISE, OAC Overview & Priorities
- Towards a National CI Ecosystem
- Conclusion

M. Parashar CISE/OAC
Cyberinfrastructure is Central NSF’s Mission & Priorities...

M. Parashar CISE/OAC
FY 2021 R&D Budget Priorities Memo

“Artificial Intelligence, Quantum Information Science, and Computing:... prioritize basic and applied research investments that are consistent with the 2019 Executive Order on Maintaining American Leadership in Artificial Intelligence and the ... 2019 update of the National Artificial Intelligence Research and Development Strategic Plan... In terms of computing, departments and agencies should work together to explore new applications in and support R&D for high performance future computing paradigms, fabrication, devices, and architectures alongside sustainable and interoperable software; data maintenance and curation; and appropriate security.

M. Parashar CISE/OAC
National Strategic Computing Initiative Update:
Pioneering the Future of Computing

Three re-focused objectives:
- Pioneer new frontiers of digital and non-digital computation to address the scientific and technological challenges and opportunities of the 21st century
- Develop, broaden, and advance the Nation’s computational infrastructure and ecosystem
- Forge and expand partnerships for the future of computing to ensure American leadership in science, technology, and innovation
CISE and AI: More than ML

Transformative science that holds promise for tremendous societal and economic benefit with potential to revolutionize how we discover, work, learn, and communicate

- Foundational, applied and translational research programs
- Cross-directorate programs:
  - NRI-2.0: Ubiquitous Collaborative Robots
  - Smart & Connected Communities
  - Smart and Connected Health
  - Collaborative Research in Computational Neuroscience
  - AI infrastructure and services
- New in FY19:
  - AI and Society (CISE, SBE, Partnership on AI)
  - Real-Time Machine Learning (CISE, ENG, DARPA)
  - NSF/Amazon Program on Fairness in AI (FY20) (CISE, SBE)
  - DCL on FEAT for CISE: Fairness, Ethics, Accountability, and Transparency for CISE Research (NSF 19-016)

M. Parashar CISE/OAC
AI cuts across NSF Big Ideas

“AI is the universal connector that interweaves all of our Big Ideas; data science is changing the very nature of scientific inquiry, and AI’s use of data has the potential to revolutionize everything we do in science.”
**National AI Research Institutes**

- Planning grants for future Institutes
- Up to six multidisciplinary, multi-institutional research institutes
- *National nexus points for universities, federal agencies, industry and nonprofits to advance AI research and workforce development*
- Anticipated investment: about $200 million over six years, beginning in FY 2020

M. Parashar CISE/OAC
AI & Cyberinfrastructure

- Providing advanced infrastructure, services for AI
- Supporting/accelerating large-scale AI, S&E+AI
- Enabling new models and paradigms for S&E discovery
- Fostering intelligent (self-managing) CI systems and services
  - Robust, secure, performant, agile, resilient, ….
  - Platform for transparency/explainability, fairness, trust, privacy, …
NSF’s sustained commitment toward smart and connected communities

- **2008**: NSF establishes CPS program
  - Studies systems that integrates computation, communication, and control into physical systems

- **2017**: S&CC program
  - Researchers working with local communities and residents to solve challenges the community is facing, in a wide variety of application

- **2019**: Civic Innovation Challenge: Ideas Competition
  - Identified challenges and priorities in your cities and communities

- **20??**: Civic Innovation Challenge
  - Research and action in the S&CC domain that is designed to build a more cohesive research-to-innovation pipeline while fostering a collaborative spirit

M. Parashar CISE/OAC
Quantum Information Science & Engineering

- **Growing capacity** in the computing and information science research community through tenure-track faculty lines
  - FY 2019 awards:
    - U Chicago, UCLA, Columbia
- **Access to emerging quantum platforms** in industry
- **Novel algorithms, architectures, and software**
- Aligned with Quantum Leap Big Idea

M. Parashar CISE/OAC
Computing education & workforce

2007
BPC-A
Broadening Participation in Computing Alliances

2010
CS10K
Training 10,000 K-12 CS teachers

2015 2016
RED CSforAll
REvolutionizing eng/cs Departments

2019
CUE

Computer Science for All (CSforAll)
Access to rigorous, engaging CS education for all K-12 students
New College Board Advanced Placement® exam launched

Computing in Undergraduate Education
Integrating computing with other fields of knowledge, challenge areas
Cultivating “networked improvement communities”
Encouraging integrating the study of ethics
The number of female students taking an AP Computer Science exam has more than doubled since the addition of CSP in 2017.

The number of Black/African American students taking an AP Computer Science exam has doubled since the addition of CSP in 2017.

The number of Hispanic/Latinx students taking an AP Computer Science exam has doubled since the addition of CSP in 2017.

<table>
<thead>
<tr>
<th>Students taking AP® computer science exams</th>
<th>2007</th>
<th>...</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>18%</td>
<td>...</td>
<td>23%</td>
<td>27%</td>
<td>28%</td>
<td>29%</td>
</tr>
<tr>
<td>Underrepresented Minorities</td>
<td>12%</td>
<td>...</td>
<td>15%</td>
<td>20%</td>
<td>21%</td>
<td>22%</td>
</tr>
</tbody>
</table>

M. Parashar CISE/OAC
Outline

- NSF Mission & Priorities
- CISE, OAC Overview & Priorities
- Towards a National CI Ecosystem
- Conclusion

M. Parashar CISE/OAC
NSF Office of Advanced Cyberinfrastructure (OAC)

Foster a cyberinfrastructure ecosystem to transform science and engineering research... through Research CI and CI research

Rapid (disruptive) changes in S&E and CI landscapes → Cyberinfrastructure ecosystem must evolve!
A new vision…

An agile, integrated, robust, trustworthy and sustainable CI ecosystem that drives new thinking and transformative discoveries in all areas of S&E research and education.

NSF’s vision for a National Cyberinfrastructure Ecosystem for Science and Engineering in the 21st Century

Overarching principles:

- View CI more holistically
- Support translational research
- Balance innovation with stability
- Couple discovery and CI innovation cycle
- Improve usability

http://go.usa.gov/xm8bU
NSF’s vision for a National Cyberinfrastructure Ecosystem for Science and Engineering in the 21st Century

Community-informed blueprints provide implementation strategies for different elements of the CI ecosystem

More information at: http://go.usa.gov/xm8bU
NSF Computational Ecosystem: Recent Investments

Leadership Class Computing Facility (LCCF)  

Phase I Computation for the Endless Frontier
- A leadership-class computational instrument with the broadest utility for all of S&E applications
- The largest CPU system on a US academic campus
- A national asset that complements other leadership-class computing investments in the US research ecosystem

Phase II is expected to an NSF Major Facility with at least 10x capability

Advanced Computing Systems & Services (ACSS)

Capacity System
- Computing without Boundaries: Cyberinfrastructure for the Long Tail of Science
- Bridges-2: Scalable Converged Computing, Data, and Analytics for Rapidly Evolving Science and Engineering Research

Exploratory System
- Ookami: A high-productivity path to frontiers of scientific discovery enabled by exascale system technologies
Clouds, Campus CI, and the NSF CI Ecosystem

- **CISE CloudAccess**
  - Explore models for providing (CISE) researchers access to Cloud services
  - *CloudBank, UCSD, UC B, UW, PI, M. Norman*

- **Exploring Clouds for Acceleration of Science (ECAS)**
  - Explore clouds as platforms for leading edge science
  - *Internet2, PI, H. Pfeffer*

- **CC*: Clouds and Campus Computing**
  - Federate campus CI
  - Integrate Cloud services/expertise into campus CI

M. Parashar CISE/OAC
Data-Intensive Discovery Pathways – The “missing middle”

Data Sources
- Instrument/Facility Portals & Data streams
- Sources & Repositories

Data-Driven S&E Opportunities
- New science drivers, users and usage modes
- End-to-end Workflows

Challenges
- Data Access: Realtime, streaming, on-demand
- Data Discovery: Knowledge networks, Intelligent data delivery
- Data Fusion: Data integration & interoperability

Science Outcomes & Results Dissemination

Data lifecycle
- Discover
- Publish, Share
- Integrate
- Collaborate
- Reuse

Cl Ecosystem: Computing, Data, Networking, Software, People

Transdisciplinary Enabling Cl

Facility / Discipline Specific Cl Solutions
International R&E Network Connections (IRNC)

- Scientific discovery as a global collaborative endeavor
  - Network connections linking US research with international peer networks
    - Support R&E network connectivity required by international R&E collaborations
    - Include performance flow measurement, monitoring, training

- IRNC Base solicitation (FY 2020)
  - Backbone and Exchange Point International Networking
  - International Testbeds
  - Engagement for Training and Human and Network Capacity Building

**NSF’s International Research and Education Network Connections (IRNC) Portfolio**

- **Backbone Awards (100Gbps+ dedicated R&E network paths)**
  - AmLight Express (multi 100Gbps US/Americas), FIU
  - TransPac4 (100Gbps+ US/Japan/Asia), Indiana U
  - PIREN (200Gbps+ US/Australia/Pacific Islands), U of Hawaii
  - NEAAR (multi 100Gbps to/from Europe), Indiana U
  - US-Africa Spectrum Study (spectrum feasibility via Brazil), FIU

- **Innovative Software defined Open Exchange Points Awards**
  - PacWave (distributed Pacific Exchange Point), CENIC
  - AtlanticWave (Miami Exchange Point for Americas), FIU
  - StarLight (Chicago International Exchange Point), NWU

- **Measurement and Operations**
  - NetSage (Measurement), Indiana U
  - Global NOC (Network Operations), Indiana U

- **Training and Outreach**
  - NSRC (Global R&E Networking Training/Outreach), U of Oregon
  - PRAGMA (Pacific Rim Grid Middleware Collaboration), UCSD
Catalyzing a Cyberinfrastructure Continuum

- Science-driven integration of cyberinfrastructure: Harnessing the computing continuum*
  - Leverage the rich ecosystem of CI resources and services at the edges, along the data path, and in the core...

- Many compelling science drivers
  - E.g., Tsunami early warning

M. Parashar CISE/OAC

Partnerships are Important to NSF and CISE

4 foundation partnerships in FY 18
- Simons Foundation: complex bio systems
- Breakthrough Foundation: Green Bank Observatory
- Stand Up To Cancer: IDEAS Lab
- Gates Foundation: BREAD

University-led, industry-focus
- I/UCRC: center co-funding (since 1973)
- GOALI: faculty, student, industry-researcher exchange
- InTrans: technology-transition co-funding for center-scale projects

8 industry partnerships in FY 18
- Joint funding opportunities
- Research infrastructure

57 interagency partnerships in FY 18
- Joint funding opportunities
- Research infrastructure
- Workforce training
- Individual projects
- with 34 agencies/departments & 7 also included international partners

30 international partnerships in FY 18*
- Joint funding opportunities
- Research infrastructure
- Individual projects

*Estimated
NSF/CISE Collaborations with Japan

- NSF recognizes value of international collaborations
  - NSF funds U.S. PIs, international partners funds their PIs

- New, joint solicitations / international tracks within existing solicitations
  - NSF Smart & Connected Communities – planning grant track with joint funding from US and Japan via JST
  - NSF International Research and education Network Connections (IRNC) – building out linkages with Japan

- International / collaborative workshops

M. Parashar CISE/OAC
An *amazing* time to be in CISE/OAC!

**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!*

M. Parashar CISE/OAC
“Make no little plans; They have no magic to stir men's blood ...”
Daniel H. Burnham, Architect and City Planner Extraordinaire, 1907.

“If you want to travel fast, travel alone; if you want to travel far, travel together”
African Proverb.

Manish Parashar
Office Director, Office of Advanced Cyberinfrastructure
Email: mparasha@nsf.gov

To subscribe to the OAC Announce Mailing List
Send an email to: OAC-ANNOUNCE-subscribe-request@listserv.nsf.gov