CISE Research Infrastructure Investments

Advanced Cyberinfrastructure
Computing & Communication

Computer & Network Systems
Information & Intelligent Systems

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National Science Board, May 2016

Innovating CISE   Innovating S&E
CISE investments are transforming science and society
NSF investments are critical to the academic CISE research community

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

- All Science and Engineering Fields: 24%
- Physical Sciences: 40%
- Engineering: 41%
- Environmental Sciences: 59%
- Mathematics: 61%
- Social Sciences: 67%
- Biology: 68%
- Computer Science: 82%

CISE budget supports modest, sustained growth across all divisions

Innovating CISE

Innovating S&E
CISE supports research infrastructure for the CISE and NSF research communities

In FY16, 55% of ACI budget supports research infrastructure.

6% of other CISE division’s budgets support research infrastructure in FY16.
CISE-led infrastructure enables discoveries

- Software Defined Networks
- HIV Capsid
- LIGO Detection
- iPlant/CyVerse
Testbeds are critical infrastructure for CISE community

US IGNITE
- Enabling a new generation of distributed gigabit apps
- $25M over 5 years
- >35 communities

NSF FUTURECLOUD
- Cloud software architecture and experimentation
- $20M over 3 years

NETWORK RESEARCH TESTBEDS
- Wide-area wired and wireless networks, network emulation
- $25M over 13 years
- >10K users

GLOBAL ENVIRONMENT FOR NETWORKING INNOVATIONS (GENI)
- At-scale virtual laboratory enabling experimentation with deeply programmable slices of the network
- $100M over 10 years
- >6500 users
Looking forward

CISE research testbeds

Advanced Wireless

- **Research**: Dynamic spectrum sharing, Millimeter-wave, Massive MIMO, SDN/NFV, Architecture, Service management
- **Testbeds**: Campus testbeds, Leveraging GENI, NSFFutureCloud; Smart & Connected Communities

Cybersecurity

- **Real-world and hypothetical scenarios**: Experimentation in isolation from production systems
- **Collaboration**: Data, scenarios, software and tools, experimental procedures, results
- Interagency collaboration in alignment with *2016 Federal Cybersecurity R&D Strategic Plan*
CISE leads an expansive view of research infrastructure driven by research priorities and the scientific process.

**CYBERINFRASTRUCTURE ECOSYSTEM**

- **Scientific Instruments**
- **Computational Resources**
- **Networking & Cybersecurity**
- **People, organizations, & communities**
- **Data**
- **Software**

**SCIENTIFIC DISCOVERY & INNOVATION**

- **OBSERVE**
- **THEORIZE**
- **HYPOTHESIZE**
- **EXPERIMENT**
- **ANALYZE**
Network connections link U.S. campuses and facilitate international research coordination

**CAMPUS CYBERINFRASTRUCTURE (CC*):** Upgrades networking capabilities for >200 campuses across 44 states to support science applications and distributed research projects.
Network connections link U.S. campuses and facilitate international research coordination

INTERNATIONAL RESEARCH NETWORK CONNECTIONS (IRNC): International network services to advance global S&E research and education
A diversity of computational resources support the nation’s data- and computational-intensive science.
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Legend:
- Large-scale computation
- Long-tail and high-throughput
- Data Intensive
- Cloud

FUTURE DIRECTIONS FOR NSF ADVANCED COMPUTING INFRASTRUCTURE TO SUPPORT U.S. SCIENCE AND ENGINEERING IN 2017-2020

FINAL REPORT - APRIL 2016

NATIONAL RESEARCH COUNCIL
Use of NSF-supported research CI is growing
Use of NSF-supported research CI is growing

- **2x** Number of active institutions **DOUBLED**
- **3x** Number of PIs per project has **TRIPLED**
- **5x** Number of active users **QUINTUPLED**
XSEDE connects people, services, and resources

Software interface

Innovating CISE  Innovating S&E
A vision for research infrastructure

Reusable and agile scientific software with consistent user entrance into an evolving research infrastructure

Cyberinfrastructure Ecosystem

Software

Data

Large facilities, instruments

Collaboration networks

National computing, data resources

Shared data, software gateway resources
A vision for research cyberinfrastructure

An open national research CI architecture

Increasing interdisciplinary sharing

Science APIs, portals, gateways

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Science APIs, portals, gateways

Increasing disciplinary emphasis

iRODS
federated storage

OSG
HPC access, community

XSEDE
open system software

single sign-on

Governance, policy, sustainability

International

private, commercial cloud

campus, national resources

NSF-supported CI ecosystem

National/International Research and Education Network

Innovating CISE

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Looking forward

Exploring the cutting edge of next-generation research CI

Data Infrastructure Building Blocks (DIBBs)

*Data-centric CI capabilities to accelerate interdisciplinary research*

Awards: Early Implementation ($4M), Pilot Demonstration ($500K)

Software Infrastructure for Sustained Innovation (SI²)

*Accelerating and sustaining software as CI*

Awards: Scientific Software Elements (SSE, $5M), Scientific Software Integration (SSI, $12.5M)

Pacific Research Platform: A West Coast big data freeway system (Smarr et al., UCSD)

CyberGIS: Evolving GIS software for sustained geospatial innovation (Wang et al., UIUC)
Looking forward

Critical support for the most demanding science projects

- 2007
  - R & D
  - Pilot System Delivery
  - System Deployment, Early Operations
  - Algorithm Improvement & Optimization
  - Education & Outreach

- 2013
  - Operations
  - System Administration
  - User Engagement
  - Education & Outreach

- 2018
  - Future Vision,
    Ongoing
  - Community
    Discussion

Blue Waters

10 years, $300M

Image courtesy of NCSA at the University of Illinois
A vision for research cyberinfrastructure

Architecting an open national data infrastructure

Science APIs, portals, gateways
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Science APIs, portals, gateways

New Data Services: Access, Discovery, Deep Analytics, Semantics

Existing CI services

Governance, policy, sustainability

international
private, commercial cloud
campus, national resources

NSF-supported CI ecosystem

National/International Research and Education Network

Innovating CISE
Innovating S&E
A vision for research cyberinfrastructure

Architecting an open national data infrastructure

Enabling and accelerating science drivers, including NSF initiatives & facilities

New Data Services: Access, Discovery, Deep Analytics, Semantics

Existing CI services

Governance, policy, sustainability

UTB, NBO

INFEWS

S&CC

Facilities, MREFC

INFEWS

S&CC

Facilities, MREFC

Existing CI services

NSF-supported CI ecosystem

National/International Research and Education Network

Innovating CISE

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Ubiquity: CISE investments are critical to science and society.

Engagement: Research infrastructure enables advances in CISE as well as the broader scientific enterprise.

Urgency: Continued and increasing investment in CISE and CISE-led research infrastructure is a national imperative.