Cyberinfrastructure and Campus Networking at the National Science Foundation

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NSF CISE
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NSF Core Mission: Fundamental Research

- $7.1 billion FY 2014 research budget
- 94% funds research, education and related activities
- 50,000 proposals
- 11,000 awards funded
- 2,000 NSF-funded institutions
- 300,000 NSF-supported researchers
Computer and Information Science and Engineering (CISE) Directorate

*Exploring the frontiers of computing*

- Promote progress of computer and information science and engineering research and education, and advance the development and use of cyberinfrastructure.

- Promote understanding of the principles and uses of advanced computer, communications, and information systems in support of societal priorities.

- Contribute to universal, transparent and affordable participation in a knowledge-based society.

*These frontiers have interfaces with all the sciences, engineering, education and humanities and a strong emphasis on innovation for society.*
NSF Cyberinfrastructure (ACI) is part of the CISE Directorate and responsible for NSF-wide CI coordination and support
ACI Mission: support advanced cyberinfrastructure to *accelerate* discovery and innovation *across all disciplines*

- Coordination role across NSF
- Interagency & international partnerships
- Supports Use-inspired Cyberinfrastructure for research, education
- Inherently multidisciplinary with strong ties to all disciplines/directorates
Advanced Cyberinfrastructure

Supports the research, development, acquisition, and provisioning of state-of-the-art CI resources, tools, and services

**HIGH PERFORMANCE COMPUTING**
- Enable scientific discovery via petascale computing: diverse, integrated, state-of-the-art HPC assets

**DATA**
- Support scientific communities in use, sharing, archiving of data by creating building blocks for data infrastructure.

**NETWORKING AND CYBERSECURITY**
- Invest in campus network improvements/re-engineering to support modern computational science. Transition cybersecurity research to practice.

**PEOPLE**
- Transform innovations in research and education into fully integrated, sustained software resources
NSF embraces an expansive view of Cyberinfrastructure motivated by research priorities and the scientific process.
NSF Opportunities for Networking and Communication R&D

- IRNC: International Research Network Connections
- NeTs: Networking Technology and Systems
- CIF: Comm & Information Foundations
- EARS: Enhancing Access to the Radio Spectrum
- CPS: Cyber-Physical Systems
- CRI: Computing Research Infrastructure
- IRNC: Computing Research Infrastructure
- cyberSEES

Networking & Communication R&D
At-scale Network Experimentation

**Infrastructure**

**GLOBAL ENVIRONMENT FOR NETWORKING INNOVATIONS (GENI)**
At-scale virtual laboratory enabling experimentation with deeply programmable networks

**US IGNITE**
Stitching together broadband islands, enabling development of gigabit applications with high-impact public benefit

**ADVANCED CYBER-INFRASTRUCTURE**
Cutting-edge computation and data-enabled capabilities at all scales

**Systems research**

**NSFCloud**
Extending virtualization from the network to end-end “cloud”

**Applications**

**Advancing science and engineering**
CISE: an expanding and expansive vision

Beyond computing apps:
- computation, data as research paradigm
- real world, complex, societal, involving humans

Computer Science Core

Commercial and science application

Technology building blocks: electrical, CMOS

Platforms, systems: PCs, servers

End of Moore's law: beyond electrical

Beyond computer: outside the box

Sciences, humanities  Nat. security  Health  Environ.  Energy  Commerce  Transport...

...
Partnerships: Many dimensions

- Promoting partnerships: NSF's strategic goal
- Partnerships build capacity, leverage resources, and increase the speed of translation from discovery to innovation.
- Collaboration and partnerships between disciplines and institutions and among academe, industry, and government enable the movement of people, ideas, and tools throughout the public and private sectors.
- CISE collaborations engage partners from:
  - Other disciplines
  - Industry
  - Government agencies: federal, state, local
  - International funding agencies
Unique Research Opportunities

Facilitating Research at Primarily Undergraduate Institutions: Research in Undergraduate Institutions (RUI) and Research Opportunity Awards (ROA): NSF 14-579

- **RUI may include:**
  - A request to support an individual research project or a collaborative research project involving PUI faculty and students at their own or other institutions.
  - A request involving shared research instrumentation.

- **ROA may include:**
  - A supplement to an existing NSF award to support ROA activities for PUI faculty.
  - Requests to rebudget funds in an existing NSF award to support ROA activities for PUI faculty.
  - Submission of a new collaborative proposal between a PUI and another institution(s), with a ROA component as a subaward or as part of a linked collaborative proposal.
Get Involved

• Volunteer to be a reviewer.
• Visit NSF, get to know your program(s) and program director(s).
• Develop transformational ideas and send your best ideas to NSF.
• Participate in NSF-funded and hosted activities (e.g., workshops, COVs, ACs).
• Participate in the CCC/CRA visioning activities.
• Develop transitional ideas for how to move from ideas and prototypes to systems deployed on testbeds to technology transfer.
• Work within your institution to support and reward interdisciplinary research.
• Work within your institution to support service to the larger computing community around the globe.
• Send us your accomplishments; advertise your research to other citizens through local radio or TV, blogs, newspaper articles, etc.
• Join NSF to serve as program officers or division directors.
CC*DNI:
Campus Cyberinfrastructure - Data, Networking, and Innovation

Kevin Thompson
CISE ACI
1st a quick reminder - Global topology r&e networking (NSF supports a part of this)
Zoom (note the different scales: international, national, regional, campus/local)
Regional Optical Networks
vBNS and High Performance Connections Program (HPNC) – 1995-2003
- National backbone and connections

International Networking (IRNC) – 1997 – present
- Connecting US to the world

Experimental Infrastructure Networking (EIN) - 2003

- Subset: Optical exchange, regional networking upgrades

EPSCoR – Research Infrastructure Improvement (RII) – 2011
- Inter-campus, intra-campus connectivity

STC program (2011 – “100G Connectivity for Data-Intensive Computing at JHU”, Lead PI: Alex Szalay)

CC-NIE 2012, CC-NIE 2013, CC*IIE 2014
ACCI Task Force on Campus Bridging

- Strategic Recommendation to the NSF #3: The National Science Foundation should create a new program funding high-speed (currently 10 Gbps) connections from campuses to the nearest landing point for a national network backbone. The design of these connections must include support for dynamic network provisioning services and must be engineered to support rapid movement of large scientific data sets. “- pg. 6, National Science Foundation Advisory Committee for Cyberinfrastructure Task Force on Campus Bridging, Final Report, March 2011


CC* DNI Synopsis

- CC* DNI integrates campus-level data & networking infrastructure for higher levels of performance, reliability & predictability for science applications & distributed research, with an explicit element supporting models for potential future national scale network-aware data-focused cyberinfrastructure attributes, approaches & capabilities.

- CC* DNI combines CC* IIE and DIBBS (Data Infrastructure Building Blocks) for 2015
Campus Cyberinfrastructure – Data, Networking, and Innovation (CC*DNI) Program

- FY15 new solicitation, NSF 15-534
- 7 categories of proposals, 2 of them are New
- Data Infrastructure Building Blocks (DIBBs) - Multi-Campus/Multi-Institution Model Implementations
  - Models for potential future national scale network-aware data-focused cyberinfrastructure attributes, approaches, and capabilities
    - sharing data beyond a single institution
- Network-centric categories (from CC*IIE)
  - Data Driven Networking Infrastructure for the Campus and Researcher
  - Network Design and Implementation for Small Institutions awards
  - Network Integration and Applied Innovation
  - Campus CI Engineer
  - Regional Coordination and Partnership in Advanced Networking
  - Instrument Networking
2015 CC* DNI Program Areas

- Data Infrastructure Building Blocks (DIBBs) - Multi-Campus/Multi-Institution Model Implementations
  - Up to $5,000,000 for up to 5 years

- Data Driven Networking Infrastructure for the Campus and Researcher
  - Up to $500,000 for up to 2 years

- Network Design and Implementation for Small Institutions
  - Up to $350,000 for up to 2 years

- Network Integration and Applied Innovation
  - Up to $1,000,000 for up to 2 years

- Campus CI Engineer
  - Up to $400,000 for up to 2 years

- Regional Coordination and Partnership in Advanced Networking
  - Up to $150,000 for up to 2 years

- Instrument Networking
  - Up to $400,000 for up to 2 years

*please refer to the solicitation for complete detail*
CC*DNI Program-wide Criteria

- Science Drivers
- Partnerships between campus CI experts and scientists
- Campus Cyberinfrastructure plan
  - plan within which the proposed network infrastructure improvements are conceived, designed, and implemented in the context of a coherent campus-wide strategy and approach to CI
  - Maximum 5-pg supplementary document addressing:
    - Sustainability of proposed work in terms of ongoing operational and engineering costs
    - Refer to solicitation for guidance on technical areas to include such as IPv6, InCommon federation, and IP spoofing
    - See example CI plans from existing awardees at http://fasterdata.es.net/campusCIplanning/
This category invests in multi-campus and/or multi-institutional regional cyberinfrastructure, to leverage high performance network paths among campuses to enable integration of new data-focused services, capabilities, and resources to advance scientific discoveries, collaborations and innovations.

Awards will serve as models for potential future national scale network-aware data-focused cyberinfrastructure attributes, approaches, and capabilities.
Network infrastructure improvements at the campus level

Network improvements include:

- Network upgrades within a campus network to support a wide range of science data flows
- Re-architecting a campus network to support large science data flows, for example by designing and building a "science DMZ" (see [http://fasterdata.es.net/science-dmz/](http://fasterdata.es.net/science-dmz/) for more information on the "science DMZ" approach)
- Network connection upgrade for the campus connection to a regional optical exchange or point-of-presence that connects to Internet2

Note - a new requirement in this category - proposals must include a summary table of the science drivers and their network requirements
A simple Science DMZ has several essential components. These include dedicated access to high-performance wide area networks and advanced services infrastructures, high-performance network equipment, and dedicated science resources such as Data Transfer Nodes. A notional diagram of a simple Science DMZ showing these components, along with data paths, is shown below:

The essential components and a simple architecture for a Science DMZ are shown in the figure above. The Data Transfer Node (DTN) is connected directly to a high-performance Science DMZ switch or router, which is connected directly to the border router. The DTN’s job is to efficiently and effectively move science data to and from remote sites and facilities, and everything in the Science DMZ is aimed at this goal. The security policy enforcement for the DTN is done using access control lists on the Science DMZ switch or router, not on a separate firewall.
CC*DNI Area#3 – Network Design and Implementation for Small Institutions

- Applicable to smaller institutions with fundamental challenges to address in networking infrastructure and resources
- Guidance is identical to Area#2 (including the importance of science use cases) with these differences:
  - Network design proposed may defer complete technical solutions and propose to develop solution in Year1 with implementation in Year2
  - Partnering in the proposal is required
  - Planning grants and requests for professional network staff support are also allowed in this area
Additional Info for Small Institutions

- Please remember – compelling science drivers are essential!
  - Note the requirement to include a table
  - Does your campus understand the sizes and types of scientific data flows from/to your campus today? Can you quantify them?
- Consider the value of partnering with a leadership institution
- Crafting a quality campus-wide Cl plan can present a challenge
CC*DNI Area#4 – Network Integration and Applied Innovation

- End-to-end network CI through integration of existing and new technologies and applied innovation
- Applying network research results, prototypes, and emerging innovations to enable (identified) research and education
- May leverage new and existing investments in network infrastructure, services, and tools by combining or extending capabilities to work as part of the CI environment used by scientific applications and users
Area#4 Examples of Relevant Activities

- Integration of networking protocols/technologies with application layer
- Transitioning successful research prototypes in SDN, and activities supported by GENI and FIA programs, to distributed scientific environments and campus infrastructure
- Innovative network solutions to problems driven by distributed computing and storage systems including cloud services.
- Federation-based security solutions for dynamic network services extending end-to-end

See solicitation text for others
CC*DNI Area#5 – Campus CI Engineer

- Support for up to one campus cyberinfrastructure engineer for up to 2 years
- Proposals should describe institutional need and planned engagement on multiple science projects
- Preference to campus network engineering and high performance networking
- Proposals should address campus commitment long term and include a sustainability plan
- NSF sees potential to establish over time a national community of campus level CI engineering and participants will be expected to participate in community engagement and building events
CC*DNI Area#6 – Regional Coordination and Partnership in Advanced Networking

- This program area seeks to build regional centers for community building, coordination and partnership through leadership activities at institutions whose expertise and resources in advanced network engineering can be leveraged and applied to partnering with other local and regional institutions.

- Proposals in this area should describe:
  - Their approach to providing a focused set of resources for regional support of advanced r&e networking;
  - Their institutional capacity and expertise in campus networking; their planned outreach and engagement activities in their jurisdiction or region—especially to smaller colleges and universities,
  - and interactions with other regions and national entities such as Internet2 and other institutional partners. These partners may, for example, be current and future proposers at smaller institutions and EPSCoR jurisdictions.

- Proposed activities may include
  - Workshops;
  - Direct and ongoing engagement at the network engineering level for coordination and support on network design and implementation
  - Network performance measurement and analysis.

- Planned activities should consider the dissemination of advanced networking techniques, building bridges to distributed science communities, and potential tailoring of advanced networking solutions to problems faced by science projects and communities.

Proposals should address deliverables and define their measures of success.
CC*DNI Area#7 – Instrument Networking

- Recognizing scientific instruments as a first-class element in research infrastructure requiring high performance reliable networking connectivity and integration.
- Proposals in this area should describe the pivotal role of the scientific instrument or instruments in need of improved network connectivity and integration. Each instrument description should include a quantitative profile of data requirements driving the networking improvements.
- Proposals may request funds for new and upgraded network connectivity, or the development of tools, techniques, and frameworks for network integration of instruments based on one or more specific examples.
- Proposals describing new approaches to network integration of instruments are challenged to describe how those approaches can be applied to other sets of instruments in the NSF community.
Regional Coordination awards made in 2014 (CC*IIE)

- #1440642 (Meehl, UCAR)/#1440568 (Hauser, Colorado)
  - “Collaborative Research: CC*IIE Region: Rocky Mountain Cyberinfrastructure Mentoring and Outreach Alliance (RMCMOA)”
- #1440774 (Monaco, Kansas St)
  - “CC*IIE Region: Leveraging Partnerships Across the Great Plains to Build Advanced Networking and CI Expertise”
- #1440659 (von Oehsen, Clemson)
  - “CC*IIE Region: Southern Partnership in Advanced Networking (SPAN)”
- #1440450 (Schopis, OSU)
  - “CC*IIE Region: Transforming a Regional Network and the Regional Community to Serve Diverse and Emerging Research Needs”

- [1 more award still pending]
- The Quilt consortium and their meetings may provide an excellent forum to share ideas in this space
Example Accomplishments from ACI Networking Programs

- (CC-NIE) UMD – developing network embedded storage and compute resources via Software Defined Networking (SDN) and exposing services to scientific applications and workflows
- (CC-NIE) U of Washington – campus networking upgrades doubled particle physics data transfers to/from PNNL to 1.4Gbps single flow (Ed Lazowska, PI)
- (IRNC) 4X capacity improvement (80Gbps aggregate) in connecting Astronomy facilities in Hawaii to US mainland
- (IRNC) 4X capacity improvement (40 Gbps aggregate) between US and South America – LSST may require 100Gbps by 2020
Another Example – U of Dayton

- Impact at Dayton – “a high performance connection...driven by our NSF strategy of providing DMZ connections for researchers with a specific need. NSF is truly helping the University of Dayton ‘raise the entire harbor’ for science and engineering work on campus and we have used the prestige of this grant to get the attention of our campus leadership to ensure the continued funding for HPC investments.

- Impact on Dayton Partners - “Our work bringing up the connections at Central State Univ (Historically Black College) has gone well. Part of our funding supports upgrades at their campus. CSU does not have deep-expertise on networking at their campus, so we sent our engineering staff to supervise the work of contractors in upgrading their fiber and connecting the new DMZ infrastructure...the NSF support has truly transformed a chunk of the CSU network into a science-ready environment that has our researchers working collaboratively with their faculty and students. The funding from NSF is making a huge difference for several faculty and students at Central State - They are working on cutting edge projects with Vijay Asari on our campus in the area of "Computer Vision”

Thomas Skill, PI (CIO) University of Dayton
Another Example – Impact on upgrading U Houston and regional capacity to 100Gbps:

- “This expands the affected student base and researchers by multiple orders of magnitude. In fact, Baylor College of Medicine alone sometimes may require sustained ~5 Gbps upload processes that may go on for a few days at this time. Their genome researchers and other biomedical researchers are leaders in the nation. The other institutions include: MD Anderson Cancer Center, Houston Museum of Natural Science, University of Texas – Health Sciences Campus, and so on. The network refresh has revamped the SETG organization to refresh their technical advisory group, decision processes, and future investment perspectives in supporting research in network science and engineering as well as better support of science data flows with more transparency and control.” – Deniz Gurkan, PI, Univ. of Houston
Utah CC-NIE Integration project: *Science Slices* (NSF #ACI-1341034)

**PI:** S. Corbató; co-PIs: A. Bolton, T. Cheatham, R. Ricci, K. Van der Merwe; **SP:** J. Breen, S. Torti

**Premise (Rob Ricci):** What if we flipped the concept and built our Science DMZ on top of SDN infrastructure, rather than just plugging our SDN testbed into the DMZ?

1) Building a dynamic Science DMZ on top of an SDN-based framework (GENI)

2) Extending slices to key campus labs, HPC center, and the Honors residential community

3) Working closely with central IT, campus IT Governance, and Utah Education Network

**Target areas:**
- Molecular dynamics
- Astrophysics data
- Genomics
- Network/systems research
- Honors students

**Leverages new infrastructure:**
- Downtown Data Center
- Utah Optical Network (BONFIRE)
- NSF MRI for novel cluster (Apt)
- Campus Net Upgrade
CC*IIE award #1340999 - Supporting Climate Applications over NDN (PI: Papadopoulos, CSU)

- **Need**: climate and other big data applications have overwhelmed existing networking and data management solutions
  - Data size and diversity
  - Naming, discovery, retrieval, sharing, etc.

- **Approach**: migrate workflows to NDN
  - Name based rather than host based paradigm
  - Easy migration: automatically translate existing ad-hoc names to structured NDN names
  - Evaluate over state-of-the-art NDN testbed deployed in partnership with ESnet

- **Benefit**: vastly simplified application and networking environment
  - Robustness and speed: in-network caching, efficient content distribution, automatic failover, security, etc.
  - Simplified management: highly structured, standardized naming across application domains
  - Trivial publishing, grouping and discovery
CC*IIE numbers for 2014

- 131 proposals received ($51M requested)
- 50 awards made
- 134 awards, 128 projects total in the program 2012-2014
  - All but 4 states participating
  - 120+ institutions
- $21M in award funding 2014
Wrap up

- CC* DNI changes each year to adapt to NSF science-driven community needs and opportunities, but the thematic remains constant – CISE/ACI recognizes the need to address CI challenges at the campus level.
- Along those lines, CC* DNI has expanded this year to encompass more than just networking infrastructure and innovation.
- With program investments spread across 120+ campuses, the NSF community has many opportunities to share experiences, coordinate CI activities across campuses, and generally work together to CI-enable advances in science.
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