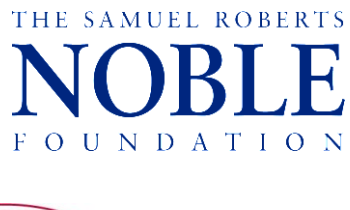
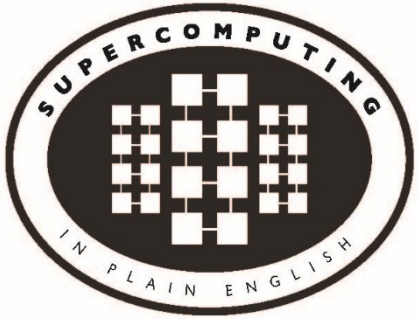
The OneOklahoma Cyberinfrastructure Initiative: A Case Study for Intrastate CI Collaboration

Henry Neeman, University of Oklahoma

University of Missouri Columbia Cyberinfrastructure Day 2016

Wednesday April 13 2016





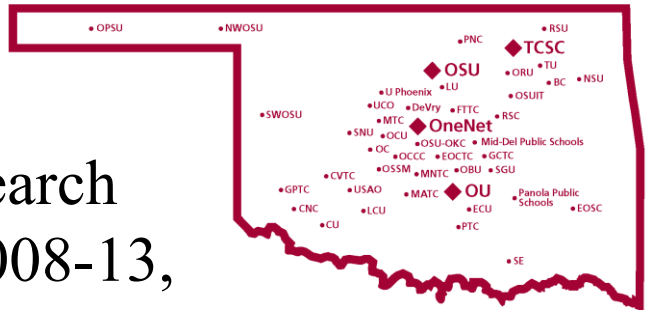
Outline

- What is OneOCII?
- OneOCII Institutions
- OneOCII Outcomes
- OneOklahoma Friction Free Network

What is OneOCII?

OneOK Cyberinfrastructure Initiative

- All academic institutions in Oklahoma are eligible to sign up for free use of OU's and OSU's centrally-owned Cyberinfrastructure resources.
- Other kinds of institutions (government, non-governmental) are eligible to use, though not necessarily for free.
- Everyone can participate in our CI education initiative.
- The Oklahoma Supercomputing Symposium, our annual conference, continues to be offered to all.
- Triggered by OK's NSF EPSCoR Research Infrastructure Improvement Track-1 2008-13, then expanded under OK's RII Track-1 2013-18.



OCII vs OneOCII

- OCII: Oklahoma Cyberinfrastructure Initiative
  - Established under Oklahoma's 2008-13 NSF EPSCoR Research Infrastructure Improvement (RII) Track-1 grant.
- OneOCII: OneOklahoma Cyberinfrastructure Initiative
  - Became OneOCII under Oklahoma's 2013-18 RII Track-1.
    - State Science & Technology plan, a required proposal component for RII Track-1, was the OneOklahoma Science & Technology Plan.

OCII/OneOCII Goals

- **Reach** institutions outside the mainstream of advanced computing.
- **Serve** every higher education institution in Oklahoma that has relevant curricula.
- **Educate** Oklahomans about advanced computing.
- **Attract** underrepresented populations and institution types into advanced computing.

OneOCII Service Methodologies Part 1

- **Access**: to supercomputers and related technologies (20 OK academic institutions to date).
- **Dissemination**: Oklahoma Supercomputing Symposium – annual advanced computing conference has reached 112 academic institutions, 143 commercial, 36 government, 20 nongovernmental (25 OK academic institutions to date).
- **Education**: "Supercomputing in Plain English" (SiPE) workshop series: 11 talks about advanced computing, taught with stories, analogies and play rather than deep technical jargon. Have reached 362 institutions (academic, government, industry, nonprofit) in 51 US states and territories and 17 other countries (16 OK academic institutions to date).

OneOCII Service Methodologies Part 2

- **Faculty/Staff Development**: Workshops held at OU and OSU on advanced computing and computational science topics, sponsored by the National Computational Science Institute, the SC supercomputing conference series, the Linux Clusters Institute, the Virtual School for Computational Science & Engineering. Oklahoma is the only state to have hosted multiple events sponsored by each of these (18 OK academic to date).
- **Informatics**: research facilitators embedded in specific research projects (and largely funded by them)
- **Outreach**: "Supercomputing in Plain English" (SiPE) overview talk (25 OK academic to date).

OneOCII Service Methodologies Part 3

- **Proposal Support**: Letters of commitment for access to OneOCII resources; collaborations with OneOCII lead institutions (4 OK academic, 1 nongovernmental).
- **Stewardship**: Research data stewardship initiative, led by Libraries.
- **Technology**: Got or helped get technology (e.g., network upgrade, mini-supercomputer, hi def video camera for telepresence) for that institution (14 OK academic to date).

OneOCII Service Methodologies Part 4

- **Workforce Development** – (39 OK academic)
  - Oklahoma Information Technology Mentorship Program (OITMP)
  - "A Day in the Life of an IT Professional" presentations to courses across the full spectrum of higher education.
  - Job shadowing opportunities and direct mentoring of individual students.
  - Institution Types: high schools, career techs, community colleges, regional universities, PhD-granting universities.
- Special effort to reach underrepresented populations: underrepresented minorities, non-PhD-granting, rural

OneOCII Institutions

OneOCII Institution Profile

To date, OneOCII has served 103 Oklahoma institutions, agencies and organizations:

- 55 OK academic
- 48 OK non-academic

OneOCII Institution Profile

To date, OneOCII has served 103 Oklahoma institutions, agencies and organizations:

- 55 OK academic
  - Universities & Colleges
    - 3 comprehensive PhD-granting
    - 20 regional non-PhD-granting
  - Community Colleges: 10
  - Career techs: 14
  - Secondary schools: 4
  - Public school systems: 4
- 48 OK non-academic

OneOCII Institution Profile

So far, OneOCII has served:

- 55 OK academic
  - 10 Minority Serving Institutions
  - 16 other institutions with above state average and national average for one or more underrepresented minorities
- 48 OK non-academic

Minority Serving Institutions

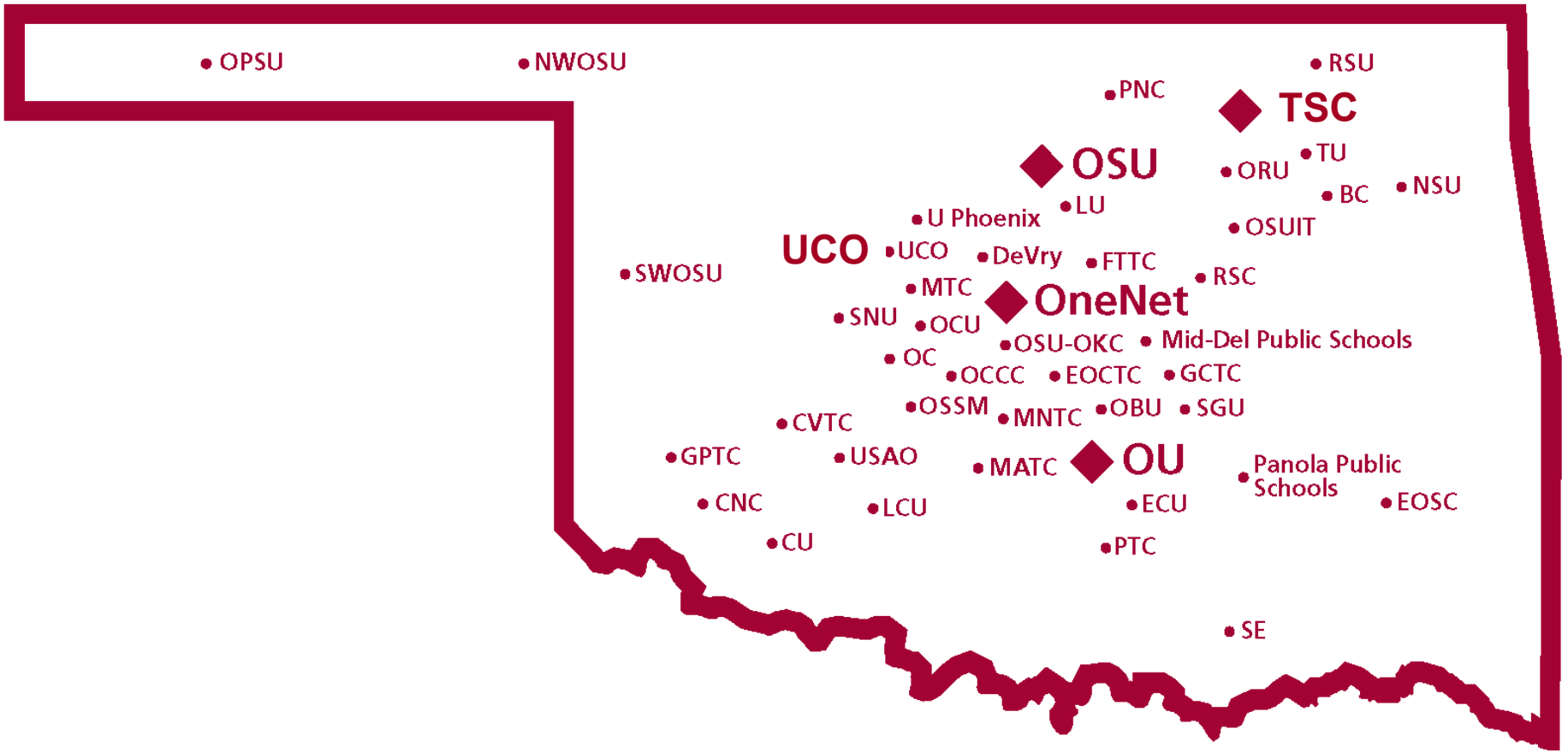
- Oklahoma's only Historically Black College or University
  - Langston U (Langston)
- Native American Serving Non-tribal Institutions
  - East Central U (Ada)
  - Northeastern Oklahoma A&M College (Miami)
  - Northeastern State U (Tahlequah)
  - Southeastern Oklahoma State U (Durant)
- Tribal Institutions
  - College of the Muscogee Nation (Okmulgee)
  - Comanche Nation College (Lawton)
  - Pawnee Nation College (Pawnee)
  - Sequoyah High School
- Other Minority Serving Insitution
  - Bacone College (Muskogee)

OneOCII Institution Profile

To date, OneOCII has served 103 Oklahoma institutions, agencies and organizations:

- 55 OK academic institutions
- 48 OK non-academic organizations
  - 16 commercial
  - 19 government
  - 2 military
  - 11 non-governmental

OneOklahoma Cyberinfrastructure Initiative



OneOCII Outcomes

OneOCII Outcomes: Research

- External research funding to OK institutions facilitated by OneOCII lead institutions (Fall 2001- Summer 2013): **$200M+**
- Funded projects facilitated: **300+**
- OK faculty and staff: **200+** in **20+** academic disciplines
- Specifically needed OneOCII just to be funded: **~$44M** (necessary but far from sufficient)
  - NSF EPSCoR RII Track-1 (2008-13, OU+OSU): $15M
  - NSF EPSCoR RII Track-1 (2013-18, OU+OSU+Noble)): $20M
  - NSF EPSCoR RII Track-2 (OU+OSU+KU+KSU): $6M ($3M to OU+OSU)
  - NSF EPSCoR RII C2 (OU+OSU+TU+LU+Noble+OneNet): $1.17M
  - NSF CC-NIE (OU+OSU+LU+OII+UCO+OneNet): $500K
  - NSF CC*IIE (OU): $400K
  - NSF CC*IIE (OneNet+GPN): $350K
  - NSF MRI (OU): $793K
  - NSF MRI (OSU): $908K
  - NSF MRI (OSU): $950K
  - NSF MRI (Langston U): $250K
  - NSF MRI (UCO): $304K
  - NSF MRI (TU): $180K
  - DOD DURIP (TU): $200K
- Publications facilitated: **over 1500**

OneOCII Outcomes: Education

Teaching: 9 institutions including 3 MSIs

- Taught parallel computing using OneOCII resources:
  - Cameron U – multiple times
  - East Central U (NASNI)
  - Oklahoma City U – multiple times
- Taught parallel computing via LittleFe baby supercomputer and OneOCII resources:
  - Southeastern Oklahoma State U (NASNI) – 3 semester sequence, multiple times
- Taught computational chemistry using OneOCII resources:
  - Northeastern State U (NASNI) – multiple times
  - Southern Nazarene U
  - Rogers State U – multiple times
- Taught Bioinformatics using OneOCII resources:
  - U Tulsa – 2 semester sequence

OneOCII Outcomes: Resources

7 institutions including 2 MSIs, plus C2 institutions

- NSF Major Research Instrumentation grants: $2.9M
  - OU: Oklahoma PetaStore, $793K (in production)
  - Oklahoma State U: Cowboy cluster, $909K (in production),
    Pistol Pete cluster, $950K (new award)
  - Langston U: cluster, $250K (in production)
  - U Central Oklahoma: cluster, $304K (in production)
  - U Tulsa: cluster, $180K
- Defense University Research Instrumentation Program
  - U Tulsa: cluster, $200K
- LittleFe baby supercomputer grants ($2520 each)
  - OU: Ron Barnes
  - Oklahoma City U: Larry Sells & John Goulden
  - Southeastern Oklahoma State U: Mike Morris & Karl Frinkle
- Networking
  - NSF EPSCoR RII C2 grant: $1.17M
  - NSF CC-NIE grant: $500K
  - NSF CC*IIE grant: $400K

OCII/OneOCII CI Grants

COMPLETED

1. Grant No. EPS-0919466, "A cyberCommons for Ecological Forecasting," OU+OSU+KU+KSU, $6M, **COMPLETED**
2. Grant No. EPS-1006919, "Oklahoma Optical Initiative," OU+OSU+Noble+TU+LU+OneNet, $1.17M, **COMPLETED**
3. Grant No. OCI-10310029, "MRI: Acquisition of Extensible Petascale Storage for Data Intensive Research," OU, $793K
4. Grant No. OCI-1126330, "Acquisition of a High Performance Compute Cluster for Multidisciplinary Research," OSU, $908K
5. Grant No. ACI- 1229107, "Acquisition of a High Performance Computing Cluster for Research and Education," LU, $250

ONGOING

1. Grant No. ACI-1341028, "OneOklahoma Friction Free Network," OU+OSU+LU+OII+UCO+OneNet, $500K
2. Grant No. ACI-1440783, "A Model for Advanced Cyberinfrastructure Research and Education Facilitators," OU, $400K
3. Grant No. ACI-1440774, "ENCITE: ENabling CyberInfrastructure via Training and Engagement," OneNet+GPN, $130K
4. Grant No. ACI-1429702, "MRI: Acquisition of a High Performance Computing Cluster for Research at a Predominantly Undergraduate Institution," UCO, $304K -- **RECENT RIBBON CUTTING**
5. Grant No. ACI-1531128, "MRI: Acquisition of Shared High Performance Compute Cluster for Multidisciplinary Computational and Data-Intensive Research," OSU, $950K
6. Grant No. ?, "DURIP-ARO: Heterogeneous Cluster for Cyber-Physical System Security Analytics," TU, $200K
7. Grant No. CNS-1531270, "MRI: Development of Heterogeneous Cluster for Cyber-Physical System Hybrid Analytics," TU, $180K

<u>TOTAL to OK under OCII/OneOCII</u>: Sep 2008-Apr 2016:

$8.8M in 12 CI grants to 8 OK institutions (OU, OSU, TU, LU, UCO, OII, Noble, OneNet)

(average of $1.25M per year in new CI grants to OK institutions)

Comparison: 2001-2008: $722K (3 grants) TOTAL (1/12 as much)

Grants That Needed OCII/OneOCII

COMPLETED

- Grant No. EPS-0814361, “"Building Oklahoma's Leadership Role in Cellulosic Bioenergy,” OU+OSU, $15M

ONGOING

- Grant No. EPS-1301789, “Adapting Socio-ecological Systems to Increased Climate Variability,” OU+OSU+TU+Noble, $20M

<u>TOTAL under OCII/OneOCII</u>: $35M in 2 grants that needed OCII/OneOCII to be fundable, to 4 OK institutions since Sep 2008

Papers About Pieces of OneOCII

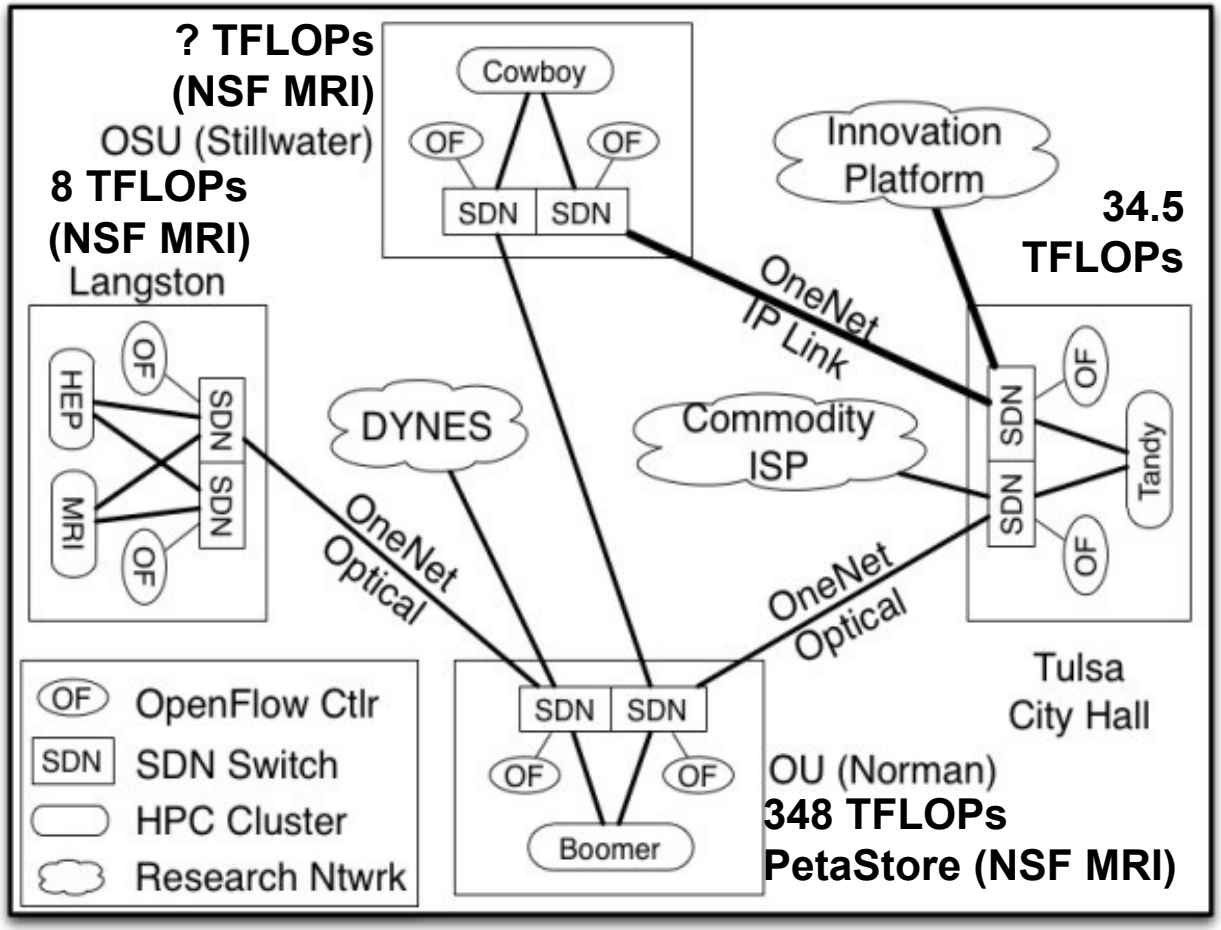
- H. Neeman, K. Adams, J. Alexander, D. Brunson, S. P. Calhoun, J. Deaton, F. Fondjo Fotou, K. Frinkle, Z. Gray, E. Lemley, G. Louthan, G. Monaco, M. Morris, J. Snow and B. Zimmerman, 2015: "On Fostering a Culture of Research Cyberinfrastructure Grant Proposals within a Community of Service Providers in an EPSCoR State." *Proc. XSEDE'15*, article 19. DOI: 10.1145/2792745.2792764.
- H. Neeman, D. Akin, J. Alexander, D. Brunson, S. P. Calhoun, J. Deaton, F. Fondjo Fotou, B. George, D. Gentis, Z. Gray, E. Huebsch, G. Louthan, M. Runion, J. Snow and B. Zimmerman, 2014: "The OneOklahoma Friction Free Network: Towards a Multi-Institutional Science DMZ in an EPSCoR State." *Proc. XSEDE'14*, article 49. DOI: 10.1145/2616498.2616542.
- S. P. Calhoun, D. Akin, J. Alexander, B. Zimmerman, F. Keller, B. George and H. Neeman, 2014: "The Oklahoma PetaStore: A Business Model for Big Data on a Small Budget." *Proc. XSEDE'14*, article 48. DOI: 10.1145/2616498.2616548.
- C. Carley, B. McKinney, L. Sells, C. Zhao and H. Neeman, 2013: "Using a Shared, Remote Cluster for Teaching HPC." *Proc. IEEE CLUSTER 2013*. DOI: 10.1109/CLUSTER.2013.6702630.
- H. Neeman, D. Brunson, J. Deaton, Z. Gray, E. Huebsch, D. Gentis and D. Horton, 2013: "The Oklahoma Cyberinfrastructure Initiative." *Proc. XSEDE'13*, article 70. DOI: 10.1145/2484762.2484793.

CI Capacity

- 2002: 1.2 TFLOPs statewide, 1 Service Provider
- 2005: 6.5 TFLOPs statewide, 1 Service Provider
- 2008: 40 TFLOPs statewide, 2 Service Providers
- 2012: 200+ TFLOPs statewide, 4 Service Providers
- 2015: 400+ TFLOPs statewide, 5 Service Providers
- 2016: 500+ TFLOPs statewide, 6 Service Providers

OneOklahoma Friction Free Network

OneOklahoma Friction Free Network



OneOklahoma Friction Free Network (OFFN)

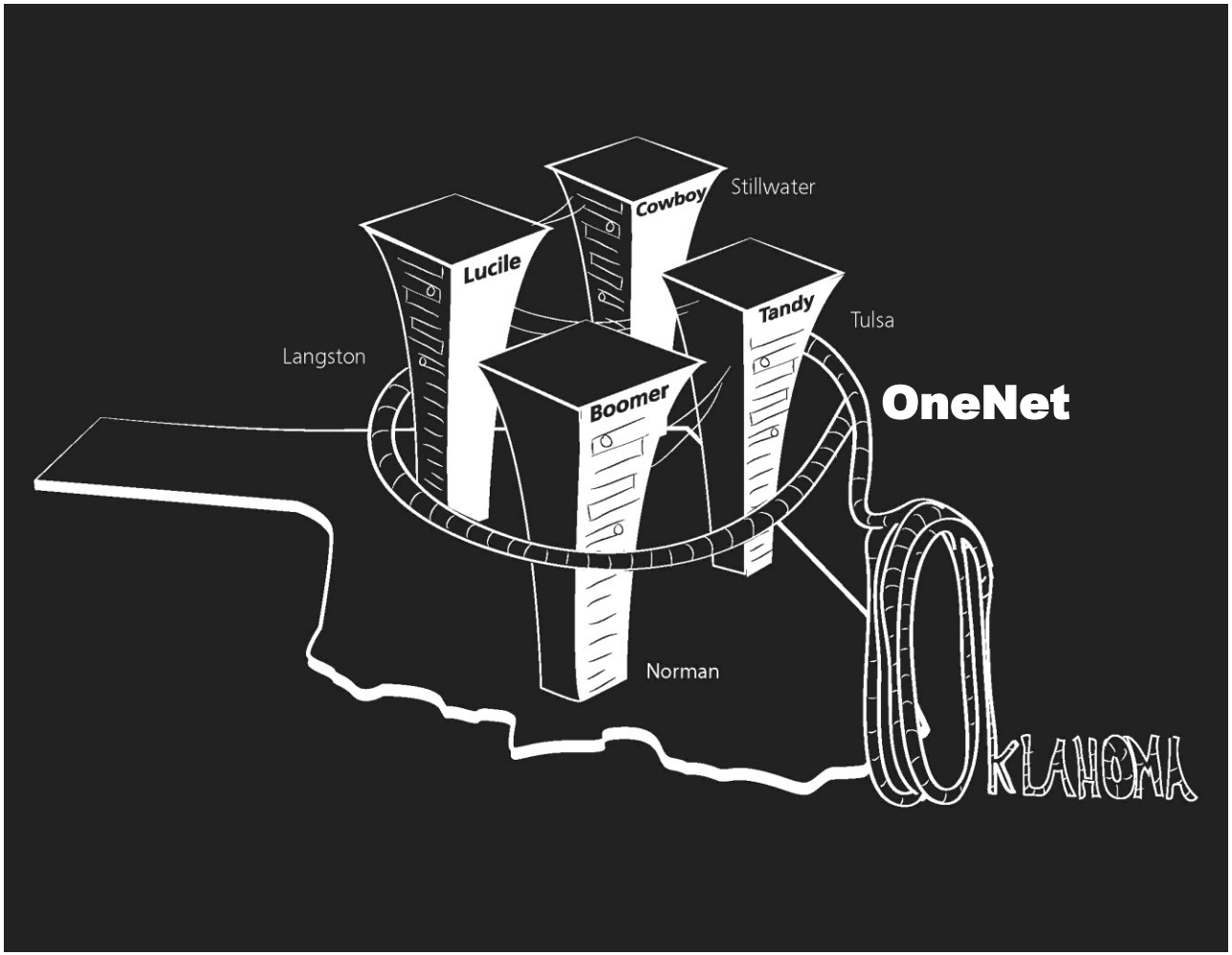
- Multi-institutional Science DMZ
- Software Defined Networking
- Dedicated 10G among the participating sites
- Aggregate compute: just over 200 TFLOPs (peak)

NSF Campus Cyberinfrastructure grant: OU, OSU, Langston U, Oklahoma Innovation Inst, U Central Oklahoma, **OneNet**

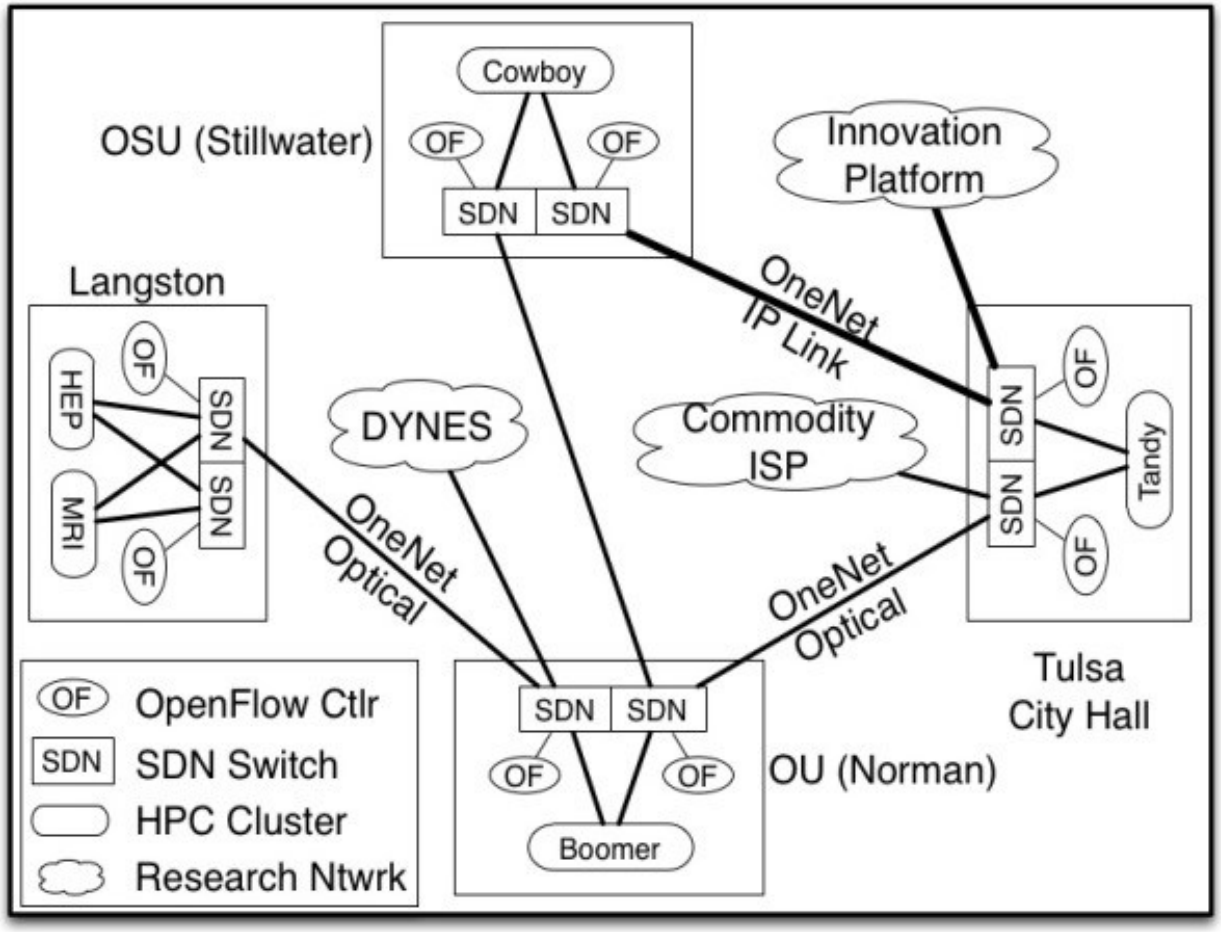
Objectives

1. Deploy and maintain, at the four institutions, a **research-only network** consisting of institutional last mile components that are independent of enterprise networks, with its internal hub collocated with OneNet.
2. Apply **Software Defined Networking** (SDN) across OFFN, facilitating end-to-end management, by researchers, of high bandwidth/high performance data flows through a distributed hierarchy of open standards tools, giving researchers a new layer of transparency into network transport.
3. Provide these capabilities – OFFN's in particular and OneOCII's in general – to all relevant researchers and educators **statewide**, and facilitate their use by fostering collaboration between research teams and institutional central IT organizations.

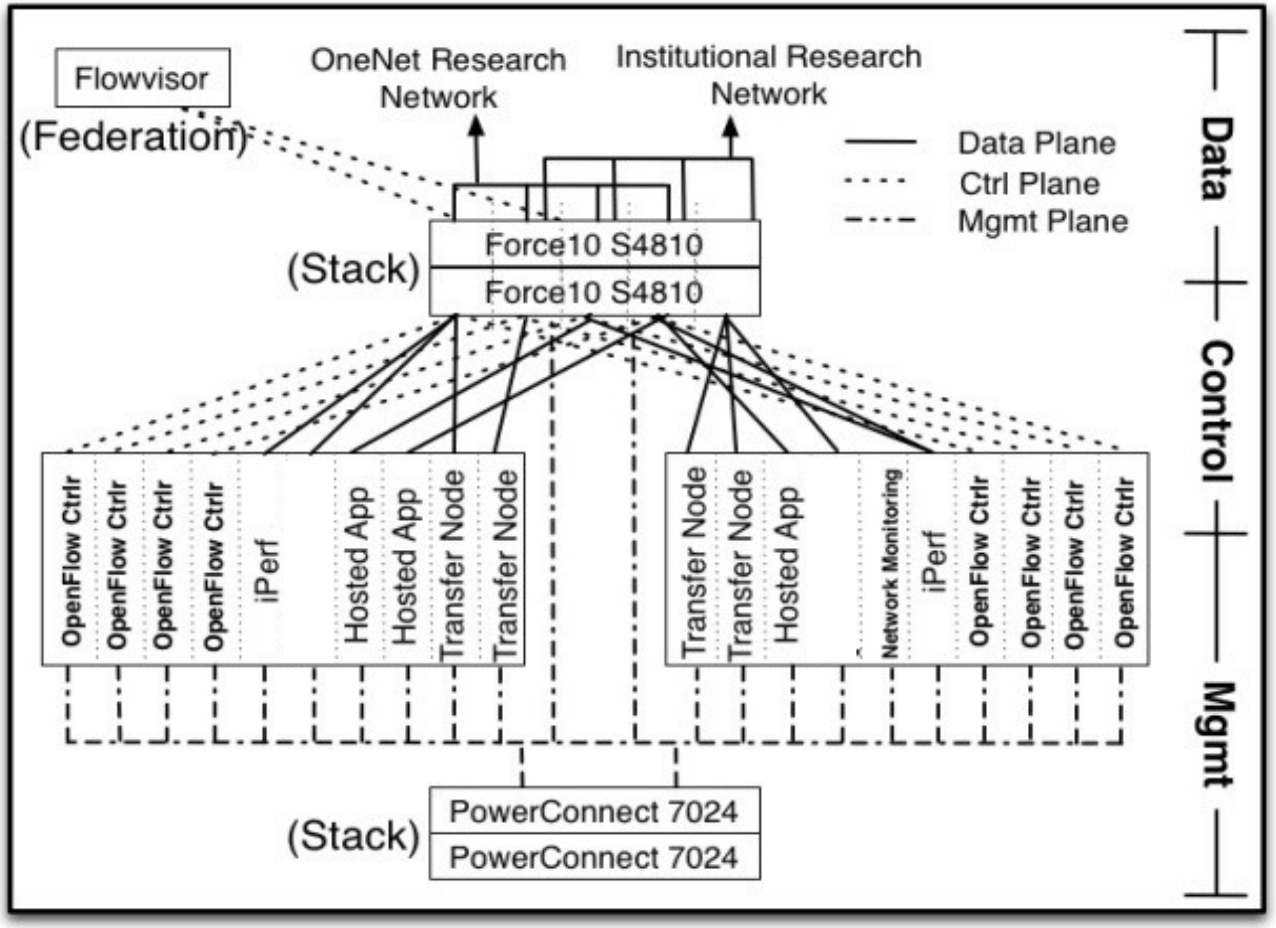
State Diagram (Conceptual)



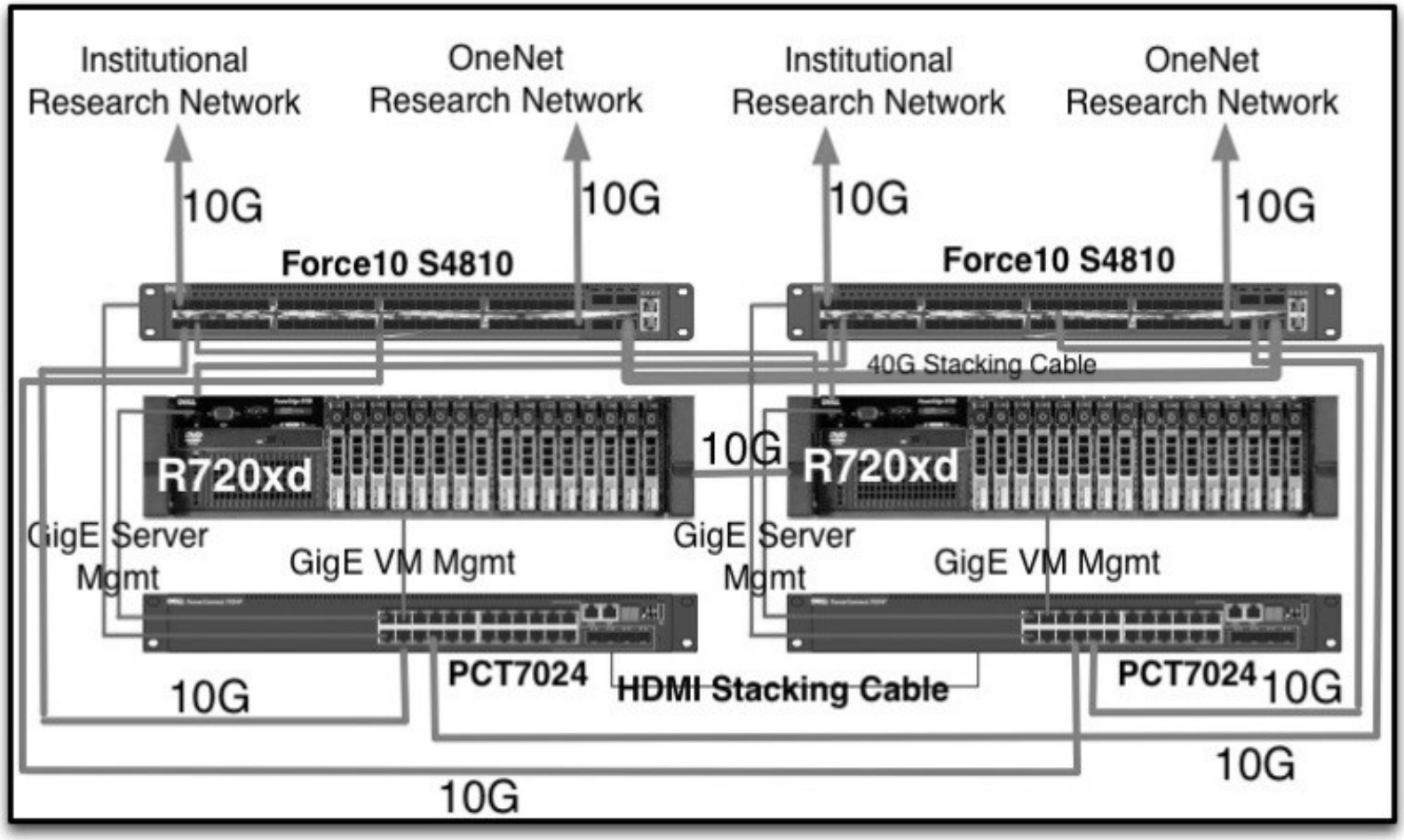
State Diagram (Logical)



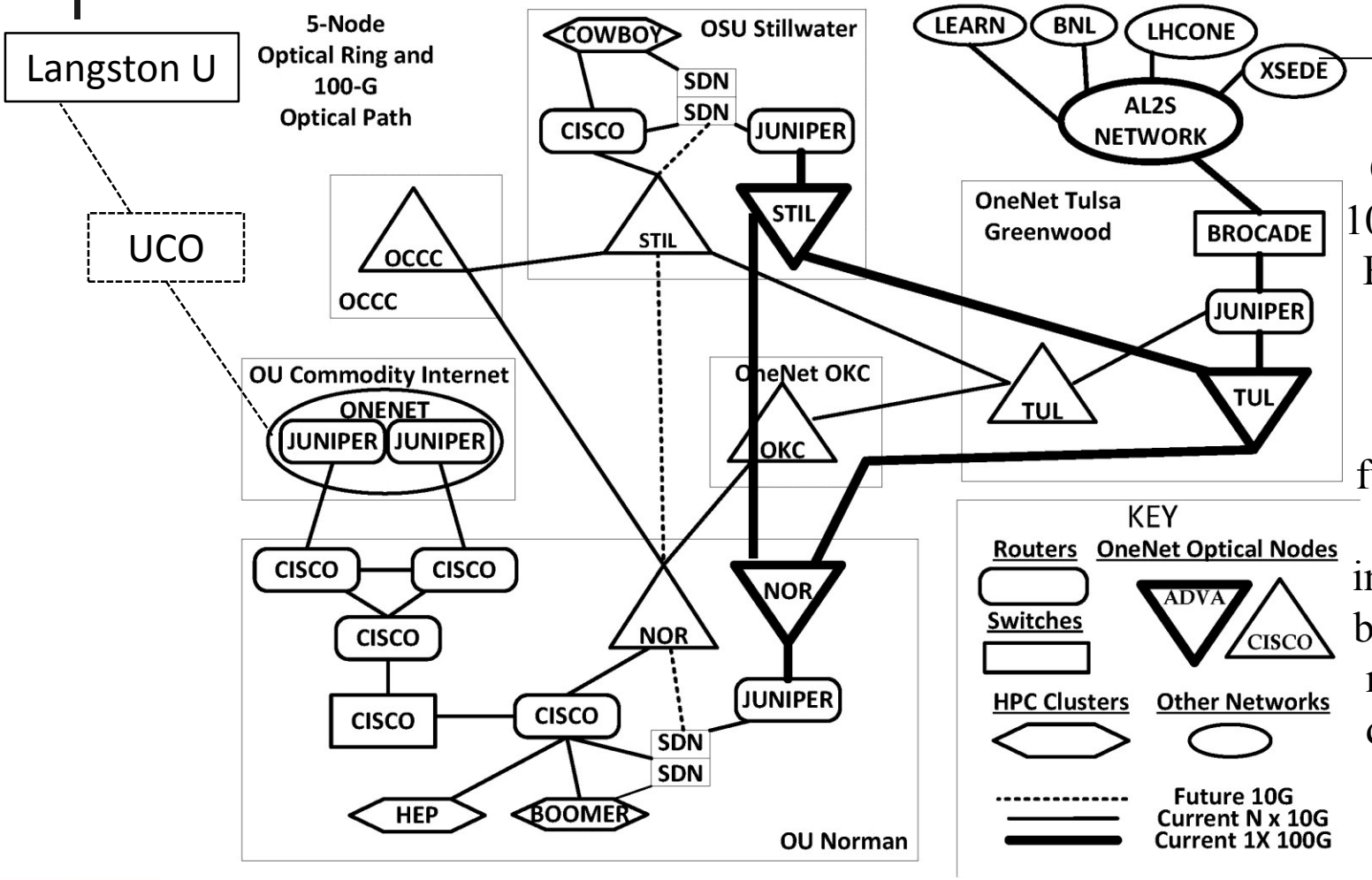
Institutional Diagram (Logical)



Institutional Diagram (Physical)



100G (OneNet)



OU Norman 100G went live Fri March 21 2014.

This was funded purely by OneNet internal funds, because of the relationships developed in OneOCII.

ACI-REF

What is an ACI-REF?

- Advanced Cyberinfrastructure - Research & Education Facilitator
- Expertise in CI and Computational & Data-enabled Science & Engineering (CDS&E)
- Work with research teams to get them productive and move forward the computational aspects of their research.

Clemson-Led ACI-REF Project

- Original Proposal
  - "The Condo of Condos"
  - 13 institutions, 4 years, $35.7M
  - Included both people (ACI-REFs) and hardware (100G)
- Funded Grant
  - "Advanced Cyberinfrastructure - Research & Education Facilitators"
  - 6 institutions, 2 years, $5.3M
  - No hardware

Phase 1: Clemson-led ACI-REF

- Phase 1 institutions
  - Clemson U (SC)
  - Harvard U (MA)
  - U Hawaii
  - U Southern California
  - U Utah
  - U Wisconsin Madison
    - All except Harvard are 2012-13 CC-NIE awardees.
    - Only Clemson U and U Hawaii are EPSCoR.
- Of 2012-13 CC-NIE awards:
  - 23% went to institutions in EPSCoR jurisdictions;
  - 46% of EPSCoR jurisdictions got an award (including OK). (Not counting TN and UT, which have graduated EPSCoR.)

Phase 2: Find Other Funding

- Phase 2 institutions
  - Arizona State U
  - Emory U (GA)
  - Ohio Supercomputer Center
  - Stanford U (CA)
  - SSERCA (FL)
  - U Oklahoma
  - U Washington
- OU is the only institution that is all of:
  - EPSCoR
  - 2012-13 CC-NIE awardee
  - ACI-REF Phase 2

OU's ACI-REF Project

OU's NSF CC*IIE Grant

- "A Model for Advanced Cyberinfrastructure Research and Education Facilitators"
- Grant no. ACI-1440783
- NSF CC*IIE program
- 9/15/2014 - 9/14/2016
- $400K
- Totally separate from the Clemson-led ACI-REF grant

OU's ACI-REF Objectives

- Data-Intensive Research Facilitation: Via Software Defined Networking (SDN) across OFFN, facilitate end-to-end management, by researchers, of high bandwidth/high performance data flows through a distributed hierarchy of open standards tools, providing researchers with a new layer of transparency into network transport at OU, among OneOCII institutions, and with ACI-REF members.
- Oklahoma ACI-REF project: Lead and facilitate adoption of the ACI-REF approach across Oklahoma, leveraging extant and emerging capabilities within OneOCII.

OU's ACI-REF Objectives

- National training regime: Provide a "virtual residency" program for Campus CI Engineers and other ACI-REFs, open to not only CC*IIE awardees and ACI-REF members but any institution that needs.
- Research Experiences for Undergraduates (REU) Sites/Supplements: Foster undergraduate research at OU via a culture of integrating REU sites and supplements into Science, Technology, Engineering & Mathematics (STEM) research, including by all research themes on this proposed CC*IIE project.

ACI-REF Role

- Research facilitation: especially in the context of SDN
- Researcher training
- Science DMZ administration
- Statewide participation: facilitating research across OneOCII
- OSCER operations

ACI-REF
Virtual Residency

ACI-REF Virtual Residency: Why?

- ACI-REFs have strong experience within their discipline (often non-CS).
- Haven't been faculty.
- Sometimes little or no research experience (especially for SDN-focused ACI-REFs).
- Even if strong research background, little or no experience with research outside their own discipline.
- No local, regional or national programs to teach people how to be an ACI-REF.

National Level of Interest

- **Proposal**
  - Polled CC-NIE awardees, MRI CI awardees, Minority Serving Institutions.
  - Interest expressed from 33 institutions in 23 states & territories expressed interest, including 3 MSIs and 19 institutions in 13 EPSCoR jurisdictions, and 7 non-PhD-granting institutions.
- **Applications**: over 60 from 49 institutions in over 30 states and territories.
- **Participants**: 50 total from 38 institutions in 26 states and territories (28 onsite and 22 offsite via videoconferencing), including 20 institutions in 12 EPSCoR jurisdictions, 5 Minority Serving Institutions, and 5 non-PhD-granting institutions.

ACI-REF Workshop Agenda 2015

- SUNDAY (evening pizza party)
  - Welcome and virtual residency overview
  - Introduction to Research Cyberinfrastructure consulting
  - How to Give a CI Tour
- MONDAY
  - Early AM: Effective Communication: How to Talk to Researchers about Their Research
  - Computational and Data-enabled Science & Engineering (CDS&E) Track
    - Mid AM: Deploying Community Codes
    - Early PM: Real user presents their CDS&E research
  - SCIENCE DMZ Track
    - Mid AM: OpenFlow - Lecture
    - Early PM: OpenFlow - Lab
  - Mid PM: CI User Support
- TUESDAY
  - Very Early AM: Project Guidelines
  - Early AM: Faculty: Tenure, Promotion, Reward System
  - CDS&E Track
    - Mid AM: Benchmarking & Tuning
    - Early PM: Real users present CDS&E research
    - Mid PM: Real users: CI consulting practicum ("speed dating")
  - SCIENCE DMZ Track
    - Mid AM: Exploring Open Daylight - Lecture
    - Early PM: Exploring Open Daylight - Lab
    - Mid PM: Real users' high bandwidth research
- WEDNESDAY
  - Early AM: Using Videoconferencing and Collaboration Technologies for Consulting
  - Mid AM: Writing Grant Proposals
  - PM: BREAK (free time)

ACI-REF Workshop Agenda 2015

- THURSDAY
  - Early AM: The Shifting Landscape of CI Funding Opportunities
  - CDS&E Track
    - Mid AM: Finding and Provisioning Remote Resources (XSEDE, OSG)
    - Early PM: Real users present CDS&E research (“speed dating”)
    - Mid PM: Catch-up on unfinished talks
  - SCIENCE DMZ Track
    - Mid AM: The Software in SDN - Lecture
    - Early PM: The Software in SDN - Lab
    - Mid PM: Real users' high bandwidth research
- FRIDAY
  - Early AM: So You Want to Write a CI Proposal
  - Mid AM: Panel: Stories from the Trenches
  - Early PM: Project work time
  - Mid PM: Project work time
  - Late PM: Project presentations from early departers
- SATURDAY
  - AM: Project presentations

2016 Workshop

- The 2016 workshop will be Aug 7-13.
- We'll have some of the original cohort #1 from 2015, plus a new cohort #2.
- Cohort #1 is currently developing the curriculum, both for themselves and for cohort #2.
- We'll be able to support some or all participants partially or fully, depending on need.
- Want to come? E-mail me and ask to be added to my HPC announcements mailing list. We'll send out info soon.

hneeman@ou.edu

National Leadership

National Leadership Part 1

- Workforce Development
  - OU CI lead Henry Neeman's NSF CC*IIE Campus CI Engineer grant is doing a "Virtual Residency" to teach people how to help researchers use advanced computing in their research.
    - Summer 2015 workshop: 50 participants from 39 institutions in 26 states and territories (28 onsite and 22 offsite via videoconferencing)
- NSF MRI grants
  - OSU CI lead Dana Brunson's most recent MRI has been plugged at multiple national meetings by the Division Director of the NSF Advanced Cyberinfrastructure division as exactly what the NSF wants to see from MRIs for CI.

National Leadership Part 2

- XSEDE (NSF-funded national supercomputing center program)
  - Campus Engagement: OU CI lead Henry Neeman and OSU CI lead Dana Brunson have been appointed XSEDE Campus Engagement Co-managers starting July 1 2016.
    - Campus Champions
    - Intra-state collaboration (next slide)
  - XSEDE Level 3 Service Providers: OSU CI lead Brunson is chair.

More States Should Do This

- More states should do intra-state collaboration for Cyberinfrastructure.
- Some states already do similar things, for example:
  - Sunshine State Educational &Research Computing Alliance (Florida)*
  - Louisiana Optical Networking Initiative*
  - Massachusetts Green HPC Center*
  - New York State HPC Consortium*
  - Ohio Supercomputer Center

  * Limited subset of research-intensive institutions
- We want institutions with CI to share with others in their states.
- We want to help other states develop their own approaches.
  - We're scheduled to work on this with 4 states in the coming 6 months.
- Ultimately, this should be normal, and expected.
- Coming soon: Regional collaboration.

Acknowledgements

- Portions of this material are based upon work supported by the National Science Foundation and the Department of Defense under the following grants:
  - Grant No. EPS-0814361, “Building Oklahoma's Leadership Role in Cellulosic Bioenergy”
  - Grant No. EPS-0919466, “A cyberCommons for Ecological Forecasting”
  - Grant No. EPS-1006919, “Oklahoma Optical Initiative”
  - Grant No. OCI-10310029, “MRI: Acquisition of Extensible Petascale Storage for Data Intensive Research”
  - Grant No. OCI-1126330, “Acquisition of a High Performance Compute Cluster for Multidisciplinary Research”
  - Grant No. ACI- 1229107, “Acquisition of a High Performance Computing Cluster for Research and Education”
  - Grant No. EPS-1301789, “Adapting Socio-ecological Systems to Increased Climate Variability”
  - Grant No. ACI-1341028, “OneOklahoma Friction Free Network”
  - Grant No. ACI-1440783, “A Model for Advanced Cyberinfrastructure Research and Education Facilitators”
  - Grant No. ACI-1440774, “ENabling CyberInfrastructure via Training and Engagement”
  - Grant No. ACI-1531128, “MRI: Acquisition of Shared High Performance Compute Cluster for Multidisciplinary Computational and Data-Intensive Research,” OSU, $950K
  - Grant No. ?, “DURIP-ARO: Heterogeneous Cluster for Cyber-Physical System Security Analytics,” TU, $200K
  - Grant No. CNS-1531270, “MRI: Development of Heterogeneous Cluster for Cyber-Physical System Hybrid Analytics,” TU, $180K
- Dell provided seed systems for the OU Research Cloud (“OURcloud”) and the OU Science DMZ.

Acknowledgements

- Portions of this material are based upon work supported by the National Science Foundation and the Department of Defense under the following grants:
  - Grant No. EPS-0814361, "Building Oklahoma's Leadership Role in Cellulosic Bioenergy"
  - Grant No. EPS-0919466, "A cyberCommons for Ecological Forecasting"
  - Grant No. EPS-1006919, "Oklahoma Optical Initiative"
  - Grant No. OCI-10310029, "MRI: Acquisition of Extensible Petascale Storage for Data Intensive Research"
  - Grant No. OCI-1126330, "Acquisition of a High Performance Compute Cluster for Multidisciplinary Research"
  - Grant No. ACI- 1229107, "Acquisition of a High Performance Computing Cluster for Research and Education"
  - Grant No. EPS-1301789, "Adapting Socio-ecological Systems to Increased Climate Variability"
  - Grant No. ACI-1341028, "OneOklahoma Friction Free Network"
  - Grant No. ACI-1440783, "A Model for Advanced Cyberinfrastructure Research and Education Facilitators"
  - Grant No. ACI-1440774, "ENabling CyberInfrastructure via Training and Engagement"
  - Grant No. ACI-1531128, "MRI: Acquisition of Shared High Performance Compute Cluster for Multidisciplinary Computational and Data-Intensive Research," OSU, $950K
  - Grant No. ?, "DURIP-ARO: Heterogeneous Cluster for Cyber-Physical System Security Analytics," TU, $200K
  - Grant No. CNS-1531270, "MRI: Development of Heterogeneous Cluster for Cyber-Physical System Hybrid Analytics," TU, $180K
- Dell provided seed systems for the OU Research Cloud ("OURcloud") and the OU Science DMZ.

Thanks for your attention!

QUESTIONS?