Organizing and the Cyberinfrastructure Workforce

Nicholas Berente
University of Notre Dame
nberente@nd.edu

James Howison
University of Texas at Austin
jhowison@ischool.utexas.edu

John Leslie King
University of Michigan
jlking@umich.edu

Stan Ahalt
RENCI / University of North Carolina at Chapel Hill
ahalt@renci.org

Susan Winter
University of Maryland
sjwinter@umd.edu

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Workshop Participants: Suzie Allard (Tennessee); Amy Apon (Clemson); Beth Bechky (NYU); Matt Bietz (UC Irvine); Aleksandr Blekh (GA Tech); Jim Bottum (Clemson); Dana Brunson (OSU); Brian Butler (Maryland); Cathryn Carson (UC Berkeley); Dorothy Carter (UGA); Hannah Cohoon (UT Austin); Noshir Contractor (Northwestern); Dan Cornfield (Vanderbilt); Steve Cox (RENCI); Peter Darch (UIUC); Matt Germonprez (Nebraska-Omaha); Sharon Geva (Michigan); Robert Haines (Manchester); Kaye Husbands-Fealing (GA Tech); Gwen Jacobs (Hawaii); Dan Lapine (NCSA); Jong Lee (NCSA); Henry Neeman (OU); Alexander Nolte (CMU); Michael Norman (UCSD); Alex Oettl (GA Tech); Susannah Paletz (Maryland); Rob Pennington (NeIC); Greg Peterson (NICS); Dan Reed (Iowa); Ralph Roskies (PSC); Carolina Salge (UGA); Steve Sawyer (Syracuse); Aaron Schecter (UGA); Dick Shaw (STSI); Andy Sherman (Yale); Steve Slota (UW); Mike Smorul (SESYNC); David Swanson (Nebraska-Lincoln); John Towns (NCSA); Anne Washington (George Mason); Kathleen Weathers (GLEON); Nic Weber (Washington); Karen Wetzel (Educause); Nancy Wilkins-Diehr (SDSC); Scott Yockel (Harvard); Youngjin Yoo (Case Western); Michael Zentner (HUBzero)

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Introduction

Science is changing dramatically in the digital age. By leveraging innovations in computing technology and associated software applications and data sets, scientific research is becoming more distributed, collaborative, and expanding in scope. Enabling this is the "cyberinfrastructure" of science. Cyberinfrastructure broadly refers to the stack of network, computing, software, data, and workforce that support science and engineering research and scholarship.

All aspects of cyberinfrastructure are dynamic, innovative, and rife with challenges. However, the workforce of cyberinfrastructure poses a particular set of challenges associated with identifying, preparing, and retaining the specialized human resources required to enable cyberinfrastructure. The skills that are scarce, yet in great demand in academia and industry, and there is no specialized training curriculum for this workforce.

This report summarizes the discussion around the cyberinfrastructure workforce in a "Research Coordination Network" (RCN) workshop held in Alexandria, Virginia, in August 2017. The workshop brought together cyberinfrastructure leaders with organization scientists to discuss potential collaborations in the domain of the cyberinfrastructure workforce. The workshop was the final in a series of seven workshops that brought together cyberinfrastructure leaders with organization scientists over the course of six years. This report will encapsulate the 2017 discussion and also link to the resources from invited speakers and reports from previous workshops.

The report is organized as follows. First, we will recap some of the issues with the cyberinfrastructure workforce and point to resources from previous workshops. Then we shift to the management of the cyberinfrastructure workforce - a persistent theme in the RCN - followed by some discussion of collaborations going forward. We conclude with a reflection on the changing nature of science and directions for the RCN participants.

Cyberinfrastructure Workforce

The cyberinfrastructure workforce ("CI workforce") is increasingly important to science, and this RCN brought those interested in the CI workforce together with organization scientists who study relevant technical work. This was the second of two workshops in 2017 on the CI workforce.[1]

[1] The earlier 2017 workshop, "Professionalization in Cyberinfrastructure," was held at the University of California Santa Barbara. Report link: https://dx.doi.org/10.2139/ssrn.3138592

In his introductory comments, John Towns (University of Illinois/XSEDE) recapped many of the issues raised in the earlier workshop.[2] In particular, he pointed out how the particular combination and variety of skills that are required for effective CI personnel are difficult to come by. He illustrated this with and example from the University of Illinois - virtually every CI job opening needed to be extended because they could not find qualified personnel (see Figure 1).

Figure 1: University of Illinois Open Cyberinfrastructure Positions (source: John Towns)

The bottom line is that CI personnel are scarce and difficult to retain. There is a shortage of skilled talent and this is both a supply and a demand problem. It is a supply problem because there are very few training and certification programs. CI personnel tend to serendipitously arrive in their roles because there is no specific major in this sort of work. Further, it is a demand problem, because these folks are in demand in industry, where they are paid significantly more than in university settings. Further, as academic demands grow, CI personnel who remain in academia have more options. As was highlighted in the earlier workshop, many participants indicated that the CI community needs to better organize itself around the production and retention of skilled talent. A starting point would be understanding the jobs and the career paths of CI personnel.

[2] Towns, J. presentation titled: "Cyberinfrastructure Workforce: or… Why Are We in Arlington Anyway?" Link: http://managingcenters.net/wp-content/uploads/2018/05/Towns-CI_Workforce_RCN-Aug-2017.pdf

During this earlier workshop, participants identified four general types of cyberinfrastructure personnel: systems facing (those that worked with computing and associated technology specialists); software facing (those that specialize in scientific software); researcher facing (facilitators and disciplinary application experts); and application facing (disciplinary community builders and coordinators). These categories were different than with those specified by NSF's Sushil Prasad in his talk on cyberinfrastructure workforce opportunities (see Figure 1).[3]

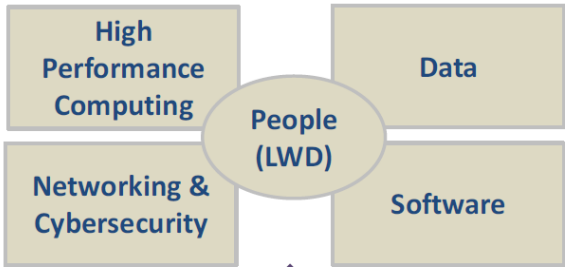

Figure 2: NSF's Cyberinfrastructure Workforce Categories (Source: Sushil Prasad)

Although there is certainly an overlap in the way the CI community thinks of the roles, the NSF view is technology-focused. In the NSF view, there was no explicit mention of researcher and community facing roles. Perhaps these were implied, but this is a marked departure from the way the CI leaders think of their roles. The CI community thinks of itself increasingly in terms of enabling science and is researcher and community facing. Technical knowledge is indeed a part of this, but not necessarily the defining part.

Towns emphasized how the CI workforce is outstripping a technological focus and involves an occupational category beyond the information technology (IT) profession. Certainly many CI personnel do identify with various IT professions, particularly around high-performance computing, but Towns indicated a number of efforts that go beyond this focus, including:

- CaRC / ACI-REF - a multi-university effort to develop cyberinfrastructure facilitators and to share knowledge across those universities
- PEARC - international conference targeted specifically at the academic research computing field, broadly defined
- XSEDE Campus Champions - XSEDE's effort to nurture cyberinfrastructure capabilities at a campus level and to facilitate research that leverages cyberinfrastructure services

[3] Sushil Prasad's presentation titled: "Innovations in Cyberinfrastructure Learning and Workforce Development"Link:http://managingcenters.net/wp-content/uploads/2018/05/Prasad-OAC-LWD-Programs-CI-RCN-Workshop-Aug2017-1.pdf

- HPC2 - A multi-university effort to coordinate and develop resources around academic research computing.
- CADRE, RMACC, GPN - Regional organizations bringing together academic scientific computing specialists from universities and industry

These additional emphases make it important to differentiate CI professionals from Enterprise IT, a theme that was echoed in the discussion sessions. Towns framed this as seeking a productive tension, suggesting that explaining the differences can be fundamental to building a stronger professional identity for CI professionals.

In particular, Towns emphasized how PEARC is a major effort that can help to strengthen CI occupations.[4] PEARC's mission involves "providing a forum owned by the community to foster exchanges around the 'state of the practice' in advanced research computing - discussing challenges, opportunities, and solutions." This is one major step in providing the keys that Towns sees for strengthening the CI workforce, which include (1) education and training opportunities (degrees and certifications, professional development); (2) advocacy for emerging profession (perception of second class status in academia); and (3) definition of the profession and associated occupational categories (titles and career paths).

Managing CI Enterprises

A theme that flowed from the origination of the RCN involved how CI leaders might draw from organization science to better manage their organizations. This is consistent with a variety of RCN-related efforts over the years, including the workshop in Michigan in 2013.[5] Strong management practices enable CI enterprises to best leverage and improve the workforce that is already in place. Further, specific management practices, such as those associated with measuring impact, can help to justify additional resources and also identify areas where leaders need to focus.

In the keynote talk for the workshop Dan Reed (University of Iowa) emphasized how science is changing and how we cannot predict how it will change, thus we do not know our specific role in this change.[6] Therefore, he suggested an iterative, six-step approach for building and extending CI enterprises:

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[4] https://www.pearc.org/

[5] The 2013 workshop was held at the University of Michigan. Report link: http://ssrn.com/abstract=2416247

[6] Dan Reed's presentation entitled: "Crossing the Intellectual Desert: Building and Sustaining Multidisciplinary Teams" Link:http://managingcenters.net/wp-content/uploads/2018/05/Reed-CI-Workforce.pdf

1. Identify and engage potential stakeholders
2. Create a vision statement/manifesto
3. Build an R&D and engagement roadmap
4. Define/launch self-funded demonstration projects
5. Demonstrate prototype outcomes
6. Refine manifesto and revise roadmap
7. Target resource opportunities

In his talk, Stan Ahalt (University of North Caroina / RENCI) underscored the key points of this approach to managing CI organizations as well.[7] He emphasized strategy setting that focuses on the unique CI workforce. The strategy process should consider "the kind of people we are." Whom he describes as: "a group of people who believe we are always right, we don't always know how to get along with others very well, and we pride ourselves on not knowing or believing that the rules apply to us." He highlighted the individuality and nonconformity of CI personnel, and at the same time the tumultuous and complex environment in which they operate. Waves of technological innovation and institutional change mark the contemporary science enterprise.

Ahalt suggests a flatter, networked organizational form with "distributed leadership" and the associated distributed accountability. Traditional hierarchical organizational forms are optimized for operational efficiency, which is not the only thing that matters in an innovative context like cyberinfrastructure. Ahalt describes an iterative strategy formation process of "searching, doing, learning, and modifying" consistent with current thinking in innovation management. According to Ahalt:

> *"Strategy should be viewed as a dynamic force that constantly seeks opportunities, identifies initiatives that will capitalize on them and completes those initiatives swiftly and efficiently… The more an organization exercises its strategy skills, the more adept it becomes at dealing with a hypercompetitive environment"*

Ahalt is RENCI's director and he shared the RENCI strategic planning process with workshop participants (see Figure 3).[8] The process involves classic strategic management practices beginning with defining vision, mission, and strategic goals for the enterprise, then mapping all activities and tasks of the organization with these goals and the specific actions of the workforce.

[7] Stan Ahalt's presentation entitled: "Empowering the CI Workforce," Link:http://managingcenters.net/wp-content/uploads/2018/05/Ahalt-EmpoweringCIWorforceAhalt180814-1.pdf

[8] Process is detailed in RENCI's strategic plan "Democratized Data Driving Discovery."
Link: http://renci.org/wp-content/uploads/2008/09/RENCI_Strategic_Plan_2017.pdf

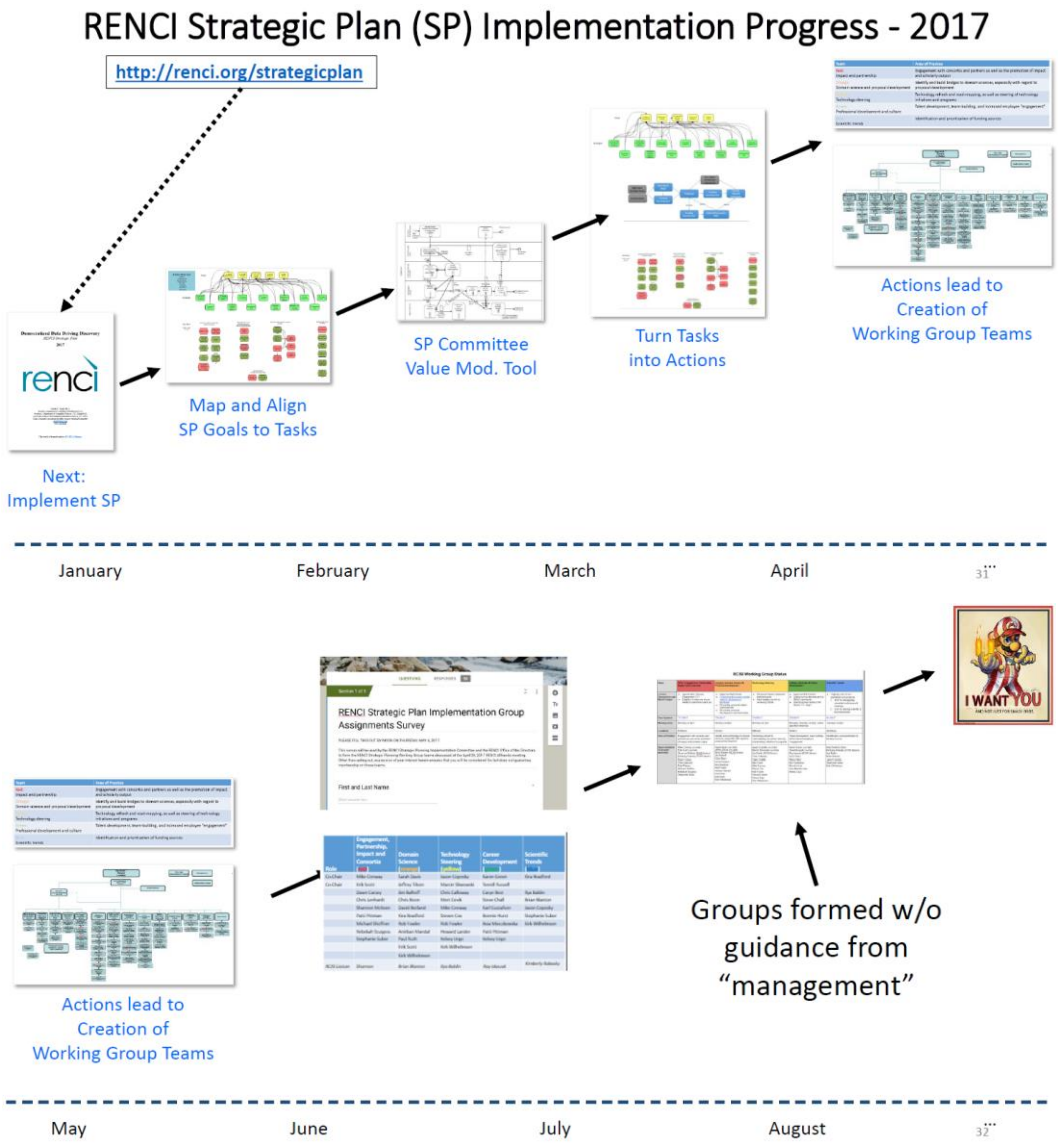

Figure 3: RENCI's Strategic Planning Process
(Source: Stan Ahalt)

Of course, strategic planning is critical to organizational management, but it is not enough by itself. Metrics and key performance indicators should be associated with activities and goals in order to demonstrate the value of science enterprises and also to evaluate performance with respect to those goals. These practices were detailed in a previous RCN-related workshop,[9] and have been leveraged at other CI enterprises to varying degrees. The exemplar in this space is the XSEDE project, a virtual CI enterprise that manages quite extensively using metrics and key

[9] See, for example, the CI management curriculum for more information: "Thinking Like a Science Executive: A Workshop Curriculum for Cyberinfrastructure Leaders." Link: https://ssrn.com/abstract=2881752

performance indicators (KPIs). Figure 4 illustrates a portion of XSEDE's work breakdown structure, where each element of the enterprise's work breakdown structure links with KPIs to evaluate, manage, and communicate the value of XSEDE.[10]

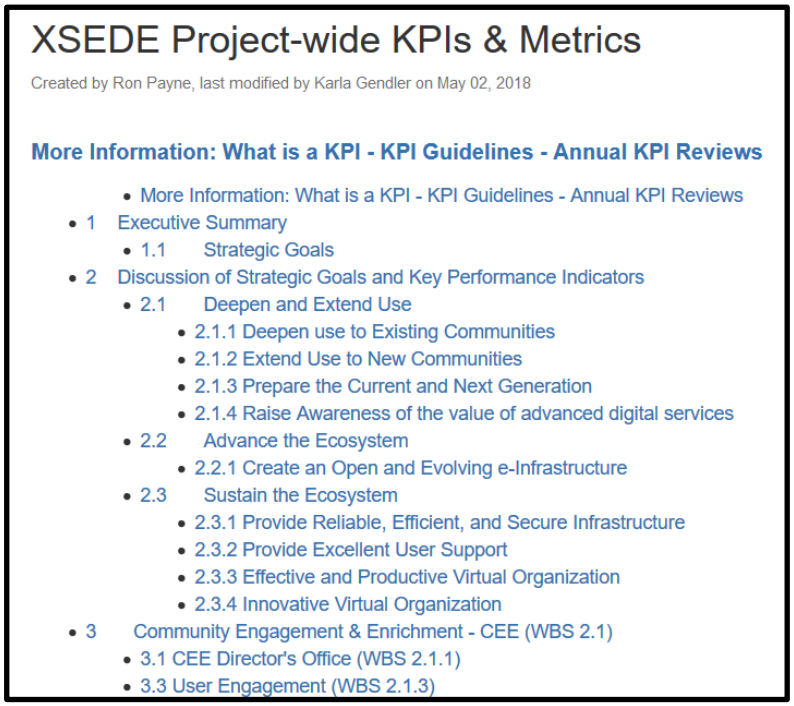

Figure 4: XSEDE's KPI-based Management
(Source: XSEDE)

A key way that CI leaders viewed organization scientists is in a consulting-type arrangement, where the organization scientists help them to run their enterprises better. Certainly some of the organization scientists are willing and able to do this, but a pure consulting-oriented relationship is rarely the ideal situation for organization scientists who are typically motivated to move their own research forward. A key goal of the workshop was to identify synergistic opportunities for collaboration between the two groups (i.e. CI leaders and organization scientists).

Collaboration between CI Leaders and Organization Scientists

This RCN was funded by the "Virtual Organizations as Sociotechnical Systems" (VOSS) Program at NSF - originally part of the Office of Cyberinfrastructure (OCI). Susan Winter (University of Maryland), the former director of the VOSS program described its original goals.[11] VOSS program ran from 2008-2014 with a budget of around $6M per year. The VOSS Program was looking to fund research into remote work, linking people and information, and "virtual organizations" such

[10] Full metrics available: https://confluence.xsede.org/pages/viewpage.action?pageId=1672103
[11] Susan Winter's presentation entitled: "Virtual Organization of Science" Link: http://managingcenters.net/wp-content/uploads/2018/05/Winter-VORCN08142017.pdf

as those enabled by CI enterprises and the CI enterprises themselves. Some of the projects VOSS funded focused on the organization of research and on research productivity and effectiveness; including the impact of organizational structures, policies, practices, and resources. Some of the projects included human resource management and other effective research management approaches, partnership models, and leadership styles, as well as incentives for scientists. Key findings of the program included understanding how scientists collaborate to gain access to resources and capabilities, and how they coordinate to manage diverse resources and solve problems. However, Winter pointed out that much of this research focused on the scientific endeavor itself and there was still very little research on the effective management CI enterprises and associated CI leadership. She indicated that this domain was poorly understood, had few organizational researchers involved, and was in dire need of more work. There simply needs to be more research into the CI space, including systematic reviews, measures, and learning dissemination. Also, according to Winter, CI enterprises need to do a better job with understanding and communicating their impacts - in particular with respect to scientific grand challenges.

Thus a key aspect of the workshop involved finding opportunities for CI leaders to collaborate with organization scientists. However, as a previous RCN workshops noted,[12] there are a number of different ways that the two groups can work together:

1. Engineering relationship - organization scientists provide CI leaders with actionable (cookbook) type answers
2. Research relationship - CI enterprises serve as research sites for organization scientists
3. Educational relationship - Organization scientists teach CI leaders in workshops and classes
4. Consulting relationship - Organization scientists serve as consultants for CI enterprises
5. Research collaboration - CI leaders and organization scientists collaborate on a problem that is mutually interesting

Each of the arrangements have advantages and challenges. The problem with the engineering relationship is that organizational management is messy, and that a cookbook approach does not handle the complexity of these situations. CI leaders looking for specific, easy answers, often find that it is much more complicated and unpredictable than they expected. However, throughout the RCN we have found that some of the simplest, well known lessons from the organizational space

[12] The 2012 RCN workshop held at Case Western Reserve University: http://ssrn.com/abstract=2204092

are well-researched going back decades, and some of that knowledge can be readily disseminated.[13]

Because many organizational issues are indeterminate and full of tensions and tradeoffs, they do not lend themselves to simplistic answers. A better alternative to teach management practice is in a classroom setting, where students can interact and discuss frameworks. This can be based on the executive education model in business schools - and one such pilot project influenced both the RENCI and XSEDE approaches.[14] Discussions also highlighted the usefulness and accessibility of teaching cases, such as the well-known *Harvard Business Review* style cases, and a desire for readable narrative descriptions of "new organizational forms." However, this approach is expensive and requires extensive preparation and funding to implement effectively. Similarly, consulting relationships can be effective, but require the appropriate organizational scientist who understands the specific challenges of CI enterprises, and also requires extensive funding.

Finally, there are the research relationships. Ideally research would benefit both the researcher and the CI organization, but this is difficult. Often research focuses very narrowly on extending well-established traditions in incremental ways. Also, much of the organization science is descriptive or explanatory - offering theories for why things are how they are - and not necessarily prescriptive studies. Nevertheless, organization scientists and CI leaders have round ways to collaborate.

During workshop there were three rounds of discussions, which clarified the issues faced, shared experiences, and lead to conceptualization of potential collaborations, including:

- A collaboration between CI leaders and organization scientists to facilitate workshops and to create standards. A follow-on workshop has already been held to develop job standards rooted in the four categories developed in the first 2017 RCN workshop.[15]
- Collaborations to understand the impact of CI enterprises on the workforce more broadly - on a state and national level. These would be rooted in a similar methodology used to describe NCSA's "diaspora" in a pilot project.[16]

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[13] For example, see prototype site: http://distributedscience.ischool.utexas.edu/

[14] CI Executive session held in Atlanta: "Thinking Like a Science Executive: A Workshop Curriculum for Cyberinfrastructure Leaders," link: https://ssrn.com/abstract=2881752

[15] This resulted in a March 2018 workshop, Link:https://carcc.org/wp-content/uploads/2018/05/CI-Professionalization-Job-Families-Career-Guide.pdf

[16] Diaspora pilot project report entitled "Impact of Cyberinfrastructure Enterprise on the Nation's Workforce: Visualizations of a Decade of NCSA's Diaspora," Link: https://ssrn.com/abstract=3028931

- Discussion of a collaborative project using social science methods to deeply explore the work that CI personnel do on a daily basis, contrasted to Enterprise IT. Could be combined with a study of job advertisements/resumes, used to inductively build a taxonomy of CI personnel jobs, shared across organizations.
- Discussion of a collaborative project of CI through a lens of social movements. How can such movements build coalitions to bring about institutional change?
- Discussion of a PEARC track for workforce issues that would involve organizational scientists.
- Discussion of a project that would include industry participants along with CI leaders and organization scientists in an RCN-type series of workshops.
- Discussion of a project that would list any available datasets (e.g., CASC mailing list archives) that give insight into CI professionals, making it easier for organizational scientists to study.
- Discussion of an RCN-like program to bring CI people and different types of industry partners together.
- Potential collaboration between CI professionals and org scientists around social movement literature, re-evaluating list of challenges for CI and drawing on social movement (rather than managerial) approaches.
- Potential workshop about interdisciplinary science, bringing CI to that, to better know how CI contributes to the functioning of interdisciplinarity.

A variety of other arrangements were discussed throughout the workshop and multiple collaborations have begun as a result of the RCN workshop series.

Conclusion

Alexander Oettl, a Georgia Tech economist delivered one of the keynote talks for the workshop, where he emphasized the "death of distance" in contemporary scientific endeavors.[17] He indicated that the number of authors per paper, non-local collaborations, geographic distance between co-authors, and collaborations across schools are all increasing. This phenomenon is in no small part due to the cyberinfrastructure that undergirds contemporary scientific activity.

In this series of RCN workshops, we brought organization scientists together with CI leaders to explore a variety of issues around the organization of cyberinfrastructure. Many important discussions took place and connections were made. More needs to be done.

[17] Alexander Oettl's presentation entitled: "Collaboration, Stars, and the Changing Organization of Science," Link: http://managingcenters.net/wp-content/uploads/2018/05/Oettl-NSF-CI-RCN.pdf

Many CI leaders agreed that the involvement of organization scientists is valuable and wanted to see more of this going forward. Some CI leaders volunteered to speak with funders about this and to include social scientists in their plans for future projects. Many CI leaders though it was crucial to have organization scientists engaged in demonstrating the value of CI work. As one CI leader said, discussing options for professional identity: “We've been wringing our hands about these things, … but the [organizational researchers] gave us some next steps … that's why these worlds had to collide at some point."

Organization scientists, on the other hand, see CI enterprises as interesting context to study occupational formation, institutional change, and innovation management. CI enterprises can be useful domains for social science experiments, and could also provide new opportunities for funding. One organizational researcher said that he was “very happy to know that people are interested in how this new profession is forming” and that it was exciting to see potential usefulness of the professions literature.

Thus there are a variety of avenues for further exploration. Although the RCN has concluded, this is the beginning of many interesting directions for collaboration.

RCN-Related Reports

Professionalization in Cyberinfrastructure (Berente, N., Howison, J., Cutcher-Gershenfeld, J., King, J.L., Barley, S., Towns, J.) – Report from the RCN Workshop in Santa Barbara, California in 2017.
https://ssrn.com/abstract=3138592

Impact of Cyberinfrastructure Enterprise on the Nation's Workforce: Visualizations of a Decade of NCSA's Diaspora (Howison, J., Berente, N., Cheng, J., Sutton, A., Naquin, H.) – Report from an impact study on the NCSA workforce.
https://ssrn.com/abstract=3028931

Thinking Like a Science Executive: A Workshop Curriculum for Cyberinfrastructure Leaders (Berente, N., King, J.L., Cutcher-Gershenfeld, J., Howison, J., and Winter, S.) – Report from the Science Executive Workshop in Atlanta, Georgia in 2013.
https://ssrn.com/abstract=2881752

Leading Cyberinfrastructure Enterprise: Value Propositions, Stakeholders, and Measurement (Berente, N., Howison, J., King, J.L., Cutcher-Gershenfeld, J., and Pennington, R.) – Report from the second RCN Workshop in Ann Arbor, Michigan in 2013.
https://ssrn.com/abstract=2416247

Virtual Organizations as Sociotechnical Systems: Exploring How Organization Scientists and Virtual Organization Leaders Can Collaborate (Berente, N., Howison, J., King, J.L., Lyytinen, K. and Wilkins-Diehr, N.) – Report from the first RCN Workshop in Cleveland, Ohio in May 2012.
https://ssrn.com/abstract=2204092

Academic Computing Management Benchmarks: Beta Version - A Report on a Pilot Survey of the Coalition for Academic Scientific Computing (CASC) Members (Berente, N. and Rubleske, J.) - Pilot Project Management Metrics for CASC.
https://ssrn.com/abstract=2313089

Managing CI Centers: An Agenda for Organizational Scholarship and Cyberinfrastructural Innovation (Berente, N., Claggett, J., Howison, J., Knobel, C.,

and Rubleske, J.) – Report from the first Managing CI Centers Workshop in Athens, Georgia in October 2011.
https://ssrn.com/abstract=2128872

Full List of RCN Participants across RCN Workshops:

1. Stan Ahalt, RENCI
2. Jay Aikat, RENCI
3. Suzie Allard, DataONE
4. Lee Allison, EarthCube
5. Amy Apon, Clemson
6. Peter Arzberger, PRAGMA
7. Dan Atkins, Michigan
8. Steve Barley, UCSB
9. Will Barley, Illinois
10. Lothar Bauerdick, OSG
11. Beth Bechky, NYU
12. Nick Berente, Notre Dame
13. Mark Berman, GENI
14. Matt Bietz, UC Irvine
15. Pernille Bjorn, Copenhagen
16. Aleks Blekh, GA Tech
17. Jay Boisseau, TACC
18. Richard Boland, Case Western
19. Jim Bottum, Clemson
20. Dana Brunson, OSU
21. Brian Butler, Maryland
22. Andrew Caird, Michigan
23. Bruce Caron, New Media Studio
24. Cathryn Carson, UC Berkeley
25. Dorothy Carter, UGA
26. Jennifer Claggett, UVA
27. Tim Cockerill, TACC
28. Hannah Cohoon, UT Austin
29. Noshir Contractor, Northwestern
30. Daniel Cornfield, Vanderbilt

31. Steve Cox, RENCI
32. Debbie Crawford, Drexel University
33. Patricia Cruse, DataONE
34. James Cuff, Harvard
35. Joanne Culbertson, NSF
36. Jonathon Cummings, Duke
37. Joel Cutcher-Gershenfeld, Brandeis
38. Peter Darch, Illinois
39. Leslie DeChurch, Northwestern
40. Thom Dunning, NCSA
41. Nathan Ensmenger, Indiana
42. Bill Feiereisen, Intel
43. Megan Finn, Washington
44. Peter Fox, RPI
45. Kelly Gaither, TACC
46. Les Gasser, Illinois
47. Matt Germonprez, Nebraska Omaha
48. Sharon Geva, Michigan
49. Sharon Glotzer, Michigan
50. Prasad Gogineni, CRESIS
51. Robert Haines, Manchester
52. Rebecca Hartman-Baker, NERSC
53. Victor Hazelwood, NICS
54. Ola Hanseth, Oslo
55. Pam Hinds, Stanford
56. James Howison, UT Austin
57. Kaye Husbands Fealing, GA Tech
58. Gwen Jacobs, Hawaii
59. Erik Johnston, Arizona State
60. Paul Killey, Michigan
61. Laurie Kirsch, Pittsburgh
62. John Leslie King, Michigan
63. Cory Knobel, UC Irvine
64. Patricia Kovatch, Mt. Sinai
65. Dan Lapine, NCSA
66. Barbara Lawrence, UCLA
67. Katherine Lawrence, Michigan

68. Charlotte Lee, Washington
69. Jong Lee, NCSA
70. Paul Leonardi, UCSB
71. Peter Levin, Intel
72. Natalia Levina, NYU
73. Michael Levine, PSC
74. Miron Livney, OSG
75. Eric Lyons, iPlant
76. Kalle Lyytinen, Case Western
77. Mimi McClure, NSF
78. Nathaniel Mendosa, TACC
79. Paul Messina, ANL
80. Jacqueline Meszaros, NSF
81. Eric Monteiro, Norwegian U of Science and Tech
82. David Moses, PSC
83. Andrew Neang, Washington
84. Henry Neeman, OU
85. Alexander Nolte, CMU
86. Mike Norman, SDSC
87. Nick Nystrom, PSC
88. Alex Oettl, GA Tech
89. Gary Olson, UC Irvine
90. Drew Paine, Washington
91. Margaret Palmer, SESYNC
92. Susannah Paletz, Maryland
93. Elena Parmiggiani, Norwegian U of Science and Tech
94. Rob Pennington, NeIC
95. Laura Patterson, Michigan
96. Greg Peterson, NICS
97. Neil Pollock, Edinburgh
98. Ruth Pordes, OSG
99. Sushil Prasad, NSF
100. Nicole Radziwill, James Mason University
101. Rajiv Ramnath, NSF
102. Dan Reed, Iowa
103. David Ribes, Washington
104. Ralph Roskies, PSC

105. Renee Rottner, UCSB
106. Joseph Rubleske, NKU
107. Carolina Salge, Wake Forest
108. Steve Sawyer, Syracuse
109. Aaron Schecter, UGA
110. Barry Schneider, NSF
111. Sarika Sharma, Syracuse
112. Richard Shaw, Space Telescope Science Institute
113. Andy Sherman, Yale
114. William Shelton, EMSL
115. David Skinner, NERSC
116. Sandra Slaughter, Georgia Tech
117. Steve Slota, Washington
118. Mike Smorul, SESYNC
119. Stephanie Beth Steinhardt, Cornell
120. Susan B. Strasser, NUFO
121. David Swanson, Nebraska Lincoln
122. Vic Thomas,GENI
123. John Towns, Illinois / XSEDE
124. Anne Washington, George Mason
125. Stephen Wasserman, NUFO
126. Kathleen Weathers, Cary Institute
127. Nic Weber, Washington
128. Phil Westmoreland, ICSE
129. Nancy Wilkins-Diehr, SDSC
130. Robin Williams, Edinburgh
131. Valerie Wiegel, Edinburgh
132. Susan Winter, Maryland
133. Scott Yockel, Harvard
134. Youngjin Yoo, Case Western
135. Alyson Young, Maryland Baltimore County
136. Eva Zanzerkia, NSF
137. Michael Zentner, HUBzero

Unconference Discussion Ideas

During the meeting participants put up suggestions for discussions sessions, then “voted with their feet”. The list below is a partial list of discussion suggestions.

- Toward a professional society?
- Toward CI degrees?
- Emerging a taxonomy of job titles/tasks in CI. (Studying job descriptions/titles, comparison to corporate jobs).
- Assessing health of technical communities.
- Assessing impact through Diaspora.
- Setting up mentoring programs.
- Discussing specific grant possibilities
- Teaching grant opportunities. Workforce development grants.
- Assessing impact: Baddier effect of CI impact?
- Outreach to industry - get in front of that?
- An RCN-like program to bring CI people and different types of industry partners together.
- Look at CI belonging through social movements literature
- Career paths: are they possible when living off soft money?
- Mapping the field of CI (Taxonomy of jobs and tasks)
- Encouraging citation of software and infrastructure