Professionalization in Cyberinfrastructure

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Introduction

Scientific research is increasingly dependent on cyberinfrastructure. Cyberinfrastructure broadly refers to the stack of network, computing, software, data, and human resources that support science and engineering research and scholarship. To make these resources available a diversity of new roles are emerging that are vital in enabling next-generation research. The skills associated with these roles are also increasingly important to industry. Examples of these roles include "cyberinfrastructure engineer," "research software engineer," "research technology facilitator," "research applications support," and "data application specialist." Although there is some effort made to professionalize these emerging roles, there are a number of challenges to their progress, including the institutional environment of universities.

By "professionalization" we refer to the process of building a legitimate profession out of a loose or emerging occupational category. Many occupations are highly professionalized (e.g., law, accounting, medicine, etc.) which have their own education tracks and well-established curricula, formal qualifications, membership criteria, and governing bodies. Professions are communities of well-vetted, trusted specialists in their particular domains.

Many believe that to encourage participation in cyberinfrastructure-related occupations, provide a career path, and gain academic legitimacy, the cyberinfrastructure workforce should professionalize. Efforts are already underway to begin exploring how different research computing and data-related cyberinfrastructure occupations can encourage participation and gain legitimacy.

In this report, we address the needs and goals of such efforts, and explore them with organizational scientists who specialize in work and workforce issues, including some who specialize in technical occupations and the professionalization of occupational fields. We brought members of the cyberinfrastructure community (high-performance computing, software, data, and infrastructure) together with organization scientists to discuss the professionalization of, and career paths for, emerging cyberinfrastructure roles. The cyberinfrastructure workforce is increasingly important to science, and this research coordination network (RCN) brings those interested in the cyberinfrastructure workforce together with scholars of technical workers and technical professions together.

The workshop was generally structured in three segments: (1) current situation in cyberinfrastructure; (2) organization science thinking about professions and occupations, and (3) potential collaborations (see detailed agenda and participant list in the appendix). The goal of the workshop was simply to foster new collaborations between cyberinfrastructure leaders and organization scientists. Next we summarize these three segments and conclude with some discussion of directions going forward.

Cyberinfrastructure Personnel: Why Professionalize?

Research is increasingly dependent on advanced computing. Cyberinfrastructure personnel ("CI personnel") select, implement, maintain and support the hardware, software, middleware, data, networking, security, and services associated with research that uses advanced computing. Beyond this, cyberinfrastructure personnel also help with the research – many CI personnel have PhDs and are domain experts in particular disciplinary fields or subfields. They leverage computing to enable science, teach scientists how to apply next generation resources, and often engage in the scientific research and move it forward in collaboration with disciplinary researchers.

Thus, CI personnel are a critical element of next-generation scientific research in a variety of different ways. Although funding agencies and universities increasingly realize this, resources do not grow as fast as the need for them. From the discussion in the workshop, there are two main issues with respect to CI personnel: CI personnel are scarce and cyberinfrastructure is different than traditional information technology ("IT"). A potential answer to these issues is to professionalize the CI field. These issues emerged during the workshop and next we summarize the discussion.

CI Personnel Are Scarce and Difficult to Keep

The funding agencies of science such as NSF have agreed that cyberinfrastructure matters, but the challenge is in staffing that mission. Finding the right people, training them, retaining them, rewarding them, and communicating the appeal and value of the work are all important concerns for the CI enterprise.

Put simply, there is a shortage of skilled CI talent. CI personnel generally require both technical skills and some experience with the research process. But there are limited options for any formal training in this combination. There are technical programs and disciplinary research programs, but none uniquely focused on linking the two in an effort to specifically develop CI personnel. Workshop participants described chronic difficulty in finding qualified applicants for CI job advertisements, laughing in agreement when hearing that almost all searches result in "search extended." CI organizations typically resort to some sort of apprenticeship or combination of formal and informal training. Many CI leaders indicated that they simply look for general characteristics such as flexibility, openness, and aptitude and they will teach other skills on the job.

Further, there is no talent pipeline seeking to join this field. Because the field is not a well-recognized area of endeavor, and there is no formal training program or curriculum, few CI personnel set out to engage in this field. Instead, they usually happen upon this occupation through some idiosyncratic set of events and find a role in the CI enterprise. As it stands, if a student were interested in pursuing a career in cyberinfrastructure, there are limited options for advising someone on the relevant degree programs and a plan for how they might develop this career. Job titles are not recognizable and are inconsistently applied across organizations – and widely there is no uniformity in the match of titles and skills across organizations leading to confusion and ambiguity about what careers look like in cyberinfrastructure.

Once CI personnel invest some time in gaining the combination of technical and research skills, they become valuable more broadly. This combination is difficult to find, and is desirable in a variety of domains – both in the private sector and across academic organizations. Academic organizations are at a disadvantage compared to private sector organizations competing for this talent due to resource and policy constraints. Budgets in universities are limited in what they can allocate for specific types of personnel in academic settings. Universities typically reserve the high salaries that CI personnel earn in the private sector for faculty, administrators, and athletics programs – staff that do not fit into these categories, such as CI personnel, are limited by organizational policy and budgetary constraints. The private sector is not limited in this regard. Talented CI personnel are valuable widely and are often lost to other options. Turnover is a major issue.

Another major issue leading to turnover of CI professionals is the reliance on grant funding, or "soft money." Since researchers often need CI personnel for major projects, they get funding for them those grants, there is uncertainty about the continued funding if the scientist does not get follow-on grants or their funding is cut. This uncertainty naturally leads CI personnel to look around for more stable forms of employment.

Therefore, CI personnel often prefer faculty, administrative, or private sector positions where they earn higher compensation. However, it is not simply a matter of compensation – other organizations also provide career paths. Faculty positions provide the classic tenure path and private sector careers typically provide more varied managerial and leadership roles – some with dual ladder career paths for more technically inclined. Once a talented individual is lost to the private industry, it is virtually impossible to recruit them back at senior levels because academic environments cannot provide adequate compensation.

Many CI professionals who stay in their CI roles do so based on their desire to work at the cutting edge of research and computing and to advance the frontiers of scientific inquiry. These personnel are then often courted by other CI organizations, leading to some turnover across academic organizations in the field – to the benefit of some CI organizations, but at the expense of others. Oftentimes location is the strongest draw for retaining CI personnel, which is not a sustainable model for a growing field of endeavor at the cutting-edge of technology. As the skills of CI personnel are in unprecedented demand, location cannot be the primary factor in retaining these critical personnel.

One major cause of personnel pipeline and retention issues that workshop participants identified has to do with the way information technology ("IT") is traditionally treated in academic contexts.

Cyberinfrastructure versus IT

One major problem for CI enterprises is that they often operate in the shadow of much larger IT organizations in the university. Cyberinfrastructure is often thought to be a form of IT – granted, a more advanced form, but still IT nonetheless. This is a problem for two reasons. First, IT typically has large budgets for administrative and infrastructural systems and much larger staffing. Second, IT is generally considered a cost center in universities – a necessary piece, but one that should focus on reliability and efficient performance. Under the shadow of IT, CI organizations are not considered vital to the strategic mission of academic organizations.

Of course, there are overlaps and parallels between the two fields. IT does networking and the CI group does networking. IT has a help desk and CI has a help desk. IT helps people around campus solve their problems; CI helps people around campus solve their problems. Because of these overlaps and parallels, the two are often equated (though in actuality they are qualitatively different). Therefore, the CI organizations inherit job titles, associated salaries, and many other already-established standards from the IT organization.

However, although there are overall parallels, CI is qualitatively different than traditional IT in a number of ways. First, the sorts of technologies that CI works with – everything from HPC to scientific software – are not well established in any way. They are at the frontier of technical innovation and performance and typically need much stronger set of skills. More importantly, CI personnel need to understand the research enterprise in a fundamental way so that they can improve this enterprise. This often requires disciplinary specialization. Many CI personnel have PhDs and deep disciplinary research training.

Further, not only is CI under the shadow of IT from a framing standpoint, oftentimes CI must compete with IT for funding. For some CI enterprises, this is their most difficult challenge. When "central IT" has its emphasis on cost containment the incentives run directly counter to the CI enterprise, which is focused on cutting-edge work that often is more heterogeneous, risky, and costly. The problem is that much of the governance of advanced computing comes as spillover from the governance developed for IT that is oriented in a different direction. A lot of time is spent trying to "fight against" or "undo" such things. This is a waste of time.

Ultimately, the distinction that workshop participants made between CI and traditional IT was one of organizational strategy. IT is a support organization and cost center – a competitive necessity for universities. Whereas CI is strategic – it can lead to competitive advantages for universities in terms of conducting impactful research, attracting additional funding, and recruiting high quality faculty and students. Where IT is a competitive necessity where performance and reliability is important bust costs should be contained, CI is a source for competitive advantage where universities should innovate and invest in key CI capabilities that will help the university to thrive. A workshop participant indicated that CI needs to "get out from under the shadow of IT and develop our own identity." An approach that to do this involved professionalization.

Professionalization of Cyberinfrastructure?

A solution to get CI out of the shadow of IT and to improve issues with scarcity of CI personnel involves establishing a stronger more recognizable standing for this community. The idea is to professionalize the community. This would involve all of the trappings of a profession – such as a clearly articulated domain, well-established job designations and career paths, training standards, and an association or governing body of some sort. With greater professionalization, the idea is, more resources – both human and financial – would flow to the community.

In his talk at the workshop challenging participants to think about whether professionalization is a good idea, John Towns (University of Illinois, NCSA, XSEDE) questioned whether, without a professional association, the CI community has a unique identity. CI personnel often affiliate with ACM (computer science) or IEEE (engineering), but here the community is lost in much bigger organizations. On the other hand, there are high-performance computing (HPC) associations, but CI is much broader than the computing portion, and at the same time focused primarily on academia. HPC associations, on the other hand, are focused on both industry and academia and primarily the computing portion of cyberinfrastructure. An academic CI association could advocate for this emerging profession.

Further, Towns suggested that standardized training in the form of CI degree programs, certifications, and formal professional development was a good idea. Towns argued that the community needs standard job titles of its own along with associated career paths. He challenged workshop participants to consider whether these are good ideas and how to enact them. Before one can discuss a profession, however, it is important to define the domain of interest.

Defining "CI Personnel"

The set of skills that CI professionals need are varied and multifaceted. Although no one person could possibly have all the skills necessary to carry on the enterprise, CI resists over-specialization and requires that practitioners span boundaries. At a minimum they need some technical skills and some experience with formal research. From a "hard" skills standpoint, CI personnel have some combination of systems administration, networking, security, software programming, data management and analysis. This is combined with disciplinary expertise in fields as diverse as physics, chemistry, genomics, weather and climate science, and population health, among others. CI personnel need some general characteristics as well: they are flexible problem solvers with strong critical thinking, analytic and diagnostic ability, and comfort with indeterminacy. They also need “soft” skills associated with interpersonal communication, collaboration, and political and cultural awareness. Further, a certain “ethos” marks the CI community – one of versatility, democratization, and openness and members in the community are expected to abide by this critical element of the culture of the CI community.

This is certainly a tall order and no one person will embody everything. Although there are a numerous combinations of these skills and attributes leading to dozens of potential roles in the CI ecosystem, workshop participants identified four general categories of CI personnel: (1) systems facing, (2) software facing, (3) researcher facing, and (4) application facing. Following is a brief description of each:

1. ***Systems Facing Roles***. These involve the design, deployment, and maintenance of the computer systems and associated networking. In CI this typically involves clusters of machines tightly integrated with a fast network. These machines are built to spec to run a particular class of application – such as computationally intensive applications like chemistry or physics, or memory intensive applications like genomics. There are various system facing roles that are different in their emphasis, including system engineer, network engineer, systems administrators (including security, operating system, or user support specialists), and others.
2. ***Software Facing Roles***. These involve the development, customization, and troubleshooting of scientific software. This includes the application software, such as specific disciplinary codes (say, for plant genomics or computational chemistry), but also generic code that can be broadly used (such as something developed for the “R” statistical package). This also includes middleware such as performance monitoring tools and low-level scripts that enable software to perform effectively. Oftentimes as researchers scale their code to large-scale cluster hardware, they use the help of a software engineer to parallelize this code to take advantage of the cluster’s capabilities.

3. ***Researcher Facing Roles***. There is an ever-increasing diversity of researchers who are using CI resources. For example, in recent years, Clemson University's CI organization went from servicing 14 departments to over 40 departments across campus. While these include the traditional science and engineering departments, it also includes researchers from business, economics, humanities, and other social sciences. Clemson, as well as a number of other universities, have created "research facilitator" roles that work with these diverse researchers to find ways to help them leverage CI resources. While all CI personnel are to some degree user-facing, this facilitator role is focused strictly on bringing new users on board to take advantage of CI capabiilties. Newer groups need more "care and feeding," according to one workshop participant. This is increasingly important as different fields are discovering the power of large-scale computational and data-driven approaches to their research.
4. ***Application Facing Roles***. Application facing roles focus on fields, or domains in science. They are different from researcher facing roles in that researcher facing roles deal with specific people, application facing roles deal with scientific fields. Increasingly, different fields and professions are developing standards and approaches for CI-based scientific activity and CI specialists help them to set these standards and guide tool development and such. Consortia like EarthCube in the geosciences, for example, run workshops and develop standards around data sharing and reuse and CI professionals work actively with the consortium and the Council of Data Facilities to bring standards to these domains. Application facing roles are institution builders working on the level of disciplinary or cross-disciplinary science fields. Application facing roles are the integrators and coordinators of the broader CI community.

Clearly, these roles are not mutually exclusive. They interrelate and interdependent. There are overlaps and the same person may play multiple roles in a given context, or different roles in different contexts. What is notable is that all of the roles are outward facing, highlighting how a fundamental element of the CI community is to act as a bridge, or boundary spanner in this emerging domain.

Organization Science: Occupations versus Professions

Organization scientists have studied professions and professionalization for decades. The division of labor results in a variety of interdependent occupational categories and some of these occupations can evolve into full-fledged professions. As categories become powerful they seek to monopolize a domain of work and some of these occupations become professions.

In perhaps the seminal work on professions, Andrew Abbott (1988) pointed out that professionalization is about monopolizing a domain of work. The profession essentially claims a "jurisdiction" over a certain domain of work and keep people from outside of the profession from working in their jurisdiction. They do this through a credentialing process whereby they form an association and identify a body of abstracted knowledge, which helps them to create and sustain barriers to entry in the profession, thereby maintaining their monopoly over the domain. Strong professions get resource providers and regulators to shape persistent institutions that reinforce their monopoly (like lawyers and doctors). Weaker professions struggle to maintain their jurisdiction (e.g. social work). The key characteristic of a profession, according to Abbott's view, is to view professions as part of an ecosystem of professions – weak and strong – that are continually battling over jurisdiction for evolving forms of work.

The key difference between a strong and weak profession – or merely an occupational category – is what organizational scientists call "legitimacy." Legitimacy refers to the way that the profession is perceived by stakeholders outside of the profession – in particular those stakeholders who control resources and establish and reinforce regulations. This is not to say that weaker professions are somehow illegitimate, it is just that the legitimacy of knowledge and jurisdictional claims of the profession must be unassailable for the profession to monopolize a domain. They cannot do it alone, they need external stakeholders such as regulators and funders to support them and help to maintain their monopoly. So the creation and maintanence of professions is fundamentally a framing and political process to gain and sustain high levels of legitimacy with outside stakeholders.

Thus, if the CI community were to pursue professionalism, they need to realize that what they are doing is making jurisdictional claims over certain emerging categories of work and they will need to understand that this is a political process. They need to frame the CI profession as the *only* legitimate body that can perform this work in the eyes of key external stakeholders such as funding agencies, university administrators, and scientific communities. In order to do this, they need to create barriers to entry through a credentialing process that is rooted in a body of abstracted knowledge. Given that the CI community already has major problems attracting a workforce, many in the workshop questioned whether this goal of monopolistic practices, barriers to entry, and a well-established abstract body of knowledge is not premature.

However, it is clear that the CI community is battling for jurisdiction – certainly with traditional IT and perhaps other science fields. In this effort, the CI community is desperately attempting to build legitimacy. Again, this does not mean that they are somehow illegitimate; it is just that the community wants *greater* legitimacy in the eyes of external stakeholders – especially resource providers (e.g., university administrators).

Steve Barley, one of the preeminent scholars of technical occupations, presented at the workshop and tried to make parallels between CI professions and the technicians in other fields that he studied (medical equipment technicians, for example). He described how technicians were seeking power and seeking respect in their respective domains. It was not professionalization, because those technician communities were not powerful enough to advance to that stage, but it was a struggle for legitimacy that he described. He expected the audience to draw analogous connections to the CI community, where it made sense. He pointed out that technicians play a buffer role between the technologies and the professions. For example, a medical device technician acts as a buffer between the doctor and the device. The technician has expert knowledge about the device and some domain knowledge of medicine, but they are not legally allowed to encroach upon the work of the doctor –even if they were capable - because of institutions that reinforce the barriers to entry to the medical profession. Further, technicians provide other boundary spanning roles such as broker and translator back and forth between the technical and domain communities. Technicians need to overlap with the domain knowledge, they have semiotic as well as sensory-motor skills, and community-wide heuristics and approaches that they draw upon to solve problems. Supervisors and higher-status professionals lack the expertise that technicians possess, and they often lack the ability to adequately evaluate performance of technicians.

Many in the workshop saw parallels between Barley's work and the CI community. However, many others – particularly some CI leaders in the workshop - responded disfavorably. They did not like being compared to technicians – the work of CI personnel is far more cutting-edge, complex, and difficult. After all, so many CI personnel have PhDs. Further, many workshop participants did not like the political elements and the need to fight for respect. They felt they were clearly respected – certainly by those they work with – they are just sometimes underappreciated by some other stakeholders.

The CI community is clearly a component in the post-industrial division of labor that marks the contemporary scientific endeavor. It is clearly not technically a profession, but one can certainly use the term in its colloquial sense. One can refer to CI as a profession in order to gain legitimacy without meeting all of the particular requirements of a profession by organization scientists. One can refer to CI personnel as "CI professionals" if one chooses, and this may work to help with the framing that will increase legitimacy. Terms matter, and perhaps using the term profession without actually attempting to build a full-fledged profession is a tactic that CI leaders may take. Words such as job titles matter for framing and establishing greater power, respect, and legitimacy. With greater legitimacy comes more resources. The structure of science is changing and the CI community could benefit from consciously claiming a jurisdiction in this evolving space and actively strengthening legitimacy with external stakeholders in that space.

Discussion & Going Forward

The goals of the RCN are to bring CI leaders and organization scientists together to foster collaboration. The 2017 Santa Barbara workshop has succeeded in initiating a number of new collaborations between CI leaders and organization scientists. However, collaboration between these two groups is not easy.

Peter Levin (Intel Corp.) highlighted this in his closing remarks. Bringing social science, strategy, and technology together is essential, but the different groups have different motivations, different cultures, and different ways of viewing the world. They want different outcomes for collaboration. We have analyzed in earlier sessions of this RCN (see Berente et al 2013) and in this session, we have again highlighted how both groups would like simplification from the other groups, while they resist simplification in representing their own domain. CI leaders would like simple actionable guidance from organization scientists, who in turn point out that organizational issues are too complex for such naïve simplification. Similarly, organization scientists would like simple definitions and categories from CI leaders, who in turn say it is far too complex to simplify in such a short medium. Now that a community is forming around this RCN, this dynamic is being increasingly understood. Simplification is a crucial move in interdisciplinary discussions, yet both sides resisted the other side's calls for simplification. It is evident that both sides need to find a better way to represent themselves outside of their fields.

Themes emerged in this workshop that were also evident in every other workshop, including challenges with demonstrating the impact of CI enterprises and thinking about interesting ways of framing the workforce development aspects of the CI community (e.g., Berente et al 2014, Howison et al 2017).

In this session a key takeaway involved the need for language. Although it is a difficult, political process, an initial step toward strengthening legitimacy of the CI community is to generate a distinctive taxonomy for its work, which would include job titles and roles and associated career paths. There is understanding that this will not be simple because of the complexity of the domain and the highly political process such standards making entails. However, it needs to be done to gain legitimacy. For instance, look at the legitimacy data analysts have created around the “data scientist” role in recent years.

Another key take away was, however useful and thought provoking organization science frameworks (such as the one Barley presented) may be, there are issues with translating these frameworks to the cyberinfrastructure space. The discomfort with issues of power and the difficulty in translating some of the ideas analogously across contexts was evident. Nevertheless, the CI leaders quickly adopted language used by the organization scientists in their discussions.

Going forward there are a number of different community building efforts as the RCN draws to a close where organization scientists can get involved as the CI community continues to grow and strengthen. For example, the PEARC conference, http://www.pearc.org/, solves the problem of establishing a conference specifically for academic CI practitioners. XSEDE is sponsoring a variety of student and apprenticeship programs and the “Campus Champions” program whereby credentialing has begun. CaRC (and previously ACI-REF) is building a community of CI facilitators across campuses of people at the front line working with researchers to get the work done. This RCN continued to build upon previous workshops to attempt to incorporate organization scientists in some way in these efforts.

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Appendices

Workshop Agenda

Monday, January 23

9:00-9:30 AM	Introductions
9:30-10:30 AM	**John Towns**, Extreme Science and Engineering Discovery Environment (XSEDE): "Cyberinfrastructure and the emerging occupations"
10:45 AM-Noon	**Breakout session 1**: Current Situation
12:00-1:30 PM	Lunch & CI Keynote Speaker: **Eva Zanzerkia**, National Science Foundation: "Opportunities and Trends in the Geosciences"
1:30-2:30 PM	**Steve Barley**, University of California, Santa Barbara: "Professionalization of technical occupations"
2:30-3:45 PM	**Breakout session 2**: Future Directions
4:00-5:30 PM	Plenary
7:00-9:00 PM	Dinner & Org Keynote Speaker **Paul Leonardi**, University of California, Santa Barbara: "Technology, visibility, and the changing dynamics of work"

Tuesday, January 24

9:00-9:30 AM	**Peter Levin**, Intel Corporation: "Building at the intersection of social science, technology, and strategy"
9:30-10:30 AM	**Breakout session 3**: Collaboration
10:45 AM-Noon	Plenary debrief
Noon	Close with box lunches

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