Research Computing Facilitators

The Missing Human Link in Needs-Based Research Cyberinfrastructure

ECAR

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Overview

As the roles of core, campus-supported IT services for research have expanded—including the emergence of cloud-based models—the benefits of on-campus human support and user engagement have become increasingly apparent. Ongoing challenges in securing research funding reemphasize a need to demonstrate significant societal impact via effective and efficient investments. At the same time, many campus research computing providers still face challenges in engaging researchers represented in the "long tail" of computing needs, where potentially significant, compute-enabled transformations to scholarship have yet to be realized. The most common models for research computing resources may already meet the significant needs of well-established or "traditional" users, typically in the physical sciences, engineering, and computer sciences. However, what additional resources are necessary to meet unrealized computational needs across research domains? Instead of asking how to bring a greater variety of researchers to established computing solutions, how do we shift to first understanding the diversity of computational requirements to inform appropriate and, perhaps, new solutions?

While the design of campus-supported research computing technologies and support models is often driven by top-down influences, such as preexisting administrative pressures and funding considerations, a complementary bottom-up approach is necessary to truly understand the actual needs of researchers. At the University of Wisconsin–Madison (UW-Madison) and a growing number of other universities, dedicated research computing facilitators (RC facilitators) are changing the way that higher education institutions approach research computing. RC facilitators serve as proactive and personalized guides, helping researchers identify and implement computational approaches that result in the greatest impact to their projects. Rather than possessing a significant depth of expertise in computational technologies, RC facilitators build and leverage their team of expert technical staff and translate the details of computational options for individual researchers. Through this two-way relationship-building approach, dedicated RC facilitators have enabled previously unimagined and significant scholarship outcomes of scale and scope across a variety of research domains, especially within the space of campus-supported research computing centers.

Moreover, facilitation practices enable significant additional benefits to research computing business models by informing the design of adaptive computing solutions beyond well-known and one-size-fits-all enterprise models that may only cater to researchers with the greatest known needs. In particular, a deliberate effort to empathize with the needs of nontraditional users of research computing services is likely to reveal significantly different business needs. At UW-Madison, for example, RC facilitators have revealed that popular high-performance computing (HPC) configurations alone are insufficient for enabling significant research transformations across domains and research methodologies, especially for nontraditional and would-be users in the social sciences, life sciences, and humanities.

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A Dedicated Human Solution: The RC Facilitator

Many IT organizations are beginning to recognize the need for increased attention to human resources as a complement to technology-based research computing solutions. Providers of research computing, data management, and other core IT services for research are directing increased human effort—among existing staff—to the activities of training and documentation, help desk–style support, and researcher surveys on the impact of relevant resources and services on their research. However, a more comprehensive set of dedicated human activities is required to fully support and proactively accelerate scholarly discovery via a role that is a novel supplement to existing research computing staffing structures: the RC facilitator.

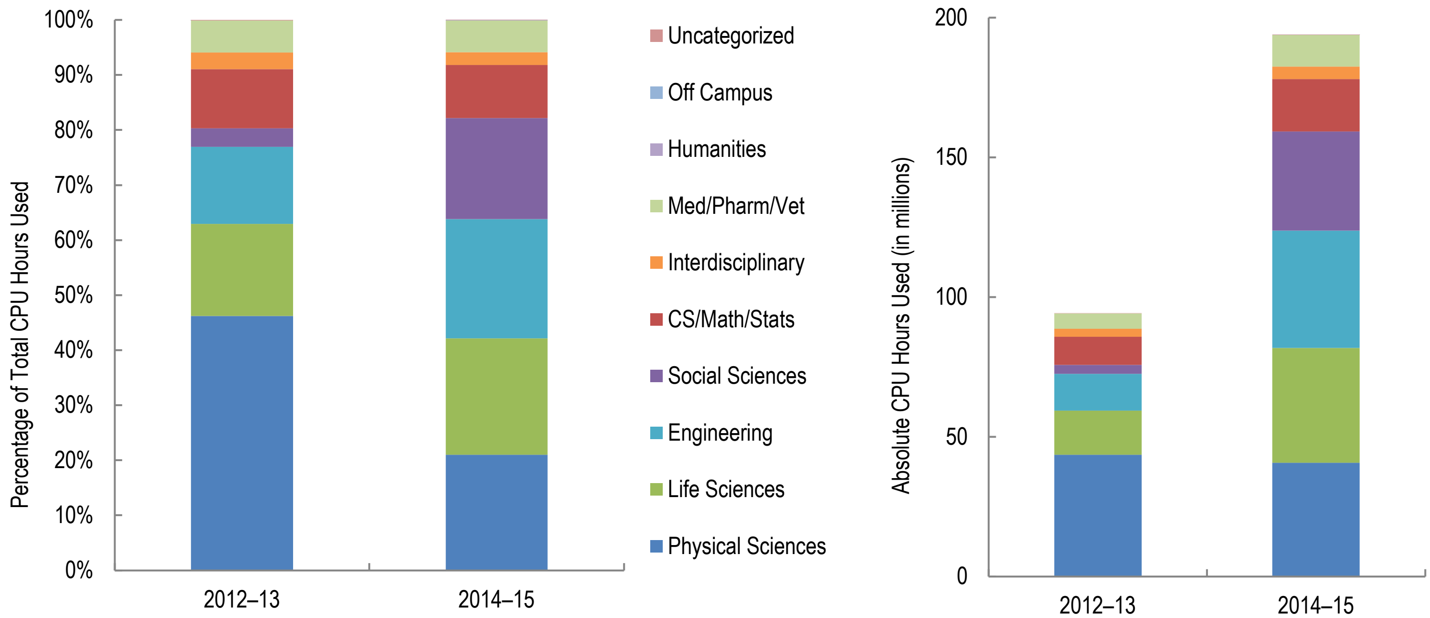
Full-time RC facilitators act at the front line of building relationships between computing providers and research communities with specific goals and activities that exceed the ability of traditional documentation-and-help-desk models.

RC Facilitation at the University of Wisconsin–Madison

Prior to 2013, research groups and departments at UW-Madison typically supported their own computational needs. In an example from 2003, the NSF-funded Grid Laboratory of Wisconsin (GLOW)[1] coordinated the sharing of high-throughput computing (HTC) capacity between clusters independently owned by seven departments in engineering and the physical sciences. Resource sharing was managed via the HTCondor software,[2] developed under Dr. Miron Livny's distributed computing research group in the Department of Computer Sciences since the mid-1980s.

Recognition of HTCondor's impact to worldwide research and to members of GLOW led to the establishment of the Center for High Throughput Computing (CHTC)[3] in 2006, with a mission of supporting HTC needs across campus, as well as the continued research, development, and deployment of distributed computing technologies including HTCondor. A number of CHTC's software developers and systems administrators provided support to researchers, but success gaps remained for research domains new to GLOW and outside the established, heavy users of computational approaches in the physical sciences, engineering, and the computational sciences.

By early 2013, and in light of still-unmet researcher needs for campus-supported HPC resources for tightly coupled computations, UW-Madison's Advanced Computing Initiative[4] recommended campus funding of CHTC as the core research computing center. Seeing the opportunity to refine staffing structures, CHTC also hired a new, dedicated research computing facilitator, a choice based on the candidate's significant background in academic research and teaching, as well as her strong interpersonal skills. Since that time, CHTC has realized significant successes in the engagement of and impact to researchers across campus, especially for faculty and students from the life sciences and social sciences, considered to be nontraditional users of large-scale computing. Based on and building on this success, a second facilitator with a similar skill set was hired in 2014. In particular, following the addition of these dedicated RC facilitators, usage of computing services by previously underserved researchers increased significantly (see figure 1). Importantly, more than 95% of usage from the life sciences and social sciences has been on an HTC-optimized compute configuration rather than a traditional HPC cluster, emphasizing the applicability of multiple compute configurations to meet needs across domains.



Note: Humanities, off-campus, and uncategorized research computing combined totaled <1% and <100,000 hours of overall CPU usage.

Figure 1. Usage of core research computing at UW-Madison, by scholarly domain

Beyond usage statistics, formal and informal feedback from faculty and their research teams has confirmed significant gains in research productivity. These include reports of greater efficiency and achievable project scope, sometimes resulting in significant methodological transformations within specific scholarly fields.[5] Furthermore, similar facilitators and facilitator-like personnel have been hired by other research IT providers and academic departments at UW-Madison and by collaborators at partnering institutions, including those within the NSF-funded Advanced Cyberinfrastructure - Research and Education Facilitators (ACI-REF) network.

Why RC Facilitators?

Many core research computing providers face a number of ongoing challenges in accelerating scholarly discovery.[6]

Appropriate Technology Solutions Require an Understanding of Research Needs

The prevalence of HPC clusters on campuses, particularly in the absence of additional compute configurations, presents a challenge for nontraditional users of large-scale research computing resources, whose computational needs typically do not require the tightly coupled compute methods (e.g., message passing interface and similarly optimized software) that are dependent on the typical HPC configuration. In addition, while many big data approaches common to the life and social sciences will scale well by breaking up the big problem into many smaller, independent tasks with HTC approaches, the job schedulers and shared file systems common to HPC clusters often perform and scale poorly when handling large numbers of separate jobs and files. Other less-prominent research computing methodologies may require high-memory capabilities or additional technology solutions that do not warrant or are unsatisfied by a single HPC cluster.

While a traditional approach to research computing services has been to focus on what is necessary to get more research onto available configurations—an approach that presupposes that existing solutions already meet most research requirements—this assumption may significantly misdirect technology and human investments by excluding the possibility that different or additional solutions may be necessary. Instead, we should be asking, "Which solutions, including human resources, are necessary to satisfy a wide range of research needs and accelerate discovery?"

A needs-based approach requires ongoing, two-way communication directly from researchers and in the context of their specific field of work in order to have a true understanding of gaps and weaknesses in research computing solutions. Communicating the evolving needs of the research community to campus IT leaders and administrators also requires appropriate on-the-ground, human effort to routinely obtain such information from researchers and to represent it bottom-up.

Research Problems Require Varied Technology Solutions

Across and within research domains, the range of computation and data support requirements will vary widely with respect to data and compute dimensions, applicable software, and culturally imposed data dissemination standards, among other research requirements. Therefore, multiple solutions may be necessary to sufficiently meet researcher needs across domains.[7] Research computing solutions intended to serve a one-size-fits-all role may in fact stifle research and discovery by allowing researchers to consider only those approaches that will scale well within existing configurations and capabilities. Furthermore, efforts to expand the use of a single technology option to a wider variety of research areas may look like the proverbial hammer in search of a nail.

A deliberate and continuous human-based effort is essential to understanding the variety of technology *and* human solutions that will enable research transformations across domains.

Researchers Possess Varied Technical Knowledge

Each researcher comes to research computing services with a unique background of computational understanding and skills. However, researchers from nontraditional user domains may be unfamiliar with existing resources and, more often, how these might apply to their own work. Researchers who lack computational knowledge and experience may also be intimidated by perceived challenges in using beyond-the-desktop computing capabilities.

An increased awareness of the applicability of research computing services, however, can only be achieved via communication with other researchers or as the result of deliberate efforts from research computing staff in the form of outreach and engagement activities that leverage applicable examples. But that is just a first step. Once awareness has been raised, researchers with little experience in command-line computing, data management practices, and other relevant skills may struggle to leverage research computing systems if they don't understand how to use them effectively, regardless of how well these systems are designed. Many new users don't know which skills to develop or where to find applicable and effective learning materials. While research computing providers have long been aware of the need for strong documentation and learning opportunities, these efforts require significant human communication skills via appropriate and perhaps new approaches to staffing that better support nontraditional users.

Effective Support Requires Scholarly Expertise

Traditional research computing staff have significant technology expertise but typically lack a strong understanding of scholarly processes and pressures. RC facilitators with previous experience integrating computation-dependent approaches for their own research endeavors can be extremely useful in helping researchers who are undertaking this kind of integration themselves. A greater knowledge of research culture, in general, also helps identify opportunities for technology exchange and transformative collaborations between researchers.

Research computing staff in traditional roles are also typically deficient in domain-relevant knowledge of research design with respect to applicable third-party software, specific analytical methods, and standards for data dissemination. Many researchers may find the task of identifying applicable and scalable computational approaches more daunting than learning to use a cluster for the first time. Furthermore, the ability of researchers to transform their work for greater dimensionality, validity, and impact is often unknowingly limited by perceptions of the scalability of methods and tools (e.g., software) selected for prior work. Therefore, a certain amount of domain-aware consulting support for researchers—beyond reactive support for their direct use of compute systems—is essential.

Facilitation Goals

The following outlines the primary goals (the *needs*) of successful RC facilitation and identifies the related major activities for achieving those goals.[8]

Proactive Engagement: Facilitation of computation-enabled discovery requires proactive support of researchers and their projects. This includes the important activities of *outreach* to inform communities on campus of various computing resources and their ability to accelerate discovery by presenting specific examples of scholarly transformations. To support researchers in the selection of research computing configurations that complement appropriate computational approaches, facilitation also requires early *engagement* with individual researchers to better understand their needs for computational resources, particularly at the beginning of a new project. It is therefore important to promote the RC facilitator role and what it can do for researchers and to establish clear pathways to arrange consultations with an RC facilitator. At UW-Madison, for example, RC facilitators meet with every researcher new to the core research computing center. Furthermore, facilitators should seek to identify opportunities for follow-up engagement with new and existing users of research computing resources, for example, in response to researchers' evolving behavior on compute systems.

Major Facilitator Activities

- *Outreach* within the research community to promote awareness of computational resources and their potential impacts
- *Engagement* with researchers to understand their needs and advise on computational strategies
- *Ongoing support* of researchers executing projects on computing resources
- *Education and training* of researchers regarding computing capabilities, best practices, and specific skills
- *Liaising* researcher connections
- *Advocating* for the needs of researchers to inform research IT design and institutional support

Personalized Guidance: RC facilitators should provide researchers with personalized support, including recommendations that cater to each researcher's level of computational experience and project needs and that explore the potential for transformative outcomes. Only after a diagnosis of a researcher's unique needs should specific resources be recommended, potentially including options beyond the facilitator's immediate compute-providing organization, such as nationally funded computational resources. Factors that may impact the selection between applicable methods and software should be clearly communicated, including the potential for transformative impact to the researcher's work, ease of implementation, scalability, and efficiency considerations that include human time and effort trade-offs. Additionally, the facilitator should help the researcher identify personalized pathways for learning any necessary computational skills.

Naturally, personalized *ongoing support* should be provided for researchers as they leverage computational resources into the future. Facilitators should serve as the first response to specific user questions and issues via multiple pathways (e.g., ticket-based e-mail and office hours), while leveraging contributions and expertise from more technical staff to identify answers and solutions. Not only is this ongoing relationship with researchers important for encouraging future reengagement, but it can also encourage researchers to ask "bigger" transformation-enabling questions that reach beyond discussions of specific research computing practices.

Teaching Researchers to Fish: The overall goal of facilitating transformations is only fully realized when researchers can foresee pathways to computing-enabled transformation for themselves. It follows, then, that a differentiating focus of RC facilitators is to contribute directly to the *education and training* of researchers in executing computational work for themselves rather than to complete tasks *for* researchers.[9] Facilitator-recommended learning roadmaps—including a combination of in-house documentation, external materials, and in-person opportunities—should enhance researchers' abilities to work toward greater capabilities and possibilities, while still encouraging researchers to ask for help and guidance. Facilitators should also empower researchers to find answers in the future, perhaps by explaining relevant troubleshooting approaches and online search methods that reveal the most relevant technical documentation. Similarly, the development and organization of in-house, facilitator-delivered learning materials should provide paths to addressing increasingly complex tasks that researchers may need to carry out on compute systems.

Building Relationships: To effectively inspire researchers to achieve more in their use of computing resources, facilitators must first establish trusting relationships and be able to empathize with the values and pressures that impact each researcher's decision from among computational options. There are significant benefits to relationships and learning outcomes[10] when researchers perceive facilitators as more like themselves. To this end, facilitators should demonstrate their role as conceptually more similar to that of a fellow researcher than that of a traditional IT staff member. The facilitator-researcher relationship is most effective when established as a partnership, similar to researcher-to-researcher interactions. As some of the few individuals on a campus with knowledge of scholarship across domains, facilitators are also uniquely poised to *liaise productive connections between researchers* and to promote peer learning among individuals with similar needs for computational methods and tools. Facilitators will naturally serve as bridges between disparate groups of researchers, connect researchers across the institution with research support staff in other units, and suggest consultations with experts in computation-focused fields such as bioinformatics, statistics, and computer sciences.[11] Not only are communicated successes from peers essential for demonstrating the potential impacts of scalable research computing to other researchers, but they also enable peer-to-peer technology exchange that accelerates the work of new users.

Advocating for Research Needs: Ideally, the facilitator-researcher relationship will also build productive two-way conversations between scholarly communities and research computing service providers, reaching beyond support models that rely only or more heavily on communication via documentation, training opportunities, surveys, and reactive help-desk support. The above facilitation approaches will enable the facilitator to more effectively understand and *advocate for researcher needs* in communication with research computing staff, leadership, and even campus administrators.

Developing Connections among Staff: Finally, the facilitator's ability to translate feedback from the research community into valuable improvements to the design of research IT resources is heavily dependent on relationships with other research IT staff, including systems administrators, network engineers, and software specialists. Facilitators will frequently need to inspire and lead contributions from more technical staff within and external to their immediate working unit for many of the preceding activities, including responses to user-reported issues and the satisfaction of real-time requirements for system configuration adjustments (e.g., account settings, software version updates, data transfer optimization, etc.). By forming connections with other personnel and gaining awareness of services in other organizations, facilitators can also better support the handoff of researchers between service providers when requirements for additional resources are realized.

Facilitator Skills and Background

Three key areas of experience and interest are relevant for successful RC facilitators: individual interests and motivation, communication and interpersonal skills, and technical knowledge.

Interests and Motivation: A core role for facilitators is to enable others to realize their own transformations, and it is unlikely that a facilitator would contribute directly enough to result in coauthorship of research publications (as compared to the role of "computational scientist"). Therefore, an effective RC facilitator should be motivated by:

- A desire to enable and support the scholarly work of others
- Interest in a wide set of research domains beyond their own area of expertise
- The ability and the desire to work in a team environment
- A desire to further develop the skills and interests relevant to effective facilitation

Communication and Interpersonal Skills: In order to effectively engage and support researchers from a variety of backgrounds and domains, facilitators should possess solid communication skills and some teaching or training experience. A successful facilitator will form strong relationships with researchers, with adjacent staff—whose technical expertise is heavily relied upon in selecting and communicating effective technical solutions for researchers—and with various stakeholders to ensure institutional support for research computing and related services. Specifically, these skills include:

- Excellent written and verbal communication, including active and empathetic listening skills and an ability to translate complex and domain-specific information for nonspecialists
- Demonstrated effectiveness and comfort in teaching and public speaking
- Success and demonstrated interest in interpersonal networking and liaising
- The desire to work in a team environment, where staff frequently depend on one another
- Leadership skills that inspire action and coordinate the activities of shared contributions

Technical Abilities: Experience in executing research projects is more essential to the role of RC facilitator than depth of knowledge for computational technologies, particularly for those who are well supported by the technical expertise of surrounding staff (e.g., systems administrators, network engineers, application specialists, etc.). In fact, deeper technical experience with specific configurations and tools tends to bias individuals toward known solutions or tools rather than supporting a more problem-focused approach that seeks to find the most appropriate solutions. Therefore, RC facilitators should possess the following:

- Prior experience conducting research projects or other significant scholarly work with some integration of relevant computational systems and tools
- A demonstrated ability to understand multiple aspects of a problem and identify appropriate solutions
- The ability to provide solution-agnostic support by focusing on research requirements and desired outcomes
- A desire for continuous learning of relevant technology topics

With this as a template, the relevant level of expertise and skills needed to support effective facilitation may vary in a number of ways, depending on local campus context, institutional support, the types of resources to be supported, and the range of scholarly communities served by the facilitator(s). Therefore, unique emphasis on specific facilitation activities and on specialization of human expertise may inform a sort of “palette” of facilitator types, even reaching beyond the scope of research computing.

For example, while the implementation of multiple, dedicated RC facilitators has had significant success at UW-Madison and other large institutions in the space of core research computing centers, the same level of human effort may be less appropriate for facilitation within a specific campus department or for services applicable to a smaller set of researchers (e.g., genetic sequencing and accompanying computational services). Smaller academic departments and research centers may also partner to support shared facilitation and IT staffing. In these cases, a facilitator with more domain-specific knowledge might work closely with researchers in selecting research methods on a wide set of technology resources ranging from personal computers and local data storage to the realization of needs for scalable research computing resources. Thus, facilitators working for specific research units may benefit even less from a deep knowledge of any specific technology solution.

Constraints within existing staffing structures and funding models may also mean that facilitation duties are satisfied in combination with other responsibilities. For example, an employee’s time may be split between general facilitation and externally funded contributions to specific research projects (where these contributions are more akin to the coauthor-worthy role of “computational scientist”). At other times, systems administrators, network engineers, or individuals in other, more technical roles may perform facilitation activities in addition to their core work. That said, when possible, dedicated facilitators—who routinely leverage the combined technical expertise of surrounding personnel—often have a greater impact.

Differences in context will also result in varying models for interaction with other roles. In research computing, facilitators may work most closely with cluster administrators and application specialists (where this role exists separately from the facilitator role) to leverage technical expertise and effort. Within specific departments or research centers, facilitators may work alongside a smaller number of employees with a wider range of technology responsibilities, from supporting local network performance and web hosting to managing local clusters and file systems. Most importantly, facilitators in separate technology-providing shops on a campus (including staff who may only spend some of their time on facilitation) should connect with one another, not only to understand each other's services and enable the handoff of researchers between needed services but also to share and enhance facilitation practices in each unit.

What's Next for Higher Education?

The RC facilitator represents a relatively novel combination of professional focus and experience. At UW-Madison, RC facilitators have successfully informed new configurations and user practices within CHTC;[12] collaborated with staff in the separate, central IT organization to inform a revamp of data storage and virtual server offerings;[13] and worked with departmental and college IT to facilitate the addition of new departmental clusters within a sharing-driven, campus HTC "grid." Demands for facilitation at a growing number of institutions may warrant additional collaborative efforts within and beyond the higher education community.

As a new role, however, the RC facilitator also presents opportunities to contribute to a community-driven understanding of the role and to further explore the challenges and questions around adoption, development, and evaluation.

Institutional Adoption and Refinement of the Role

Continued implementation of RC facilitators is likely to lead to long-term, far-reaching gains to research computing business models and scholarship outcomes across the higher education community. There is also significant potential for collaborative efforts to refine the practices of facilitation and necessary skills across multiple research IT resources (e.g., data services, networking/transfer capabilities, compute resources, etc.) and to understand where necessary deviations from the research computing–driven model might exist.

An existing effort within this space has been undertaken by the ACI-REF project, an NSF-funded collaboration to research and define the facilitation role and to develop a model for expanding a professional network of facilitators. Contributors[14] to ACI-REF have implemented facilitators or adjusted existing roles to support the standards of facilitation, primarily within the scope of research computing but also within a variety of administrative structures and research IT business models. The group is also publishing best practices of facilitation, consistent with many of the ideas in this bulletin, in order to promote the adoption of RC facilitation practices in higher education and beyond.[15] These efforts, as well as opportunities for less-formal interinstitutional collaboration, will continue to inform early adoption of the facilitator role at other institutions. Furthermore, lessons learned from campus RC facilitation are likely to supplement ongoing interactions between higher education IT organizations and industry partners, providing potential benefits for research-relevant technology resources such as commercially available software and cloud solutions.

Development of Research IT Professionals

Although this bulletin outlines general RC facilitator skills, additional recommendations for enhancing facilitator knowledge and capabilities—including a more detailed review of the implications for adjacent staffing roles—may be possible. What existing training opportunities are appropriate, what extent of participation in external communities and conferences should research IT leadership support for facilitators, and what new professional development opportunities should be explored? Similarly, how can the higher education IT community contribute to best practices for the development of RC facilitators and adjacent roles (e.g., research systems administrators, network engineers, etc.) and support these opportunities across institutions?[16] Initial successes at UW-Madison indicate local campus benefits of a network of RC facilitators; a broader network of RC facilitators across higher education should have similar benefits that might also be realized across research technology roles and beyond the space of research computing. Input from more institutions and technology contexts will be needed to help realize these opportunities in the future.

Evaluating RC Facilitator Impacts

Demonstrating the realized impacts that researchers and research computing providers feel as a result of effective facilitation can be challenging. It is especially difficult to demonstrate true causal relationships between facilitator implementation and scholarship outcomes, given the ever-growing state of most campus-supported research computing resources and a number of other factors affecting research productivity, regardless of the effect of facilitators. Furthermore, impacts to scholarship that truly reflect the satisfaction of facilitation goals are difficult to represent with quantitative metrics alone. Not only are evaluations of transformative impact and accelerated discovery problematic to quantify and standardize across multiple researchers and domains, but they also should include qualitative indicators of the *extent* of transformation and describe the quality of researchers' resulting contributions to their specific scholarly fields.

Some indicators of broad impact may be available via easy-to-quantify metrics such as usage of computing systems by various demographics, facilitator-researcher engagement meetings across domains, the number of researchers trained in facilitator-driven learning opportunities, and facilitator-impacted publication counts. Significant qualitative outcomes may be reflected in survey responses and less-structured statements from researchers, including reported increases in computational understanding and perceptions of the impact of facilitators on their work. However, these measures must be taken together with individual context from representative researchers, without ignoring constructive criticisms. There remains a potential to incorporate a more diverse set of evaluation experiences across institutions, scholarly communities, and research IT service types.

Conclusion

Facilitators bring a needs-focused approach to research computing support and bring scholarly problems to the forefront of design decisions by technical staff and leadership. With major transitions for research computing technologies on the horizon, adaptive staffing models become a necessity within adaptive business models. Human-driven and productive interactions with users of existing technologies are essential to the successful adoption of emerging computational research approaches for transformative impacts to scholarship. There is tremendous potential for RC facilitators, who bridge the gap between researcher capabilities and computational systems capabilities to achieve business models for research computing and related IT services that are truly informed by researcher needs. There is a demonstrated need to understand the benefits of RC facilitation, the complementary nature of RC facilitation activities, and the importance of this role in designing research IT staffing structures. Campus CIOs and institutional research leaders have the opportunity to change the conversation from a focus on monolithic computing architecture to a focus on how to best serve researchers. Empowered facilitators, combined with leaders who support and listen to them, are the key to advancing institutional capabilities. We need to continue this conversation until the balance tilts in favor of the crucial human side of research computing.

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Notes

1. See Grid Laboratory of Wisconsin.
2. See HTCondor.
3. See the Center for High Throughput Computing.
4. See the Advanced Computing Initiative.
5. Overall, the number of research groups with compute usage increased from 126 to 188 from fiscal year 2012–13 to 2014–15, representing an increase of roughly 50% in the engagement of research groups. Additionally, 33 projects with new usage in 2014–15 alone were from the life sciences, social sciences, and humanities. For more details of specific impacts, including researcher testimonials, see the 2014–15 status report of the Advanced Computing Initiative.
6. Though this bulletin does not provide a detailed consideration of specific financial challenges, we note here and elsewhere the potential for *human* impacts to cost-benefit optimizations at the interface of research cyberinfrastructure services and scholarship.
7. For example, the July 2015 ECAR working group paper *Research Computing in the Cloud: Functional Considerations for Research* identifies weaknesses in the ability of emerging cloud-based solutions to meet the needs of MPI-based computation, which essentially requires a typical HPC cluster configuration. At the same time, the paper also highlights the better match of non-HPC solutions in the cloud for large numbers of high-throughput (uncoupled), loosely coupled, and high-memory computations, acknowledging a need for multiple solutions to cover a range of computational methodologies for research.
8. Though specific strategies for each goal and activity are included here, these are also well described in ACI-REF's *Best Practices of Facilitation*, one of the NSF-funded project's key deliverables for the research cyberinfrastructure community.
9. For example, facilitators of research computing resources may have a more positive impact by teaching researchers how to install third-party analytical software for themselves rather than leaning on system-wide installations, which often limit compute scalability for parallelization approaches or may restrict researchers to only considering the use of preinstalled software options and versions.
10. Leo Porter, Mark Guzdial, Charlie Mcdowell, and Beth Simon, "Success in Introductory Programming: What Works?," *Communications of the ACM* 56, vol. 8 (2013): 34; Catherine H. Crouch and Eric Mazur, "Peer Instruction: Ten Years of Experience and Results," *American Journal of Physics* 69, vol. 9 (2001): 970.
11. At UW-Madison, facilitators have even successfully encouraged and supported the formation of communities for researchers and research staff within a variety of compute-related focuses, from microbial ecology to the digital humanities to research systems administration.
12. These changes include big data support, large memory compute capabilities, and mixed high-throughput/high-performance ("HTPC") compute optimization. For more information, see the Advanced Computing Initiative Report: July 2014-Dec 2015.
13. These changes provide greater amenability to research access patterns and work to mitigate funding constraints.
14. Contributors currently include Clemson University, Harvard University, University of Hawaii, University of Southern California, University of Utah, and UW-Madison.
15. ACI-REF, *Best Practices of Facilitation*.
16. There may also be opportunities for the higher education community to discuss career trajectories and support for facilitators within and beyond higher education. The Advancing Research and Computing on Campuses (ARCC) conference, for example, seeks to expand conversations surrounding standards for research computing technologies and necessary human resources. The conference, held March 22–24, 2016, included programming specific to facilitation and other research cyberinfrastructure roles in 2015 and 2016, led by members of the ACI-REF project.