A Research Computing and Data Capabilities Model for Strategic Decision-Making

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Research Computing and Data is changing at an accelerating rate, while the range of fields and disciplines depending on the cyberinfrastructure is expanding and becoming increasingly diverse. This poses significant challenges to academic institutions as they try to effectively assess and plan for the necessary support infrastructure to keep pace with the needs of researchers. We present a Research Computing and Data Capabilities Model that identifies the range of relevant approaches to fully support and enable research computing and data on campuses. This model allows institutions to assess their current capabilities, and provides structured input into strategic decision making, using a shared community vocabulary. We describe the background of the Model, key concepts and features of the Model and an associated assessment tool, initial experience in the community and lessons learned, and a roadmap for further development.

CCS Concepts: • **General and reference → Computing standards, RFCs and guidelines**; **Evaluation**; • **Social and professional topics → System management**.

Additional Key Words and Phrases: Research Computing and Data, Research IT, Cyberinfrastructure, Capabilities Model, Maturity Model, Assessment, Strategy.

ACM Reference Format:
Patrick Schmitz, Claire Mizumoto, John Hicks, Dana Brunson, Gail Krovitz, James R. Bottum, Joel Cutcher-Gershenfeld, Karen Wetzel, and Thomas Cheatham III. 2020. A Research Computing and Data Capabilities Model for Strategic Decision-Making. In *Practice and Experience in Advanced Research Computing (PEARC '20), July 26–30, 2020, Portland, OR, USA.* ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3311790.3396643

Manuscript submitted to ACM

1 INTRODUCTION

Research Computing and Data[1] (RCD) is changing at an accelerating rate, while the range of fields and disciplines depending on the cyberinfrastructure is expanding and becoming increasingly diverse. This poses significant challenges to academic institutions as they try to effectively assess and plan for the necessary support infrastructure to keep pace with the needs of researchers. This infrastructure includes equipment, software, data, and, of course, people, each of which has different rates of change. While there is overlap between RCD and enterprise IT, there are important differences. RCD is an integral part of the research process, and is typically measured on agility, responsiveness, innovation, and on advancing research. Enterprise IT is a more broadly focused set of campus infrastructure services, typically measured in stability, reliability, and more general service measures.

The challenges in supporting RCD are especially acute for smaller institutions and emerging research computing and data support organizations, who may not have experience in this domain and often lack the resources to develop an analysis framework for strategic planning. In addition, many institutions particularly want to assess their capabilities in comparison to peer institutions, or to a broad segment of the community. Finally, the lack of a common vocabulary for the various aspects of RCD support hinders efforts of the community to discuss and plan coordinated efforts to advance support of and for research and researchers.

We present a Research Computing and Data Capabilities Model that identifies the range of relevant approaches to fully supporting research computing and data. This model allows institutions to assess their current capabilities, and provides structured input into strategic decision making, using a shared community vocabulary. The Model has a focus on the frontlines of RCD infrastructure, across a range of perspectives and interactions with their associated audiences (i.e., a focus on researcher-facing, data-facing, software-facing, systems-facing, and/or strategy and policy-facing roles). An associated assessment tool is available as a spreadsheet-based questionnaire, allowing teams to collaborate on a private or shared self-assessment of an institution's levels of capability on each element. The tool provides a summary of coverage across the different "facings."

This RCD Capabilities Model is designed to be useful to a diverse mix of stakeholders on the front lines supporting researchers, including campus RCD practitioners, along with the principal investigators and research team members (faculty, staff, etc.) with whom they work, and campus leadership.

The definition of a common vocabulary and criteria for describing research computing and data also provides a means of benchmarking an institution relative to peer institutions, and/or to various segments of the community. Finally, the Model will enable institutions to contribute to a community dataset that will provide a baseline of capabilities coverage. This baseline dataset will provide important insight into the state of support for research computing and data across the community, and within specific sectors and regions.

The Capabilities Model was developed through a collaboration among the Campus Research Computing Consortium (CaRCC) [5], Internet2 [13] , and EDUCAUSE [9], with support from the National Science Foundation (NSF OAC-1620695); it reflects the input and review from a diverse set of universities (large and small) and related organizations.

2 RELATED WORK

The idea of capabilities models for IT has been around for some time, but often takes the form of fairly broad qualities [10]. In [4], a capabilities model for IT is described with example features, and a mapping to a set of key roles, and

[1] "Research Computing and Data" (abbreviated as RCD) includes technology, services, and people supporting the needs of researchers and research, and is intended as a broad, inclusive term covering computing, data, networking, and software. The National Science Foundation (NSF) uses the term "cyberinfrastructure," and others use "Research IT"

[11] describes eight digital capabilities for higher education and a corresponding maturity and technology deployment assessment; both of these are focused much more broadly and provide much less specificity than our model. In [2], the point is made that research computing and data resources are needed across a broader range of institutions than just R-1 universities, and similarly across a wider set of research domains. They reference a maturity index that is no longer available. EDUCAUSE also provides a Core Data Service [7] that focuses generally on IT in higher education, but has much less granular coverage of RCD topics; it does however describe a community dataset. [12] provides a detailed capabilities assessment tool leveraging a shared community vocabulary and is a good example of our approach in another domain (Information Security). [14] comes the closest to our work, but is focused narrowly on academic health centers, and it provides less detail regarding the actual capabilities; as a result, their model is less useful as a guide to strategic planning, and makes no mention of benchmarking or peer comparison support.

3 HISTORY AND BACKGROUND OF THE MODEL

In January 2017 Internet2 formed an External Advisory Group (EAG) co-chaired by John Moore (Internet2) and Jim Bottom (Internet2). Invitations to join the EAG were sent out to a broad group of individuals from the community, mainly from universities but also from regional and national network providers. The invitations were sent to people in various roles, including researchers, research computing directors, network managers, administrators, CIOs, and faculty. The EAG started working with partners to develop a zeroth order cyberinfrastructure (CI) readiness maturity model that would allow campuses to answer a set of questions and determine where they are on the path to CI maturation. Identifying strengths and gaps would allow a national team to target workshops and help to shape audiences. In early 2018, the EAG started planning around two projects:

(1) CI Resource Platform - Build a community- maintained and Internet2-coordinated platform of information about existing and emerging CI resources.
(2) CI Maturity Model - Develop a process for engaging campuses to discuss and evaluate their need for CI help.

In April 2018, Internet2 hired Joel Cutcher-Gershenfeld as consultant to lead the development of the Maturity Model. Joel joined the EAG and started an effort to gather feedback from the community on relevant dimensions for "maturity," using a stakeholder alignment approach. Key stakeholders relevant to the Capabilities Model include the RCD professionals, researchers, students, libraries, campus administrators, funders, associations, data repositories, HPC network organizations, commercial providers, nonprofit organizations, and others.

The initial discussions concerning developing a Maturity Model were focused around answering the questions "What level of technical depth is required to determine CI maturity at an institution" and "What are system, software, and data facing elements and who are the key stakeholders for each facing". The conversations evolved into the formal facings mentioned below and that are used in the current Capabilities Model.

The EAG looked at other existing survey/models to provide guidance and to avoid duplicating other similar efforts in the community. EDUCAUSE [7] and a survey conducted by The Quilt [16] were used as references and members from those groups were invited to join the EAG. The EAG began the process of defining stakeholders for the model and planning an in-person workshop to develop the maturity model content.

A Maturity Model development workshop was organized and held in December 2018 in Denver, CO. The workshop group consisted of the EAG members and other subject matter experts from the community, including people in technical roles (network engineers, HPC/HTC managers, data managers, researchers, etc.) as well as administrative roles (CIO, AVPR, etc.), with Joel Cutcher-Gershenfeld serving as facilitator. An effort was made to select people with

experience across a range of roles and perspectives; we grouped these individuals using the concept of facings that emerged from a February 2017 "Professionalization in Cyberinfrastructure" workshop [1], and that was incorporated into further work by the CaRCC CI Professionalization working group [6]. In addition, the institutions represented included both large and small institutions, public and private universities, several EPSCoR states, historically black colleges and universities (HBCUs), and several organizations that provide infrastructure.

3.1 The Five Facings

The Model recognizes different roles that staff and faculty fill in supporting Research Computing and Data, with names that reflect who or what each role is facing (i.e., focused on). It is worth noting that larger organizations may have a team associated with each facing role, while smaller organizations may have just a few people who cover these different roles (i.e., a given staff member may engage in multiple facings).

(1) **Researcher Facing Roles.** Includes research computing and data staffing, outreach, and advanced support, as well as support in the management of the research lifecycle. Example roles include: *Research IT User Support, Research Facilitator, CI engineer*[2].
(2) **Data Facing Roles.** Includes data creation; data discovery and collection; data analysis and visualization; research data curation, storage, backup, preservation, and transfer; and research data policy compliance. Example roles include: *Research Data Management specialist, Data Librarian, Data Scientist.*
(3) **Software Facing Roles.** Includes software package management, research software development, research software optimization or troubleshooting, workflow engineering, containers and cloud computing, securing access to software, and software associated with physical specimens. Example roles include: *Research Software Engineer, Research Computing support.*
(4) **Systems Facing Roles.** Includes software package management, research software development, research software optimization or troubleshooting, workflow engineering, containers and cloud computing, securing access to software, and software associated with physical specimens. Example roles include: *HPC systems engineer, Storage Engineer, Network specialist.*
(5) **Strategy- and Policy Facing Roles.** Includes institutional alignment, culture for research support, funding, and partnerships and engagement with external communities. Example roles include: *Research IT leadership.*

3.2 First Versions of the Model

Groups of workshop participants with relevant experience were created for each facing, and they developed the initial survey questions in that area. There was much discussion about the number and granularity of the questions, and an initial set of several hundred questions was consolidated and pared down to the roughly 150 in the current public version. The structure of these questions is described more fully in section 4, below.

During the Spring of 2019, the group continued to refine and augment the model and develop hands-on workshop material to train people how to use the Model and get feedback on its effectiveness. An important goal was that this model be useful to all institutions, regardless of the size or state of their research enterprise. We heard from some institutions that "maturity" could feel judgmental or otherwise have negative connotations, and so it was resolved to change the name to the "Capabilities Model."

[2] "CI Engineers" have different roles at different institutions, and some might (also) be in the Systems Facing roles.

Table 1. Excerpt from the Researcher Facing Sheet

Research Computing and Data Staffing
Do researchers have access to introductory **user support and training** related to the use of research computing and data resources available at local, regional, and national level? I.e., are there researcher-facing engagement and support staff who provide this?
Are researcher-facing staff provided with **professional development and networking opportunities**?
Do researcher-facing staff have the skills and capacity to **broadly support researchers across levels** (graduate students to PIs) **and across domains** with information about the use and effectiveness of new technologies?
Can researcher-facing staff effectively **serve as advocates** for the research community **to leadership and IT governance?**

3.3 Initial Feedback from the Community

The first public workshop to present the Model was held in July 2019 at Practice and Experience in Advanced Research Computing (PEARC19) [15], as a half day workshop. This provided an important venue to test-drive the Model and receive community feedback. This workshop had 46 participants from a range of schools across the country (another dozen or so would-be participants were turned away due to room size limitations). The Model received an enthusiastic response. The participants felt that the Capabilities Model would be useful in assessing their current state, understanding their situation relative to their peers and the broader community, and as an input to their strategic planning processes.

A second public workshop was held at the EDUCAUSE Annual Conference 2019 [8] (as a full day workshop), which provided further feedback from the community. Sixteen campus leaders participated in the workshop, with a deeper dive into the details of the Model and how it would actually be used in strategic planning. Participants each created a personalized copy of the assessment tool for work at their institutions, and again showed enthusiasm for the Model and its potential.

Participants from institutions who were just starting to spin-up RCD efforts found the Model and workshop particularly relevant to help them define their needs.

4 STRUCTURE AND FEATURES OF THE CAPABILITIES MODEL AND ASSESSMENT TOOL

There are four key concepts that underlie the Model, around which the tool is organized. The primary organizing concept is that of the Five Facings, defined above; the other three are: Deployment at Institution; Multi-Institutional Collaboration; and Service Operating Levels/Support Levels (described in sections 4.2 to 4.4, below).

The initial version of the assessment tool has been implemented as a spreadsheet, developed in Google Sheets to facilitate collaborative work among campus teams conducting an assessment. The tool is presented as a series of sheets, each of which represents one of the facings as described in section 3.1, above. On each of these sheets there is a list of questions that represent key aspects or factors associated with supporting Research Computing and Data; the questions are grouped into themes both for general usability of the tool, and as well to provide a more granular summary of capabilities (an excerpt is presented in Table 1).

For each row, an assessment team will answer the question from three perspectives or lenses, which are the three concepts mentioned above and described in sections 4.2 to 4.4, below. Each answer (chosen from a drop-down list) has

a corresponding numeric value, and these are combined to produce a coverage value for the row. The tool supports differential weighting of each lens in the calculated row value, so that, for example, the Multi-Institutional Collaboration value has less weight than Deployment at Institution and Service Operating Level. The calculated row values are further combined to produce a summary coverage value for the thematic groupings, and for the facing as a whole.

It is possible that certain questions will not apply to a given institution (e.g., if an institution has no researchers working with sensitive data, a question about secure storage for this data may not apply); assessment teams can mark such a question as not applicable, and the lack of coverage in that area will not (unfairly) reduce the summary coverage value.

As an assessment team works through the tool, they may identify specific questions as an area of priority in their institutional planning. A column in the facing sheets allows them to mark these priorities (these values do not contribute to the coverage values and are just for local strategic planning work). This is an example of a specific feature that was added in response to feedback from users of the early versions of the tool.

An important aspect of support for RCD recognizes that different domains have different needs, and different traditions. Researchers in the physical sciences have a long history of computational methods, and yet researchers in the social sciences and even (digital) humanities are increasingly adopting computational and data-intensive methods. To reflect this in the Model, an additional section on each Facing sheet captures the level of support provided across a range of high-level domains at the institution (Arts and Humanities; Computer Science and Engineering; Health and Life Sciences; Physical Sciences; and Social Sciences). This section may have greater impact for some facings (e.g., recognizing that providing researcher facing support for humanities researchers is quite different than for physical science researchers), while for other facings there may be less distinction by domain (e.g., where systems facing functions, and/or strategy and policy facing functions are shared across the institution).

In addition to the facings sheets, the assessment tool also presents a summary sheet that rolls up the assessment results into a single page for use in presentation to leadership. The summary page includes the coverage values for each facing sheet (which can be expanded to the more granular thematic groups), as well as a graphical summary, and a summary of the questions that the team marked as a priority for the institution. Throughout the tool, conditional formatting is used to provide a heat-map visualization of areas that have stronger and weaker coverage. The summary page is illustrated in Figure 1.

4.1 The Five Facings Sheets

The assessment tool defines one sheet for each facing; each sheet poses questions about aspects of RCD for the associated role. For each question, the assessment team indicates institutional coverage according to the Model aspects defined in sections 4.2 to 4.4, below. Institutions that work with the assessment tool generally involve people who work in the different roles, to fill out the respective section.

In early versions of the tool, each facing had a single list of questions that rolled up to a single summary coverage value; in response to requests for more granularity in the summary, and to help respondents orient themselves as they work through the questions, we added thematic groupings to the questions on each facing sheet. The assessment tool has just over 150 questions, with about 20 to 30 on each facing except for the Systems Facing sheet, which has 57 questions in a two-level grouping structure.

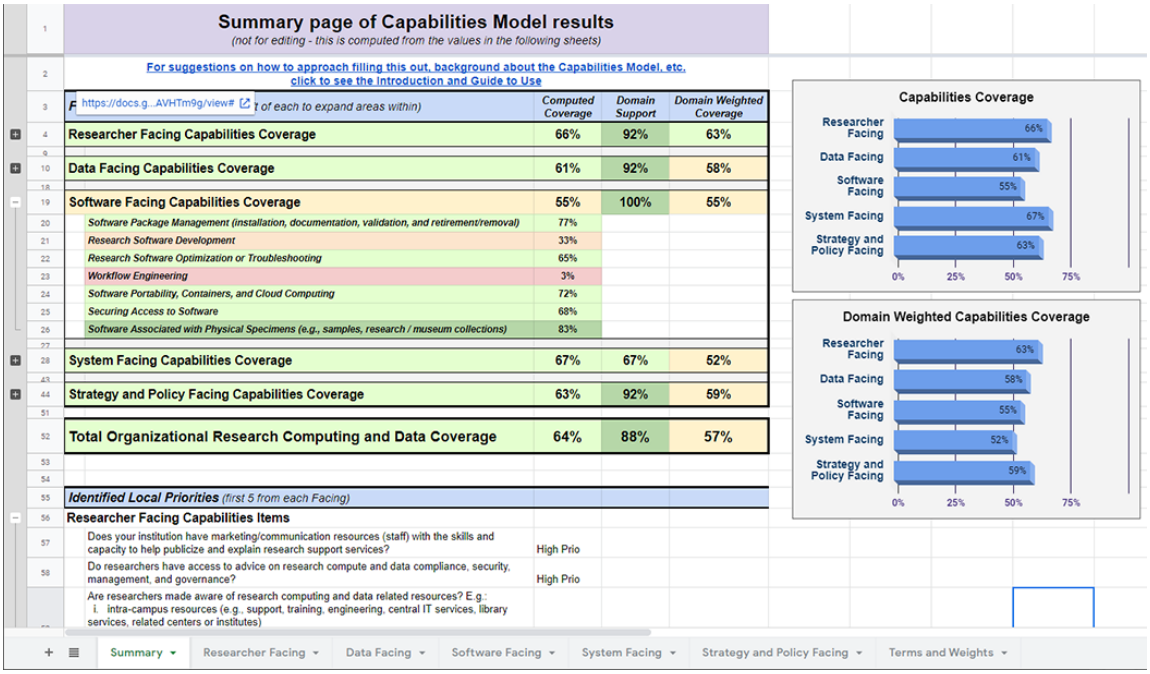

Fig. 1. Summary Page of the Assessment Tool

4.2 The "Deployment at Institution" Lens

The Model assessment tool asks organizations to rate the level of deployment within their institution, for each of a series of aspects or factors associated with supporting RCD. Note that it should not matter how or where support is implemented (a lab, a central campus facility, a national facility, or the cloud). The point is whether researchers have access and are supported for effective use.

Broadly speaking, deployment is a rating of the level and especially the breadth of support across the institution. The deployment levels are presented below [3]

(1) **No deployment or support** (and no work underway).
(2) **Tracking potential use** (real exploration underway).
(3) **Planning, piloting, and initial deployment** (work towards a production service, possibly including pilot or exploratory service).
(4) **Deployment to parts of the institution** (production-quality technical capability or service is in place, but only to certain users, departments, etc.).
(5) **Deployment institution-wide** (full production-quality technical capability or service is in place, with deployment providing equitable access institution-wide).

We note that if the local cost model makes access challenging for some groups (e.g., schools or departments), or if support staff lack skills or capacity for the full range of institutional domains, this may not constitute an institution-wide deployment.

[3]These levels parallel those used in the EDUCAUSE Core Data Service (CDS) data survey regarding service and technology deployment [7].

4.3 The "Multi-Institutional Collaboration" Lens

The Model assessment tool also asks organizations to rate the level of collaboration across institutions, for each of the aspects or factors of support for RCD. In the typical case of a university campus, multi-institutional would refer to collaborating with other universities (e.g., across a state system, with other universities in a region, or with some set of national or even international peers). For a narrower scope of institution (e.g., a College of Engineering, a Medical School, etc.), multi-institutional could also refer to collaboration with other schools or colleges in the same university. The levels are

(1) **No existing multi-institutional collaboration**
(2) **Exploring multi-institutional collaboration**
(3) **Piloting multi-institutional collaboration**
(4) **Sustaining multi-institutional collaboration**
(5) **Leading multi-institutional collaboration**

This factor is not as heavily weighted as the others in the Model but is seen as an important aspect of supporting research computing and data, given the highly collaborative and distributed nature of research. Beyond the R1 institutions, resource constraints may make multi-institutional collaboration essential. There are now initiatives under way, for example, among HBCUs and Tribal Colleges and Universities (TCUs) with collaboration on RCD seen as key to their accomplishing together what they cannot do separately.

For certain activities, the technology or service itself may be part of a collaboration (directly sharing resources among collaborating partners). For others, the staff supporting the service may be part of a community of practice/expertise that develops or shares resources like documentation, training materials, etc. Even for activities that are very locally or inwardly focused (e.g., aspects of data center operation), there can be collaboration on everything from the development and management of the data center, to defining the standards and best practices for staff who perform key functions.

4.4 The "Service Operating Levels/Support Levels" Lens

As organizations and services mature, support transitions from ad hoc projects, to repeatable and defined services, and eventually to managed activities that work to optimize the service operations and functionality. A common model for describing and structuring this activity is known as IT Service Management (ITSM). Although RCD services do not typically follow ITSM or change-management processes common in enterprise IT, ITSM in this context is characterized by adopting a process approach towards management, focusing on researcher needs and IT services for researchers rather than IT systems, and stressing continual improvement [3]. The Capabilities Model includes this dimension to let organizations assess the robustness, resilience, and sustainability of the support for a given aspect or factor of Research Computing and Data.

While not all activities are easily understood as "services," the concept may be mapped to "activity" or "practice," to translate the Service Operating Level to each activity or factor. For the Strategy and Policy Facing sheet, a number of institutions struggled to understand these levels, and so we adjusted these terms for that facing in the Model to more closely map to those activities and practices. The levels are:

(1) **No existing service or support / No existing support or awareness**
(2) **Substantial Risk of Failure / Very limited Support, and At Risk**
(3) **Lights-On Only / Minimum Resources & Commitment**
(4) **Basic/Economy / Basic Sustained Support and Awareness**

(5) **Priority/Premium / Strong Support, Awareness, Commitment**

5 EXPERIENCE WITH THE MODEL

While we continue to gain experience in the broader community, we have received very strong positive feedback from our early efforts in several venues and engagements.

5.1 PEARC19 Workshop

The in-person workshop at PEARC19 referenced in section 3.3 above, could have easily filled a room double the capacity of the venue provided. Workshop evaluations were strongly positive. Comments included:

"This may have been the most useful workshop I've been to regarding research."

"This was excellent—such a great intro."

"Clear and helpful facilitation of workshop."

5.2 EDUCAUSE 2019 Workshop

The full-day workshop held at EDUCAUSE 2019, referenced in section 3.3 above, was a deep dive meant to include a smaller number of participants, with more opportunity for individualized attention and institution-specific dialogue. In particular, participants discussed how the model would be integrated into the strategic planning processes on their respective campuses. Evaluations were very positive; 95% of the evaluations were "Excellent" and the participants thought the full-day workshop was the appropriate engagement timeframe. Comments included:

"Best session ever! Thank you for all of your work and a great presentation."

"Great session with concrete take-aways."

"Great to leave the workshop with an actual tool to be used with campus leadership."

5.3 UC-wide Research IT Discussion Group

The University of California 10-campus system, including 5 medical centers and 3 DOE national laboratories, receives over $5 billion in research contracts and grants annually. The support activities for research computing and data look different on each campus and are at varying stages of development. In June 2019, members of the CaRCC Capabilities Model working group presented the Model to the UC Research IT Committee bi-annual meeting and to the UC Research Facilitators annual workshop, both consisting of representatives from each UC location. As this was in the early stages of the Model, the meeting was a demonstration of the existing beta version and a discussion of how it might be used at each campus. The positive response was overwhelming, and feedback was incorporated into subsequent versions of the tool.

5.4 Individual Engagements

In September 2019, members of the CaRCC Capabilities Model working group were invited to present the tool to San Diego State University's Research Technology Working Group. SDSU is an R2 institution that recently committed to growing their research computing and data support campus wide. SDSU's Research Technology Working Group is committed to the growth of their research support and were interested in the tool as a way to measure the state of their services and to plan for the future. The meeting content was designed to be predominantly hands-on use of the tool, with a very short demonstration/introduction. The group spent the majority of their time working through the Model, discussing actual campus situations and asking questions of each other and the CaRCC representatives.

5.5 Common Observations

Workshop participants who regularly work with campus leadership reported that the Model will be of significant value as they work to establish and explain needs and priorities in their RCD programs. On a similar note, participants noted the value of having a common rubric and language for talking about research computing and data support. They commented that the Model will simplify discussions and collaboration within the community.

Many institutions are very interested in the capacity to benchmark their capabilities against peers and are eager to have some sort of community dataset that enables this (although there is also broad interest in privacy controls over individual institutions' data). This is a priority for our work going forward (see also section 6.1, Roadmap for the RCD Capabilities Model).

5.6 Lessons Learned

A wide range of research institution representatives participated in the early sessions, and their input and comments shaped the foundation for the Capabilities Model. However, despite best efforts to be inclusive of a range of perspectives, the initial public workshop revealed a number of aspects to be added or clarified in subsequent versions of the Model. Feedback from workshops and information sessions provided vital guidance for improvements. Some of the issues that stood out in particular:

- There was a significant tension between keeping the number of questions to a modest range and having questions that were too broad.
- We initially modeled software-facing and data-facing roles together but were convinced that there is sufficient distinction between these to justify separating them.

Additionally, it became clear that the Model is not easily used without guidance documents and proposed webinars and help sessions. The on-site session with San Diego State University provided the development team with the understanding that in-person and personalized guidance could be most productive with some institutions. This also informed our outreach and support plans going forward.

6 CONCLUSIONS AND NEXT STEPS

We have described a Capabilities Model for Research Computing and Data, developed through a collaboration of organizations that are closely engaged in this work. The Model reflects the contributions of many subject matter experts across a range of roles, and representing a diverse set of universities and organizations. The Model and the associated assessment tool have met with enthusiastic response from the community at a series of workshops, presentations, and focused engagements; participants at these events have also contributed to the refinement of the Model and the tool to produce an initial version that is now in public use. The model helps institutions answer the questions:

- How well is my institution supporting computationally- and data-intensive research, and how can we get a comprehensive view of our support?
- What is my institution not thinking about or missing that the community has identified as significant?
- How can my institution (and my group) identify potential areas for improvement?

In addition, the interest within the community for a community dataset that aggregates the assessments of many institutions has been very high, and strongly motivates the next phase of development to produce a tool that enables this functionality.

6.1 Roadmap for the RCD Capabilities Model

The next phase of work on the RCD Capabilities Model builds upon the work completed to date to provide an assessment tool and associated supporting documentation and support resources. Our plan draws upon early experience with users of the (Google) spreadsheet implementation of the questionnaire, and an associated signup form that gathers basic demographic data about each institution using the tool. We are gathering and documenting requirements for an online (web-based) version of the questionnaire that is backed by a database, as well as a dashboard that allows users in the community to understand their assessment in the context of the broader community of institutions. This dashboard will also provide important insights into the state of the community as a whole, and in segments of interest (e.g., geographic regions, Carnegie classifications, EPSCoR eligible schools, MSIs, etc.).

This next phase continues as a collaboration among CaRCC, Internet2, and EDUCAUSE. We expect to coordinate with and benefit from the experience EDUCAUSE has in providing their annual Core Data Service survey and are open to working with other groups willing to provide input and help. The timeline to develop the next version of the tool is subject to continued/renewed funding (undertaking and sustaining these efforts is a challenge).

Going forward, the continuing commitment is for the Capabilities Model to reflect the evolving work of supporting research computing and data, helping organizations and institutions to adjust and align their capabilities to address changes in technology, and the expanding use of data, software, and compute resources across virtually all fields and disciplines.

ACKNOWLEDGMENTS

This work has been supported in part by an RCN grant from the National Science Foundation (OAC-1620695, PI: Alex Feltus, "RCN: Advancing Research and Education through a national network of campus research computing infrastructures – The CaRC Consortium"). The Model, the assessment tool, and other associated resources were developed with the generous contributions of time and expertise from the 2018 workshop participants, and the working group members: Alex Feltus, Ana Hunsinger, Cathy Chaplin, Claire Mizumoto, Dana Brunson, Deborah Dent, Doug Jennewein, Gail Krovitz, Galen Collier, Jackie Milhans, James Deaton, Jen Leasure, Jill Gemmill, Jim Bottum, Joe Breen, Joel Cutcher-Gershenfeld, John Hicks, John Moore, Karen Wetzel, Mike Erickson, Patrick Schmitz, Preston Smith, Timothy Middelkoop, and Thomas Cheatham. In addition, individuals at a number of Universities provided valuable feedback on early versions of the model and assessment tool, for which the working group is very grateful.

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