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Building Support for Research Data Management: Biographies of Eight Research Universities

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Abstract

Academic research libraries are quickly developing support for research data management (RDM), including both new services and infrastructure. Here, we tell the stories of how eight different universities have developed programs of RDM support, focusing on the prominent role of the library in educating and assisting researchers with managing their data throughout the research lifecycle. Based on these stories, we construct timelines for each university depicting key steps in building support for RDM, and we discuss similarities and dissimilarities among universities in motivation to provide RDM support, collaborations among campus units, assessment of needs and services, and changes in staffing.

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Introduction

As data gain recognition as stand-alone outputs of scholarly research with the potential to be re-used or re-purposed and thus accelerate advances in knowledge (Atkins et al., 2003; Hey, Tansley and Tolle, 2009), academic libraries are increasingly developing infrastructures and services to support the management of research data on their campuses (Heidorn, 2011; Monastersky, 2013; Tenopir et al., 2012). In 2012, data curation was identified as one of the top ten trends in academic libraries (ACRL, Research Planning and Review Committee, 2012). In 2013, a survey of Association of Research Libraries (ARL) members found that 100% of responding libraries offer at least one type of data support service, 74% offer services that specifically support research data management (RDM), and many are planning to expand their range of data services (Fearon et al., 2013).

Although most academic libraries are moving toward providing services to support RDM, the paths taken by each institution are unique and defined by place-specific pressures and needs (Kouper et al., 2013; Zilinski et al., 2013). A recent report comparing the experiences of three institutions (University of Wisconsin-Madison, University of Massachusetts-Amherst, and Tufts University) reveals both commonalities and differences in approaches to developing new programs of RDM support (Raboin, Reznik-Zellenk, and Salo, 2012). For instance, although the initial focus of librarians at all three institutions was on providing consultation regarding data management plans (DMPs) for grant applications, there were substantial variations among institutions in the amount of administrative support for these efforts. Similarly, an earlier report containing case studies of six universities (Purdue University, University of California-San Diego, Cornell University, Johns Hopkins University, University of Illinois-Chicago, and Massachusetts Institute of Technology) highlights differences in how each institution supports e-science, such as whether support programs are enacted in an institution-wide or unit-specific manner, the role of the library, the types of services provided, and strategies for developing a workforce equipped to support the needs of science researchers (Soehner, Steeves, and Ward, 2010).

Here, we tell the stories of how eight universities (Cornell University, Emory University, Johns Hopkins University, Pennsylvania State University, Purdue University, University of Illinois at Urbana-Champaign, University of Michigan, University of Virginia) are developing programs of RDM support, concentrating on the prominent role of the library in providing services to educate and assist researchers with managing data before, during, and after their research projects. An analysis of these stories allows us to identify both similarities and dissimilarities in initial motivation to provide research data services, collaborative relationships among the library and other campus units, focus on particular research domains, approaches to assessing needs and services, and changes in staffing. As a complement to the 'snapshots' of library RDM support provided by the recent ARL survey (Fearon et al., 2013), our case studies, or 'biographies', of the approaches taken by different institutions showcase the current state of RDM support at several research universities and give insight into how these support programs emerged and evolved over time.

Methods

All eight selected institutions are research universities classified by the Carnegie Foundation[1] as having 'very high' research activity. This selection consisted of both public and private universities with student populations ranging from approximately 7,000 to over 80,000. Although the institutions were at different stages of developing programs of RDM support, all employed at least one staff member whose job duties were fully dedicated to RDM.

Semi-structured interviews with representatives of the institutions were conducted between October 2012 and December 2013. Interviews occurred by telephone and were typically one hour in duration. Interviewers asked several questions belonging to four different categories: context, content, infrastructure, and challenges/opportunities. Context questions pertained to the historical origin of RDM support at the university, the current state of RDM support, and the assessment of RDM support needs or outcomes. Content questions pertained to the people involved in providing RDM support, the types of services offered, the types of repository systems used, and university policies on RDM. Infrastructure questions pertained to funding models enabling the provision of RDM support and the role of library, information technology, and/or supercomputing facilities. Challenges/opportunities questions pertained to staffing, outreach to researchers, and addressing discipline-specific or interdisciplinary needs. Interviewers collected responses to the questions in spreadsheets, which were subsequently checked for accuracy by the interviewees.

Summaries of the interviews were written to highlight the unique aspects of RDM support at each institution. These summaries were read and approved by the interviewees.

Cornell University

Cornell University is a research university in Ithaca, New York with a student population of over 14,000 undergraduate and 7,000 postgraduate students. As New York State's federal land-grant institution, Cornell is a partner of the State University of New York and also home to a private endowed university. Cornell hosts more than 100 interdisciplinary research centers, institutes, and laboratories, including two national research centers: the Cornell High Energy Synchrotron Source and the Cornell NanoScale Science and Technology Facility. To support this thriving research environment, Cornell University Library seeks to meet researchers' data management needs through participation in Cornell's RDM Service Group (RDMSG)[2].

RDMSG launched in 2010 after the National Science Foundation's announcement of DMP requirements for future grant proposals. However, prior to this announcement, campus-wide groups were already working toward addressing RDM challenges, including the library's Data Working Group that formed in 2006 to monitor developments in data-related activities on campus and recommend strategic opportunities for the library to engage in data curation. This group later evolved into the library-led Data Executive Group, comprised of members from a variety of campus organizations such as Cornell Advanced Computing and the Cornell Institute for Social

1 The Carnegie Classification of Institutions of Higher Education: http://classifications.carnegiefoundation.org

2 Cornell University, Research Data Management Service Group: http://data.research.cornell.edu

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and Economic Research. Another campus group, supported by the Office of the Vice Provost for Research, was the Data Intensive Science Organization for Virtual Exploration and Research Service Group, which sought to develop cross-disciplinary data archival and discovery tools between 2008 and 2010. The efforts of these groups, which comprised expertise in technology, software, and RDM, were essential to the establishment of the RDMSG.

As a virtual organization, RDMSG is composed of a management group, a consultant group, and implementation teams (Block et al., 2013). The management group includes decision-making administrators from campus service providers such as the library, Cornell Advanced Computing, the Cornell Institute for Social and Economic Research, campus Information Technology, other stakeholders (e.g., chief information officers from the Ithaca and Weill campuses), and a staff coordinator. The consultant group consists of science, geographic information systems, metadata, and medical librarians; scholarly communication experts; a senior policy advisor; and staff from other campus service providers. Implementation teams consisting of various campus service provider staff conduct assessments, provide outreach and training, and initiate new projects. RDMSG is sponsored by the Office of the Vice Provost for Research and the University Librarian and is guided by an 11-member faculty advisory board.

Complementing their strong web presence, RDMSG members offer researchers guidance and instruction on various aspects of RDM, such as preparing DMPs, intellectual property and copyright, data publication, metadata, data analysis, use of the eCommons[3] institutional repository, and best practices for data management. RDMSG members also connect researchers to campus service providers with expertise in data storage, high performance computing, collaboration tools, and sensitive information. Campus service providers offer these services as part of RDMSG while functioning based on separate funding models.

Emory University

Emory University is a private research university in Atlanta, Georgia with approximately 14,000 students, nearly half of which are graduate or professional students. Since 1996, the Electronic Data Center[4] at Emory University Libraries, originally staffed by a Coordinator of Numeric Data Services and joined by a Coordinator of Geospatial Data Services in 2007, has helped researchers locate and prepare existing datasets for analysis. In 2011, recognizing its potential to provide more comprehensive research support and inspired by advances in RDM made by other academic libraries, library representatives participated in the ARL/Digital Library Federation (DLF)/Duraspace E-Science Institute[5], which resulted in two major outcomes: (1) the hiring of a Data Management Specialist and an e-Science Librarian/Council on Library and Information Resources (CLIR) Postdoctoral Fellow in 2012, and (2) the formation of an RDM working group consisting of these two staff members, Electronic Data Center librarians, science and social science librarians, health science informationists, the University Archivist, the Scholarly Communications Librarian, and the User Experience Librarian.

These actions quickened the library's pace in developing services to support RDM. One of the first major efforts of the RDM working group was conducting a survey- and

3 Cornell University, eCommons@Cornell: http://ecommons.cornell.edu
4 Emory University Libraries, Electronic Data Center: http://edc.library.emory.edu
5 E-Science Institute: http://www.arl.org/focus-areas/e-research/e-science-institute

interview-driven needs assessment of campus researchers to gain insights into their data management practices and perspectives[6]. Librarians used this needs assessment as a way to reach out to researchers, and the results are currently being used to guide the development of appropriate data-related services spanning the entire research lifecycle. In addition to talking to researchers, RDM working group members are systematically holding conversations with campus administrators to further understand the RDM resources that already exist on campus and to forge new partnerships. They also enabled institutional authentication to the online DMPTool[7] and provide data management workshops for researchers. Furthermore, plans are underway to provide discipline-specific support for DMP preparation, assistance with data documentation, and education on best RDM practices for new graduate students.

Despite the sharp uptick of engagement in RDM initiatives, the library faces several challenges to developing a full RDM support program. For instance, OpenEmory[8], the library's open scholarly works repository, is approved by the Emory University Faculty Council to accept only peer-reviewed journal articles. Therefore, the library is exploring alternative ways of providing infrastructure for data sharing and preservation, such as collaborating with the Georgia Institute of Technology to participate in a multi-institutional pilot implementation of the Dataverse Network, led by the Southeastern Universities Research Association. Members of the RDM working group have primarily utilized grassroots approaches to developing and marketing their services, and any extension of the library's current level of support is limited by having only one staff member whose time is fully committed to RDM. However, recent changes in library administration, the absorption of the Electronic Data Center into the new hybrid Center for Digital Scholarship, and a new top-down directive to provide recommendations for RDM support, including a formally chartered RDM working group with broader representation from Emory Libraries and Information Technology, present new challenges and opportunities for developing services in cooperation with other campus units, which could effectively meet needs associated with all phases of the research data lifecycle.

Johns Hopkins University

The Johns Hopkins University (JHU) is a private research university in Baltimore, Maryland with approximately 5,000 undergraduate and 2,000 postgraduate students. JHU is a world leader in both teaching and research and has ranked first among US universities in research and development spending for decades. To support the unique and diverse research environment on campus, the Sheridan Libraries at JHU have pioneered the development of data infrastructure over the last decade, culminating in the launch of the JHU Data Management Services (JHUDMS)[9] in 2011 as a result of "research and development, prototyping, needs assessment, capacity building and sustainability planning" (Choudhury, 2013).

Three events and milestones over the course of the development of JHUDMS are particularly worth noting. First, an important series of dialogues was held between the Sheridan Libraries and faculty members to discuss the provenance, archiving, and

6 Emory Libraries and Technology, Research Data Management – Faculty Survey Results: http://guides.main.library.emory.edu/datamgmt/survey
7 University of California, DMPTool: http://dmp.cdlib.org
8 OpenEmory: http://open.library.emory.edu
9 JHUDMS: http://dmp.data.jhu.edu

preservation of different types and levels of scientific data, particularly data generated by the Sloan Digital Sky Survey. By working with faculty from community-based projects, the Sheridan Libraries came to better understand the complex nature of scientific data and are now better prepared to meet researchers' data needs (Choudhury, 2013). Second, in 2009, the Sheridan Libraries received an NSF DataNet program award to launch the Data Conservancy[10], which aimed to build software underlying sustainable infrastructure for data sharing, access, re-use, and preservation with a focus on interdisciplinary science. Third, in 2012, the Data Conservancy successfully deployed an alpha release of its software to launch the JHU Data Archive, a data repository for JHU researchers (Mayernik et al., 2012). The JHUDMS now encompasses a continuum of storage, archiving, preservation, and curation layers to support RDM and data sharing through the JHU Data Archive (Shen and Varvel, 2013).

Other highlights in the process of the JHUDMS development include synergy among research and development and business planning efforts with two Sheridan Library departments – the Digital Research and Curation Center and the Entrepreneurial Library Program. To prepare for the official launch of the JHUDMS, these two units worked to identify the data management needs of researchers by conducting a survey of researchers receiving NSF funding, analyzing institution-wide trends in NSF proposals and awards, performing a cost analysis of data storage and disaster recovery, piloting DMP support, developing a sustainable business model, and submitting a budget request to the Provost.

Today, the JHUDMS provides researchers with both pre-award and post-award research RDM support (Pralle, 2012). The costs of pre-award services are covered by JHU Deans and offered without direct charge to faculty or grants. During this initial consultation service, the JHUDMS provides expert guidance on developing DMPs by working through a questionnaire[11] that represents the core framework for data management consultations (Choudhury, 2013). Post-award services consist of detailed data management support and data archiving into the JHU Data Archive. A post-award fee is written into grant proposal budgets by researchers wishing to utilize the services. This fee, which is subsequently charged against grants at 2% of total direct cost, provides five-year archiving of the project's data with the option for an extension. Each deposited dataset is given a digital object identifier (DOI) for attribution and citation.

In addition to consultation services, the JHUDMS also provides campus-wide training in best practices for RDM, with more specialized training sessions (e.g., managing data with personal identifiers, tools for data encryption and back-up, etc.) planned for the future. At the moment, some in-depth services (e.g., unlimited archiving of data indefinitely) are out of scope (Pralle, 2012). In summary, the JHUDMS presents a case in which library initiatives and activities were successful in designing comprehensive research data services that were launched within a relatively short period of time.

Pennsylvania State University

Pennsylvania State University (Penn State) is a public research university comprising 24 campuses across the state. Today, Penn State is one of the largest US universities, with enrolment totalling approximately 76,000 undergraduate and 9,000 graduate, medical,

10 Data Conservancy: http://dataconservancy.org

11 Data Management Planning questionnaire: https://dataconservancy.org/education/data-management-planning/

and law students. Moreover, Penn State's total research expenditures have dramatically increased by $241 million (~40%) over the last ten years.

To help support this thriving research environment, in 2012 the University Libraries and Information Technology Services launched a repository service, ScholarSphere[12], built using the Hydra/Fedora technology stack. The service enables faculty, staff, and students to collect their work in a single location and create durable and citable records of their papers, presentations, publications and datasets. Using this service, researchers can also comply with funding agency requirements for RDM and publicly share the outputs of their projects. The release of ScholarSphere also marked the creation of its home department, Publishing and Curation Services, which is based in the library's Research and Scholarly Communications office. Publishing and Curation Services offers services to help faculty and students carry out a lifecycle management approach to research workflows, experiment with new scholarly methods and tools, and widely disseminate the products of their research whether they be datasets, conference presentations or article pre-prints. As a repository that accepts datasets, ScholarSphere represents an important start to the library's RDM services.

In 2011, prior to the launch of ScholarSphere and the creation of Publishing and Curation Services, the library charged a team to develop resources to help researchers comply with the NSF's DMP requirement. The Research Data Management Services Team, consisting of eight full-time employees including four subject specialists, began leading the library's inreach and outreach activities for data curation. Through such engagement, the Research Data Management Services Team was successful in: 1) distributing an internal survey to assess the RDM needs of faculty who were current or pending principal investigators on NSF grant-funded projects, 2) communicating with researchers about the emerging ScholarSphere repository service, and 3) piloting a data curation profile project by interviewing a researcher about his data and documenting the findings.

In addition to RDM, Publishing and Curation Services also supports scholarly publishing (e.g., online journals) and digital scholarship (e.g., research investigations leveraging digital humanities tools and methodologies). The department works collaboratively with liaison librarians as well as other library units, such as Digitalization and Preservation, the Special Collections Library, Information Technology, and Digital Library Technologies. In response to requests for help from researchers, Publishing and Curation Services also created new positions such as a Publishing Services Web Developer and Digital Humanities Research Designer. The library also plans to hire a Copyright Program Officer and a CLIR/DLF Data Curation postdoctoral fellow, two employees who would work closely with Publishing and Curation Services.

Despite this progress, challenges still await, such as understanding the requirements for supporting preservation of and access to restricted data and continuing to develop programmatic outreach opportunities for educating graduate students and early-career faculty in RDM. What does it cost to implement a full-on, library-based data curation service? Who needs to be involved? What does 'service' mean in such a context, particularly if this is a chance for librarians to act as research partners with faculty and students? How can such services be sustained yet evolve over time? These are only a few of the questions for which Publishing and Curation Services is trying enact viable, flexible solutions.

12 ScholarSphere: https://scholarsphere.psu.edu/

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Purdue University

Purdue University is a public research university in West Lafayette, Indiana with over 39,000 students, including 7,400 graduate and professional students. Offering over 70 graduate programs, the campus is also home to Discovery Park, a $600 million research and learning complex, and Research Park, the largest cluster (100+) of technology-based companies in the state, thus fostering a diverse and active research environment.

In 2004, the Dean of Libraries was challenged by the University President to engage the library in strategic interdisciplinary campus initiatives. In response, librarians worked with faculty on specific projects that revealed challenges in data organization, description, dissemination, and discovery. Awareness of these library consultations grew among researchers and through conversations between the Dean of Libraries and other administrators, leading to the formation of research and data services in 2005 and the establishment of the Distributed Data Curation Center (D2C2)[13] in 2006. Today, the library's RDM efforts are organized into three parts, which together provide a continuum of services to researchers and students.

1. Purdue University Research Repository (PURR) and D2C2.

Consultation services and related resources, such as the DMPTool, are embedded into PURR[14], a scientific collaboration tool built on the HUBZero platform. Promoted and maintained by D2C2, PURR represents an institutional collaboration among the Purdue Libraries, the Office of the Vice President for Research, and Information Technology allowing researchers to create project space to share and use research datasets, with project web pages and social network features for research team members. PURR facilitates scientific collaboration, publishes and assigns DOIs to datasets, and provides Ask-a-Librarian chat or e-mail 'data reference' services. The repository manager is automatically contacted by the Office of the Vice President for Research when researchers indicate using PURR within their DMPs or informally contacted via word-of-mouth as a result of librarian-faculty relationships built over time. Liaison librarians work closely with the repository manager to incorporate the use of repository services during data management planning. Faculty consultations also encompass identifying metadata schemas, discussing target datasets for dissemination, and research workflows and practices. As librarians may collaborate closely with researchers on developing strategies for the management and dissemination of research data, they sometimes become co-PIs on grants. The library also hosts Databib[15], an online annotated bibliography of data repositories useful for data producers and users, librarians, funding agencies, and publishers.

2. Data and Metadata Group

Liaison librarians engage in a range of services related to data reference, consultation, and collection development. A centralized Data and Metadata Group, formed in 2013, develops RDM expertise, resources, and tools and provides ongoing RDM training to librarians. This team leads efforts related to the Data Curation Profile Toolkit and Data Information Literacy that help librarians actively engage with researchers. Each group

13 D2C2: http://d2c2.lib.purdue.edu
14 Purdue University Research Repository (PURR): https://purr.purdue.edu
15 Databib: http://databib.org

member maintains ties with a specific library unit to explore issues and needs for disciplinary constituents and provides additional consultation and expertise for liaison librarians. The group currently includes a metadata specialist and three data specialists who have dotted lines reporting to three library divisions. A remaining challenge, however, is that subject librarians have many responsibilities and cannot fully devote themselves to research data service demands. Yet as data information literacy needs grow, it is possible that their teaching and instruction will incorporate more data-related components.

3. Research and Collaboration

Collaborating with researchers on interdisciplinary projects will continue to be a service provided by D2C2. Until recently, the D2C2 research unit was comprised of an Associate Dean of Research, two Data Service Specialists, and one Interdisciplinary Research Librarian, who investigated and developed solutions to data curation challenges. Now, however, the Data and Metadata Group trains and collaborates with subject librarians on data-related issues within particular disciplines and is helping the library expand beyond research-focused projects to offering a more formalized services program.

University of Illinois at Urbana-Champaign

The University of Illinois at Urbana-Champaign is a public research university with approximately 32,000 undergraduate and 11,000 post-graduate students. In 2006, the university library, which is one of the largest in the United States, launched a repository for scholarly materials called Illinois Digital Environment for Access to Learning and Scholarship (IDEALS)[16] based on a DSpace platform.

Since 2010, the library has been a key voice within campus-wide discussions on the storage and management of research data. In particular, there have been two primary task forces – the Data Storage Services Task Force and the Campus Data Stewardship Task Force – comprised of representatives from a broad spectrum of campus research and administrative organizations, including the library, Office of the Chief Information Officer, College of Media, Center for Multimedia Excellence, College of Engineering, School of Chemical Sciences, Materials Research Laboratory, Office of the Vice Chancellor for Research, and Office of the Registrar.

Within the Scholarly Commons unit of the library, services to support the management of research data have primarily been designed and implemented around IDEALS and led by the IDEALS Coordinator. In part due to the library's participation in the ARL/DLF/DuraSpace E-Science Institute in 2011, liaison librarians have begun to play a more prominent role in providing research data services by offering RDM workshops to faculty and students, reaching out to researchers, and providing consultation on DMPs. The library has also begun to create new positions that are specifically designed to provide data support, including a Life Sciences Data Services Librarian and an Engineering Data Services Librarian. Engineering librarians, in particular, have been most heavily involved in RDM initiatives, although more recently a digital humanities librarian has also taken an active role in supporting the production and preservation of research data. However, a relatively small number of librarians take

16 IDEALS: https://ideals.illinois.edu

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responsibility for supporting the data management needs of researchers, and there is currently no centralized data center or physical place in the library from which data services are provided. As such, the development of additional research data services may follow a reorganization of the library, primarily after filling a new position of Director of Research Data Services.

University of Michigan

The University of Michigan is one of the nation's leading public universities with approximately 43,000 students. Research is central to the university's mission and conducted throughout its 19 schools and colleges and 200 centers and institutes. With a total annual research and development expenditure of over $1.5 billion, the University of Michigan is a thriving environment fostering highly collaborative and interdisciplinary research.

Since the early 2000s, the University of Michigan Library has been central to the development of RDM services through the work of a data librarian and its strong affiliation with the Inter-university Consortium for Political and Social Research (ICPSR), which has in its 50-year history provided global leadership in data access, curation, and methods of analysis in social science research. The hiring of a full-time Spatial and Numeric Data Services Librarian in 2005 initiated an expansion of services that later included implementation of the institutional repository, Deep Blue[17], in 2006. Concurrent with the library's growing data services, campus-wide discussions on data began within a Blue Ribbon Panel, commissioned by the Associate Vice President for Research Cyberinfrastructure/Chair of the Information Technology Council and the Chief Information Officer/Associate Vice President for Information Technology Services to provide campus leadership for the "why, what, and how of research data strategy" (Blue Ribbon Advisory Panel for Research Data Strategy for the University of Michigan, 2011). These campus conversations, in addition to increasing data needs among researchers, motivated the library to develop comprehensive RDM services. In 2011, the library issued a report detailing the extent of its role and identifying shared responsibilities with campus units, while also recognizing the need to have a library representative present within high-level campus discussions to spearhead the development and implementation of RDM services.

To fulfil this role, an Associate University Librarian for Research was hired in 2012 and began leading the unit's mission of "preserving and providing access to the traditional and emerging areas of the scholarly record" around the research lifecycle[18]. Around the same time, two CLIR/DLF Data Curation postdoctoral fellows were hired to conduct research and assessment of the data landscape to inform the planning and implementation of RDM services. To identify potential partnerships, the library participated in the ARL/DLF/DuraSpace E-Science Institute in 2012, leading to the investigation of relationships among stakeholders through interviews of campus administrators. Parallel to this effort, various library data initiatives were launched, including the Emergent Research Working Group that builds awareness of campus research around the research lifecycle, the DataCite and ORCID Task Forces that develop campus approaches for identifying datasets and researchers, and the Research Lifecycle Committee that investigates the library's service model for supporting

17 Deep Blue: http://deepblue.lib.umich.edu
18 University of Michigan Library, Research Unit: http://www.lib.umich.edu/research-unit

research and data lifecycles. A pivotal event was the appointment of a Research Data Services Director in 2013 to oversee these data initiatives and further development of research data services, which is "a growing network of services throughout the library across all phases of the research data lifecycle."[19] Together, the Associate University Librarian and Research Data Services Director framed data services into four key areas: 1) Education, Awareness, and Community Building; 2) Infrastructure; 3) Policy and Strategy; and 4) Consultation and Services.

Recently, additional data initiatives are continuing to further awareness of RDM, such as the Digital Preservation Practitioners Group in collaboration with ICPSR and Data Forwards[20], a newsfeed on worldwide RDM developments. In 2013, another CLIR fellow was hired as an e-Science Librarian to help develop data services, an official website was launched, and a DMP pilot for the College of Engineering began. At present, the library is helping prepare librarians to support researchers' RDM needs through data education workshops. To accelerate the development of data services, the library is planning to formally assess researchers' data needs and to hire a Research Data Services Manager to build and promote the four key areas.

Although library research data services are growing, identifying whom to build partnerships with in a highly decentralized campus is a major challenge. Adjusting to recent changes in library administration also presented a challenge yet served as an opportunity to advance from creating a foundation for research data services to focusing on the next phase – preserving digital research products and supporting digital research workflows.

A distinguishing feature of the library's research data services is that it is not an isolated unit but rather permeates throughout the entire library culture, through reshaping roles of subject liaisons, developing new channels of communication, forming collaborations among different library units, and seeking to build and maintain partnerships with other campus units. This growing research data services network promotes the recognition of data as scholarly output and helps to engage campus researchers throughout the research lifecycle.

University of Virginia

The University of Virginia is a public research university in Charlottesville, Virginia with approximately 15,000 undergraduate and 6,000 postgraduate students. To remain distinctive among institutions of higher education and to support an increased dissemination of and access to outputs of scholarly research, the university adopted an Open Access Policy in 2010. In 2011, the University of Virginia Library established Libra[21], an institutional repository built using Fedora/Hydra software, and started to accept deposits of scholarly manuscripts. In 2012, Libra was expanded to accept deposits of research data.

Although librarians have long assisted faculty members with research, scholarly communication, and digital curation, the library's provision of data services solidified between 2009 and 2012. The highlight was the Scientific Data Consulting (SciDaC) group, which launched in 2010 to address emerging NSF DMP requirements, meet other growing data needs, and advance data services designed around the library's existing

19 University of Michigan Library Research Data Services: http://www.lib.umich.edu/research-data-services

20 Data Forwards: http://dataforwards.wordpress.com

21 Libra: http://libra.virginia.edu

open access-related services. This development and implementation of data services initially resulted from collaboration between the library and the Information Technology research computing lab. Also, science librarians reached out to individual faculty members to serve as 'data champions' and to help identify and meet researchers' data management needs. Although a formal campus-wide task force concerned with research data management has never existed at the university, the members of SciDaC have served as a communication and coordination channel across campus units.

The launch of SciDaC helped to provide more systematic data stewardship, and it initially met campus needs relatively well. Yet, SciDaC has quickly evolved over the last few years. The group is now comprised of four full-time employees and has included several summer interns who have worked with researchers in a variety of domains (e.g., sciences, social sciences, and digital humanities). As scientific data is no longer their exclusive focus, the group evolved into the Data Management Consulting Group[22] in 2013 to reflect their broader approach. Furthermore, the concept of research and data lifecycles has played a central role in shaping the group's data services.

The library's successful engagement in providing data services was enabled by their outreach strategies, especially their strong web presence and collaboration with four other Virginia institutions in providing data training materials and workshops. Within these inter-university collaborations, the Data Management Consulting Group in particular has taken a lead in designing and offering data management 'bootcamp' to educate early career researchers (e.g., graduate students) about issues and best practices in RDM.

Discussion

Institutional Timelines of Building RDM Support

A closer look at these 'biographies' allowed us to create timelines depicting key steps in the development of RDM services and infrastructures at different research universities (see Figure 1). These timelines show that the launch of services supporting the acquisition and analysis of data ('data services') and infrastructure supporting the preservation and sharing of scholarly manuscripts ('IR', institutional repository) typically precedes the planning ('assessment') and implementation of services specifically designed to support the management of data around the research lifecycle ('RDM services'), including data preservation and dissemination ('data IR'). For instance, like several other academic libraries, Cornell University and Emory University Libraries began to help researchers locate and use existing datasets in the 1980s-90s, when the availability of portable media, such as floppy disks and CD-ROMs, increased the accessibility of government and social science datasets (Kramer, 2010). Then, with the development of digital repository software such as DSpace in the early 2000s (Smith et al., 2010), academic libraries, including those at Cornell University, University of Michigan, Purdue University, and University of Illinois, began collecting, indexing, and distributing pre-prints, theses and dissertations, and/or published papers produced by students and faculty (Crow, 2006).

22 University of Virginia Library Research Data Services Data Management Consulting Group: http://dmconsult.library.virginia.edu

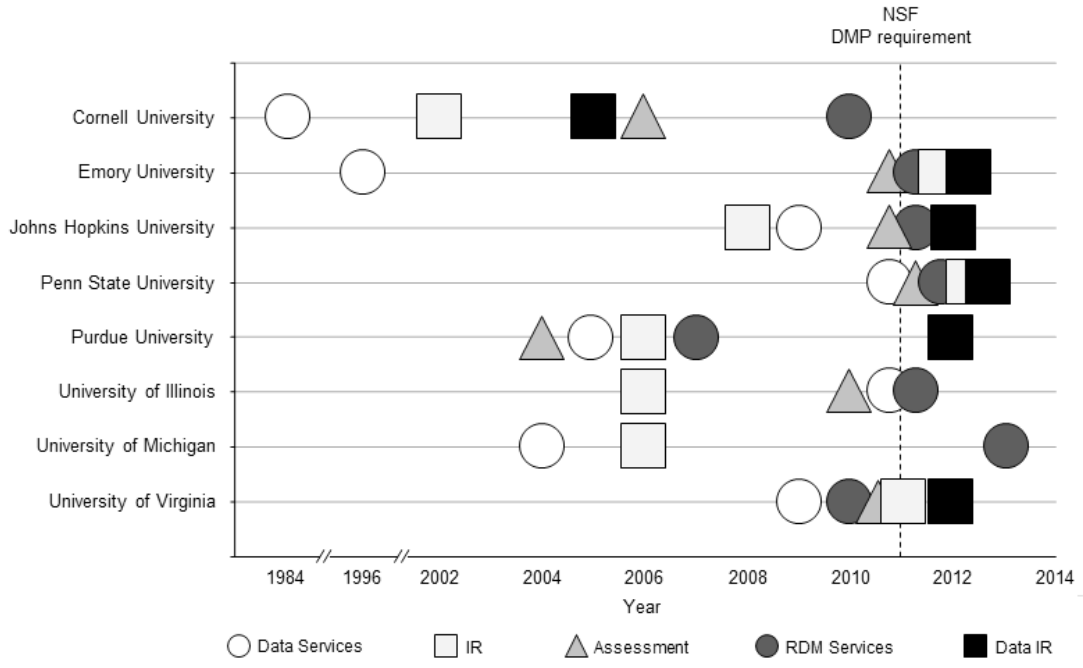

Figure 1. Institutional timelines showing key steps in developing RDM support.

This provision of assistance with the discovery, use, preservation, and dissemination of digital scholarly materials set the stage for academic libraries to begin providing support for RDM. As shown by our institutional timelines as well as ARL survey results (Fearon et al., 2013), most libraries began offering this type of specialized support around 2011, when the NSF enacted requirements for DMPs as components of grant applications[23]. Although libraries at many institutions, such as Johns Hopkins University, Penn State University, and Emory University, launched RDM services and institutional data repositories (i.e., repositories that are either data-specific or were explicitly expanded to accommodate data) around the same time, one anomaly to this pattern is Purdue University, which began offering RDM services several years before establishing a data-specific repository. It is also notable that Purdue University began offering RDM services several years before the NSF's DMP requirement, perhaps because administrators and D2C2 members were exceptionally responsive to growing national conversations about the important role of data in advancing scientific research (Atkins et al., 2003). Despite these general commonalities, the timelines of the eight different universities are clearly very different from each other, underscoring previous observations that every academic library forges its own unique path toward developing RDM support (Kouper et al., 2013; Raboin, Reznik-Zellenk, and Salo, 2012; Zilinski et al., 2013).

Motivation for Providing RDM Support

As previously noted, the NSF's announcement of DMP requirements in 2010 and implementation of those requirements in 2011 was a key event compelling universities

23 NSF Data Management and Sharing Frequently Asked Questions: http://www.nsf.gov/bfa/dias/policy/dmpfaqs.jsp

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to provide greater RDM support for campus researchers (Hswe and Holt, 2011). Many universities quickly responded to this event by assessing campus RDM needs, offering RDM services, and/or building or expanding digital repositories for the preservation and dissemination of research data. Providing guides or workshops on DMP requirements, consulting on DMP preparation, and configuring use of DMPTool are at the forefront of the RDM services offered by many universities (Fary and Owen, 2013; Fearon et al., 2013). Furthermore, some universities, such as Johns Hopkins University, have largely designed their RDM support programs around the grant lifecycle, formalizing the types of support provided during pre-award and post-award periods.

Another impetus for developing RDM support was attendance at the ARL/DLF/Duraspace E-Science Institute, which was specifically mentioned by librarians at Emory University, University of Illinois, and University of Michigan as playing an important role in helping librarians bolster their support for e-science and RDM. Integrating the stories told by these eight universities with the responses of surveyed ARL member institutions (Fearon et al., 2013) unveils several other motivating factors, including the action of forward-thinking university or library administrators, the recognition of opportunities for libraries to provide more comprehensive research support with the growth of e-science and other forms of technologically intensive, data-driven investigation, and what could be considered 'peer pressure' or a desire to follow the lead of other academic libraries with burgeoning programs of RDM support.

Campus Partnerships and Administrative Backing for RDM Support

Although the library is often the driving force behind the development and/or implementation of RDM support, these efforts are often accomplished through partnerships with other campus units. Notably, in many of the profiled universities, such as Cornell University, Penn State University, and the University of Illinois, programs of RDM support either grew out of or currently depend on campus-wide collaborations and initiatives, with university research offices, advanced research computing facilities, and campus information technology departments being prominent library partners. In other cases, the library plays more of a single-handed role in building RDM support. For instance, the data management services provided by Johns Hopkins University were largely borne out of a NSF DataNet award to the Sheridan Libraries.

Institutional approaches to developing RDM support could also be categorized as top-down (i.e., propelled by administrative decisions) versus bottom-up (i.e., 'grassroots', propelled by staff interests). For example, a previous report highlights differences among universities in levels of administrative support for RDM service development (Raboin, Reznik-Zellenk, and Salo, 2012). In particular, librarians at the University of Wisconsin Madison chose to exceed the boundaries of their original charter to launch DMP services without the blessing of administrators and have since gone on to create a successful and wide-reaching curriculum of RDM-focused workshops, courses and bootcamps, illustrating that a high level of administrative support need not be critical for initiating new programs of RDM support.

Multidisciplinary Nature of RDM Support

Several academic libraries, such as those at Cornell University and Emory University, have a long history of providing data services that have been primarily aimed at helping researchers access and use government and social science data. More recently, due to requirements for DMPs or data sharing plans by federal agencies that

fund science, engineering, and medical research (e.g., NSF, National Institutes of Health), as well as the tendency of these research areas to generate large amounts of data, academic libraries have generally paid a disproportionate amount of attention to the curation and preservation of research data from the sciences (Creamer et al., 2012; Gabridge, 2009; Westra, 2012). However, it appears that libraries are now broadening their support to encompass not only science data curation but also curation of social science and arts and humanities data.

For instance, the University of Virginia library initially formed a SciDaC group that focused on addressing data needs in the sciences, but this group later reorganized into a Data Management Consulting group including personnel who work with researchers in a variety of domains including the social sciences and digital humanities. Librarians at Emory University are currently aiming to offer discipline-specific RDM support, such as specialized services and educational opportunities targeted at researchers in the arts and humanities (Akers and Doty, 2013). Furthermore, Penn State University and the University of Illinois recently hired new digital humanities librarians who specialize in RDM. This expanding support for RDM in the humanities (Muñoz et al., 2012; Muñoz and Renear, 2011; Sula, 2013) aligns well with reports that researchers in the humanities and social sciences are as likely or more likely to take advantage of library support for research and data management planning compared with researchers in the sciences (Fearon et al., 2013; Schwartz, 2013).

Assessment of RDM Needs and Services

Formal assessments of researchers' RDM needs have been conducted many academic libraries (e.g., Bardyn et al., 2012; Wells Parham et al., 2010; Parsons et al., 2013; Scaramozzino et al., 2012; Gu et al., 2012), including Cornell University (Steinhart et al., 2012) and Emory University (Akers and Doty, 2013). For the most part, these assessments were undertaken to understand researchers' data management practices and identify gaps in data-related services on campus, with the goal of informing the development of new programs of RDM support. Fewer assessments have focused on measuring the perceived or actual effectiveness of library-provided RDM services and infrastructure in terms of researcher uptake, satisfaction, or funding proposal success. Librarians at Johns Hopkins University and the University of Virginia are gathering feedback from faculty as part of a follow-up to each DMP consultation, and librarians at Purdue University are keeping records of the faculty who indicate their intention to deposit data into PURR within their DMPs. However, because reports indicate that researchers' use of research and data-related services is still somewhat low (Fearon et al., 2013; MacColl and Jubb, 2011), further assessments of their utility and effectiveness should help refine and/or redirect the growth of library RDM service programs, similar to previous studies of the use (or non-use) of institutional repositories (Davis and Connolly, 2007; Foster and Gibbons, 2005; Kim, 2010).

Changes in Staffing and Job Responsibilities

The creation of new library services that more comprehensively support research and RDM often requires staff who possess specific skill sets or knowledge bases. This need can be met by hiring new staff with training or experience in data curation, subject expertise, or technological proficiency (Kim et al., 2013) and/or by re-skilling or 'upskilling' existing staff (Cox et al., 2012; Aukland, 2012). The recent or planned hiring of new staff members was often noted among the eight profiled universities;

these new positions include postdoctoral fellows (Emory University, University of Michigan, and Penn State University), digital humanities librarians (Penn State University and University of Illinois), life sciences and engineering data services librarians (University of Illinois), data management specialists (Emory University), and research data services managers (University of Michigan) or directors (University of Illinois). Also, some universities discussed ways in which existing librarians received RDM-related training and/or guidance on how to integrate RDM support into their job responsibilities. In particular, the D2C2 team at Purdue University created the Data Curation Profiles Toolkit to help librarians actively engage with how researchers manage their data (Witt et al., 2009) and published articles on how librarians can apply their reference and instruction expertise to talk to and educate researchers about RDM (Carlson, 2012; Carlson et al., 2011).

In addition to enhancing skill sets, efforts to more fully support RDM may also involve re-defining the job responsibilities of librarians, such as less time spent on collection development and basic library instruction and more time spent directly engaging with graduate student and faculty researchers. Consistent with the results of the ARL survey (Fearon et al., 2013), our findings indicate that libraries often adopt more than one approach to changes in staffing – both incorporating RDM support into the job responsibilities of existing staff members and bringing in new staff members who are exclusively focused on RDM. Furthermore, the addition of new dedicated personnel is often associated with the re-organization of staffing structures, such as that which has recently taken place at Purdue University, the University of Illinois, and the University of Michigan.

Conclusion

Despite differences among universities in their approaches to and timelines of building support for RDM, most institutions face common challenges in developing successful RDM support programs. For instance, many academic libraries grapple with how to reach out to and interest researchers in improving their data management practices and in taking advantage of library-provided RDM services and infrastructure. Another challenge is funding the creation of new staff positions and infrastructure, which involves decisions as to whether the library should absorb the costs or whether researchers (or their grants) should be charged on a per-use basis. Furthermore, nearly all libraries struggle with staffing issues, including how to add the provision of RDM support into the responsibilities of librarians who are already carrying full loads. Learning how different institutions confront and overcome these challenges can help academic libraries in earlier stages of developing RDM support to create and implement new services and tools more efficiently and effectively, thereby benefitting not only individual researchers but also the greater scholarly community and society.

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