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The Development and Impact of DL Funding in the United States

Jeffrey Pomerantz
Songphan Choemprayong
Lori Eakin

School of Information and Library Science
University of North Carolina at Chapel Hill
CB 3360, 100 Manning Hall
Chapel Hill, NC 27599-3360
<pomerantz, songphan, eak>@unc.edu
t: (919) 962-8366
f: (919) 962-8071

Abstract

This chapter traces the history of digital libraries (DLs) in the United States through the funding sources that have supported DL research and development over the past decade and a half. A set of related questions are addressed: How have the mission and goals of funding agencies affected the types of projects that have been funded? What have been the deliverables from funded projects and how have the goals of the funding agencies shaped those deliverables? Funding agencies have exerted strong influence over research and development in DLs, and different funding agencies have funded different types of projects, with varying sets of concerns for driving the various fields that feed into DLs. This paper will address the impact that DL funding has had on the development of research in the field of Library and Information Science, as well as on the practice of librarianship.

Introduction

Digital libraries (DLs) have emerged as one of the most vibrant areas within library and information science (LIS). DLs exist at the intersection of many, if not most topics within the field of LIS, and introduce much from computer science (CS) and other fields into the mix as well. As a result, developments in these fields have influenced research and development on DL-related topics. Furthermore, the fields and subdisciplines that feed into DLs are themselves active areas of research and development, funded by a range of agencies. Some of these agencies fund DL and DL-related projects specifically, while some have agendas in which DLs simply play a role alongside other types of projects. This chapter traces the history and development of DLs through the funding sources that have supported them, and investigates the goals of the funding agencies and the impact that these goals have had on both the current shape of DLs and on the profession of librarianship in general. This history and development is extracted from the literature on DLs, from the earliest DLs and DL-like projects to the present day. A few informal interviews were conducted with researchers involved in DL projects early in their history,

but these were not a primary source for this chapter, serving instead to point the authors to bodies of literature to review.

DLs, like physical libraries, are expensive to build and expensive to maintain. Since their inception, DLs have commanded large sums of money, and have benefited from major funding initiatives from many organizations. Funding for DLs, however, differs in at least one important respect from funding for physical libraries. A physical library necessarily reflects the mission of its host institution, be that a city, a school, a university, a corporation, or any other organization. In order to justify its existence, therefore, a physical library must demonstrate that it assists its host institution in fulfilling its objectives, whether those objectives are educational, political, financial, or anything else. DLs, on the other hand, are often grant-funded research and development projects, testbeds in which new technologies and new processes are tried out, often with a longer-term timeline for payoff in fulfilling institutional objectives. The goals of a physical library are shaped to a great extent by the goals of its host institution, which is generally also the library's primary funding agency. The goals of a DL are also shaped by the goals of its funding sources; however, these sources are not necessarily tied to the institution that hosts the DL. For example, the Canadian Council on Social Development (Scott, 2003) notes that grants, as generally unrestricted and unaudited forms of support, tend to allow a much greater level of process and content freedom to their recipients than do other forms of funding. The goals of DL projects, often being grant-funded, may be different than the goals of the DL's host institution. As a result, DLs must balance the goals of the library (and of the profession of librarianship in general) with the goals of its funding agencies. This difference between DLs and physical libraries is of course a difference of degree and not of kind, since even traditional libraries receive funding from various sources.

As a DL moves from being a testbed to a viable operational entity, it often loses some of the freedom from institutional restrictions that it originally was granted during its start-up phase. In most cases, a DL that originates within an institutional environment must find a way to integrate its operations with the mission of its host institution as time goes on.

This is likely to impact its financial structure, sometimes placing additional pressures on its funding requirements. Indeed, in a study of the DL programs in Digital Library Federation (DLF) member libraries, Greenstein & Thorin (2002) found that "core funding" – funding provided by the institution, not from external sources – was essential to libraries in funding their DL programs as they matured. Further, as Letts, Ryan, & Grossman (1997) point out, because grants tend to support the start-up stage of projects, they often fail to provide incentives for these projects to focus upon organizational goals such as the long-term ability for the initiative to support routine overhead costs and organizational capacity, which are essential factors in long-term sustainability. Those factors are often considered more carefully in projects' later stages, either due to requirements from longer-term governmental funding initiatives or restrictions placed upon the program by its host institution as it begins to receive more core funding.

Given that DL research and development is more heavily funded through grants than most other work in libraries, then, it has had the potential to radically reshape the field of LIS and the profession of librarianship via the relative freedom to implement innovative new technologies and experiment with new services. But has it actually done so? As this chapter explores the history of funding for DLs, the question of just what that funding has paid for over the years will be addressed, and the impact of DLs and DL-related technologies will be explored. In fact this impact extends beyond what can be explored here, since DL funding has led to far more than the development of DLs: database and publishing ventures, software development, even Google has been supported by DL funding sources. It is also difficult, if not impossible, to establish a direct cause-and-effect relationship between historical events. DL funding has had an impact on a great many areas within LIS and librarianship, but it is unreasonable to suggest that this funding is the sole influence. This chapter will therefore attempt to disentangle the influence that DL funding has had on LIS and librarianship, as opposed to other influences, but this influence will be interpreted liberally.

One of the greatest challenges in writing any paper about DLs is simply defining the term "digital library." Definitions of DLs abound in the LIS and CS literature, and reviewing

these definitions requires an entire paper unto itself (as, for example, Borgman, 1999). Instead, two representative and widely-cited examples are presented here. Arms (2000) defines a DL as a "managed collection of information, with associated services" (p. 2). Borgman (1999) defines DLs as "a set of electronic resources and associated technical capabilities" that are "constructed, collected and organized, by (and for) a community of users" (p. 234). Most definitions of DLs include the elements that Arms and Borgman introduce: a DL is a collection of electronic materials; that collection is managed and organized; it is created and managed by one or more user communities; and technical and user services are provided that add value to the materials. Duguid & Atkins (1997) extend this definition by suggesting that a DL is "an environment to bring together collections, services, and people in support of the full life cycle of creation, dissemination, use, and preservation of data, information, and knowledge" (Introduction section), thus introducing the social function of DLs.

These definitions are useful for most purposes, but are too broad for the purposes of this chapter, given the need to identify funding sources that support DL work specifically, and exclude funding that supports other types of managed digital collections, such as digital archives, institutional repositories, electronic publishing initiatives, and others. Consequently, a purely pragmatic definition will be employed: a funding source will be said to support DL work if the Call for Proposals, Program Solicitation, or other documentation states that it supports DL work. Additionally, a funded project will be said to be a DL if the published literature on that project states that it is a DL. This definition would be insupportable in the context of formal DL research, as it opens the door to all manner of semantic imprecision; however, semantic imprecision needs to be allowed here. As will be discussed below, the term DL was not always in widespread use, and projects that evolved into DLs were called by other names first. This pragmatic definition of DLs also allows different agencies the latitude to define DLs differently, which, again, might be insupportable in other contexts. This latitude is, however, precisely what is needed here: given that different agencies may define DLs differently, and fund DL projects accordingly, what impact have these different approaches had on the development of DLs and on librarianship?

A significant limitation of this chapter is that it focuses exclusively on DL initiatives and funding streams based in the United States. There are extensive and important DL initiatives around the world (e.g., the European Digital Library Project, www.edlproject.eu; the Digital Library of China, www.d-library.com.cn; multiple digital collections from the National Library of Australia, www.nla.gov.au/digicoll/), and there are many collaborative efforts between institutions in the U.S. and other nations (e.g., the Digital Library Federation, www.diglib.org). This chapter will not address these initiatives, though the authors suggest that a chapter or a book on DL initiatives worldwide would be a fascinating read and well worth someone's time to write.

Prior to the Digital Libraries Initiative

The first large-scale funding effort for DL projects was the National Science Foundation's Digital Libraries Initiative (DLI), which will be discussed in detail below. However, the idea of the DL did not emerge, Athena-like, mature and armored, from the head of the National Science Foundation. Rather, there were many streams of research and development that presaged DLs and directly fed into DL research and development. For example, in his vision of libraries of the future, Licklider (1965) predicted that by the year 2000 computers would be able to provide automated library services that could be simultaneously accessed by numerous users. Even earlier, Vannevar Bush described his now-famous "memex" as "a sort of mechanized private file and library" (1945), foreshadowing personal DLs of sixty years hence (Beagrie, 2005). By the late 1970s, technology development was beginning to have a profound impact on libraries. Observing this trend and projecting its future, F. W. Lancaster published his now classic Toward Paperless Information Systems, in which he described the "library in a box," a system which he predicted would shake the foundations of traditional, physical libraries and lead to an ever-increasing number of computerized libraries (Lancaster, 1978). Lancaster recognized the significant cultural and technical difficulties involved in achieving such technological change to libraries, but he also pointed out that it was more than a pipe dream: in the late 1970s the CIA was already engaged in a project to build a

prototype system that would allow widespread storage, indexing, and searching of large bodies of documents (Sapp, 2002).

Such early thought experiments and prototype projects encouraged libraries to act as early adopters of many computer technologies designed to manage a range of functions (Borgman, 1997; Kilgour, 1970). For example, as early as the mid- to late-1960s, libraries adopted innovations such as databases of published and gray literature (Nuefeld & Cornog, 1986), machine-readable cataloging records (McCallum, 2002; Spicher, 1996), and databases for sharing these records (Borgman, 1997). These early uses of technology began the shift towards what Buckland (1992) refers to as the "electronic library" and Rusbridge (1998) the "hybrid library": libraries that utilized technology both to manage their administrative operations and to deliver materials to patrons. Publishers too were experimenting with computer and network technology for delivering materials as early as the 1960s (Peek & Pomerantz, 1998). Most of these, however, were experiments with alternative forms of delivery for scholarly journals and other forms of scholarly communication. As such, these projects were not framed as being library-related, except insofar as the published content might be delivered to libraries and library users. While it is clear in hindsight that these projects were precursors of DLs, they were described at the time as publishing or database ventures.

During the 1980s, a number of research studies to explore the possibilities for electronic libraries were conducted by and in physical libraries, and funded by traditionally library-oriented agencies. In 1986, The University of Texas at Austin received a grant from the Council on Library Resources (CLR) to conduct a study on users' interest in digitized images (Libraries for the Future, 1998). Also supported by CLR, in 1988 the University of Hawai'i at Manoa conducted a study of users of full-text databases (Libraries for the Future, 1998). In 1989, two projects supported by the U.S. Department of Education were launched by Ohio State University and The University of Houston to develop a prototype system for "intelligent information retrieval" and an "intelligent reference information system" (Libraries for the Future, 1998). In 1988, the Online Computer Library Center (OCLC) – always an active funder of studies on the creation and use of electronic

information in libraries – conducted a self-funded project called Bibliographic Control and Document Architecture in Hypermedia Databases, to identify potential designs "for electronic documents that enable algorithmic derivation and generation of a variety of bibliographic representations" (Hjerppe, 1989, p. 6). Today, all of these projects might be framed as DL services.

Perhaps the first DL both funded and developed by a library was the American Memory Project, launched in 1990 by the Library of Congress (Lamolinara, 1995a; Bellinger, 2002). This project will be discussed in more detail below. Another early library DL project was Project Open Book, launched in 1991 by the Yale University Library and supported by the Commission on Preservation and Access (which later merged with CLR to become CLIR, the Council on Library and Information Resources) (Conway, 1996; Conway & Weaver, 1994). Both of these projects focused on digitization of materials and preservation issues, however, rather than on collection building or the technical aspects of DL development.

Identifying the first funded project that might reasonably be called a DL (in or out of a library) is quite difficult. One of the earliest examples is the University of California, Irvine's Thesaurus Linguae Graecae, a project which originally began in 1972 with funding from the Andrew W. Mellon Foundation as a CD-ROM database collection, and which has since developed into a widely used web-based DL of classical texts (www.tlg.uci.edu). Like the TLG, many early DL projects were originally distributed on physical media: American Memory, for example, was originally distributed on laser disc. In part bound by the limitations of the physical media, many early DL-like projects were efforts undertaken by a single institution, with no connection to other related projects, thus differentiating them from later, networked DLs. Further, before the term "digital library" came into widespread use, the TLG and other projects were often simply called "databases."

Perhaps the first project that was described in writing as a DL (rather than as a database or a form of publishing) was the Envision project (Fox, et al., 1993; Heath, et al., 1995).

Envision was a project to develop a digital collection of computer science materials, specifically bibliographic records and full text from several publications produced by the Association for Computing Machinery (ACM). Envision was referred to as a DL, however, only in the published literature written about the project; in the grant proposal, Envision was described as a "hypermedia database" (NSF, 1993). When the Envision project was launched in September 1991, the term "digital library" was not yet in widespread use.

The first use of the term "digital library" in print appears to have been Kahn & Cerf's 1988 report to the Corporation for National Research Initiatives, in which they describe an architecture for a DL system as a "new kind of national information infrastructure" (p. 3), on par with other critical national infrastructure such as the highway and telephone systems. In July 1992 the NSF held a Workshop on Electronic Libraries, while in December 1992 a second NSF workshop was called Workshop on Digital Libraries (Fox, 1993): at the NSF and among the workshop attendees, at least, a terminology shift had taken place in the intervening six months. Griffin (1998) notes that the reason for the adoption of the term "digital libraries" rather than any alternative term was that "'electronic' refers primarily to the nature of the technologies which operate on information and 'virtual' implies a synthetic environment which resembles the original, physical environment... 'Digital' refers to a representation of information on electronic (and other) media." The term "electronic library" is still used, though nowadays this term more often refers to portals to a wide range of electronic publications, often provided by government agencies, as in the case of the Florida Electronic Library (www.flelibrary.org) and the Michigan eLibrary (www.mel.org).

Surprisingly, during all of the time that research was being conducted by libraries on functionality for electronic libraries, and library-like functionality was being developed outside of libraries, little attention was being paid to these trends by the mainstream communities of library science researchers and librarian practitioners. Neither of two reports that articulate research agendas in LIS in the 1980s (Cuadra Associates, 1982; Matthews, 1989) mention DLs among their research priorities. Even after the DLI had

been underway for several years, DLs were largely ignored in the context of agenda-setting for the profession of librarianship. The report from Libraries for the Future (1998) acknowledged that the DLI "will doubtless shape the future of information research and access," but nevertheless somewhat myopically excluded the DLI from its analysis of funding trends in library research, in part because "most of the work is being done by researchers in computer science and information science, with comparatively little input from traditional library researchers." (p. 13) As predicted in the Libraries for the Future report, the DLI, and DLs in general, did indeed shape the future of information research and access, with far-reaching impact for library research and the profession of librarianship. One cannot fully understand the impact of the DLI without considering the overall environment in which it was created.

Programmatically, the DLI was a subcomponent of the High-Performance Computing and Communications Initiative, set up under the auspices of the High-Performance Computing Act of 1991, an act passed in large part to ensure that the United States maintained its global economic and military superiority, a concern to the nation in the late 1980s. Americans had emerged from the Cold War worried about the United States' ability to adapt and survive in a global economy no longer driven largely by military expenditures (Savage, 1994). Increasing competition from abroad fueled these concerns, and the 1987 stock market crash and recession, followed by a renewed recession in the United States in 1990 and 1991, led Americans to the startling recognition that the country's foreign competitors were potentially in a better economic position than the U.S., largely due to their technology policies. Specifically, the economies of both Germany and Japan, recognized as our prime technological competitors, continued to thrive in the early 1990s while that of the U.S. stagnated (Mitchell, 1997). When then-senator Al Gore introduced his "National High-Performance Computer Technology Act" (a.k.a. the "Gore Bill") in 1989, his statement that "the nation which most completely assimilates high-performance computing into its economy will very likely emerge as the dominant intellectual, economic, and technological force in the next century" reflected much current economic and political thinking (S. 1067, 1989). Indeed, the military had long recognized the potential benefits of computing technologies for defense purposes: in

a 1981 report the Department of Defense (DoD) had noted that "the military power of the United States is inextricably tied to the programmable digital computer" (Yudken & Simons, 1988). In fact, military (especially DoD) funding of computer science research rose dramatically between 1977 and 1985, well overtaking the funding provided by the NSF, and sparked intense debate regarding the appropriate role for military spending in both basic and applied computer science research (Thompson, 1986; Yudken & Simons, 1988; Winograd, 1991). A compromise bill that allowed both economic and military goals to be achieved and that re-balanced and clarified the relationships between the top federal funding agencies was clearly a winning combination. As a result, the amended Gore Bill was passed in 1991 as the High-Performance Computing Act of 1991. This bill led to the implementation of the National High-Performance Computing and Communications initiative (NHPCC), which identified DLs as one of four fundamental applications that have "broad and direct impact on the Nation's competitiveness and the well-being of its citizens, and that can benefit by the application of HPCC technology and resources" (FCCSET, 1994, Section VI).

In short, the political climate in the U.S. in the early 1990s was favorable to a large-scale, multi-agency project that would utilize the NREN and would lead to new research in high-performance computing. In addition, computing and networking had already been widely adopted by research and educational institutions across the U.S., and had achieved speeds that made it conceivable for the bill to call for transmission rates nationwide of "one gigabit per second or greater" within five years (Zakon, 2003). In this environment of computing and networking power and political support for harnessing this power, the recommendation to develop DLs could gain traction, as perhaps never before or since in the history of the United States.

The NSF's Digital Libraries Initiatives

Digital Libraries Initiative

Thus, while the idea of DLs did not originate with the NSF and in fact predated the DLI, the DLI nevertheless marked a turning point in the history of DLs by focusing attention on DLs as a legitimate area for research and development. Specifically, three NSF-sponsored workshops held in 1991 and 1992 had a strong influence on the DLI, and consequently on DLs as they exist today: the October 1991 Invitational Workshop on Future Directions in Text Analysis, Retrieval and Understanding, held preceding that year's ACM Special Interest Group on Information Retrieval (SIGIR) conference (Lesk, Fox, & McGill, 1991); the July 1992 Workshop on Electronic Libraries; and the December 1992 Workshop on Digital Libraries (Fox, 1993). These workshops were themselves the culmination of discussions between program directors at a range of federal agencies, including the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), and the National Aeronautics & Space Administration (NASA). These three agencies were to go on to fund the DLI, along with a host of other agencies that could benefit from the development of and access to shared online collections of materials.

These workshops were also the culmination of discussions between researchers in fields that were to feed into DLs, and between researchers and program directors. It was no accident, for example, that the 1991 workshop was held alongside that year's SIGIR conference: the workshop participants were prominent researchers in the field of information retrieval (IR) and related areas. Lesk, Fox, & McGill (1991) list a wide range of research areas related and complementary to the DL work that they propose; many of these were (and still are) central to DLs, including such areas as indexing and classification, interface design, hypertext, natural language processing, and knowledge representation, to name only a few. There were many funded projects in all of these research areas in 1991 and before, a few of which have been discussed above. Funding for IR and related areas itself grew out of a federal focus in the late 1980s on funding research on networking and infrastructure. Griffin (2005) notes that this focus was due to concerns that the U.S. was lagging behind other nations (specifically Germany and Japan) in the area of large scale computational science, and the concomitant desire to rapidly develop the United States' capabilities in this area. As often occurs with technological

developments, however, the infrastructure development made possible by this federal support brought about unintended consequences: specifically, the popularization of computing and networking technology. The development of the World Wide Web then led to the development of tools designed to ease non-experts' use of the Web, including search engines and better interfaces. Mass use of online resources led to the need for better ways to organize and retrieve the data now widely available, and the need to make more high-quality data available. In their recommendations, Lesk, Fox, & McGill articulated what must have been the zeitgeist of the 1991 workshop: that diverse threads of IR-related research already underway could be applied to the development of an online library that would not only enable electronic access to materials, but could also benefit the education and research communities.

A number of recommendations came out of the 1991 and 1992 NSF workshops, both for the NSF specifically and for the community of researchers and funding agencies generally. The overarching recommendation from these workshops was for the NSF to launch "an initiative to build a basic science, engineering, and technology library on-line, available over the Internet/NREN, and for research regarding building and exploiting it" (Lesk, Fox, & McGill, 1991, p. 12). Lesk, Fox, & McGill also stated that existing infrastructure and technology must be used wherever possible in building this "library on-line." The National Research and Education Network (NREN) was singled out as "the most important resource" to bring to bear on this library. The NSF, as the agency that coordinated the NREN and the High Performance Computing and Communications initiative (HPCC), was singled out as the logical federal agency to launch this initiative.

While influential, the recommendations from the 1991 and 1992 NSF workshops were not the sole influence on the creation of the DLI. From a broader perspective, the DLI was the result of a happy confluence of a congenial political environment, a positive economic climate, and the then-state of the art of computing and networking technology. Without all of these elements in place, the various federal agencies involved in the DLI might have been unlikely to engage in such a large-scale and financially intensive initiative, especially during a period in which a federal budget deficit and economic

recession were growing concerns to the nation's citizens. The fortunate convergence of these factors, however, set the stage for future DL research and practice.

It is worth pointing out that the "precursor" DL projects (those that were not yet being called DLs: e.g., the American Memory Project, the Envision project, etc.) were all projects to develop collections of digital materials. The DLI therefore has the distinction of being the first funded research project on DLs, a project specifically to develop new technologies and to explore issues involved in building and maintaining DLs. Indeed, the DLI and DLI-2 remain to this day among the few basic research projects on DLs.

Six grants were awarded under the DLI: to Carnegie Mellon University, the University of California at Berkeley, the University of California at Santa Barbara, the University of Illinois at Urbana-Champaign, the University of Michigan - Ann Arbor, and Stanford University. The total amount awarded under the DLI was $26.8 billion; the average amount of these awards was $4.5 million. Five of these grants were to schools of Computer Science; only one was to a school of Library and Information Science (the University of Michigan). The University of California at Berkeley and the University of Illinois at Urbana-Champaign, however, both have LIS programs (and had when the DLI grants were awarded), and researchers from these programs collaborated with the principal investigators on the grants to these institutions. While the DLI's goals were not directly derived from the High-Performance Computing Act of 1991, the projects funded under the DLI did address some of those agencies' responsibilities. The six funded projects developed DLs containing a range of formats of materials, including the full text of periodical publications, images, maps, audio and video recordings, and large data sets. The University of Michigan, for example, was one of the institutions involved in The University Licensing Project (TULIP) project, Elsevier Science's project "to jointly test systems for networked delivery to, and use of journals at, the user's desktop" (Borghuis et al., 1996), and the University of Michigan's DLI proposal was an extension of their efforts in that project. The University of California at Santa Barbara proposed to develop a DL of spatially-indexed information, including collections of maps and images. Carnegie-Mellon University, in addition to other work, proposed to study the economics

of charging for online content. The University of Illinois at Urbana-Champaign proposed to conduct sociological and economic analysis of DL use. Thus the DLI projects covered a very broad range, the work on which was, as Lesk, Fox, & McGill (1991) had suggested, divided between "the creation of the library and the research on its exploitation" (p. 20) – in other words, between collection development and basic research.

As often happens with technology, an event that could not have been predicted dramatically changed the course of the DLI projects. In November 1993, the National Center for Supercomputing Applications (NCSA) released Mosaic version 1.0. Mosaic was the first graphical browser application for the World Wide Web and, unlike previous hypertext applications, enabled the integration of both text and images into hypertext documents. This integration of text and images was the tipping point for the popularization of the internet, and within months, Mosaic had achieved a user base of millions of users worldwide (NCSA, 2007). The DLI program announcement was released in the autumn of 1993 (Griffin, 1998), and the start date for projects was September 1994. Project proposals were therefore written during that intervening year: in other words, precisely at the time that Mosaic was first released and was gaining a user base. It would have been nearly impossible during that year for anyone to predict just how much Mosaic would change the internet and users' interaction with it, and as a result, the DLI project proposals did not address the Web. With the advent of the graphical Web, however, the Web became the obvious platform for the dissemination of the materials in these DLs, thus employing HTTP as the protocol and the browser the interface for this dissemination.

Limitations of the DLI

The DLI was perhaps as important for focusing attention on DLs as an area for research and development as it was for its support of the individual projects it funded. As the first major funding program for DL-related projects, however, there was much that it did not and could not do. The DLI received a good deal of criticism, often from the very

researchers who were funded by it, and who were naturally in a position to see its limitations. Criticism of the DLI focused largely on four points: its primarily CS-driven agenda, a lack of connection to libraries and other cultural institutions, little attention to user needs, and too little attention to evaluation.

As mentioned above, five out of six grants under the DLI were provided to CS programs; only one went to an LIS program. According to Saracevic and Dalbello (2003), only two projects focused on specific domains or topics, while the remaining four focused on the development of domain-independent technologies (p. 8), echoing the divide between collection building and basic research. To be fair, however, the connection between theory and practice was in fact a component of the DLI agenda from the beginning: the DLI's call for proposals required that funded projects "will digitize a significantly large and important information collection, or use an existing collection, to serve as an experimental platform to demonstrate scale-up potential and as an experimental testbed for the research proposed" (NSF, 1993). In other words, the NSF required that projects create and disseminate useful collections, both as project deliverables and as environments for basic research. Nevertheless, this supposed disconnect between theory and practice in the DLI added fuel to the criticism that the DLI agenda was largely "set by the computer science community" when in fact there were "other constituencies whose voices need to be heard" (Levy, 2000, ¶19).

Griffin (1998) identified some of these other constituencies, such as "libraries, museums, art departments, schools of music, archeology, history and other humanities departments" (Conclusion section, ¶3), thereby suggesting that research and development for DLs needed to expand to encompass cultural institutions of all types. Although some DL-like projects in cultural institutions predated the DLI (e.g., the American Memory Project and the Thesaurus Linguae Graecae), these were piecemeal efforts, largely disconnected from each other and from the DLI projects (Saracevic and Dalbello, 2003); the DLI projects themselves focused on technology rather than collection building and management. Although all of the DLI projects built their own testbed collections, the published literature contains little discussion of the scope of these collections.

Others also recognized this disconnect between DL research and practice (Hirtle, 1999), and identified other research areas within that gap. Schatz and Chen (1996), for example, argued for increased attention to user needs, suggesting that "large-scale testbed" collections are necessary "as the only method for determining which information system features are actually useful in practice" (pp. 47-48). Griffin (1998) echoed this sentiment, bemoaning the "unnatural separation between the producers and consumers of digital libraries" (Conclusion section, ¶3) and arguing for increased collaboration between researchers and users.

Evaluation was also an area of concern for DLI. Evaluation is always a challenge, and it was especially so for the DLI projects, since they were interdisciplinary and aimed to fulfill the goals of multiple agencies. Bishop (1995) articulated four levels of evaluation for the DLI projects: adequacy of the collection, functionality, interface, and usability; search and retrieval performance and behavior; effect on the work and processes of users; and public policy implications. She further commented that "the six projects are devoting varying amounts of attention to each of these evaluation levels" (Synchronizing Work Across the Six DLI Projects section, ¶2). Griffin (2005), however, argues that the impact of and new research questions raised by a project are often apparent only in the "latter stages of the research program" (Critique of the DLI Program, ¶4).

Another drawback of the DLI was the short-term nature of the funding it provided. The DLI provided funding for projects for four years, which, as anyone who has been involved in the development of a DL knows, is insufficient time to bring a DL project to maturity. Years after the conclusion of the DLI, Griffin (2005) argued that the DLI's "funding models did not work optimally, particularly for the mid-size, longer-term, interdisciplinary research and testbed projects" (Critique of the DLI Program, ¶2). This comment echoes Griffin's comment of years earlier, that "larger-scale projects require several years to complete and require a stable and predictable funding stream to retain essential staff and resources" (DLI Program Constraints section, ¶1). Of course, this problem is not unique to the DLI: stable funding is a challenge for any grant-funded

project, and DL projects in particular, since DLs tend to span disciplinary boundaries, and "research agencies tend to be limited to support of those research activities and infrastructure building that stay within their defined missions" (DLI Program Constraints section, ¶2).

These criticisms of the DLI had a significant impact on the scope of the DLI Phase 2. DLI-2 was more interdisciplinary, and had a stronger focus on collection development and user needs. Additional public and private agencies were included in DLI-2 in order to provide support from an interdisciplinary perspective. Evaluation was a more central concern for DLI-2, corresponding with an increased focus on evaluation within the NSF as a whole (Directorate for Education and Human Resources, 1998). Not all limitations of the DLI were, or could be, addressed by the DLI-2, however. Furthermore, increasing awareness of DLs led to an explosion in the number of DL-related projects, and researchers and practitioners working on such projects. This created a need for funding sources beyond the NSF, and these funding sources presented themselves, in the form of both public and private agencies.

Digital Libraries Initiative Phase 2

Before discussing the projects funded by sources beyond the NSF, however, the NSF's two other DL initiatives will be addressed briefly. In 1997, the NSF sponsored the Planning Workshop on Distributed Knowledge Work Environments, which has come to be known as the Santa Fe workshop (Duguid & Atkins, 1997). The Santa Fe workshop, like the workshops in 1991 and 1992, brought together the community of researchers working in DL-related areas (naturally including researchers from the original six DLI projects) to brainstorm about the possible futures for DLs, and to make recommendations to the NSF about the need for a continued funding program focused on DLs. Perhaps unsurprisingly, the consensus from the Santa Fe workshop was that there was a continued need for a Digital Library Initiative. Workshop participants identified three "central issues" in DL research: systems, collections, and users.

By 1998 the High Performance Computing and Communications initiative had evolved into the Federal Computing, Information, and Communications (CIC) programs, with a narrowed focus on developing technologies for scientific applications and education (NSTC, 1999). The DLI-2 was part of the Human Centered Systems (HuCS) Program of the Federal CIC Program. The overarching goal of the HuCS program was to enable "increased accessibility and usability of computing systems and communications networks" (NSTC, 1999, p. 5); the goals of the DLI-2 therefore remained consistent with those of the DLI. Griffin (1998) points out that although the DLI-2 accounted for only about 0.6% of the total budget for the CIC, it was considered to be "a CIC R&D Highlight, testimony to both to its achievements and to the mounting importance of the area generally" (DLI and the Federal Context: HPCC section, ¶4).

Twenty-eight projects were funded under DLI-2, including a continuation of four of the six DLI projects (Fox, 1999). The two DLI projects that were not continued by DLI-2 were, however, continued by other funding sources (Fox, 1999). Conversely, some of the projects funded by DLI-2 were underway prior to DLI-2 (Saracevic and Dalbello, 2003), funded under other NSF programs, by other federal agencies, or by the projects' host institutions. Eight DLI-2 projects had a specifically undergraduate emphasis, investigating various ways in which the materials in DLs could be utilized in undergraduate education in a range of disciplines. As early as the 1991 NSF workshop, DLs were seen as presenting a benefit to education; this perspective was clearly at the forefront at the NSF, as recommendations concerning access to educational materials and use of technology from the NSF's review of undergraduate education ("Advisory Committee to NSF,", 1996) clearly informed the DLI-2 program.

The DLI-2 was funded collaboratively by the original three agencies behind the DLI (NSF, DARPA, and NASA) but also by additional federal agencies, including the National Library of Medicine (NLM), the Library of Congress, the National Endowment for the Humanities (NEH), the Federal Bureau of Investigation (FBI), the Institute for Museum and Library Services (IMLS), the National Archives and Records Administration (NARA), and others (NSF, 1998). These agencies contributed large sums

to DLI-2, incurring about twice the expenditures of the DLI (Lesk, 1999), but they also played a significant role shaping the projects funded by DLI-2 – and the DL projects more generally – in a variety of ways. Brogan (2003) observed that major DL initiatives "cluster around the mission of those government agencies supporting the Digital Library Initiative Phase 2 – predominantly in the sciences and cultural heritage" (p. 7). Similarly, Griffin (1998) acknowledges that the DLI-2 addressed "a narrower technology research agenda than DLI" (DLI Programmatic Context section, ¶6). On a more positive note, however, Griffin suggests that the potential range of DLI-2 projects was "expected to involve content in subject areas across the continuum of human interest" (DLI Programmatic Context section, ¶7). Schatz and Chen (1999) likewise suggested that DLI-2 "presages the even bigger efforts recommended in the PITAC report" (Research initiatives section, ¶5), referring to the 1999 President's Information Technology Advisory Committee report, which recommended a substantial increase in federal support for information technology research. DLI-2 funded projects within the three central issues in DL research identified during the Santa Fe workshop – systems, collections, and users – and "across the information lifecycle," but de-emphasized projects to digitize collections. It is of course impossible to separate the practical issues of DL collection development from the basic research on these collections and the technologies underlying and serving them; each relies on the other. The fact that DLI-2 de-emphasized digitization therefore created a need for other funding sources that could step in and fund the many cultural institutions that desired to digitize their unique and valuable collections.

National Science Digital Library

Even before the DLI-2 program ended in 2004, the NSF had already launched another DL program: the National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) (NSF, 2000). The idea of such a DL predates the DLI-2, however, having been proposed while the DLI was still underway (Wattenberg, 1998; Zia, 2000). The scope of the NSDL is, quite obviously, materials that may contribute to

education in science, technology, engineering, and mathematics, referred to as STEM education, or alternatively SMET or SMETE.

The NSDL is a program of the NSF's Directorate for Education and Human Resources (EHR), Division of Undergraduate Education (DUE), while the DLI and DLI-2 were programs of the Information & Intelligent Systems (IIS) Division of the NSF's Computer and Information Science and Engineering (CISE) Directorate. This change in directorates is telling. From as early as the 1991 and 1992 NSF workshops, a central element of the conception of a DL was that it should benefit education, in particular undergraduate education. It was appropriate for the first major DL initiative that the projects funded under the DLI focused largely on developing the infrastructure to make DLs possible, and less on collections and their uses. With work on infrastructure well underway, some projects funded under the DLI-2 were able to focus more on developing collections, and services that could be provided to add value to those collections. As mentioned above, several DLI-2 projects focused on undergraduate education. By moving its DL initiative into the EHR, the NSF emphasized their increased focus on undergraduate education as a central element of DLs. The EHR oversees the NSDL program, but sister directorates to the EHR, including the Directorate for Mathematical & Physical Sciences, the Directorate for Geosciences, and the Directorate for Biological Sciences, provide "significant co-funding" (NDSL, n.d., Funding section).

This focus on education is demonstrated in other ways as well. When it was established in 2000, the NSDL program solicited proposals in four "tracks": Core Integration System, Collections, Services, and Targeted Research (NSF, 2000). The Core Integration track was the extension of the infrastructure-related work begun in the DLI and DLI-2; the purpose of the Core Integration track was to coordinate between all of the NSDL projects, develop standards and requirements, and develop and maintain the "central portal" to the NSDL (Core Integration System Track section). The Collections track supported projects to develop DL collections that would be accessible through the NSDL's "central portal," such that the NSDL became a collection of collections. The Services track supported projects "to develop services to increase the impact, reach,

efficiency, and value of the digital library in its fully operational form" (Services Track section); what constituted a service was conceived broadly, to allow room for innovative uses of the materials within the NSDL. The Targeted Research track supported short-term projects that could be applied to the other three tracks, such as user studies, or development of new applications or interfaces. By 2002, the Core Integration effort had become established as an ongoing component of the NSDL project, conducted by a stable group of institutions (NSF, 2002); this perhaps is an indication of how critical a central "command and control" group is for a large distributed collection of collections. In 2004, the Collections Track was replaced with the Pathways track; instead of supporting projects to develop new collections, the Pathways track supported projects to "assume a stewardship role for the educational content and/or the services" under the NSDL, and to "aggregate the efforts of existing resource providers" (NSF, 2004a, Pathways Track section). With the shift from Collections to Pathways, the NSDL began to emphasize sustainability of existing projects by organizations or consortia, "beyond the period of NSF funding" (Program Description section). Sustainability is, however, an ongoing effort, as demonstrated by a survey conducted by the NSDL's Sustainability Standing Committee (Giersch, 2003).

The NSDL program has supported the development of many DL collections of materials useful for education in the various STEM fields. Some of these DLs were developed from the start with NSDL funding, and some existed prior to the NSDL program (e.g., the Digital Library for Earth System Education, DLESE, www.dlese.org). The many projects funded under the Services track span a wide range of types of services, and address the full lifecycle of educational materials from creation to dissemination to review to reuse (for a complete list of projects funded by the NSDL, see nsdl.org/about/?pager=projects). What unifies these projects, however, is that their overarching purpose is to increase the reach and usefulness of the materials in the NSDL. For example, the Instructional Architect (ia.usu.edu) enables instructors to create lesson plans and learning objects from materials across the NSDL's many collections, and package and share these educational materials (Recker, 2006).

Proliferation of Funding Streams

The criticisms of the DLI discussed above, and the increased interest in DLs that the DLI helped to create, led the NSF to modify the program goals for the DLI-2 and again for the NSDL in favor of projects to deliver operational DLs and services to add value to DLs. In addition, in the 1990s other agencies began to provide large sums to fund DL-related projects. Lynch (2005) characterizes the period from about 1994-2004 as "the first time that digital library research could really get substantial programmatic funding from the major research funding agencies in the United States" (¶ 5). He also notes that many of these same agencies funded precursors to DLs, but that this programmatic funding served to legitimize DLs as a field of research.

As might be expected, the direction of the DLI projects were initially shaped by the missions and requirements of their agencies funding the DLI: the NSF, NASA, DARPA, EPA, and others. With the DLI in place, however, other agencies rapidly began to see the potential for DLs to support their own goals, causing "divergent evolution" among DLs, such that DLs emerged that reflected the varying concerns and purposes of their founding institutions, original funders, managing organizations, and user bases. This divergent evolution is certainly at least partly responsible for the "competing visions" of the nature of DLs referred to by Borgman (1999), and the lack of clarity as to precisely what a DL is, which persists to this day (Lagoze, et al., 2005). Additionally, as Griffin (1998) points out, "digital libraries projects can extend in scope well beyond agency missions, and demand support beyond a single agency's means" (DLI Program Constraints section). Therefore, many DL-related projects have been funded by multiple agencies, though like the DLI, this support is often coordinated by a single agency. This section presents some of the most prominent agencies that have funded (and continue to fund) DLs and DL-related projects, the motivations of these agencies for doing so, and some of the outcomes of this support. The next section presents the impact that this longer-term "evolution" of DLs and the widespread interest in them has engendered.

Larsen and Wactlar (2003) point out that significant DL initiatives have been funded by large scale federal agencies (e.g., NARA, NASA, NSF, DARPA, NIH, and NEH); smaller yet still significant federal and state agency programs (e.g., the Library of Congress' National Digital Library Program, and the University of California's California Digital Library); private foundations such as the Andrew W. Mellon Foundation and the Alfred P. Sloan Foundation; and private industrial research projects, such as IBM's and Sun's efforts. Although the number of funding agencies focusing on DL projects may only be in the dozens, as Schonfeld (2003) points out, there may be hundreds of projects that have created significant DLs. For example, while the W. K. Kellogg Foundation does not explicitly fund DLs or even technology in libraries in particular, it has supported several DL-related initiatives through its Youth and Education and Learning Opportunities program areas (W. K. Kellogg Foundation, 2007). Kellogg has funded projects and studies on service-oriented and operational aspects of DLs (e.g., Lamolinara, 1995b; Library of Congress, N.D.; University of Michigan, 1996; N.D.). Additionally, Kellogg supported one of the earliest DL policy projects through Harvard University (Greenstein & Thorin, 2002) and LIS education and curriculum regarding DLs (e.g., Durrance, N.D.; Fox, 1996). These projects will not be discussed further here, however, as another chapter in this volume is dedicated to LIS education funding. It is simply not possible to discuss all of the potentially relevant projects and funding agencies that have shaped the development of DLs. Consequently, only those agencies and projects that have had the most direct and profound impact on library science and the profession of librarianship are discussed here.

Library of Congress

Libraries have traditionally been early adopters of technology for promoting dissemination of and access to information resources, and the technology of DLs was no exception. One of the first large-scale DLs developed outside of the DLI project umbrella, and, as mentioned above, perhaps the first developed by a library was the Library of Congress' (LC) American Memory Project. American Memory actually predates the DLI, having been launched in 1990, though at that time it was distributed on

physical media (CD-ROM and videodisc) rather than via the internet (Lamolinara, 1995a). As soon as the world wide web entered the public eye, the LC, like the DLI projects, began to disseminate materials via the web and the web browser.

In 1994, the LC began the National Digital Library Project (NDLP) to expand their digitization efforts, with the goal of digitizing five million items by the year 2000, a goal which was met and exceeded (Library of Congress, N.D.b). The LC's digitization efforts were a two-phase effort: phase one was the American Memory Project, in which "unique historical collections [and] extensive bodies of primary-source materials of the Library were digitized" (Davis, 1998, p. 198). A component of this project was to develop a model for sharing electronic materials between libraries. Phase two continued the digitization of materials in the LC's collections, and also began to digitize materials from other libraries.

From the beginning, given the sheer scope of digitizing the LC's collections, the LC's digitization and digital library efforts required a "concerted effort and partnerships among many entities" (Davis, 1998, p. 199). These efforts were funded by a collection of agencies in addition to Congress. The National Digital Library project was initially established with $13 million in private sector donations, followed by a $15 million appropriation from Congress and an additional $48 million from the private sector (Library of Congress, 2004).

The American Memory Project still exists (memory.loc.gov), making it one of the oldest extant DLs; it is also one of the largest collections of any DL. From early days, LC has developed creative organizational structures to support the American Memory Project, partly out of the need to find novel ways to manage a DL program of much larger scope and complexity than had been attempted by any other entity before it. In 1996, for example, LC partnered with Ameritech to offer a three-year competition in which individual projects could receive funding to build digital collections that would then be available on the American Memory website. A total of twenty-three awards were made during this period, supporting the efforts of thirty-two organizations (Library of

Congress, N.D.a). This creativity has paid off in the novelty of design and the variety of collections: Time Magazine named American Memory one of the ten best Websites of 1996, calling it a "treasure trove of memorabilia converted into easily downloadable recordings, images and text" (Bellafante & Corliss, 1996). The site also placed among the six finalists in the Education category of the National Information Infrastructure Awards Program in 1996. It has continued to rack up awards and citations for creativity of design and usefulness of content since its inception over a decade ago. American Memory has also been a leader on the research front, having conducted perhaps the first user evaluation by any DL project (Library of Congress, 1993).

The LC continues to fund digital library-related initiatives under the NDLP. In 2000, the LC launched the National Digital Information Infrastructure and Preservation Program (NDIIPP), a grant program funding research into digital preservation as part of an effort "to implement a national digital preservation strategy" (NSF, 2004b). NDIIPP was originally funded by an appropriation from Congress of nearly $100 million, "with $75 million contingent on a dollar-for-dollar match from non-federal sources." (Lefurgy, 2005) The funding was provided for the LC "to lead a national planning effort for the long-term preservation of digital content." (Friedlander, 2002, ¶1) NDIIPP has tackled the problem of digital preservation on many fronts, including the creation of preservation networks of multiple institutions and types of institutions (Smith, 2006), and the interoperability and transfer of digital archives between institutions (Shirky, 2005). NDIIPP has also worked on developing standards, including the Audit Checklist for the Certification of a Trusted Digital Repository, which outlines the requirements for an institution to consider itself a "Trusted Digital Repository" (Kaczmarek, et al.,2006). A Study Group sponsored by NDIIP and the U.S. Copyright Office is, as of this writing, investigating Section 108 of the U.S. Copyright Act, with the goal of providing "balanced, solid recommendations for revising Section 108 to meet the way libraries work in the Digital Age" (Harris, 2006, p. 36). Thus, via NDIIPP, the LC has been marshaling the efforts of many different organizations and agencies from business, government, and academia. Currently, there are over 36 individual partners working on 12 primary projects, along with 10 additional grant recipients working on specific aspects

of digital preservation research. In addition, over 150 government representatives from all fifty states have participated in workshops associated with this project.

However, the future of NDIIPP's activities may hang on the balance of political and economic agendas. After the February 15 passage of P.L. 110-5, as part of an across-the-board series of funding cuts, Congress rescinded $47 million of NDIIPP's approved funding (LibraryJournal.com, 2007), thereby also threatening "an additional $37 million in matching, non-federal funds that partners would contribute as in-kind donations." (Barksdate & Berman, 2007)

However, the LC continues to provide leadership in the design of DLs. The LC maintains a number of Research Centers online, including the American Folklife Center (www.loc.gov/folklife/), the Geography & Map Reading Room (www.loc.gov/rr/geogmap/), and the Recorded Sound Reference Center (www.loc.gov/rr/record/). These Research Centers maintain extensive online collections in addition to their considerably more extensive physical collections; the LC does not even present these collections as DLs, but in any other hands they would clearly be so. Unlike most DLs, some of these Research Centers have also developed resources for their online collections more commonly associated with traditional physical libraries, such as bibliographies, guides, and finding aids. In short, from the very earliest days of DLs, the LC has been on the cutting edge of the development of DL collections and of services within DL environments.

Institute for Museum and Library Services

The Institute for Museum and Library Services (IMLS) is the only federal agency with Congressionally-granted statutory authority to fund digitization projects (Ray, 2004). As Ray points out, while other federal agencies also fund digitization projects, the IMLS was created specifically to "make increased online public access to library and museum content an agency priority" (p. 249). This mission has inevitably led the IMLS to focus much of its energies and granting on DLs and DL-related projects.

The National Leadership Grant program is one of the IMLS' largest granting programs, and has supported many digitization projects in both libraries and museums since the creation of the IMLS in 1996. Indeed, the creation of a federal agency whose mission includes funding digitization projects was timely for both libraries and museums, and significantly contributed to the "widespread acceptance" that Fox (1999) points out "of the broadening of the digital libraries field; not only libraries but also museums and archives are within scope" (Assessment and Conclusion section, ¶ 3). Some portion of most libraries' collections, and often most or all of the collections held by museums and archives are unique. Part of the purpose of these institutions is to make these collections available to users, but access to these collections has traditionally been limited to users who could physically visit the library, museum, or archive. With the advent of the World Wide Web, it quickly became clear that access to unique collections could be greatly expanded by digitization. Libraries, museums, and archives tend, however, to be chronically under-funded, and it is often difficult to justify new projects in a tight budget cycle. Thus the very existence of the IMLS' National Leadership Grant program was a boon to these cultural institutions, and, the present authors suggest, single-handedly greatly expanded the amount of cultural heritage materials available online.

The IMLS has launched many efforts to support cultural institutions in making cultural heritage materials available online. One of the earliest efforts was two studies of the status of new technology adoption and digitization in museums and libraries conducted in 2001 and 2004 (IMLS, 2002; 2006). These studies investigated the goals, plans, policies, practices, hindrances, and funding of digitization activities conducted in museums and libraries, as well as the roles played by IMLS. Institutions surveyed included museums, both public and academic libraries, State Library Administrative Agencies (SLAAs); archives were included in the second study. The studies also compare digitization activities between small, medium, and large institutions based on annual budgets. The results from the studies provide insights about trends and developments in digitization activities, and the needs of cultural institutions – data which is very useful for IMLS in shaping their programs.

The Framework of Guidance for Building Good Digital Collections (NISO Framework Advisory Group, 2004) articulates many principles concerning digital collections, digital objects, metadata, and projects as a whole. As of this writing, a third edition of this document is in progress, supported by the IMLS. The Framework document was developed "to encourage institutions to plan their digitization practices strategically in order to develop collections that will be accessible and useful for the long-term, and that can integrate with other digital collections to support a growing network of broadly accessible digital information resources" (p. iv). This document, along with a number of others, are indicative of the IMLS' efforts to encourage libraries and museums to think strategically about the future of cultural heritage institutions, and, as stated in the IMLS' mission, to "connect people to information and ideas" (www.imls.gov/about/about.shtm).

Since 2004, the IMLS has also sponsored the WebWise Conference, which was one of the first and has become one of the most important conferences to address issues faced by cultural institutions in making resources available digitally. Every year, many cultural institutions present their most recent research and innovations at WebWise, as examples for other institutions, and every year's conference has a theme that reflects current thinking and concerns for libraries and museums in making digital materials available online.

In short, the IMLS has provided leadership to cultural institutions in the arena of digitization and the development of useful and sustainable collections of cultural heritage materials online. The IMLS occupies an important niche in the environment of DL funding, in that it brings museums and archives under the DL umbrella, and focuses specifically on DLs as vehicles for the dissemination and sustainability of cultural heritage materials.

Andrew W. Mellon Foundation

Although the Andrew W. Mellon Foundation (hereafter referred to as Mellon, www.mellon.org) has not historically had an explicit interest in libraries per se, libraries have nonetheless often been in a position to fulfill some of the social functions that are of interest to Mellon. Mellon's mission is "to aid and promote such religious, charitable, scientific, literary, and educational purposes as may be in furtherance of the public welfare or tend to promote the well-doing or well-being of mankind" (Mellon, 2006). Beginning in the late 1970s, Mellon began to fund individual digitization projects and projects to develop CD-ROM databases of individual collections of materials. For example, the foundation provided some of the start-up funding to enable the University of California at Santa Barbara to develop the Thesaurus Linguae Graecae (Mellon, 1978). It also supported the work of the Association of Research Libraries in Washington to build a database of materials in microform and funded numerous electronic catalog projects that paved the way both for future digitization projects and for the sharing of collections via the Internet. These library- and DL-related projects were funded under the Higher Education and Scholarship program, historically the largest single program area for Mellon's giving. Almost every year since 1987, approximately 50-70% of all of Mellon's grants have been within this area, with total annual appropriations in this area ranging from almost $32.5 million to over $132 million. After 1990, Mellon's digital library-related funding skyrocketed until, by 2005, spending on DL-related activities represented over 70% of Mellon's total giving.

Indeed, over the years, enough grants under Higher Education and Scholarship have been oriented toward libraries that in 2004 Mellon created the Scholarly Communication program area, to support the "creation, dissemination, accessibility, and preservation of high-quality scholarly resources" (Mellon, 2007). Much of Mellon's grant-making in this area has supported digital initiatives such as JSTOR (www.jstor.org), its offshoot ARTstor (www.artstor.org), and Mellon's new "incubation" institution, Ithaka Harbors, Inc., which was launched "to accelerate the productive uses of information technologies for the benefit of higher education worldwide" (Ithaka Harbors, 2007).

JSTOR, arguably the flagship of journal archiving, was initially the brainchild of Mellon's then-president William Bowen, who envisioned the project as a means for saving library space by enabling back issues of journals to be digitized, indexed, and made available on the Internet, thereby allowing libraries to drop their physical holdings of those issues (Bowen 1995; Schonfeld, 2003). The original space-saving impetus rapidly shifted, however, to a recognition of the potential reduction in communications costs and increased access that users of electronic forms of communication would enjoy. Although Mellon realized that it was not interested in permanently assuming the role of either a production shop or publishing management enterprise, it did recognize that the type of back issue archiving it was proposing could provide a great deal of value to scholars, students, and research institutions. It simultaneously realized that the archiving mission it desired was unlikely to be offered via the private market in any manner that would help to allay the rapidly increasing scholarly communications costs with which libraries already were burdened, and that the capital costs involved in a for-profit version of a JSTOR-like entity would require a huge capital outlay that would in fact make the archival-oriented mission of JSTOR take back seat to more profit-driven motives (Schonfeld, 2003). As a result, Mellon engaged in the management of the initial prototype development and when the viability of JSTOR was verified, aided in the creation and funding of an offshoot non-profit entity, led by former Mellon researcher Kevin Guthrie, that subsequently took over the management of JSTOR production activities.

Host Institutions

This section has thus far focused on agencies that fund DL programs, but increasingly, DLs are being funded by libraries themselves, and by libraries' host institutions. Often, however, these programs are begun with and/or supplemented by funding from sources external to the library. In a study of the DL programs in Digital Library Federation (DLF) member libraries, Greenstein & Thorin (2002) found that "core funding" (funding provided by the institution, not from external sources) was essential to libraries in funding their DL programs. As Greenstein & Thorin suggest, an institution may allocate

funds to DL programs in a variety of ways, and these funds may come from a variety of sources both within and without the library's budget. Interestingly, "as digital library programs mature, reallocated library funding becomes more important" (p. 9). The implication of this last point is that numerous DL programs in libraries are launched using funding from external agencies, but sustained using funding from the library's budget. The present authors suggest that this is as it should be, and corresponds to other library services and programs once their value has been established: virtual reference services, for example, are often launched using grant funds but later integrated into the library's "core funding" (McGlamery & Coffman, 2000).

Many DL projects in libraries have been launched with funds awarded through the IMLS' Library Services and Technology Act (LSTA) program (Byrd, et al., 2001). One of the goals of the LSTA is to "develop library services that provide all users access to information through local, state, regional, national, and international electronic networks" (Institute of Museum and Library Services, 2007), which clearly includes digitization and DL projects. Within the authors' own state, the North Carolina Exploring Cultural Heritage Online (NC ECHO, www.ncecho.org) program is a collection of digital library "special collections of North Carolina's libraries, archives, museums, historic sites, and other cultural institutions." NC ECHO is not only funded via the LSTA, but it awards grants of its own "that support collaborative digitization projects among the state's libraries and partner cultural institutions" (North Carolina ECHO, 2007).

Byrd, et al. (2001) note that the Library of Virginia received funding from both the LSTA and Mellon for a specific sub-project within its larger Digital Library Program. This is a common approach to project funding for libraries: to seek funding for specific sub-projects under a larger umbrella. This is made necessary by two facts that should, by this point in this chapter, be clear: first, DL projects are usually longer-term efforts than any single grant or award would allow, and second, DL projects are often broader in scope than any single agency would be interested in supporting through a single funding program. Two DLs that have existed for over a decade thanks to this patchwork approach to funding are Documenting the American South (DocSouth, docsouth.unc.edu) and the

Perseus Digital Library (www.perseus.tufts.edu). Since its launch in 1996, DocSouth has received support from "the National Endowment for the Humanities, the Institute of Museum and Library Services, the Library of Congress/Ameritech National Digital Library Competition, the State Library of North Carolina, and private foundations" (Norberg, et al., 2005, p. 286). Perseus has been similarly successful over the years in finding support from a range of sources, both private and public (Crane, 1998, 2000).

DocSouth is, as of this writing, over 11 years old, and Perseus is nearly 22 (though early Perseus prototypes in the mid-1980s were, like the American Memory Project, distributed on CD-ROM rather than online; Crane, 1998). These are mature DL projects by any metric, and as Greenstein & Thorin (2002) suggest, as they have matured they have been sustained in part by funding from their host instititutions' libraries. Indeed, the recent adoption of DocSouth by the University of North Carolina Library System's newly created Carolina Digital Library officially brings that DL within the fold of the wider institution. French (2003) describes a DL supported even more integrally by its host institutions: the California Digital Library (CDL) is a joint undertaking of the ten campuses of the University of California system, and these ten universities all share the costs of maintaining the CDL. These DLs are all supported in part by "core funding": their host institutions allocate some funding to these DLs as a recurring budget item, like any other resource provided by the institution. Even these mature DLs are not supported entirely by core funding, however, and it is not currently clear that, given the total costs of a DL project, it would even be possible for a library or consortium of libraries to entirely support a DL project.

One project that has gambled on the ability of a consortium of institutions to support a DL, however, is the Internet Public Library (IPL, www.ipl.org). The IPL originated as a project in a graduate seminar in the School of Information and Library Studies at the University of Michigan in the Winter 1995 semester. In the winter of 1995, the graphical web was a mere year and a half old, and so still novel for many. The goal of this seminar was to address issues involved in integrating the web with libraries (Internet Public Library, 2007). What resulted was the IPL as we know it, and has led to new ideas about

the nature of libraries in a networked environment. Two characteristics of the IPL make it unique as a DL. First is that the IPL is a "link farm": the collections within the IPL are not digitized versions of material held by physical libraries, nor born-digital materials created by the IPL, but rather are collections of links to resources hosted by others. Importantly, however, these resources are vetted as quality materials, and annotated by librarians and library school students. Second is that the IPL incorporates a human-mediated question answering service, similar to the online reference services that are offered by many physical libraries' reference desks (Pomerantz, et al., 2004). Indeed, the IPL's question answering service predates many libraries' online reference services. To the authors' knowledge, the only other DL that has integrated a reference question answering service is the AskNSDL (nsdl.org/asknsdl/) service, which as of this writing is apparently defunct. Integrating a question answering service into a DL raises a number of issues, which are explored by Pomerantz (2003), including the extent to which the answers themselves should be included in the DL's collection. The IPL also presents an interesting case study in funding. From its founding through 2006, the IPL was funded by the University of Michigan and a series of grants from a range of funders. In January 2007, the IPL moved to Drexel University and, in addition to continued and new grant funding, is now supported by a group of library schools referred to as the IPL Consortium (Lazorko, 2003). This is a creative twist on Greenstein & Thorin's (2002) notion of "core funding": the IPL relies in part on funding from institutions for which it can play a role in fulfilling the institutional mission. By providing services to library schools such as opportunities for students to participate in question answering and the management of a DL, the IPL is positioning itself as a resource for the entire community of library educators.

It is interesting to note that DL work within libraries and within the field of library science generally has often been criticized for ignoring the extensive research on DLs being conducted outside of libraries and the field of library science. As mentioned above, the report from Libraries for the Future (1998) largely ignored the DLI, except, paradoxically, to acknowledge that it was expected to "shape the future of information research and access" (p. 13). Borgman (1999) notes that the DLI is also barely mentioned

in Books, bricks and bytes: Libraries in the twenty-first century" (Graubard & LeClerc, 1998), a collection of articles exploring the place of DLs in libraries and librarianship. As in many professional fields, there has traditionally been a split between research and practice in the field of library science / librarianship. For libraries working on DL projects to ignore the DL research from other fields, however – perhaps specifically because it comes from other fields – is to unnecessarily hamstring library-based DL projects.

Impact of DL Funding

Sociologist Anthony Giddens has noted that "whenever we analyse large swathes of history, we are liable to find ourselves with an aggregate of 'causal influences' rather than conclusive generalizations about why things 'had to happen' as they did." He stresses further that this is because "there are no patterns of universal causation in the social sciences – that is to say, conditions in which circumstance X will, and must, always be followed by circumstance Y" (1991, p. 206). Not only must ideas about social influence rest upon interpretive assessments, they are reflexive: as Borgman and colleagues have noted, "each encounter influences the next" (Borgman et al., 1996). An example of this type of reflexivity can be found in Borgman and colleagues' final report to the NSF on the 1996 UCLA-based workshop "Social Aspects of Digital Libraries." Borgman et al. claim that the participants at this workshop coined the term "social informatics" (Introduction section, ¶3). Within only a few months of that workshop, the term "social informatics" began to be widely used by the NSF and in the published journal literature (Bishop & Leigh, 1996; Kling, Rosenbaum, and Hert, 1998), as well as in the name of a new academic research organization (Indiana University's Rob Kling Center for Social Informatics). Given this set of historical facts, it is not possible to identify one single causal influence for the now-widespread adoption of the term or the idea of "social informatics."

This reflexivity of influence is particularly apropos when reviewing the historical impact that funding agencies have had on DL research and development; in particular, one is

struck by the reciprocal influence of research and practice on funding agencies' decisions. Teasing out the impact of funding streams on DL research and development forces one to face a huge number of interrelations that occurred over time. As only one example, the funding for DLI led to new knowledge and ideas about DLs, which influenced the agencies funding the DLI, leading to the recognition that new types of research and development were required to continue the momentum that the DLI initiated. Although it is impossible to find a strict cause-and-effect relationship by which funding agencies set in motion a few well-oiled gears that then determined the future path of DLs according to the agencies' pre-set agendas, it is nevertheless possible to identify themes and trends throughout the many and varied interactions that have led to the current state of DL research and development. The identification of themes and trends offers interesting insights into the relationship between funding and DL development.

For example, a brief review of citations and acknowledgments (Giles & Council, 2004) indicates that DLI and DLI-2 have had tremendous impact on DL research. A search of the CiteSeer Scientific Literature Digital Library (citeseer.ist.psu.edu) identifies 64 unique documents published between 1995 and 2004 that explicitly cite or acknowledge DLI or DLI-2, and a further 515 citations to this set of 64 documents. It is reasonable to assume that there are, and will continue to be, additional "generations" of citations. The same is no doubt also true for publications from DL projects funded by other organizations (though publications from NSF-funded projects are especially easy to track, as the NSF provides specific language for authors to include in acknowledgments; NSF, 2007b, Chapter VI, section E.4.a.). Thus DL projects continue to influence the DL research community, through an expanding ripple effect in the published literature.

This influence is not confined to the published literature, of course, but extends to the field of LIS and the profession of librarianship in a host of ways. It is nearly impossible to capture the totality of the impact that DLs, and the funding streams that have made them possible, have had. Developments in DLs have had an impact on research and education in fields as diverse as computer science and classics, even on areas of software development as widely dispersed as Optical Character Recognition (OCR) and

Geographic Information Systems (GIS) (Ogle & Wilensky, 1996). In particular, at the time of DLI and DLI-2, the NSF did not recommend as strongly as they do today that all funded research projects include an evaluation component (Frechtling, 2002). Griffin (2005), however, claims that the return on investment of the DLI program was high by any measure, suggesting potentially large economic impact in addition to the intellectual. Moreover, every DL project has had its own impact on librarianship and the library research communities, and on society in general. This section summarizes the impact of the DL projects and funders discussed above, in several areas.

Impact on DL-related Research Areas

Given that the DLI emerged from the umbrella of the High-Performance Computing Act of 1991, it is only natural that high-performance computing has, from the beginning, been intimately tied to the development of DLs. That connection continues to this day, though with a semantic shift: instead of "high-performance computing," the term more commonly used now is "cyberinfrastructure." Griffin (2005) notes that the term cyberinfrastructure was coined in the late 1990s, "referring, initially, to the assemblage of high performance computing and networking resources generally available to researchers and educators" (Digital Libraries and Cyberinfrastructure section). The NSF convened a Blue Ribbon Panel to evaluate the NSF's then-current investments in cyberinfrastructure, and to "recommend new areas of emphasis" for the NSF to support cyberinfrastructure (Atkins, et al., 2003, p. 5). The report from this panel, which has come to be known as the Atkins Report, has since set the tone for the NSF's funding of cyberinfrastructure research and development. Further, DLs remain central to fulfilling the potential of cyberinfrastructure: one of the goals for the NSF is to "support state-of-the-art innovation in data management and distribution systems, including digital libraries and educational environments that are expected to contribute to many of the scientific breakthroughs of the 21st century" (NSF, 2007a).

Many other organizations as well have articulated ways in which libraries, both digital and physical, may take advantage of the NSF's cyberinfrastructure efforts. The

Computing Research Association (2005), for example, discusses how STEM education may take advantage of the "unprecedented access to educational resources, mentors, experts, and online educational activities and virtual environments" (p. 4) that work in cyberinfrastructure will make available, and DLs are included among the virtual environments discussed. Focusing on the humanities and social sciences, the American Council of Learned Societies launched a commission "to articulate the requirements and potential contributions of the humanities and social sciences in developing a cyberinfrastructure for information, teaching, and research" (American Council of Learned Societies, 2006, p. 1). The report from this commission argues for libraries to develop and maintain collections of digital objects generated by humanities and social science scholarship that may in turn inform scholarship. Finally, the Association of Research Libraries convened a forum to address the impact that cyberinfrastructure will have on the "ARL's three strategic directions: scholarly communication, information policies and other public policies, and the roles of libraries in transformations of research and education" (Goldenberg-Hart, 2004, p. 1). The rough consensus emerging from this forum was that while the roles of libraries and experts in libraries may change, the library as an institution must play a central role in managing resources in the e-sciences. In short, libraries are universally included in the landscape of social institutions that will be affected by cyberinfrastructure but are at the same time necessary for cyberinfrastructure to fulfill its full potential as a tool for change.

As the tools and technologies that cyberinfrastructure enables have become more readily available to researchers in all fields, interdisciplinary and international collaborations that make use of those technologies have proliferated, giving rise to what is often referred to as e-Science (Hey & Trefethen, 2003). The resulting explosion of data being generated by e-Science researchers and the data collection instruments they employ has generated a "data deluge," made possible in part by the improved technical capabilities from high performance computing research. For example, since 2000, an award has been made at the International Conference on High Performance Computing, Networking, Storage and Analysis (supercomputing.org) for the High Performance Bandwidth Challenge, a competition for cutting-edge network applications; the goal of this competition is to

support the sorts of scientific endeavors that can only be accomplished with very large data sets and very high data transmission speeds. Moreover, DLs have come full-circle in their role in high-performance computing initiatives: having arisen out of such initiatives, DLs are now being employed to address some of the new issues arising out of them. Borgman, et al. (2007), for example, propose the use of DLs as mechanisms for organizing and managing the deluge of data being produced by scientific fields, and outline a set of functional and technical requirements for such DLs.

Although the idea of the semantic web emerged prior to the term cyberinfrastructure (Berners-Lee & Fischetti, 2000), the two are closely intertwined. Proponents of the semantic web suggest that it "may be viewed as an infrastructure for supporting the objectives outlined" by the Atkins report (Miller, 2003). Sure & Studer (2005) suggest that semantic web-related technologies enable the development of common naming schemes for digital objects and the repositories in which they are stored, and suggest that such technologies are important in DLs for such purposes as interface design, user profiling, and personalization. Perhaps even more important, however, is the possibility for semantic web-related technologies to aid in interoperability between DLs and to improve end-user searching. The JeromeDL (Kruk, 2005), for example, is a case study of a DL that employs semantic web-related technologies for browsing and searching.

Central to the organizational functionality of DLs is the use of metadata. Just as a physical library could not exist without classification schemes, neither could a DL exist without metadata schemes. Several metadata initiatives are ongoing, all of which are potentially relevant to DLs, but are also broader in scope than DLs alone. The Dublin Core Metadata Initiative (DCMI, dublincore.org), for example, has developed a set of fifteen broad and generic metadata elements called "Unqualified, or Simple, Dublin Core" (as opposed to the wider set of elements and refinements called "Qualified Dublin Core") that may be used to describe any resource. The DCMI element set is widely used in DLs, but it is also widely used in other domains, where a number of communities of interest have developed community-specific extensions to the DCMI. The education community, for example, has developed an extensive set of elements to describe

educational resources (dublincore.org/groups/education/), as part of the work funded under the NSDL (Sutton, 2004; Greenberg, 2005; Liddy, et al., 2006). Other communities have developed their own extensions to the DCMI as well (see: dublincore.org/projects/).

Metadata is only one of many fields that have benefited from DL funding sources. From the very origin of DLs, the field of IR has been one of the most closely tied to DLs. Ironically, however, Smith (2000) found that DLs have implemented only a very narrow range of search features. Nevertheless, a great deal of IR-related work has been funded by DL funding programs, in particular the NSF's initiatives. Much of this IR work has been on improving traditional text retrieval (e.g., Shneiderman, Byrd, & Croft, 1998), but much of it also is concerned with retrieval of other media, including images (e.g., Tang, Avula, & Acton, 2004), audio (e.g, Downie, 2003), and video (e.g., Christel & Huang, 2003; Yang, Wildemuth, & Marchionini, 2004).

One of the best-known and most significant impacts of the IR aspect of DL research and development is the invention of the search engine Google (www.google.com). Hart (2004) relates that Google's founders Larry Page and Sergey Brin were graduate students working on Stanford University's DLI project when they developed a prototype search engine that they called BackRub, due to its functionality of counting incoming links (i.e., backlinks) to web pages (Battelle, 2005). BackRub was later renamed Google, and Google Inc. was incorporated in 1998 (Google, 2007). Since 1998 Google has been one of the great success stories of the technology industry, having become nothing short of a cultural phenomenon.

Google has also had a profound effect on libraries. Of course, web search engines existed prior to the advent of Google (WebCrawler having been the first, released in April 1994; InfoSpace Inc., 2007), and many alternatives for searchers continue to exist. Due to its popularity and ease of use, however, Google has significantly contributed to changes in people's expectations for searching, providing strong implications for library search tools. Indeed, some libraries have begun to rethink library automation and the way that services are provided based at least in part on Google's influence (Bibliographic Services

Task Force, 2005), and some libraries have integrated tools provided by Google into the services provided online by the library (Pomerantz, 2006). Google has even had an impact on library education, as there have been at least two courses in library schools devoted to Google: one at the University of Washington (Flash, 2004) and one at the University of California at Los Angeles (polaris.gseis.ucla.edu/jrichardson/Courses/19.htm).

Scholarly Publishing

Dissatisfaction with print as a medium for disseminating scholarly publications was evident as early as the mid-1940s (Bush, 1945). In 1962, the Chemical Abstracts Service published Chemical Titles, the first-ever journal in electronic format, and by the mid-1970s there were several projects underway experimenting with the dissemination of scholarly works in networked environments (Peek & Pomerantz, 1998). These projects were not originally framed as DLs, but they had a significant impact on the later development of DLs: for example, as mentioned above, the University of Michigan's DLI project extended their efforts as part of Elsevier Science's TULIP project (Borghuis et al., 1996), and the Envision project (Fox, et al., 1993) evolved into the Association for Computing Machinery's DL (portal.acm.org/dl.cfm). Awareness of DLs, combined with dissatisfaction with traditional scholarly publishing, access to the web, and the availability of tools to easily create web content, had – and continues to have – a profound impact on the scholarly community. This impact has manifested itself in at least two ways: the creation of new venues for publication and scholarly communication generally, and the creation of new vehicles for disseminating already-published works.

Two of the most prominent DL-related publication venues are D-Lib Magazine (www.dlib.org) and the Joint Conference on Digital Libraries (JCDL, www.jcdl.org). D-Lib was established in 1995 by a grant from DARPA, as a venue for publications from DLI projects (Griffin, 2005), and since 2006 has been funded by the NSF and produced by the Corporation for National Research Initiatives (CNRI) (Corporation for National Research Initiatives, 2007). The JCDL is the result of a merger between two conferences

(hence the "joint"): the ACM Conference on Digital Libraries and the Institute of Electrical and Electronics Engineers (IEEE) Forum on Research and Technology Advances in Digital Libraries, both first held in 1996. The ACM and IEEE merged these conferences to form the JCDL in 2001. Since their inception, both D-Lib and JCDL have become established as among the most important publishing venues for DL-related work. Even though D-Lib is not a peer-reviewed publication (submissions are vetted by the editor), it is one of the most influential publications in the DL arena, including as it does research articles, news on current DL-related events and projects, and featured DL collections. An indicator of its influence is that D-Lib is the journal most widely read in DL courses (Pomerantz, et al., 2006). JCDL is similarly influential, as it is one of the few conferences where attendees come from the range of institutions with an interest in DLs: LIS and CS programs, academia, corporate research centers, and libraries alike.

One of the reasons that D-Lib is as influential as it is may be that it is freely available online, which Lawrence (2001) has shown increases citations to articles. While the term "Open Access" was not yet in widespread use when D-Lib was established in 1995, D-Lib nevertheless represents what Harnad, et al. (2004) call the "gold road" of Open Access (OA) publishing: "following" the gold road is to publish an article in a journal that is freely available to readers on the web, while following the "green road" is to publish an article in a subscription-based journal but to self-archive it online. In short, the purpose of OA publishing is "to make possible an unprecedented public good" by making scientific literature freely available online to the reader (Chan, et al., 2002). While the OA movement can be traced to the mid-1960s (Suber, 2007), it crystallized with the Budapest Open Access Initiative in 2002. Since that time, a number of scholarly publishers have revised their copyright agreements to explicitly allow authors to self-archive preprints and/or postprints – see, for example, the SHERPA RoMEO Project (Securing a Hybrid Environment for Research Preservation and Access, Rights MEtadata for Open archiving), which provides a list of publishers and details of their copyright agreements (www.sherpa.ac.uk/romeo.php). Additionally, some federal funding agencies have developed policies to encourage funded investigators to make their publications available in OA venues: the National Institutes of Health (NIH), for example, "requests

and strongly encourages" authors to deposit postprints of publications in PubMed Central (www.pubmedcentral.nih.gov) (NIH, N.D.).

Other paths to the OA green road also exist, as authors can put their own work online on their personal websites, or in an OA archive. Many OA archives exist: perhaps the first was the open-access FTP preprints archive for the journal Behavioral and Brain Sciences, introduced in February 1991. This was followed closely by the Mathematical Physics Preprint Archive (mp_arc, www.ma.utexas.edu/mp_arc/), launched in July 1991, and by perhaps the best-known OA archive, arXiv.org, which includes preprints in the fields of Physics, Mathematics, Computer Science, and Quantitative Biology, which was launched in August 1991 (Suber, 2007). The field of Library and Information Science has two OA archives: dLIST (dlist.sir.arizona.edu) and E-LIS (eprints.rclis.org). In addition to discipline-specific archives, archives exist that contain only specific types of publications, such as the Networked Digital Library of Theses and Dissertations (NDLTD, www.ndltd.org), as well as those that are specific to institutions, such as DSpace at MIT (dspace.mit.edu). Institution-specific OA archives overlap considerably with institutional repositories, which Crow (2002) defines as "digital collections capturing and preserving the intellectual output of a single or multi-university community" (p. 4), although an institutional repository does not necessarily have to be OA. Further, the distinction between OA archives, institutional repositories, and DLs is fuzzy at best.

DL-related projects have also impacted scholarly communication by creating new vehicles for disseminating published works. JSTOR, discussed above, was developed by Mellon to provide libraries with online access to journal backfiles. JSTOR'S goal was to decrease the storage costs and increase the convenience of accessing these materials (Schonfeld, 2003). JSTOR is not unique; other journal backfile repositories currently exist, though as of this writing JSTOR is the only project of its kind that is financially self-supporting. Further, subscription databases existed and libraries subscribed to them for decades prior to the founding of JSTOR. What is particularly interesting about JSTOR, however, is that it embodies the shift away from the "hard-copy" approach to

archiving and access traditionally employed by libraries and other institutions. JSTOR has emphasized the importance of archiving in the electronic environment by creating a business model that financially links access and archiving: with the exception of two-year colleges, all university libraries that subscribe to JSTOR pay a fee that includes both access and archiving costs. According to Schonfeld, in the hard-copy era, only the wealthiest libraries could afford the expense of archiving. In the current electronic era, however, all universities participating in JSTOR partake of reduced archiving costs, and gain access to journals that many would otherwise not have been able to afford.

In July 2007 the American Association for the Advancement of Science (AAAS) announced that it would end its participation in JSTOR as of the end of 2007, and that therefore content from Science Magazine would no longer be contributed to JSTOR (AAAS, 2007). The AAAS stated that this decision was made so that the AAAS could "assume the full responsibility for maintaining a complete electronic archive of its flagship publication" (¶5). In January 2008 the AAAS reversed that decision and rejoined JSTOR. Details of the new agreement between JSTOR and the AAAS are confidential, but changes from the previous agreement are "related to price and to linking of articles within JSTOR to other articles" (Guterman, 2008). On the one hand, the AAAS' renegotiation indicates that publishers, even those that assume the responsibility of archiving their own content, see the value in third-party journal backfile repositories. On the other hand, this incident demonstrates that cooperation with publishers is central to the viability of third-party repositories, and that such repositories are highly vulnerable to pressure from publishers. How relationships between publishers and repositories develop over the next few years, and the influence of OA publishing on these relationships, may have significant impact on the future of scholarly publishing, and on libraries' access to scholarly publications.

Impact on Libraries

OA archives, third-party collections, and other new venues for disseminating published work have had a profound impact on libraries. The existence of materials that are

accessible via the library but not part of the library's collection has the potential to change the purpose of the library catalog from a tool for bibliographic control to a more general portal to the internet (Thomas, 2000). Further, the availability of materials via the library that are not under the library's control changes the very definition of a library collection (Lee, 2000). Libraries have thus had to re-evaluate their role in an increasingly networked environment. Since the advent of the subscription literature database, and increasingly since the advent of the DL, libraries have been moving from a model of ownership of materials to a model of access to materials.

While libraries have been increasingly providing access to online collections created and maintained by others, they have simultaneously been creating their own online collections. As discussed above, libraries are increasingly launching their own DL programs, using grant funding and moving towards "core funding" (Greenstein & Thorin, 2002). As libraries create DLs (and other digital content) Troll (2001) suggests that they "become publishers" (The Changing Environment section). Indeed, Wilkin (2005) presents the case that acting as publishers, even to the point of replacing university presses, is central to libraries' mission of "connecting users with information... [and] as disseminators of information" (Libraries as Publishers section). While many libraries may be unwilling to replace their institution's university press, increasingly academic libraries are partnering with university presses to make scholarly work available. One of the largest-scale library-press collaborations as of this writing is The Ohio State University Press' Open Access Initiative (www.ohiostatepress.org/books/openaccess.htm).

As disseminators of information, libraries have always explored the many vehicles for this dissemination, and as libraries increasingly provide materials online, this means exploring the software options for dissemination of these materials. As far as the current authors can determine, Greenstone (or rather, at the time, New Zealand Digital Library Software) was the first application ever developed specifically for the purpose of creating DLs, the first project having been launched in 1995 (Witten & Bainbridge, 2007, p. 148). As the 1990s progressed, the idea of developing tools to assist librarians and other

collection developers to build their own DLs and DL-like collections, such as archives and collections of commercial content, became increasingly popular. Following Greenstone, a number of applications for building DLs or DL-like collections have emerged: Flexible Extensible Digital Object and Repository Architecture (Fedora, www.fedora.info), DSpace (www.dspace.org), EPrints (www.eprints.org), and CONTENTdm (www.dimema.com), to name a few of the more commonly-used applications. Each of these is intended to serve a different (though similar) function: Fedora is intended for building general-purpose repositories (Staples, Wayland, Payette, 2003), DSpace is designed to manage research materials and scholarly publications (Smith et al., 2003), CONTENTdm is designed for collections of images (Bunker & Zick, 1999), and so on. It is therefore important to point out that these DL-like applications are not competing for "market share" as it were, but rather each fulfill a different niche in the DL ecology. There is, unfortunately, only one article that the authors are aware of that presents a comparison of these applications (Goh, 2006); the authors suggest that more such work would be useful for librarians and other DL builders who are deciding on an appropriate platform.

Developing DLs is expensive, in terms of both money and staff time. In order to partially alleviate these expenses, libraries have begun participating in collaborative initiatives to digitize materials in their collections. Often these initiatives are coordinated by third parties, such as Google Book Search (books.google.com), and the Open Content Alliance (OCA, www.opencontentalliance.org). Both the Google Book Search project and the OCA have partnered with many libraries, and as of this writing are in the process of digitizing materials from these libraries' collections. These initiatives are not "traditional" DLs: the OCA refers to itself as an archive, and Google Book Search does not make the full text of all materials available to users (though Google does make full text available to the library that owns the digitized material). While these initiatives cannot realistically be called DLs, they fulfill a role within DL programs in libraries, as libraries move to digitize significant parts of their collections.

DLs have had an impact on libraries as institutions, and the functions that libraries perform. Consequently, DLs have also had an impact on the profession of librarianship, and the functions that librarians perform, both within and without the library. If libraries are disseminators of information, it is in large part because librarians are present to assist users and to help put that information in context. Griffin (1998) suggests that one of the most valuable aspects of DLs "is their ability to preserve and extend discourse – to provide richer contexts for people to interact with information. The real value of digital libraries may prove to be in their ability to alter the way individuals, groups, organizations etc, behave, communicate, and conduct their affairs" (Introduction section, ¶6). This aspect of DLs places librarianship squarely in the forefront, as the profession whose function it is to preserve discourse and to assist those who are extending discourse – but this also signals significant changes to how these functions will be performed.

Impact on the Profession of Librarianship

Libraries were one of the earliest adopters of computer and network technology, in the service of dissemination of and access to information resources: the MARC standard, for example, was developed by the Library of Congress in 1965; and the Linked System Project was conceived in the late 1970s to enable the exchange of bibliographic data between library networks (Fenly & Wiggins, 1988). As tools for the dissemination of and access to information, DLs were likewise quickly adopted by libraries as well. Integrating DLs into more "traditional" library functions has always been a challenge, but many forms of integration have emerged to fill that "ecological niche." Two major themes emerge from this integration: DL-related initiatives that span multiple libraries, and changes to the profession of librarianship itself.

The Digital Library Federation (DLF, www.diglib.org) was founded in 1995 with the goal of implementing "a distributed, open digital library... accessible across the global Internet," to be composed of digitized and born-digital materials from member and other libraries (Bennett, et al., 1995). In order to bring this goal to fruition, the DLF has naturally had to become involved in management, funding, standards, evaluation, and a

range of other areas of DL research and development. The DLF has emerged as one of the few agenda-setting initiatives in the DL arena, and it has accomplished this due to the strength and diversity of its membership, which includes colleges and research universities at which DL projects are taking place, national and state libraries in the U.S. and abroad (e.g., the Library of Congress, the British Library, the California Digital Library), and many of the major institutional players in the library arena (e.g., OCLC, the Coalition for Networked Information). By providing support for new research and development projects, hosting forums at which DL researchers and practitioners can disseminate findings and discuss their work, and publishing reports on specific DL-related issues, and demonstrating leadership generally, the DLF has established itself as one of the most influential institutional leaders in the DL arena.

Other multi-institution initiatives have addressed more specific issues faced not only by DLs, but by collections of digital content of all types. Projects such as LOCKSS (Lots of Copies Keep Stuff Safe, www.lockss.org), Building Resources for Integrated Cultural Knowledge Services Project (BRICKS, www.brickscommunity.org), and the Open Archives Initiative (OAI, www.openarchives.org) provide policies and technical solutions to assist institutions to manage various aspects of the lifecycle of digital content, from collection to dissemination and exchange to preservation. Librarians have inevitably participated closely in projects such as these.

Participation in such projects signals a change in the skills that librarians require – and indeed, are expected to possess even to be hired in the first place. Since the advent of DLs, several authors have articulated sets of skills that librarians need to possess in order to develop and manage DL collections and services (Tennant, 1998, 1999; Croneis & Henderson, 2002; Choi & Rasmussen, 2006). These skills break down into three categories: technological skills, management and interpersonal skills, and library-related skills. Technological skills include knowledge of specific applications, standards, and systems. Management skills include project management ability, leadership ability, flexibility, and grant-writing skills, among others. Library-related skills include knowledge of both technical services and user services: knowledge of indexing,

cataloging, and metadata; archiving and preservation practices and standards; and how to conduct reference and other user services. In short, the skills that librarians need to possess in order to develop and manage DL collections and services are arguably the same as the skills that librarians need to possess in order to conduct any form of library work in the modern age, though a far greater emphasis is placed on technological skills than ever before.

These technological skills are, however, utilized in the service of the same functions that librarianship has always performed. While the rise of e-Science and the "data deluge" discussed above is causing many fields to attend to the unfamiliar issue of managing large data sets, librarians are perfectly familiar with managing large volumes of information. A few fields have addressed this issue by establishing their own data repositories, complete with standardized formats and tools to manipulate the data. In more fields, however, data is stored locally by individual researchers, and not widely shared, thus impeding the ability of researchers to build on each others' work. In some ways, this state of affairs is to be expected: researchers' skills are in collecting and analyzing data, not necessarily in organizing that same data. It is, in fact, the skills of librarians that are needed in these cases. Partially in response to the increase in the number of scholarly fields that are generating large data sets, therefore, many academic libraries have begun offering "data services," which includes the management of data sets on behalf of researchers, and reference-like public services to assist users to use this data (Read, 2007; Cook, Hernandez, & Nicholson, 2001). A new category of librarianship has thus emerged in academic libraries to fulfill these functions: the data librarian. While the profession of data librarian is just beginning to emerge and its scope to be defined, it is a good example of the changes to the profession of librarianship currently underway that have been brought about in part by DL-related technologies. The Association of Research Libraries has taken a leadership role in defining the scope of data librarianship – or, as the ARL refers to it, "data stewardship" (ARL, 2006). In their report to the NSF, the ARL recommends that the NSF should support a number of stewardship initiatives, including funding research and development, and educational efforts.

Data librarianship is only one area in which new roles are being identified that libraries and librarians will assume in the future. As these new roles evolve and become more clearly articulated, librarians will need to be trained to fill those new roles. DL funding has had a significant impact on the development of the profession of librarianship, and consequently on library education. Another chapter in this volume addresses funding for LIS education, however, and so this issue will not be discussed further here.

Library 2.0

The authors do not claim that all of the impacts discussed so far in this section are direct results of work on DLs; rather, all that is claimed is that DLs and DL-related technologies had some influence on these projects. In this section, the authors will go even further out on a limb and will discuss the idea of "Library 2.0." Library 2.0 is not a DL, nor has it emerged from "traditional" DL funding streams, but the authors suggest that it shares some characteristics with DLs, and that the emergence of the idea of Library 2.0 was influenced by DLs and ideas about the future of libraries that have emerged from DL initiatives.

Habib (2006), in one of the most thorough discussions of Library 2.0 to date, points out that there is no agreed-upon definition of the term, but proposes the following: "Library 2.0 describes a subset of library services designed to meet user needs caused by the direct and peripheral effects of Web 2.0" (p. 9). Habib then suggests that Web 2.0 can be understood as a set of "key concepts and methods" (p. 11) that are united in the goal of enabling users to contribute content, functionality, and services to existing web-based resources. While the idea of Web 2.0 was only formulated in 2005 (O'Reilly, 2005), the idea of online resources benefiting from user contributions considerably predates that, from Kranich's (2004) description of the information commons to Marchionini's (1999) description of the "sharium" as a DL environment.

Habib (2006) suggests several ways in which Web 2.0-related ideas may affect libraries, including "application of these concepts and methods to library services. An example of

this would be to allow user tagging in the OPAC" (p. 22). Indeed, this application is currently being pursued, both formally and informally. Spiteri (2006) discusses ways in which folksonomies (metadata created collaboratively by users) can be used to supplement the controlled vocabularies used in libraries' online public access catalogs (OPACs). She suggests that combining controlled and uncontrolled vocabularies may aid users in searching the OPAC, and that providing features to allow customization in OPACs may enable users to personalize their usage experience. Less formally, a number of services have emerged on the web in the past few years that emulate or extend traditional library services. LibraryThing (www.librarything.com) is a prime example of this: LibraryThing is a web-based service that assists users to catalog their books, and enables social networking-like functionality around the books in users' catalogs. In short, LibraryThing extends and, perhaps more importantly, makes available to the individual user the functionality of the OPAC, by providing a simple cataloging interface and a shared uncontrolled vocabulary.

Habib (2006) also suggests that libraries may make more direct use of Web 2.0-related technologies to provide services (p. 22). LibraryThing has recently launched a service to make this possible: LibraryThing for Libraries is a service to enhance OPAC records with content from LibraryThing (www.librarything.com/forlibraries/). Like LibraryThing, many Web 2.0 services harness the efforts of individuals in the service of the community. In this vein, Beagrie (2005) discusses personal DLs, though he prefers instead the term "digital collection." Beagrie defines digital collections as containing "material from the individual's private life, work, and education, as well as from external communities and content sources" (Defining Personal Digital Collections section). Personal digital collections, according to Beagrie, may be solely for personal use, or may be shared with defined communities of which the collector is a part. And just as services are provided in physical libraries to add value to the collections, so too Beagrie discusses the sorts of services that may be provided to add value to personal digital collections. One of the types of services that Beagrie (2005) discusses is the management of personal data on remote servers, analogous to data librarianship, only at a personal rather than an organizational level. Beagrie also discusses web-based services like blogging applications

and Flickr (www.flickr.com) as enabling the creation, organization, and sharing of personal content.

None of these applications and services are DLs or even services that are commonly provided by DLs. However, they have grown, at least in part, out of an idea of DLs as community spaces, just as physical libraries have (Pomerantz & Marchionini, 2007). Furthermore, applications for libraries that utilize Web 2.0 concepts and methods are at the vanguard of new types of services that have the potential to have an impact on DLs, just as they have had an impact on physical libraries. If Library 2.0 means enabling users' contributions to library content, functionality, and services, then Library 2.0 and "Digital Library 2.0" may be so inextricably linked as to be indistinguishable.

Conclusion

DLs have emerged in the past decade as one of the most active areas of library research and practice. In part, this is due to the large sums of money that have been and continue to be spent by many funding agencies on DLs and DL-related projects: in this, as in many areas, innovation and progress tend to follow the money. In part, however, this vibrancy is due to the fact that DLs exist at the intersection of most or arguably all of the areas in modern librarianship. As such, DLs have focused attention – and funding – on libraries and librarianship as few areas of research and development ever have. With the popularization of the internet and the proliferation of full-text resources online, there has been much ink spilled on the topic of the "death of the book" and its corollary, the death of the library (see, e.g., Nunberg, 1996). The authors suggest, however, that the vibrancy of DLs and DL-related funding programs are strong evidence that rumors of the death of the library have been greatly exaggerated. Agencies such as Mellon that have little or no stake in libraries per se, but rather fund educational, scientific, and other social programs, have provided funding to libraries for DL projects. Technical fields such as CS have discovered areas of overlap in research and development with LIS, and many fields in both the sciences and the humanities have discovered a need for the skills possessed by librarians. The image of the profession of librarianship is undergoing a change (Jesella,

2007), and the authors suggest that the spread of DLs is at least partly responsible for the rise in the public's interest in the profession of librarianship.

It seems clear that DLs will continue to exist in some form, despite significant concerns about their sustainability and long-term preservation of digital objects. There is much about the future of DLs, however, that is unclear, including how DLs will be integrated into libraries and other cultural heritage institutions. Levy & Marshall (1995) suggest that "the better word for these evolving institutions is 'libraries,' not 'digital libraries'" (p. 83), and suggest that DLs will both transform and become integrated into libraries. Time will tell if DLs will indeed become integrated into larger institutions, or if they will remain as separate entities. This has implications for the future of DL funding: will agencies that currently fund DL projects under programs that are not specifically library-related continue to do so if DLs become more tightly integrated into libraries?

It is also unclear how DLs will be integrated into organizations and institutions other than libraries. The IMLS in particular has provided leadership in developing DLs in museums, archives, and other cultural heritage institutions, and consequently in strengthening ties between libraries and these types of institutions. Further, as more and more fields of study are affected by the "data deluge" brought on by access to powerful data collection instruments and inexpensive computing, these fields will discover the need for DLs and the skills possessed by (digital) librarians. Will the skills of digital librarianship diffuse out from libraries to become common knowledge in cultural heritage institutions and scientific fields – and in the public domain generally – as knowledge about searching electronic sources has with the popularization of search engines? Or will it instead be librarians that diffuse out from libraries, to become "embedded" in other fields and institutions, as is starting to happen in the health professions (Davidoff & Florance, 2000)?

DLs are at least partly responsible for the increase in recent years in grant funding to libraries and library-related projects. DLs have therefore been a boon to libraries, but this is a mixed blessing: the future of external funding for libraries is at least partly tied to the

future of funding for DLs. While the sustainability of DLs is a significant concern, libraries have always excelled at maintaining ongoing funding (even if this funding has been chronically inadequate). Thus there is a natural affinity between libraries and DLs where funding is concerned: libraries are established as an institution that receives a steady stream of funding, while DLs focus attention on the library and are a point of interest for funders. DLs have already transformed, and will continue to transform libraries, and it is clear that this influence goes in both directions. As Levy and Marshall (1995) suggest, it may indeed be that the term DL needs to fade away, so that DLs may become more fully integrated into libraries and other institutions. This may even be the best possible future for DLs: no single area remains a popular target for funding forever. Should this prove to be the future of DLs, however, it must be within the larger context of an environment in which the collection, management, and dissemination of digital materials is valued. Funding agencies must learn to see the value in DL-like projects across fields; political structures must support infrastructure and basic research to make such projects possible; and librarians and other knowledge workers must provide education and support to designers and users of DLs. DLs may lose their name, but they seem likely to survive by becoming integrated into the infrastructure of cultural and scientific institutions universally.

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