The Future of Knowledge Creation and Production in University Research Programs and Their Effect on University Libraries

A Dissertation presented to the

Faculty of the Simmons College Graduate School of Library and Information Science

In partial fulfillment of the requirements for the Degree of Doctor of Philosophy

By Tyler Walters

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Peter Hernon, PhD, Chair	Date
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Peter Hernon, Ph.D., Committee Chair

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Abstract

The dissertation presents possible future directions for research programs at U.S. universities and their effects on the organization of universities and their libraries. The investigator posits four original scenarios produced for this study that describe Grand Challenge-level research program development in U.S. research universities. The scenarios articulate how these universities' research enterprises might take part in an emerging global research ecosystem that is being shaped by economic, political, cultural, and technological forces. The university managerial leaders involved in research administration can utilize the scenarios in planning for how they might respond to certain forces and drivers effecting the development of their research programs. The leaders, in turn, may understand better the decisions to be made in moving a university forward strategically to realize its goals in the global research environment.

The study also examines how the libraries of the participating universities may evolve based on scenario 1, "Thriving interdisciplinary research, solving global Grand Challenges," which is the scenario most favored by the research directors. Four case studies are offered, produced from interviews with the case library directors. They highlight the directors' approaches to managerial leadership and organizational culture change with a goal of producing

a library that is relevant and vital to its university's role in the developing global research ecosystem. New library roles are articulated, focusing on managing research outputs, supporting research and scholarly processes, developing technologies and content, and partnering with researchers on research teams and as consultants. The case studies reveal that the more vigorously adapting libraries are differentiated from the lesser adapting libraries according to the level of resources available, technology infrastructures in place, and strategic partnerships created and maintained.

This study emphasizes the role of research and library directors in developing and communicating strategic directions to effect change in a U.S. university. Each library director's response to the favored scenario gives insight into how libraries may approach transformation in the face of momentous change in the university research enterprise due to external drivers. Examining the impact of these drivers through scenarios developed from an institutional perspective aids administrators in planning for how their universities will respond.

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Dedication

This dissertation is dedicated to all the ‘light chasers’ who I have come to know during my lifetime, especially my wife, Therese. May all our children grow up to be light chasers too.

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Chapter One

The Future of Knowledge Creation and Production in University Research Programs and Their Effect on University Libraries

As libraries at U.S. research universities renew their missions to discover, disseminate, and apply knowledge, they are faced with many challenges. Among these are the exponentially high volumes of information in digital form to be managed, deficient methods for web-enabled shareability and access, and paucities in understanding how best to authenticate and use digital research information generated from previous research projects in subsequent initiatives. New knowledge creation[1] itself is transforming greatly due to technological and economic change, as well as shifts in public policy. Universities increasingly are supporting research through computational means (e.g., via high-performance computing, extensive data analysis, and online storage of vast amounts of digital data). This new "cyberinfrastructure" undergirds most contemporary research processes (Atkins et al., 2003; National Science Foundation, 2007). Universities are witnessing a new cross-disciplinary approach to e-Research,[2] one which encompasses e-Science, e-Social Sciences, and the Digital Arts and Humanities.

New research in the sciences, social science, and humanities is making use of data-intensive computing[3] and has the potential to introduce new research methods and foster new

[1]One type of new knowledge creation is organizational knowledge creation, which is the formation of new ideas through interactions between explicit and tacit knowledge. The knowledge creation process consists of socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit), and internalization (explicit to tacit) (Nonaka, 1994, pp. 15-21; Nonaka, Toyama, & Konno, 2000, pp. 26-29).

[2] E-Research is defined as "research activity that is supported by… high-performance computers, large databases, scientific instruments, and/or associated facilities connected by high capacity communication links, and used in a cooperative manner to solve otherwise intractable problems." See Crossley et al. (2005), page 4.

[3] Data-intensive computing involves "processing large volumes of data typically terabytes or petabytes in size and is typically referred to as Big Data" (see Middleton, 2010, pp. 83-84).

virtually-based communities (American Council of Learned Societies, 2006; Hey, Tansley, & Tolle, 2009). These new methods center on generating, curating, and analyzing research data from experiments, observations, and simulations; developing and exploring models and simulations; enabling computation and storage of data at extreme scales; and enabling dynamic virtual research environments and laboratories (Crossley et al., 2005).

Scholarly and scientific discoveries increasingly are supported by digital data analysis-based methods of inquiry, as articulated by Hey, Tansley, and Tolle (2009). High-performance computing capabilities will become critical to many disciplines as researchers develop expertise in data annotation, analysis, visualization, and manipulation (National Science Board, 2005). Currently, datasets commonly range from the gigabyte and terabyte levels up to the petabyte range; however, researchers are likely to see datasets reaching the exabyte to zettabyte[4] range within the next decade. Higher levels of computing will accelerate research and subsequent scientific and scholarly breakthroughs. Entire academic disciplines and interdisciplinary domains are likely to evolve more quickly than previously possible. Ultimately, scholarly and scientific discoveries will depend on advanced computing as computer scientists strive to provide progressively higher levels of processing power and data storage.

The potential for rapid new knowledge discovery is tethered to technological developments such as new database designs, workflow systems, analysis and visualization tools, and cloud-computing breakthroughs. However, knowledge creation and production (KCP) also will increasingly be impacted by how well researchers collaborate with each other as well as

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[4] One exabyte is equal to approximately 1,000 petabytes, and one zettabyte is equal to approximately 1,000 exabytes.

with advanced technologists and information scientists. Online "collaboratories" are already spanning institutional and national boundaries to connect researchers. Some examples include CARMEN, http://www.carmen.org.uk, a neuroscience virtual research community; the iemHUB, http://iemhub.org, a virtual research community for environmental science (integrated environmental modeling); and the CLEERhub, http://cleerhub.org, a virtual research collaborator for engineering education research. Software platforms for virtual research communities are likely to evolve rapidly as software designers gain insights from virtual community platform users. Some current examples include HUBzero, http://hubzero.org; MyExperiment, http://myexperiment.org; Islandora, http://islandora.ca; and gCube, http://www.gcube-system.org/. Another tool supporting virtual communities is VIVO, http://vivoweb.org/, a social networking tool allowing researchers to create profiles and provide links to fellow researchers, publications, data, and analytical tools (Walters & Skinner, 2011). Given developments in virtual research communities and high-performance computer processing, the next generation of scientists may conduct research very differently from their predecessors.

While e-Research is becoming more predominant and cyberinfrastructure needs are growing, policies and funding supporting such developments at universities are shifting on a grand scale. The Great Recession beginning in late 2007 and the consequent drastic reduction in university budgets has caused growing anxiety about public funding. Concomitant with the public divestment in U.S. public research universities, research programs are moving increasingly toward government, private philanthropic, and, in particular, corporate sponsorships for funding. Corporations are funding larger and more multi-institutional research portfolios aimed at solving problems, such as providing clean water, creating efficient fuels, and preventing

intercontinental diseases (Lieberwitz, 2003). The acceleration of technology transfer from research to commercialization is now a part of the research cycle. A growing public-private interest pushes new knowledge production cycles to reach new markets and achieve positive societal and financial benefits faster.

Public policy is also shifting in dramatic ways, including the enactment of new federal laws, regulations, and policies, and university policies requiring open access to publicly funded research data and publications. These policies advance knowledge creation in new and accelerated ways by reducing barriers to accessibility of research knowledge. The National Institutes of Health (NIH) Public Access Policy (NIH, 2003, PL 110–161) and the National Science Foundation (NSF) Data Sharing Policy (NSF, 2011) are examples of laws that mandate open access to research articles, data, and other scholarly output produced from the research initiatives they fund. Specifically, they require the deposit of research publications and datasets in open repositories, such as the NIH's PubMed Central and the Protein Data Bank. The NIH policy requires that these research materials be made available publicly in PubMed Central within one year of publication in a scholarly journal. Major research universities such as Harvard University, the Massachusetts Institute of Technology (MIT), Purdue University, and the University of Kansas have created institution-wide open access policies requiring deposit of the research publications their faculties produce within one year of publication.

Universities and research funding agencies have come together in the Budapest Open Access Initiative (Open Society Institute, 2002) to declare that open access to research is necessary to scientific and cultural advancement. Approximately 600 organizations and 5,500 individuals signed this document. Researchers, funders, host institutions, libraries, and the public

all benefit from the public policy shift toward open access because it provides access to research results without the hindrance of technical and financial barriers. The effect of the policy shift parallels the impact made by the rapid development of a new cyberinfrastructure in that they both have accelerated the pace of research, new discoveries, and KCP. Research universities engaged in KCP are now witnessing growing social policies supporting research output that is quickly available via the Internet.

Much of the impetus for services to support the production, management, accessibility, and preservation of digital research data has come from federal policies such as the NIH Public Access Policy (NIH, 2003) and the more recent NSF Data Access and Management Policy (NSF, 2011), which require researchers who receive grants to make their project data publicly available. As a result, funders, researchers, and publishers face ongoing challenges to provide persistent identifiers and linkages between research publications and the datasets they cite. Because of these federal mandates, researchers are seeking institutional services and infrastructures to manage their data.

The Role of University Libraries

The external forces on and subsequent changes to KCP at leading research universities are forcing institutions of higher education to adapt in order to maintain and advance their positions as major knowledge producers. In turn, the services supporting KCP, such as producing, managing, disseminating, and preserving knowledge, must adjust as well. University libraries are establishing electronic publishing programs; digital repositories (to disseminate content and foster information discovery, use, and preservation); research data consulting and management programs (to assist researchers with the lifecycle management of their digital data);

and research commons and digital laboratories (where new software tools ranging from the ubiquitous AutoCAD to the esoteric NVivo are available to knowledge creators and producers) (Gold, 2007a, 2007b). All of these types of services aid the production of new knowledge.

In the early 2000s, university libraries began creating digital repositories as a first step toward providing relevant information services for research programs producing unique digital objects. Repository software systems such as EPrints (2000), DSpace (2002), and Fedora (2003) emerged and grew rapidly across the United States, Europe, Australia, and other parts of the world. In 2002, only a handful of library-based digital repositories existed (Staples, Wayland, & Payette, 2003). By 2012, there were over 2,200 (University of Nottingham, 2012). These repositories maintain access to and preserve digital intellectual output produced by an institution's faculty, students, and other researchers (Crow, 2002). This output includes journal articles, research reports, technical papers, theses and dissertations, annual reports, audio/video, notes, datasets, and myriad other related products.

Leading university proponents of the digital institutional repository built services that began with little to no content and grew to hold tens of thousands of objects and experience well over one million downloads annually. MIT was perhaps the first in the United States to develop such services, creating its DSpace software system in a partnership between MIT Libraries and Hewlett-Packard Corp (Smith et al., 2003). Other universities experiencing early success with repository services include Ohio State University and its KnowledgeBank repository (opened in 2003) and Georgia Tech with its SMARTech repository (opened in 2004), both based on the DSpace platform (Rogers, 2003; Walters, 2006). The University of California was also an early adopting institution, but for the entire 10-campus system. The California Digital Library

(Hughes, 2004) operates the UC system eScholarship repository. Digital repositories have become core services over the past 10 years. They provide early evidence that university libraries can adapt to changes in academic research processes, find new roles, and create new information services.

From 2006 to 2008, research data services emerged in university libraries. Today, such e-Research services range from repositing research data into the library's digital repository to allowing research teams to generate metadata, choose software and digital file formats to work with, consult on research projects, design workflows, complete digital management plans, and obtain advice on data rights and policy issues. By offering these capabilities to researchers, university libraries provide value-added services that spur research productivity.

Three research university libraries exemplify the best in new information services for e-Research: the libraries at Johns Hopkins University (JHU), the University of California San Diego (UCSD), and Cornell University. Johns Hopkins has perhaps the most prominent library program. Since the mid-2000s, the JHU Library has been working with the university's astrophysicists and the Space Telescope Science Institute (located in Baltimore, MD) to manage and reposit astronomical data (e.g., telescopic images of the night sky). More recently, the data program has evolved with the founding of Hopkins' Institute for Data Intensive Engineering and Science as well as the NSF-supported Data Conservancy, which curates an array of science and engineering data. Johns Hopkins' trend-setting experiences have blazed a path for other university library-based data services programs (Choudhury, 2008).

The UCSD libraries have collaborated for some years with the San Diego Supercomputer Center (SDSC), a unit of UC San Diego. Together, they provide research data services ranging

from metadata creation to storage and preservation. As an outgrowth of this work, they established the Chronopolis data preservation and curation service, which provides services beyond UCSD to any research institution. Chronopolis currently works with DuraSpace and its DuraCloud service to provide data management through cloud-based storage. The UCSD Libraries–SDSC partnership has shown universities that existing expertise from disparate units can combine to create new services in support of e-Research (Minor et al., 2010).

Another exemplary institution is the Cornell University Library. In partnership with Cornell Information Technology (IT) and other research-intensive units, the Cornell Research Data Management Services Group (RDMSG) was formed during the 2009-2010 academic year, leveraging the DataSTAR data repository services established earlier by the library. The RDMSG is a multiunit, campus-wide service organization that provides Cornell researchers with data management services. The RDMSG is comprised of a wide range of personnel from information technology to data, policy, and various academic disciplines to assist researchers as they produce and implement data management plans and navigate a suite of data management services. These services are designed to meet researchers' needs throughout the research process and include data creation, aggregation, analysis, description, preservation, and access (Block et al., 2010). The Cornell RDMSG demonstrates how libraries and members of several other IT and research units can provide a diverse set of research data-related services to researchers needing this new cyberinfrastructure (Gold, 2007b).

The third major information service on the university research landscape is library-based e-Publishing. Experimentation with publishing in web-based academe ranges from self-publishing through blogs to formally published, free, open access journals. E-Research as a

concept implies that researchers generate many types of digital research objects and, as such, these objects can be linked as supporting material in electronic publications. Multimedia, digital datasets, audio/video, spreadsheets, and databases can be part of the published scholarly record. In addition to changes in scholarly communication due to new Internet and digital technologies, economic and public policy changes also have a large impact. The aforementioned open access policies by funding agencies and universities alike, as well as the rise of open access nonprofit publishing companies, are driving change. Consequently, new e-Publishing programs are developing rapidly in many university libraries (Walters, 2012).

Some of the most noteworthy library-based e-Publishing services are located at the libraries of the University of Pittsburgh, Columbia University, and the University of Michigan. The University Library System at the University of Pittsburgh formed the ULS E-Journal Publishing Program to assist scholars and researchers in moving journals to an electronic publishing platform and neither charges for publishing services, nor charges readers for access to the journals the program publishes electronically (Suber, 2007). As long as they relate to the university's mission and programs, the University of Pittsburgh works with those who want to start new scholarly e-journals as well as converting print and subscription-based journals to electronic and open access; however there is a formal review process. Their program illustrates how a single university library can have a major influence on scholarly journal publishing. The ULS e-Publishing program is a member of the Open Access Scholarly Publishers Association (OASPA)[5] and publishes and implements the open access (OA) model with every one if its hosted journals. As of 2011, the ULS is scaling up its operations to produce about 100 e-

[5] For more information on the OASPA, see http://oaspa.org/.

journals.[6] As of 2013, it publishes about 30 journals in cooperation with the University of Pittsburgh Press.[7]

Columbia University Libraries has become a major publisher, but has taken a different approach than Pittsburgh. Through the Libraries' Center for Digital Research and Scholarship (CDRS) and its Center for New Media in Teaching and Learning (CNMTL), it specializes in publishing e-journals in the education field as well as all manner of publications and journals produced by units of Columbia University. The library e-Publishing program publishes more than 75 publications produced and sponsored by Columbia University faculty and academic units. Columbia Libraries' CNMTL produces journals and video-based materials related to teaching and learning and the use of new digital technologies. The CNMTL supports new scholarship that is shaping the future of the education. CDRS concentrates on providing e-Publishing services to Columbia researchers and university offices. It converts existing publications to electronic form and provides open access to them. CDRS now publishes and hosts a large majority of Columbia's publications.[8] Both the Pittsburgh and Columbia examples show how two libraries can serve important scholarly communication roles within the new e-Research paradigm.

The University of Michigan is perhaps the largest example. In 2012, the university employed approximately 40 people in the MPublishing program, a division of the University of Michigan Libraries administrated by an associate university librarian of publishing, the only such

[6] Communicated to the author by Rush Miller, director, University of Pittsburgh Library System, during a telephone interview in December 2011.
[7] For more information on the University of Pittsburgh's e-journal publishing services, see http://oscp.library.pitt.edu/uls-e-journal-publishing/.
[8] Communicated to the author by James G. Neal, Vice President of Information Services, Columbia University, during a telephone interview in December 2011. For more information on Columbia's CNMTL, see http://ccnmtl.columbia.edu/, and for Columbia's CDRS, see http://cdrs.columbia.edu.

position with this title known to exist in the United States (Hawkins, 2012). MPublishing resulted as a consequence of the merger between the University of Michigan Press and the Libraries' Office of Scholarly Publishing. The program offers repository services as well as a variety of others, including copyright and publishing consultation, journal publishing, and print on-demand. MPublishing has produced print and e-books, conference proceedings, print and e-journals, web-based digital projects, and e-textbooks. MPublishing declares that it provides "academic publishing services that are responsive to the needs of scholars, and that foster a sustainable economic model for academic publishing. We also educate and advise the U-M community on copyright and publishing matters, and we advocate for the broadest possible access to scholarly communication everywhere." The emphasis of MPublishing has been to gather university publishing resources under one organization, the university library, and focus on digital production as well as open access. The leaders of MPublishing believe this is the leading economically sustainable approach to scholarly publishing.[9]

Clearly, changes in research programs at major research universities have influenced library information services. The power of the Internet and digitization to change the very nature of research, as well as evolving international and local economies and shifting public policy, are all factors affecting how universities support and conduct research programs. Consequently, these drivers significantly impact the services libraries choose to expand and emphasize. The likelihood of further changes in university research programs due to uncertainties regarding technology, economies, and public policy will continue to shape university libraries as they strive to support the rapidly developing e-Research environment.

[9] Communicated to the author by Melissa Levine, lead copyright officer, University of Michigan Library, Publishing Division, during a telephone interview in December 2011. For more information on MPublishing, see http://www.publishing.umich.edu/.

Problem Statement

Given the changes impacting research programs at major universities, university libraries are transforming to support new KCP in a cyberinfrastructure-enabled world. Some research can be comprised as a thoroughly digital process today, which makes it an information-intensive process, and libraries and other curating organizations can manage these digital resources for additional users and uses. However, no study has examined how these future changes in research programs and their institutional-level (e.g., the research university) environments will impact university libraries and, in turn, how the libraries will respond. The purpose of this study is to fill this void by exploring the visions that guide research universities as they strategically develop their research programs and examining how university libraries will transform their services to support KCP in research programs. The study also looks at what new library–university unit partnerships might be formed to facilitate university adaptation to the new driving forces.

The study results will assist library managers as they design knowledge production-related services. It will help them understand more about the vision, strategies, infrastructures, services, and partnerships needed to develop these services. They will acquire a more comprehensive understanding of how university libraries are adapting to serve as highly collaborative partners in research environments. The study's results serve as a guide for libraries and allied university units such as information technology (IT), all of which are developing services to support the future knowledge production needs of their universities and are transforming to become an integral partner in university research.

In addition, the results will prove beneficial to those planning future IT or research policy development at universities. Given the interdisciplinary nature of KCP in research programs, the

study's findings will also interest academic researchers in computer science, engineering, and other fields with a heavy emphasis on e-Science and e-Research, such as bioinformatics, ecoinformatics, and the digital humanities and e-Social sciences.

The Future through Scenarios

This is a scenario-based research study. Scenarios are stories about the future environments in which organizations will operate and how they will adapt to achieve their missions. Scenarios offer plausible stories representing the consequences of external forces, usually economic, technological, political, and cultural. Institutions and organizations can use these stories for strategic planning.

Giesecke (1998) has offered a framework for developing scenarios for libraries. This framework reveals key forces driving a certain phenomenon and the most uncertain factors shaping the particular phenomenon fifteen years into the future. The approach creates possible futures that service organizations (e.g., universities and libraries) can respond to through strategic planning. Scenario development is based upon a matrix derived from the key forces and the most uncertain elements. Descriptions of each scenario are written in detail with stories that illuminate and illustrate the traits found in each quadrant. Further, Mietzner and Reger (2005) offer criteria for good scenarios:

- Plausibility - each scenario is likely to happen;
- Differentiation - each scenario differs from one another, and as a group, they postulate several futures;
- Decision-making utility - each scenario provides insight that assists future planning; and

- Challenging - each scenario challenges traditional perceptions of the future.

According to Martino (1970), accurate and successful planning with scenarios has a limited timeframe. His research has shown that 15 years represents the limit of predictability and that accurate predictions decline beyond this period. Martino was an early proponent of the Delphi method, a group communication approach used to gather feedback from individual study participants who usually are separated geographically. The method involves designing questions to elicit responses from study participants who assist the investigator to refine understanding of a certain phenomenon, or in the case of this study, to refine written scenarios. The question and feedback process is anonymous and places the investigator in control of the flow of information. Giesecke's approach in conjunction with Mietzner's and Reger's scenario criteria and Martino's Delphi method combine to ensure meaningful scenarios that are useful for planning.

There is a difference between developing and discussing scenarios and conducting scenario planning. Many organizations engage in strategic planning based on scenarios they develop or acquire from other sources. Most scenario-related activities described in reports and literature are this type. The current study does not engage in strategic planning for organizations. Instead, it focuses on the research process inherent in scenario development. The scenarios created throughout this study can be used by organizations such as university libraries for strategic planning as they prepare to meet the challenges presented by the driving forces. Further, they can review the set of scenarios and the resulting research as they adapt any scenario to their own situations.

Literature Review

Several noteworthy studies conducted on the national and international level have employed the axis-based scenario development method. Studies in countries such as Scotland (Abd El Ghaffar, Alberding, Nicholsky, & Lai, 2005) and England (Huisman, de Boer, & Botas, 2011) are prominent examples. A few notable European and international higher education scenario studies exist as well. These have been produced by groups such as the European Commission (EC, 2011), the Organization for Economic Cooperation and Development (OECD, 2005, 2008, 2009), and researchers from the University of Twente Center for Higher Education Policy Studies of the Netherlands (Enders, File, Huisman, & Westerheijden, 2005). While Europe is the focus of the majority of additional studies, other countries that participate in western-style economies and have a large population of English language speakers such as South Africa (Southern African Regional Universities Association [SARUA], 2012) and Malaysia (Universiti Sains Malaysia [USM], 2007) have undertaken in-depth scenario development exercises, as well.

Most of these studies do not investigate how universities will organize research programs within their institutional settings or how the drivers identified in the studies will shape the universities for the long term. They make only cursory remarks about how research is organized and conducted in the future at their universities, noting action steps such as participating in grid-based research or joining the Internet2 Consortium. The study authors' recommendations reflect national aspirations, such as claiming their countries' universities will become "regional R&D hubs" (USM, 2007) or will "contribute to socio-economic innovation and development" (SARUA, 2012). These studies do not explain why becoming a regional leader in research is

desired, let alone describe how research will be conducted, organized, and funded at the university, national, or regional level.

Most of the scenario studies focus on identifying and describing the drivers to upcoming higher education development. Their shared key interest is in furthering the education of the national or regional populations to sustain and drive their economies. Moreover, the chief concern is economic, not academic research program, development. These national- and regional-level planning initiatives seek to understand trends in areas such as information and communications technology and public policy as they relate to the national economy (Abd El Ghaffar et al., 2005). Internationalization is also a major theme in higher education scenario planning because the planners desire to understand its impact on national and regional economies and, in turn, on higher education and the need for a skilled workforce (Abd El Ghaffar et al., 2005). One study highlighted "human capacity" as a main driver, that is, having enough skilled people to develop a nation's higher educational system and maintain the national economy (SARUA, 2012).

Foreign and International Scenario Drivers

Several driving forces and elements are common in the existing scenario studies. In fact, their authors identify the higher education drivers that have significant impact on their economies. The theme of international integration in higher education appears in the "global university" scenario (EC, 2011), where universities openly cooperate and collaborate across national borders and have well-defined linkages for technology transfer between universities and industry. Other scenarios describe the "open university," where internationalization of education occurs, but it is between universities and rarely involves corporate interests. Research is

described in global university scenarios, albeit briefly, but only because organizational leaders were attempting to put together the best researchers to address an identified research challenge and provide solutions (EC, 2011; OECD, 2008). Technology also is a widely used axis in scenario planning. Study authors regularly want to forecast if information technology will be widely available and highly developed or not so developed and difficult to access (Abd El Ghaffar et al., 2005; OECD, 2009; SARUA, 2012). Subsequently, there is an attempt to rationalize higher education investments and expenditures on technology as a way to maximize the impacts of teaching, learning, and research. Current studies have focused on how to achieve this within the European Union or in southern Africa.

Privatizations of higher education as well as public-private partnerships in the public university setting are common drivers. Some scenario authors have gone as far as developing scenarios for "Higher Education, Inc.," the "corporate university," and the "differentiated university landscape," announcing that the for-profit higher educational institution is a fixture in the upcoming higher education landscape (EC, 2011; OECD, 2008; USM, 2007). Other studies have developed a three-tiered approach to higher educational institutions: (1) a small cadre of research-intensive universities, (2) many "grand universities" that are comprehensive and conduct both research and teaching and engage in learning, and (3) the private, for-profit university that meets the needs of the national population to acquire knowledge and skills (Huisman et al., 2011). These studies acknowledge a growing role for private, for-profit higher educational organizations as well as the internationalization of higher education in general through more coordination, especially in the European Union. The bifurcation of higher educational systems is a commonly expressed outcome because of the identified drivers. Future

scenarios divide universities into research-intensive versus teaching and learning-intensive universities (Huisman et al., 2011). When describing university research in such a scenario, typically it is divided, with government funding basic research, and private, for-profit corporations funding applied research (OECD, 2009). However, scenario authors tend to focus on the higher educational system-level and do not detail future changes at the single institutional level. They also focus on the university's teaching and learning roles and rarely address changes to research programs within the universities.

Other predominant scenarios appearing in several planning reports are in complete contrast to the open and global university scenarios. These scenarios describe universities that meet local community educational needs and remain state run (OECD, 2009; USM, 2007). Still others describe scholar-led universities that essentially remain the same as they have in past decades and centuries, where the university serves learning for learning's sake. There is accountability to funding agencies; however, the university is autonomous and sustained (USM, 2007). The European Commission (2011) describes a most desirable scenario where the "knowledge triangle" of universities, governments, and private entities come together and work in harmonious coordination to further knowledge acquisition and discovery across the EU nations. Other scenarios offered include the "a' la carte university," which is student-led and market-driven, meeting the educational needs of students anytime, anywhere. In a related scenario called the "invisible university," universities are market and technology-driven. They follow a highly decentralized organizational model, much like the community-driven, open source software model, and they serve students' educational needs as determined in the open marketplace (USM, 2007).

While these studies, their drivers, and scenarios promote understanding of higher education, they lack information pertaining to three important areas that are germane to the current study. First, few of them actually focus on change and development of university research programs. Instead, they concentrate on changes in teaching and student learning and they forecast how to equip a population with the knowledge and skills necessary to help a nation succeed economically in the early twenty-first century. Second, they do not mention whatsoever the role of university libraries in teaching and learning or research programs. Third, none of the studies provides a nationwide scenario study of higher education in the United States nor addresses a U.S. geographical region or a group of states.

U.S.-Based Scenario Studies of Higher Education

Only one statewide scenario study exists, and it was conducted by the 10-campus University of California system (UC, 2006). The other U.S. example is from the University of Arizona and its brief scenario planning documents (Caldwell, 2001, 2009; Caldwell & Couturier, 2004). None of the scenario-related studies in these two states addressed research, nor did they generate axis-based key driving forces and uncertain elements from which the scenarios would be derived. The University of California report (2006) provides a system-wide vision and strategies to guide the university toward 2025. The study looks at the state's changing demographics, its economics, the poor condition of its K-12 educational system, the undergraduate and graduate educational needs of its people, the research needs of California, the state's place in a global society, and the continued growing financial challenges facing higher education and California in general. The UC study serves much the same purposes as its foreign

counterparts, that is, to identify a vision and strategies to develop a robust economy and an educated workforce.

The four scenarios put forth by the UC study are:

1. "Beyond the tipping point." Financial support for the UC comes too late and academic programs degrade precipitously.
2. "Virtuous circle." California's economy has a strong recovery, and there is renewed public investment in the UC, which will be in a position to make economic improvements by increasing the educated populous and through new scientific discoveries via its research programs.
3. "UC polytechnic." The state provides more money for its K-12 schools, which then better prepares high school graduates for college in California.
4. "Complimentary campuses." State funding continues to decline, but the UC is able to grow its teaching/learning and research programs by adopting strategies similar to other university systems across the globe: the UC campuses will specialize, creating unique centers of excellence in research, yet all will strive for excellence in undergraduate education. This approach is complimentary, not overlapping or duplicating research efforts. (UC, 2006, pp. 19–20)

Regarding research programming and internationalization, the UC report asserts some definite strategies. For instance, the report's authors state, "As national borders further recede in importance in the dynamics of the global economy, our state will need to be a leader in engaging the global community in commerce, in cultural exchange, and in developing solutions to problems of common concern around the world" (UC, 2006, p. 14). The main strategy is to

create the unique centers of excellence outlined in the fourth scenario and to coordinate and collaborate internationally. Perhaps the leading example of this strategy is the California Institutes for Science and Innovation, described as an "unprecedented three-way partnership involving the state, California industry, and the University of California" (p. 33). The Institutes also work directly on research initiatives with several universities in China, and the authors point out that the relationship between California and China is economically significant and culturally and historically salient. This research arrangement is reminiscent of the "knowledge triangle" scenario put forth by the European Commission (2011). While the UC report presents some strategies regarding its research enterprise and its intent toward internationalization, it does not treat in-depth the changes that research programming at the institutional level must likely go through. The report also identifies the system's libraries as a critical infrastructural resource and service, but does not describe the libraries' needs to transition and how they will accomplish these transitions in response to the strategic development of the UC's research program (UC, 2006, p. 41).

The documents referring to the use of scenarios and scenario planning for the University of Arizona provide even fewer details regarding their research program or library. The most recent Arizona report (Caldwell, 2009) describes two polarized scenarios: "Celebrating Tradition" and "Organizational Metamorphosis." The report states the first scenario is "one of maintaining traditional values and approaches while doing what is necessary to survive the present; the future is assumed to be a series of relatively consistent incremental changes and a continuation of the current vision." The second scenario acknowledges that "the world has changed and the university needs to make major changes in both the short term (driven by

financial constraints) and the long term (guided by strategic choices)" (p. 13). The Arizona documents focus mostly on the state-level political landscape and positioning the University of Arizona well within it. They do not address transitions in the development of research programs or any internationalizing components. Given the dearth of scenario-based planning in the U.S. focusing on research programs and related library services, the current study provides new insight.

European Scenario Studies of University Research Trends

Two Euro-centric scenario studies delve into the future characteristics of university research programs and internationalization. The University of Twente study led by Enders et al. (2005) provides some commentary on organizing research activity in each of the three scenarios they put forth. The study focuses on Europe and acknowledges a global context, noting that academic research and development can and may be transferred to other world regions such as Asia, Latin America, and South Africa. Enders et al. did not comment on U.S. research universities and the role of university libraries; however, they did discuss organizing research initiatives in cross-institutional teams with diverse funding sources:

> Most have organised their research in inter-faculty and inter-university units that are comprised of flexible and semi-permanent teams in self-organised centres with control over, and responsibility for, costs and revenues. Face-to-face contact with partners interested in knowledge transfer forms the basis for cooperation with business and increasingly with other organisations and interest groups. Strategic alliances, the insourcing of private R&D, and mixed university-company campuses are organisational responses to the new mix of

> funding opportunities, changing university research missions and novel research technologies. Academics themselves are the major players and drivers of these developments towards a greater overlap between the realms of academia and the commercial world. (pp. 82–83)

Further,

> "Big science" is increasingly undertaken by cross-national tailor-made consortia that draw on top university based researchers and their counterparts from the public and private sectors. Despite a number of expensive ERC programmes to encourage European research networks, the self-perception and scientific practice of Europe's leading centres continues to be unashamedly international. Exclusive European networks are seldom those at the cutting edge. (pp. 92–93)

The Enders et al. study illustrates how to organize research programs differently and explains how internationalization in particular can drive their transformation.

The OECD (2009, pp. 145–178) also reports on research directions with an international perspective. The work, based on an examination of research program development from the 1980s to the 2000s, offers four axis-based scenarios: (1) open collaboration, (2) national interest promotion, (3) international research marketplace, and (4) new public management (pp.173–178). The report discusses a "massification of academic research" occurring; meaning the amount of academic research conducted was up massively over the 20-year period addressed by the study. The OECD also indicated that there was a 52 percent annual growth rate in research articles from 1988 to 2005 among member nations (the data include the United States, as well).

In addition, from 1981 to 1999, the OECD countries experienced a 127 percent growth in the number of university researchers. Given that the OECD conducted the research across all of its 25 member nations, the trend of increased research production, scholarly articles, and personnel indicates a growing internationalization in research activity.

The OECD report (2009) discusses several other characteristics of transition for the academic research institutional transition. Traditionally, research universities have been known for producing basic research. However, the OECD notes that non-academic sectors such as government agencies, non-governmental organizations (NGOs), and private corporations also perform basic research. Thus, research universities are asking if basic research, as opposed to applied and industry-based research, is where they want to focus their resources. The OECD also posited a scenario for OECD countries called the "new public management." In this scenario, university funding is less public with rapidly growing sources of private funding; however, through government regulation, these private resources are monitored closely and are expected to serve societal needs to produce highly educated and skilled national populations and generate research results of high societal value (OECD, 2009). The described scenario is reminiscent of the current environment at public research universities in the United States. The OECD claims that heightened governmental regulation is a new driver for higher education and research development and offers that the other new, major driver is technology in the form of "new computing and networking opportunities." Moreover, the OECD asserts that research trends will support open, international collaboration and an international research marketplace where funds for research are sought, national interests within certain research sectors are promoted, and there is a new "social contract" between public and private interests to fund and regulate research

activity. The Enders et al. (2005) and the OECD (2009) studies set the context and suggest likely drivers to consider in the current study.

University Library-Related Scenario Studies

Since approximately 2009, many library-related scenario development and planning studies have been conducted. Librarians and researchers have undertaken scenario development to examine future roles for the Federal Depository Library Program (FDLP) in research university libraries (Hernon & Saunders, 2009) and in public libraries (Chadwick, DiPlato, LeConge, Rubin, & Shaffer, 2012), digital libraries (Vignesh, 2009), academic health science libraries (Ludwig, Giesecke, & Walton, 2010), scholarly communication (Carpenter, Graybill, Offord, & Piorun, 2011), on the future of the book (Staley, 2012), and with publishing services in university libraries (Walters, 2012). The scenario study of Walters relates closely to the current study. Specifically, it examines U.S. libraries of major research universities and their role in KCP via library publishing services. While the current study reviews and examines a wide variety of digital services in support of research, especially conducted through internationally composed research teams, the former study examines the one particular service of library publishing services.

The Cawthorne dissertation (2013) makes use of scenarios and case studies to envision a new future for U.S. university research libraries. This study is a qualitative study based in interviews with provosts, library directors, and library human resource officers. It keys on new roles for these libraries and how organizational transformation will occur, with a specific examination of organizational development being coordinated by the human resources officer. The resulting work is intended as material that can guide provosts and library directors in

mapping a library's strategic directions and its organizational human resources. The Cawthorne study differs from the current study in that the later focuses on KCP in the emerging global research environment and how universities will develop their research programs to be successful, while the former study focuses not on this specific and emerging research environment, but takes a broader look at the forces impacting libraries and their organizational transformation.

There has been other scenario studies looking at the future of higher education and academic libraries' roles within it (Staley & Malenfant, 2010). This particular study, conducted for the Association of College and Research Libraries (ACRL), presents 26 possible scenarios for academic libraries in the year 2025. Staley and Malenfant (2010) state, *"*The scenarios represent themes relating to academic culture, demographics, distance education, funding, globalization, infrastructure/facilities, libraries, political climate, publishing industry, societal values, students/learning, and technology*"* (p. 3). Yet, very conspicuously, they do not address the theme of research specifically in the ACRL study. However, that study references the future of the research process and states libraries must adapt: "Libraries will need to reconsider what their relevance is in the research process. We need to start considering what our 'deeper meaning' is to researchers to ensure that we fit into this new model. I feel strongly that we will have a role; it will look different from our role now, and we need to be careful not to cling to past practice for nostalgic reasons" (p. 10). While this quote highlights the changing environment—the transforming academic research process and libraries' role within it—the study itself does not offer specific scenarios, strategies, or roles for libraries to consider while planning.

A recent volume edited by Hernon and Matthews (2013) reviews the future of academic and public libraries with library scenarios being the foundational method highlighted by the

authors. First, it covers the relevant literature relating to scenarios in both the academic and public library setting. In the academic category, the authors offer six original scenarios for the reader's consideration:

1. The present is the future. This library retains its traditional services and units with a focus on managing collections, which the majority of are now in digital form. Adding digital components to the library's programs is the dominant theme, involving, web site that support user request forms, text messaging, self-checkout, and wireless printing.
2. Press a button library. With a vast majority of information resources available online through the library, its major role is serving as the content licensing service. Managing physical collections is no longer a major consideration. The library also concentrates on converting library print collections space into student learning spaces.
3. The library is a learning enterprise. The library concentrates on learning and pedagogies, working with teaching faculty, and providing instructional spaces. It teaches information and visual literacy concepts, partners with other student-related academic services and hosts some of them in the library. The library engages in evaluation and assessment to improve its related programs.
4. Expanding service roles. The emphasis is seamless access to information and data where the library is the designer of information systems. The library leverages cooperatives to achieve savings and capacities in managing and providing access to a burgeoning arraying of online resources. Library employees are embedded in

research projects, digital initiative-related centers, instructional design and assessment, and in developing instructional content.

5. The library as the campus scholarly communication publisher

   The library sees supporting the scholarly communication cycle as its core mission, which involves creating, disseminating, and producing knowledge for teaching, learning, and research purposes. It possesses a technology infrastructure to conduct the library's work on the home campus and beyond. The library integrates the institutional repository, university press, and rights and acts as a publisher.

6. The library as a more active research partner

   The library becomes a partner in technology- and data-intensive research disciplines nationally and internationally. It develops relationships and partnerships with many other academic departments and centers engaged in e-Research activities. Library employees serve on research teams and work principally on data management issues.

There are guest essays written by four academic library directors who consider these scenarios and react to them. They concentrate on two themes in their responses: scholarly communication and library physical space. Two of the directors offer perspectives on scholarly communication in liberal arts colleges. The two others focus on library space and space planning specifically. Hernon and Mathews also review some trends and current developments in

academic library space that impacts the futures of libraries, particularly more recent initiatives like the HathiTrust and the Digital Public Library of America (DPLA).[10]

Two additional scenario-based planning initiatives within academic library communities attempt to focus on future research directions, translating them into paths of development for library services. Both are meant to serve as guiding documents for libraries to engage in strategic, long-range planning, but one is not based on rigorous scenario development research.

The first, based in the United Kingdom, is known as the Libraries of the Future Project (LotF). It was sponsored by the British Library, the Joint Information Systems Committee (JISC), Research Libraries UK, the Research Information Network, and the Society for College, National, and University Libraries. The project's report focuses on how different types of higher education institutions interact (research-intensive, teaching/learning-focused, and private/for-profit) and how they collaborate with government, private corporations, and regional economic groups and industries (Curtis et al., 2012). The scenarios describe the future legal, technological, economic, and governmental environments in which research takes place in the UK as well as how librarians and library services may evolve to support future research projects. The LotF project's scenarios focus on the national level (UK) and more on whether higher education institutions will become private institutions operating in the marketplace or state-controlled entities with a mission dedicated to the common good. The report also focuses on whether they will be relatively open institutions, available to a broad section of the population for learning purposes, or closed and rather elitist, carefully guarding their educational offerings and research products that they see as unique, having financial value, and, thus, intellectual property (IP)-

[10] For more information on the HathiTrust, see http://www.hathitrust.org/ and for the Digital Public Library of America, see http://www.dp.la/.

protected. While the LotF scenarios do much to advance an understanding of research-supporting environments and the role of libraries, they lack any focus on the interaction between research programs and the parent university or on how this relationship manifests itself in new research organizations inside and outside of the university.

Next, the Association of Research Libraries (ARL) developed scenarios relating to academic research during 2009-2010 (ARL, 2010). The ARL and a group of its member library directors designed the scenarios and an associated toolkit for use by member libraries in their strategic planning as they transition in response to certain driving forces affecting university research (i.e., social, technological, economic, and political/regulatory forces). The scenarios focus on whether the research enterprise is aggregated (controlled by disciplines, countries, or institutions) or diffused (left up to individuals and loosely coupled organizations of a virtual or location-based nature) and whether individual researchers are constrained or unconstrained by resources, technologies, policies, and their own creativity. The scenario overviews describe the larger milieu in which researchers perform research, followed by fictional stories casting an individual researcher in each scenario. The ARL 2030 scenarios are useful because they take a global view of where research may be growing and shrinking nationally and regionally. They also capture the perspectives of library directors on research program development since they served as the study population in ARL's scenario development work. The scenarios also comment substantively on the nature and sources of research funding and tend to focus on the experience of the individual researcher in the larger scenario environment. However, they do not look at how the institutional setting of the research university itself may change because of the scenarios and how, within the university, transitions in research program development and

organization might occur. They do not capture the perspectives of research directors on research program development, since they were not the subjects of the study. The ARL scenarios also do not comment on the transitions that university research libraries may undergo and the roles they may take on as a result. The ascendancy of scenarios and scenario planning for college and university libraries is being witnessed through the many studies presented in this study's literature review, all produced within the past five years.

Procedures

A Delphi panel of 12 research directors, that is, vice presidents of research or their designees, was selected. In Phase One of the study, this panel responded to research questions designed to generate scenarios of research program development at their universities. These questions and the contextual objectives appear in Table 1.1. Phase One. In Phase Two, a group of library directors at research university libraries was selected to answer a set of questions. Their responses were then used to formulate case studies. This phase addressed the other set of objectives and questions appearing in Table 1.1, Phase Two. The resulting research program scenarios and university library case studies help library managers understand the forces influencing research program development at U.S. research universities and, in turn, how university libraries will evolve in response.

Table 1.1
Research Objectives and Questions

Research Objectives: Phase One	Research Questions: Phase One
1. Identify the key forces that will shape U.S. university research programs by 2028	What key forces will impact the shape and contour of U.S. university research programs by 2028?
2. Identify the most uncertain elements that will shape U.S. university research programs by 2028	What are the most uncertain elements that will have an impact on the shape and contour of U.S. university research programs by 2028?

3. Identify the major elements that support and/or hinder the research program development in U.S. universities by 2028	What major elements will support and/or hinder U.S. university research program development by 2028?
4. Identify the strategic responses of U.S. university research programs to the driving forces and elements shaping them by 2028	What are the strategic responses of U.S. university research programs to the driving forces and elements shaping them by 2028?
Research Objectives: Phase Two–case studies	**Research Questions: Phase Two-case studies**
1. Identify how university libraries envision their response to the changes in U.S. university research programs based on the driving forces and elements affecting them	How will university libraries respond to the changes in U.S. university research programs based on the driving forces and elements affecting them?
2. Identify the new library services needed to support new knowledge creation and production in U.S. university research programs	What new library services need to be pursued and established to support new knowledge creation and production?
3. Identify the new library–university unit partnerships needed to establish new library services for the research programs	What new library–university unit partnerships are necessary to establish them?
4. Identify if any new partnerships between the university library and organizations outside the university are needed to establish new library services for the research programs	What, if any, partnerships between the library and any organizations outside the university are needed to establish them?
5. Identify what is needed to sustain library services supporting new research program development in U.S. universities by 2028.	How will the library sustain its suite of services supporting research program development? What are the technologies needed and what are their characteristics? (Open/proprietary? Cloud/non-cloud? Outsourced/insourced? etc.) What are the expertise areas and skills required? Will the services require more or less financial support than current library levels, and what will be these sources of support?
6. Identify which leadership approaches and strategies will be used to transform libraries in support of university research program development and directions by 2028.	Which leadership approaches and strategies will library directors use in transforming the library to achieve the university's vision for research program development by 2028?

7. Identify the elements that either support or hinder the development of the library to support successfully U.S. universities' research program development.	What are the elements that sustain and/or hinder the library's ability to support U.S. universities' future research program development? What should libraries do to prepare for the realization of these elements?

Research Design

The participants for both phases were determined by reviewing research universities that are members of the Southeastern University Research Association (SURA). While founded in the Southeast of the United States in 1980, SURA represents research universities beyond the region and includes standard member institutions in Delaware, the District of Columbia, Maryland, Massachusetts, Oklahoma, Texas, West Virginia, and in Regina, Saskatchewan, Canada, as well as affiliate members in Idaho and Ohio. There are 63 SURA standard research university members. SURA coordinates many interinstitutional research programs among its member institutions, government agencies, and private research organizations. Noteworthy SURA collaborative programs include research in information technology; coastal, ocean, and environmental sciences; and particle physics as related to energy research. SURA's leading consortial approach to research program development is the Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News, Virginia. SURA operates the Jefferson Lab for the U.S. Department of Energy through Jefferson Science Associates, LLC, a SURA/Computer Sciences Corporation. The Jefferson Lab supports the member institutions involved in energy research.

The investigator reduced the number of research universities eligible for participation by identifying those SURA members that are also members of the Association of Research Libraries

(101 research universities in the United States[11]) and those classified by the Carnegie Foundation as "Research University-very high activity (RU/VH)"[12] institutions (108 research universities in the United States). When crosschecked between these three groups, 25 research universities meet the criteria for inclusion in the study. These research universities, through their memberships and classifications, demonstrate a very high commitment to research activity. Table 1.2 lists the 25 research universities, organized by state.

Table 1.2
Research Universities with Membership in SURA and ARL that are also Carnegie Foundation-Classified as Research University-Very High Activity Institutions

State	Institution
Alabama	University of Alabama
District of Columbia	Georgetown University George Washington University
Florida	Florida State University University of Florida
Georgia	Georgia Institute of Technology University of Georgia
Kentucky	University of Kentucky
Louisiana	Louisiana State University Tulane University
Maryland	University of Maryland
Massachusetts	Massachusetts Institute of Technology (MIT)
North Carolina	Duke University North Carolina State University University of North Carolina--Chapel Hill
Oklahoma	University of Oklahoma
South Carolina	University of South Carolina
Tennessee	University of Tennessee Vanderbilt University
Texas	Rice University Texas A&M University University of Houston

[11] As of January 21, 2013, 125 institutions were members of ARL. Of these, 101 are U.S.-based research universities.
[12] For the Carnegie Classification of Institutions of Higher Education, see http://classifications.carnegiefoundation.org/.

	University of Texas--Austin
Virginia	Virginia Tech University of Virginia

Next, the investigator used stratified sampling, the "grouping of the units composing a population into homogeneous groups (or strata) before sampling" (Babbie, 2012, p. 212; Wildemuth, 2009, p. 119). Such a method improves the representativeness of the study sample. The investigator stratified the 25 institutions into the major, homogeneous divisions of research universities: public land grant (AAU member), public land grant (non-AAU member), public non-land grant, and private. Membership in the American Association of Universities (AAU) reflects a university that supports a much larger and broader base of research. Three AAU member public land grant universities, five non-AAU public land grant universities, nine public non-land grant universities, and seven private universities were identified through stratified sampling. The investigator then applied purposive sampling to determine the twelve participating institutions. Purposive sampling is where the investigator selects the sample based on who she or he thinks is appropriate for the study, relying "on the expert judgment of the person selecting the sample" (Babbie, 2012, pp. 190–191; Wildemuth, 2009, p. 121). In Phase One, the investigator studied three participating research universities from each of the four strata, for a total of 12.[13]

Once the dissertation committee approved the list of universities and the Institutional Review Board of Simmons College granted its approval as well, the investigator approached each research director at the twelve universities through a formal e-mailed letter inviting the director to participate. In each case, the research director initially contacted was the university's vice president, provost, or chancellor for research (referred to in this study as "VPs for research"

[13] There are only three AAU member public land grant universities from which to choose.

or “research directors”). A member of the Virginia Tech (VT) Office of Research and dissertation committee members Camila Alire and Joan Giesecke assisted the investigator. They also assisted with making contact with the appropriate research directors at each university. The participation of the dissertation committee and the Virginia Tech Office of Research helped ensure the appropriate institutional participation targeted for this study. Where beneficial, the investigator used personal and professional contacts between the dissertation committee and the VT Office of Research to make the initial contacts and to elicit responses from each director. One university declined to participate in the study in any form. Eight of the universities' VPs for research chose to participate directly in the study, and three appointed another senior research administrator in their office to serve as the participating research director.

University libraries selection. For Phase Two of the study (library case study development), the investigator applied the same selection criteria used in Phase One, with one additional criterion. The library directors were selected from those university libraries currently operating the following digital programs or services:

- e-Publishing (e.g., e-journals, e-conference proceedings, e-books, blogs, databases, or websites);
- e-Research/e-Science (e.g., data curation and preservation, data analysis and visualization, data consulting services, data management planning, virtual research community support); and
- Digital repositories and collections (digital collections supporting the humanities, including institutional repositories).

After the investigator reviewed the library websites of the 25 universities meeting the Phase One criteria, 18 university libraries meet the additional criterion of offering digital programs and services.[14]

As in Phase One, the 18 university libraries were stratified into the major research university divisions. There are four public land grant non-AAU universities, three public land grant AAU universities, six public non-land grant universities, and five private universities. Through purposive sampling, the investigator proposed four university libraries, one in each of the four strata, to include in Phase Two.

To determine the four university libraries that participated in Phase Two, the dissertation committee reviewed and approved the final selection. The investigator then invited each library director to participate by way of a formal letter and made use of the personal and professional contacts between dissertation committee members, the investigator, and the library directors to elicit their responses and participation. In the end, the first four library directors to be contacted consented to participate in Phase Two of the study.

Table 1.3
List of 18 Research Universities for Selection of Library Directors

Category of Institution	Selected Institutions
Public Land Grant (non-AAU)	North Carolina State University University of Georgia University of Kentucky University of Tennessee
Public Land Grant (AAU)	Texas A&M University University of Florida University of Maryland
Public Non-Land Grant	Florida State University Georgia Tech University of Alabama

[14] This review was performed on January 17, 2013.

	University of North Carolina–Chapel Hill University of Texas at Austin University of Virginia
Private	Duke University George Washington University MIT Tulane University Vanderbilt University

Scenario development. The planning timeframe for the scenarios is limited to a 15-year period (Martino, 1970). Thus, the scenarios depict the year 2028. The investigator developed the scenarios to address how the driving forces identified will shape future research programs in major research universities. These forces were determined based upon scenario-based reports and literature on university research trends and the key forces (e.g., economic, technological, political, and cultural) involved. Figure 1.1 depicts the scenario axes used in this study, and Table 1.4 identifies the major forces, the key driving force, and the most uncertain force used to develop the initial scenarios. The scenarios concentrate on the leading key force (i.e., international competitiveness)

and explore how this force impacts university research program development over the next 15 years. The scenarios also examine the status of the most uncertain force, that is, whether entrepreneurial and interdisciplinary centers or traditional academic departments will dominate within U.S. research universities. Table 1.5 is the scenario question and context, which is comprised of the central question to be address in the scenarios as well as background information on the driving forces. Table 1.6 describes the initial scenarios.

Figure 1.1
Scenario Axes

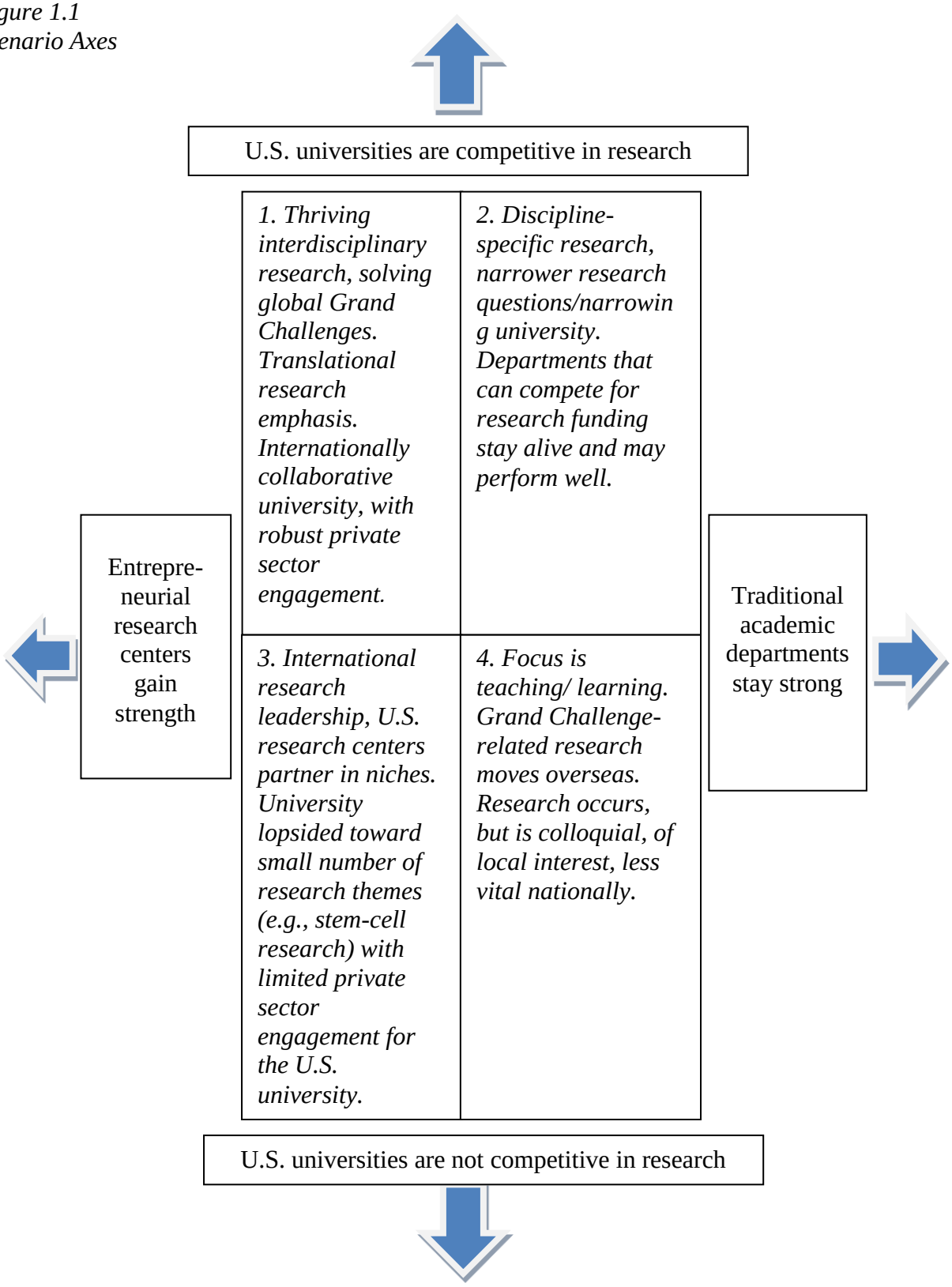

Table 1.4
Major Forces

MAJOR FORCES
How will globalization and entrepreneurial approaches impact research program development in U.S. universities over the next 15 years?
Economic
• Trends in U.S. • Public funding for research and research universities
• Trends in internationally-based research funding
• Entrepreneurial business models in place in research centers
• Public-private partnerships, and sometimes internationally-based, to carry out major research initiatives
Political
• Public support (or lack thereof) for U.S. research universities
• Governmental rules and regulations mandating the public access and sharing of research data and information
• Intellectual property and copyright online digital datasets and other tangible research outputs
• International cooperation on "grand challenge-like" research initiatives
Cultural
• University members' adoption of new entrepreneurial and interdisciplinary research centers as a legitimate and desired approach to framing research problems, funding research, conducting research teams, and making discoveries
• The public and governmental demand for research data and information to be available on the "free web"
• Increases in researcher and small/international/multiuniversity-based research groups as self-publishers of their data and information objects

Technological
• Cyberinfrastructure to support international, multiuniversity research communities and their virtual environments
• Growing high-performance computing and networks to process "Big Data"
• Technologies to diffuse research data and information globally with increasing rapidity and access and with dramatically dropping information dissemination costs per byte via the Internet
Key force: *Economics*. How will economic forces over the next 15 years impact U.S. research universities and will their research programs be competitive internationally? Issues range from trends in U.S. public funding of research and the growth of public-private partnerships to the impact of globalization, specifically international collaboration and cooperation in research.
Most uncertain force: *Cultural.* The widespread adoption of new entrepreneurial interdisciplinary research centers as the primary means by which faculty and other researchers are organized. Much tension lies between the traditional, classic mode of university faculty organization, the academic department, and the entrepreneurial/interdisciplinary research center. In many cases, they compete for financial resources, facility and technology infrastructures, and the time and energy of university faculty. If a trend in a particular direction becomes evident, it will have a significant impact on how research is funded as well as how universities organize and leverage their research programs.

Table 1.5
Scenario Question and Context

Central question
How will globalization and entrepreneurial approaches impact research program development in U.S. universities over the next 15 years?
Background
The economic, technological, political, and cultural environments surrounding research program development in U.S. research universities are undergoing rapid and permanent change. There are many uncertainties in these environments, specifically regarding their impact on how universities organize and perform research on an international scale. Universities increasingly are supporting new research through computational means, or cyberinfrastructure, that require high-performance computing, extensive data analysis, and vast amounts of online digital storage. This development is spurring the rise of a new cross-disciplinary approach referred to as "e-Research," which encompasses e-Science, e-Social Sciences, and the Digital Arts and Humanities. The new knowledge creation and production (KCP) that occurs in research programs will be linked increasingly to how well researchers collaborate among themselves as well as with advanced technologists and information scientists. New online collaboratories are spanning institutional and national boundaries and connecting researchers virtually. The economic and policy foundations of university-based research are shifting on a grand scale, as well. The Great Recession beginning in late 2007 and the consequent drastic reduction in university budgets is causing great angst regarding public funding. Research programs are increasingly sponsored by government, private philanthropic, and corporate entities. Public

policy is also shifting in dramatic ways, including the enactment of new federal laws and regulations as well as agency-level and university policies requiring open access to publicly funded research data and publications. Some policy shifts are having the effect of accelerating research and new discoveries, while others are slowing the pace of research by introducing new controls and regulation. These drivers and the subsequent changes to leading research programs are forcing U.S. research universities to adapt in order to maintain and advance their positions as knowledge producers.

The convergence of such strong influences on U.S. research universities will shape the future role and direction of research program development. To serve these research programs, university libraries play a role in research, discovery, and innovation through information and data services. In response to changes in research programs, they are establishing services such as electronic publishing programs; digital repositories (to disseminate research content and foster its discovery, use, and preservation); research data consulting and management programs (to assist researchers with the management of their digital data); and research commons and digital laboratories (where new software tools are available to knowledge creators). All of these services aid new knowledge production and support research programs.

The scenarios developed in this study will help research universities and their libraries plan for the potential forces, uncertainties, and eventual directions they will take regarding research program development and related information and data services.

Table 1.6
Description of the initial scenarios

Scenario 1

Thriving Interdisciplinary Research: Solving Global Grand Challenges

Global Context

There are many robust research initiatives thriving on a global scale. They are aimed at solving many Grand Challenges[15] in research such as sustaining the environment (e.g., providing clean air and water), eradicating certain diseases, creating new biotechnologies, sustaining soils and agriculture, developing and sustaining renewable energy sources, and creating new information and communication technologies (ICTs) that rapidly evolve and reflect how individuals in a society work, entertain, and learn. A truly integrated global economy exists and demands some developments to improve societal conditions internationally as well as produce new goods and services that will serve as new economic engines. The global economy is healthy, yet is always looking for the next trend in goods, services, and technologies to sustain its growth. Governments, universities, private corporations, and private nonprofit research organizations have learned how to collaborate and fund research jointly to address the rising global challenges. They work together through national and international boards to determine the nature and priority of funded research agendas.

Many of the nations involved in the research initiatives have laws and regulations

[15] "Grand Challenges" (GCs) in research are defined by the National Science Foundation as being fundamental problems of science and engineering, with broad applications, whose solutions would be enabled by high-performance computing resources. It is also recognized that GCs also require extraordinary breakthroughs in computational models, algorithms, data and visualization technologies, software, and collaborative organizations uniting diverse disciplines (National Science Foundation, Advisory Committee on Cyberinfrastructure, Task Force on Grand Challenges, 2011), p. xiv.

requiring that government-funded research is open globally after a one-year period from the release of information and data. Governments recognize that global access is important; it may spur on innovation rapidly since many more researchers and private citizens will be able to work with the information. Corporations support the policy on open access to government-funded research since they have access to their competitors' research quickly and recognize that competitors may become collaborators in an upcoming research initiative.

U.S. University-based Response

Translational research is the focus, where findings diffuse from fundamental research to practical applications quickly. For many years, university-based research has remained too compartmentalized, based on academic domains. However, many universities and national governments in Europe, North America, Asia, India, the Middle East, South America, Australia, and New Zealand work together through interdisciplinary and transdisciplinary methods to optimize the diffusion. The world's leading research universities cultivate teams of researchers that contribute to these large-scale, internationally based research initiatives, many of which are funded for a decade. University administrators direct most internal resources and policy development toward fostering flexible and agile research organizations that gather the most renowned researchers from needed disciplines. These organizations work through an elaborate global network of researchers, constantly seeking new initiatives and associated funding. The university research groups collaborate internationally to respond to an agenda, apply for funding, conduct research, and spur the growth of the economies through private and public enterprises.

The universities, governments, corporations, and private nonprofit research organizations collaborate in developing and managing robust virtual community-based ICTs. They provide the

cyberinfrastructure required for the internationally connected university groups to collaborate, deliver research products, and work with private and public enterprises to translate findings into goods and services from which people, nations, and companies benefit. High-performance computing cycles are readily available and developed within international university- and government-based consortia. The research groups self-publish their research products (e.g., data, notes, commentaries, audio-visual media, reports, and publications) through their virtual research communities and other government-managed research repositories. They also use their universities' library-based publishing services to produce, disseminate, and manage their research products. The mix of corporate, government, and university researchers is changing constantly since the research funding goes to the best collection of researchers for a particular project.

Scenario 2

Discipline-specific Research: Narrower Research Questions, Narrowing University

Global Context

While there are many international research agendas developed and underway, they tend to be focused within a disciplinary framework. For example, environmental scientists, who only on great occasion collaborate with engineers, business and policy researchers, and sociologists to explore these challenges, address clean air and water issues alone. Likewise, computer scientists and engineers work on information technology, agricultural scientists address agricultural issues, and medical scientists address disease control and eradication. Governments, universities, and corporations have some marked success with transcending their national and organizational

boundaries to conduct pathbreaking research, yet there are limitations to the research due to the boundaries established by academic disciplines and departments. The global economy is healthy, yet is always looking for the next trend in goods, services, and technologies to sustain its growth. The economy cycles up and down and new discoveries in science and technology do not develop quickly and consistently enough to help the global economy maintain an upward trajectory. Research funding is plentiful and coordinated internationally among governments, corporations, universities, and private funding entities. Addressing Grand Challenges is the focus; however, it occurs only within a narrow set of disciplines.

Public policy and law tend to be more developed in areas where the advancing academic fields are involved. For instance, policies regarding the degree of confidentiality and openness of research information are not applied across national governments, but rather occur at the agency level within a single national government. These agencies have agreements with their international counterparts to support research development and the open sharing of information. Corporations have mixed reactions to this approach. While corporations want access to research themselves, they are hesitant to share data because their competitors would also have access to the research results.

U.S. University-based Response

The universities have developed chiefly within their academic departments; hence, much of the resources, technology, and policy reinforce this arrangement. The research questions universities are able to address are narrow in scope. Therefore, they tend to develop highly successful departments in only a few areas since the university's resources are not leveraged across departments and colleges very well. Departments such as biotechnology/bioengineering,

computer science and engineering, and crop/soil/water environmental sciences are among those that have developed excellent platforms of researchers and infrastructures from which to compete for funding and collaborate with similar departments at leading research universities across the world. Many departments do not have the resources to develop the high-grade infrastructures and research capabilities needed to compete and collaborate at an international level. The individual university's reputation is built on only a highly select number of fields.

The successful departments collaborate regularly with governments, corporations, nonprofit research organizations, and other universities internationally. University and national research technologies are more aligned with the specific needs of a few fields, yet they have developed robust infrastructures that are comprised of Internet-based virtual research communities, repositories for research products, software production tools, and high-performance computing, which is developed at the university and national levels. The universities and departments self-publish their research products and through field-based publishers, virtual communities, and other government-managed research repositories. Much of these ICTs and related research services are concentrated within certain scientific domains.

Scenario 3

International Research Leadership: U.S. Research Centers Partner in Niches Global Context

Several research areas critical to confronting Grand Challenges are being led by universities and governments in world regions such as far eastern Asia and India. Specifically, China is the research leader in information technology, agriculture, and biotechnology; India is a leader in information technology and agriculture; and countries such as France lead in

biotechnology and Brazil in agriculture and biotechnology. Many of the nations leading the research have laws, regulations, and tax structures that provide great impetus for their universities to conduct innovative research. These national governments wish to be seen as world leaders in research, and therefore have adopted policies to ensure free and public access to research findings worldwide. They want to impress and make sure that other countries can see their leadership in research.

The faltering U.S. economic environment has been a major contributing factor to the rise of research leaders outside of the United States. The U.S. government's research funding has been shrinking consistently during the past 15 years, falling 25 percent during this period. At the same time, expensive U.S. government regulation and oversight of university-based research for the past 15 years has risen markedly. Many U.S. universities estimate this has added 15 percent to their overall research costs. Corporations, which have long been a dedicated partner in funding university-based research, have been experiencing difficulties. Corporate-related taxes by U.S. states and the federal government have risen 15 percent during this period, and corporations are finding it difficult to fund broad-based and longitudinal research projects as they used to do. The corporations' research dollars are focused tightly on specific, narrower applied research programs aimed at improving specific sectors of their goods and services portfolios. They are looking for quicker and more targeted financial gains from research.

U.S. University-based Response

U.S. research universities have spent many years building entrepreneurial, interdisciplinary research centers; however, due to funding constraints, increased regulation, and regulatory costs, they are competitive in only certain areas of research. Consequently, many

research portfolios of U.S. universities are no longer competitive with their international counterparts. They have had to retrench, focus, and salvage a small number of research areas where they can compete and contribute globally. Many of these are in the medical and environmental research domains. A prime example of this phenomenon is in stem cell research. A small number of leading U.S. biotechnology research centers partner in aspects of the research with French universities that dominate this research field. Stem cell research is legal in France and well-funded by the French government and the European Commission; however, in the U.S. it is highly regulated with many federal legal restrictions and, subsequently, not well funded. Moreover, research centers at U.S. universities partner internationally in particular niche' areas with foreign universities that are leading the Grand Challenge research.

In order to collaborate internationally and maintain competitiveness in areas such as medical, biotechnology, and environmental research, U.S. university research centers develop strong cyberinfrastructure so they can collaborate on virtual research teams spanning the globe. They possess top-flight high-performance computing and scientific research facilities in the niche' areas to keep pace with their international counterparts. While some of the funding comes from the U.S. universities and state and federal governments, interested corporations also supply funding. However, funding for research support and cyberinfrastructure also come from foreign governments, universities, and corporations that are leading the research initiatives.

Scenario 4

Teaching and Student Learning is the Focus:
Grand-Challenge-related Research Moves Overseas

Global Context

By 2028, U.S. unemployment stays steady between 10-15 percent as many industries and services have shifted their bases to China and Southeast Asia, India, Brazil, and to a smaller extent, Russia. While corporations are concerned about U.S.-based employment, they see their consumer and employment markets growing internationally, and consequently, do not spearhead U.S. business investment as much as they have in past years. Their research investments also go overseas, to the leading foreign research universities. The aforementioned countries, along with a select few in Europe (e.g., France, Germany, Great Britain, and Ireland), possess the world's leading research universities and related organizations. Grand Challenge research initiatives clearly have moved overseas, and only the most highly ranked U.S. research universities (about 10 in total, mostly private universities) remain robustly involved in such research portfolios.

U.S. University-based Response

The U.S.-based governments and universities collaborate to invest in and improve degree programs and accelerate graduate rates. The objective is to increase Americans' employability, thereby keeping the U.S. involved in global economic growth. Consequently, universities have slowed their development of high-end, entrepreneurial research centers significantly. Traditional academic departments dominate as the prevailing university organizational structure. Research is occurring in U.S. universities, but focuses much more on issues of local, state, and regional interest, and less on national or international interest.

Instead of developing cyberinfrastructure and services for research programs, U.S. universities and governments concentrate on developing *cyberlearning* systems, specifically virtual learning environments (VLEs). In addition, they focus on developing instructional content for the VLEs. The desired outcome is to improve graduation rates and have graduates enter the job market as quickly as possible. The universities want governments in the U.S. and other stakeholders to view them as the leading skill-building agencies in the new economy.

The universities understand that for the U.S. to reduce its long-term unemployment problem, they must graduate students more quickly while preparing them for the competitive international employment market. They also are under pressure from the U.S. federal and state governments to provide an affordable education and keep student debt low. In this environment, U.S.-based research focuses on improving state and local economies and supporting cultural interests; research tends to remain in the traditional academic departments. Only the uppermost echelon of U.S. universities participates in large-scale, internationally coordinated research.

University library case studies. A case study analyzes an organization, individual, or event and the external and internal forces acting upon it (U.S. General Accounting Office, 1990; Yin, 2014). That analysis is descriptive and sometimes attempts to explain the set of circumstances impacting the organization, individual, or event. The investigator adhered to the case study development process as put forth by Yin (2014).

Multiple case studies examine how the university libraries from four different institutional settings will design and implement their services in response to the research university scenarios. Further analysis of the case studies investigates the similarities and

differences in the responses, analyzes the scenario forces and their impacts on libraries in their institutional settings, and determines how specific conditions provoke the libraries' responses. The cross-analysis of the case studies yields a more in-depth description of the issues faced and more unique insights than examining any single case study.

To develop the library case studies, the investigator collected the library directors' responses to the questions posed by the investigator, analyzed them, and incorporated them into two rounds of revised versions of the case studies. The library directors reviewed and commented on the case studies during these two rounds. After the first round of question responses, the directors each reviewed the first complete draft of their library's case study and provided feedback as to its accuracy and appropriateness. The investigator then incorporated their feedback into the second draft. The participating library directors were given an opportunity to review the second draft and provide feedback. The investigator then incorporated this second and final round of feedback into the final version of each library case study.

Methodology

This study relies on two methods of data collection, the Delphi method and semistructured interviews. The investigator utilized both methods to develop the research program scenarios in Phase One and used the semistructured interview process to examine the application of the most favored scenario to the library case studies in Phase Two.

Delphi method. The RAND Corporation created the Delphi method beginning in the 1950s, when it used the method to aggregate a wide range of opinions about future environments and circumstances to tailor a response. Its goal is to remove independent, subjective information or opinion and find objective trends and commonalities. In particular, investigators employ the

Delphi method where data and information do not yet exist or are extremely difficult or expensive to obtain (Landeta, 2006). The Delphi method is a "method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (Linstone & Turoff, 1975, p. 3). It collects the opinions of individual experts involved in a study for the purposes of setting a framework for future organizational decisions and direction. The panel of experts may be separated geographically; they also remain anonymous throughout the Delphi process.

The Delphi method uses questions designed to capture quantifiable answers. (The questions for the Delphi panel in this study appear in Table 1.7.) The panel of experts (e.g., in this study, the research directors) receives the questions in successive rounds, usually a minimum of two rounds. After the first round, the investigator gives the experts a summary of the group's answers along with other pertinent information regarding their answers. During the second round, the investigator asks the panel experts to review the responses and then revise or add to their answers. As in the first round, the investigator asks the questions of each expert individually so that the opinion of other experts and persuasive interaction between them are not factors to consider when analyzing the answers. The techniques deployed in the Delphi method have been found effective and generally accurate (Rowe, Wright, & McColl, 2005). In fact, the Delphi method can be up to 95 percent reliable for future forecasting (Parente, Anderson, Myers, & O'Brien, 1984).

Table 1.7
Questions for Delphi Panel of Research Directors

1. To what extent do you agree or disagree with the key force (i.e., U.S. research university international competitiveness or non-competitiveness)? What others would you consider?
2. To what extent do you agree or disagree with the main element of uncertainty (i.e., entrepreneurial, interdisciplinary research centers gain strength in research universities or traditional academic departments stay strong)? Do you view this as the most significant point of uncertainty? What others would you consider?
3. Are there any scenarios that are significantly different from the four posited that you would suggest?
4. What are the elements that you agree and disagree with for each of the four scenarios?
5. How would you title each scenario?
6. Do you have a favored scenario and what would it take to achieve that future? What are you doing now to realize this scenario?
7. What are the elements that support and/or hinder the scenarios and what should universities do to prepare for their realization?

In this study, there are two rounds of reviewing the scenarios and answering questions. Using the research directors' first-round responses, the investigator revised the scenarios. Then the directors were asked to review the updated scenarios and give feedback on their efficacy. The feedback was incorporated into a second draft of the scenarios, and the directors were given the opportunity to review the second draft and again provide feedback. The investigator then

reviewed the second round of feedback and completed the final versions of the scenarios. The investigator looked for any signs of consensus arising from the research directors' responses, although consensus is not a requirement of the Delphi method.

Semistructured interviews. During Phase Two of the study, the investigator first conducted semistructured interviews following the guidelines put forth by Wildemuth (2009, pp. 232–240). Throughout the interview process, the study participants (i.e., the library directors) assisted in shaping the research. Table 1.8 presents the questions for the library directors. As explained by Beck and Manuel (2008), the investigator designs the questions to probe the study participants' life worlds and the investigator "must allow their respondents to express themselves fully in order to study those worlds" (p. 70).

The investigator conducted the interviews by telephone on a one-on-one basis between the investigator and the interviewee, that is, the research director for the research program scenarios and later the library director for the library case studies. Semistructured interviews provide for a fixed list of questions asked in a particular order, as do structured interviews; however, they allow for variations in the questioning process in the midst of the interview. Wildemuth (2009, p. 233) stated, "Semistructured interviews give the interviewer considerable freedom to adjust the questions as the interview goes on and to probe far beyond a particular respondent's answers to the predetermined questions." In the current study, the research directors were asked a different set of questions than the library directors. The investigator anticipated the possibility of the interviewee wanting to expand on a given answer, and at times the investigator followed up a response with a different question than the next one on the list. The semistructured interview method gives the interviewer the ability to probe the interviewee's perspective and

follow particular points as they arise during the interview, which allows the investigator to collect a more in-depth set of narrative data.

Table 1.8
Questions for Library Directors Participating in the Case Studies

Given the 15-year trajectory of university research program development described in the favored scenario, how do you see the following library areas and services responding?
1. Infrastructure: a) What changes will occur within your facilities? b) What changes will occur to your information technologies?
2. Managing scholarly and research content: a) What kinds of content will be managed by the library? b) What kinds of content won't be managed by the library?
3. Services: a) What kinds of new services do you foresee? b) What happens to the current services offered by your library?
4. Partnerships: Do partnerships between the library and any organizations outside your university need to be established?
5. Library organizational development: a) What changes will occur in your library's organizational culture? b) What changes will occur in your library's approaches to leadership and management?

c) Human expertise – which hard skills, soft skills, and work perspectives will be needed? d) What changes will occur in your library's organizational structure?
6. Specific university contexts as they affect the library: a) How will your library partner and/or collaborate with faculty, students, and other personnel involved in research? b) What incentives will be put in place for your library to transform in the direction you indicated above? c) What barriers will your library face as it transforms in the direction you indicated above?
7. Please identify and discuss any other relevant aspects of the library and university not specified above.

After collecting the signed "Informed Consent" forms from each prospective interviewee, the investigator conducted the interviews.[16] The forms grant permission to the investigator from the interviewee to record each interview for confidential research purposes only. The recording of interviews and reviewing of transcripts, summaries, and notes were guided by the process put forth by Rubin and Rubin (2012, pp. 190–191). The investigator took comprehensive notes during each interview and captured the discussions via a digital audio recorder. The investigator analyzed the notes and recordings for themes and trends that arose from the question responses and ensuing discussions.

[16] A copy of this form appears as Appendix A of the dissertation.

Confidentiality. Throughout the study, each institution involved in developing the scenarios and case studies was assigned a letter (e.g., A). The investigator worked with study participants to conceal their identities in a satisfactory manner. Individuals were given a number (e.g., 1) to disguise their personal identity. The investigator coded each set of interview notes according to an institution's assigned letter and a participant's assigned number. These are stored as computer files (in MS Word format .docx) and maintained on a password-protected, secure hard drive. The investigator will maintain these files for one year after the study, at which time he will destroy the identifiable data.

Data quality. The scenarios adhere to the four criteria for good scenarios, as put forth by Mietzner and Reger (2005). Giesecke, a member of the dissertation committee, and Elizabeth Tranter, Chief of Staff, Vice President of Research, Virginia Tech, reviewed, provided feedback, and approved the scenario axes (i.e., the key force and the most uncertain element as presented in Figure 1.1). They also agreed on the significance of the key forces and the most important uncertain elements, as well as the content of the scenarios.

Virginia Tech (VT) was chosen as a pretest site for Phase One, that is, the research-scenario development phase. This is the home institution of the investigator, who serves as VT's library director. The pretest at VT examined the investigator's data collection methods to ensure that the interview questions and scenario development methods produced consistent and meaningful data that meet the study's research objectives. The study's questions for the Delphi Panel of research directors were evaluated and improved to ensure that the questions would be understood, enabling study participants to perform their roles in the study successfully. Likewise, a pretest for Phase Two—case study development with the library directors—took place at VT

with dissertation committee members Alire and Giesecke. This pretest was conducted after Phase One, when the research program scenarios were finalized. Throughout the pretesting, Phase Two questions for the library directors were also evaluated and improved to ensure the questions would be understood by the library directors, thus enabling them to perform their roles in the study successfully.

Based on the pretesting and criteria review, the investigator used the feedback from members of the dissertation committee to improve the Phase One draft scenarios and participant questions and the Phase Two participant questions. After receiving the pretesting feedback and completing the revisions, the investigator received approval of the scenarios for Phase One and the participant questions for both phases.

Conclusion

The current study delivers research-based, institutional-level scenarios representing research universities in the United States as they develop their research programs through 2028. Past studies focus on the economics of national and international regions (e.g., the European Union) and concern how their higher educational systems will respond to foster the knowledgeable, skilled workforces required by their economies. Only the OECD's (2009) globalization scenario-based study addresses the role of research in a broader international context. Only this study, however, examines how these forces and scenarios play out internationally for individual organizations, that is, at the institutional level, let alone at research universities in one country. The study's results can help improve the development of university research programs and aid university libraries as they strive to support them. Moreover, the study engenders an improved understanding of the drivers and forces at work in the emerging global

research and evolving economic ecosystems and offers insights into the strategies, infrastructures, policies, services, and partnerships required by institutions and nations to become successful in these new environments.

The next chapter describes the process of creating and finalizing the research program development scenarios with the Delphi panel of participating research directors. It focuses on the responses and broader feedback given by the participants via the questions asked by the investigator during the interview process. The chapter reviews the second round of unique and significant feedback provided after the scenarios were revised based on first-round responses. It also reviews each director's favored scenario selection and explores why that person made the choice. In addition, titles chosen for each scenario by the participants are reviewed, helping to explain how individual directors interpret each scenario. The chapter also documents items the research directors agreed or disagreed with as they read the scenarios throughout the two rounds. The chapter goes on to describe what the research directors are doing now to attain their favored scenario and which factors they see as major hindrances to reaching it. The participating research directors also offered three alternate scenarios, which are included in Chapter 2.

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Chapter 2

Research Directors' Feedback on the Scenarios

Of the 12 proposed research universities selected for the study, 11 agreed to participate. One of the three in the "public university AAU member" category declined. As a result, research directors from only two universities in this category participated, and directors from three universities in each of the other three study categories participated.

First-Round Responses

The first round responses review the scenarios' key force and the main element of uncertainty. Also covered are the alternate scenarios suggested, elements of agreement or disagreement in the scenarios, suggested scenario titles, the favored scenario chosen by the research directors, hindrances to achieving the favored scenario, post-round one scenario revisions, and the revised scenarios.

Key Force

The research directors were asked if they agreed or disagreed that international competitiveness in research is the key force shaping U.S. university research programs. They were also asked what other force they would consider as key. Nine of them agreed strongly that international competitiveness is the key driving force shaping future U.S. university research programs. This includes, they said, the programs at their own universities. Two of the directors disagreed that the key force is international competitiveness. One of them thought cultural and political forces are more key than the internationalization of research. Specifically, he stated:

> American freedom to pursue new ideas and the application of ideas is most important. This (cultural value) is what has made America different and great in an economic and technological sense in the last century. This is the key differential in the world today. It is why the European Union is non-competitive, and why the Soviet Union failed to work well. It is why China is facing massive civil unrest and a crashing internal finance system that will drag their whole economy backwards in the near future.

American culture today places little value on entrepreneurialism in research and business, he claimed, and this is why today's private corporations are "sitting on the sidelines and not investing their private equity in the U.S., nor in applied R&D [research and development], that could assist the country in retaining the U.S.' global economic lead and the U.S. research universities as research leaders." Another research director also disagreed that research internationalization is the key force:

> A university doesn't do research, individual faculty members do. Professors look for the best partner to conduct research. They don't look at the university as a partner or for partners. Faculty pursue their own research, not centers. Centers are about resources and only resources. It's about access to funding. There is tons of individualism in the research enterprise.

Given this situation, this director said the "impact of globalization and entrepreneurial approaches on research program development in U.S. universities over the next 15 years will be negligible." Further, this director stated that university research "will look much like it does today. It's a mix. The mix constitutes our strength. Centers, non-centers, individuals, groups, etc.

Universities are not national laboratories, they field the curriculum. Universities have lasted a long time because of this mix."

Main Element of Uncertainty

Nine of the participants agreed that how research universities organize their research programs in the future, via entrepreneurial interdisciplinary research centers or through traditional academic departments**,** is the main element of uncertainty. Among those agreeing, one expressed that these two organizational schemes "do not have to be mutually exclusive, and that they can co-exist and foster each other's development." Similarly, another director stated that "there doesn't have to be tension between entrepreneurial research centers and academic departments" and thought that "there is and will be, however, tension between research and teaching." Yet another director stated, "The development of entrepreneurial interdisciplinary research centers does not have to develop within the research university, they can develop outside of them and be an independent public or private research center." A fourth director further articulated, "Centers are all about getting funding." Other participating research directors made similar observations, clearly seeing the entrepreneurial interdisciplinary research center as the chosen path forward.

One of the disagreeing directors (who also disagreed with international competitiveness being the key force) claimed:

> It doesn't make much difference if research goes toward the entrepreneurial research centers versus the traditional departments. Both of these models can work well if people work together and collaborate. In this sense, the most uncertain force is the larger "cultural force" I discussed earlier: whether we can

> as a nation retain the habit of investing in early-stage uncertain visions, or whether we will instead become a nation of incrementalists who just try to data-mine efficiencies from existing information and existing know-how, and become non-competitive as a result.

The second disagreeing director (who also disagreed with international competitiveness being the key force) believed that the uncertainty of "center vs. department just didn't matter much." However, the overwhelming sentiment of nine of the directors was that, as one director put it, "moving toward entrepreneurial research centers is a done deal." The entrepreneurial interdisciplinary research center is becoming the organizational model upon which research universities in the United States compete and engage in the growing internationally collaborative research paradigm.

Alternate Scenarios

When asked if they could envision any scenarios that differed largely from the four posited in this study, three offered one alternate scenario each. Further, each explained how the alternatives relate to the study scenarios.

Table 2.1
Alternate scenarios

"A threat is out there"
The U.S. government decides to no longer support research in institutions of higher education. These institutions are "under attack" as the governments (federal and state-level) do not want to fund them. Today there are 400 research universities in the United States, but no more than 100 of them will be research universities in the future. They cannot keep raising

tuition and are not allowed to do so. The states are providing some base level of funding, but they do not want to fund them more than they are currently. Therefore, a great "sorting out" is coming. For the universities no longer engaged in research, they will embrace online education where their students will never have to set foot on campus. These universities become job- and career-oriented. This scenario is dependent on developments in the United States' political landscape and is similar to Scenario 4 (see Table 1.6) offered in this study; however, universities do not conduct research because the federal and state governments consciously decide to not fund them to do so any more.

"Competitive innovation ecosystem"

There is a "virtuous cycle" in which the translation of knowledge to new goods and services creates market growth and jobs, which then feed back into new basic research needs and funding and then cycle to new products, and so on. This type of virtuous cycle leads to the growth of interdisciplinary work and economic strength while also reinvesting in basic and/or traditional silos and depth. The entrepreneurial research centers and traditional academic departments are not mutually exclusive, as portrayed in this study's scenarios, but rather are complementary and integrative, completing this virtuous cycle. By seeing what global or social or market challenges exist, the basic thinker and scholar gets better at basic research, and the same is true of the applied researcher. The same is also true of the arts learning from the sciences and vice versa in order to improve associative thinking and creative solutions or creative/imaginative works of art. The right brain and left brain work in concert, not separately. This scenario is essentially a combination of this study's Scenarios 1 and 2 and is the key to a thriving economy and society (see Table 1.6).

"Things remain the same"

In 15 years, the nature and organization of research programs in the United States' research universities remain about the same as they are today (in 2013). However, this scenario vision is subject to problems that develop in society, e.g., wars, depression, and other forms of social upheaval. The research community writ [sic] large is an unintended victim of these upheavals. Universities do not look to research centers to aggressively seek research funds, but rather look to principal investigators (single PIs as well as co-PIs in groups) to aggressively seek research funding. In the end, individualism in research reigns. This scenario relates somewhat to Scenario 2 (see Table 1.6) offered in this study, but with much more emphasis on the single researcher (as opposed to the academic department) and his/her great ideas that will "rule the day" in the U.S. research community.

These additional scenarios reflect possible futures if certain drivers become dominant in the U.S. research ecosystem. Interestingly, these scenarios range from the extreme negative consequences for U.S. research on one end of the spectrum (i.e., "A threat is out there"—the federal defunding of research), to the status quo in the middle of the spectrum (i.e., "Things remain the same"), to a positive alternate scenario on the opposite end of the spectrum (i.e., "Competitive innovation system"). Offering these additional scenarios indicates that the U.S. research ecosystem is at a crossroads. However, the research directors participating in this study resoundingly are clear about the desired path, that is, that of Scenario 1, "Thriving interdisciplinary research, solving global Grand Challenges." A few research directors even

postulated that their universities will achieve this scenario or no longer be competitive as leading research institutions.

Elements of Agreement or Disagreement

The directors were asked: "Which elements in each of the four scenarios do you agree or disagree with?" Almost all feedback referred to elements of disagreement, elements not yet present, or elements that needed to be augmented in the original scenarios. Both general comments about all scenarios as well as scenario-specific comments were offered.

General comments relating to all scenarios. Several themes in the interviews pertained to all four scenarios. Perhaps the most pervasive of these concerned federal research funding, congressional support, and the public's perception of research, specifically regarding its economic and societal benefits. One director reflected the sentiments of several participants when he said, "The notion of research as a Public Good is under attack, which is reducing federal research funding as well as restricting the research areas in which researchers are engaged." These directors clearly are concerned about congressional gridlock on a variety of issues, including science policy in general, the autonomy of the National Science Foundation, and decisions over which countries the United States will collaborate with to conduct research. They also discussed the growing public perception that research universities in the United States are not worth funding with federal tax dollars as much as they have been in the past. The pressure by federal and state governments to keep tuition and student debt low applies to all scenarios. The overarching regulatory environment with its "national laws and policies regarding the administration of research and research information will play a more prominent role than

currently assigned in all the scenarios. This includes the role of open access policies at the national and institutional levels."

Maintaining and growing a current base of funding in general is seen as a leading, critical concern. As described above, many pressures threaten to reduce research funding. Two of the research directors pointed out government obligations to provide critical but costly social services reduce funding for research. Among these are medical care, police and fire services, K-12 education, roads, highways, sewers, and clean water supplies. One research director articulated, "There is potential for research funds to be increasingly limited due to the need to support large-scale social services especially among dense human populations. Keeping social programs in the black means there will be a growing pressure on research funding." When looking to other sources for additional funding—for instance, corporations or the university itself—the research directors felt the prospects of these groups raising their research funding are not good. One research director commented, "Universities spend 20 percent of their own money on research and development on their own campuses. Maintaining this level of R&D will be an ongoing challenge, especially for public institutions." Regarding corporate funding, another research director said: "Corporate research funding won't bail us out of any research funding constraints. Their research funding is minor for most universities, not more than 5 to 6 percent, and is not likely to rise."

The research directors thought about other elements common across the four scenarios. For instance, computational approaches in research will continue to grow and will be invested in at a rapid rate. The University of Pittsburgh, it was noted, for example, invested $110 million to create a bioinformatics department. Another director commented on entrepreneurial research

centers: “We will witness the rise of entrepreneurial research centers being established and growing outside of the research university. These will be private, nonprofit entities, and they (will) become significant players in global research activity and important partners for the United States’ research universities to partner with.” Some of the research directors are concerned about research project leadership and idea generation, stating, “There needs to be room for the free-thinking single investigators. Otherwise, great people will be left out of the process.” However, another director commented that “the single principal investigator (PI) will be hard pressed to remain funded in the coming environment; there will be more interdisciplinary research with multiple PIs.” Given the diverse approaches to organizing large-scale research, another director posited that “U.S. research leadership is likely to be in certain specific fields no matter the scenario. The U.S. can’t lead every research area.” If the United States does not lead in every major research field, one contributing factor may be due to China’s rise on the global research stage. Several research directors talked about the China phenomenon, with one stating: “The Chinese growth in research capability is a threat to U.S. research initiatives over time, regardless of the scenario.” Below the directors comment on each specific scenario.

Comments on scenario 1. Scenario 1 is the favored scenario among most of the directors; therefore, they did not spend much time commenting on what they agreed with. Most believed this is an “exciting scenario and is very robust” and they hope to move in this direction at their respective universities. Given this, the directors tried to identify items of disagreement and offered thoughts on how to improve the scenario. Most notably, the commenting directors thought that “it will take more than 15 years to achieve this scenario and learn how to collaborate globally with myriad partners,” even among those universities fiercely committed to this

direction. One research director expressed that, while the global nature of the scenario is very appealing and desirable, he believes, "Research will still be more nationally focused while working on Grand Challenges." This observation highlights the difficulties U.S. research universities face when they aspire to model Scenario 1 (see Table 1.6).

Several comments were made about the approach to open access (OA) as described in the first draft of the scenario. One observed, "There will be different classes of governments (i.e., different national governments) that may not honor open access. Corporations would not support OA for research that they support." Another research director disagreed that having a one-year access embargo period, then open global access after that period is a good development. This director made another reference to corporations, stating, "Corporations will not support open access to research they are involved in because it will undermine their long-term competitiveness." It is interesting that two research directors when commenting about OA policy brought up how corporations would regard it. The current OA policies at federal agencies and U.S. universities address federal and private nonprofit (e.g., Howard Hughes Medical Institute) research; they do not include research sponsored by corporations or other types of private, for-profit organizations.

The research directors held differing opinions regarding research team composition. One director agreed with the scenario's assertion that churning or changing team members as the team moves from one project to the next is a good approach; the goal is to create teams composed of the best people possible so that the universities involved can remain competitive in the grant proposal and research processes. However, another research director felt this assertion "is not real," stating, "Researchers and disciplines evolve, and if the team continues to get

funded, it should not break apart." There was one noteworthy reaction to the assertion in the draft scenario that researchers will have access to plenty of networked digital storage and computer processing capabilities. One research director responded, "We still won't have enough compute cycles, and this is likely to always be the case." This observation highlights the challenges inherent in future cyberinfrastructure development.

Comments on scenario 2. There was some consensus among the research directors that Scenario 2 is too narrow. It focuses on research within departments and disciplines, as opposed to being interdisciplinary or transdisciplinary. This consensus verifies the preference toward Scenario 1. Regarding Scenario 2, one research director stated, "Barriers between departments and disciplines are breaking down; nothing out there is building up boundaries between departments." It is worth pointing out that this observation is about the relationship between academic departments and academic disciplines, as opposed to academic departments and entrepreneurial interdisciplinary research centers, as posited in this study. Another research director predicted the focus will shift to research centers and academic departments will be a shrinking concern: "U.S. research universities will not be as competitive if we stay in departments, at least not on a large scale. Research contracts will move on to the global scale, so we need centers to be globally competitive." This same research director also said, "U.S. universities will still be attached to Grand Challenge problems in this scenario. Researchers will not be working strictly in their own fields." Several directors disagreed sharply with the notion that research funding will be plentiful for those departments and PIs who can remain competitive. In short, several responded with comments similar to: "I do not think research funding will be abundant," as opined by one research director. On open access, a comment was

shared: “Corporations will be hesitant to share data due to their competitors then having access to it.” Another director, responding in a similar way, expressed that problems will arise because local and national law and policy will not always align with international law and policy, a situation that will hamper the sharing of research data and information.

Comments on scenario 3. The participating directors agreed factors in place today could make U.S. research universities lean toward Scenario 3. They pointed out these factors may grow in intensity and dominance in the research ecosystem, thereby reducing the universities’ international competitiveness. In particular, the directors commented frequently that their universities are “struggling with the regulatory environment.” They discuss how regulations increase making costs, requiring more time to administer research, and restricting it from occurring. Currently, there is also a rising political will to restrict research, as seen in the Congress. This, they noted, is dangerous for research universities, and if it continues, may have deleterious effects. A research director commented, “China may attract human capital due to its overbuilding of research facilities. It may pay great sums of money to attract leading researchers back to China who are China-born and U.S. educated and employed.” The specter of a rising China as a mecca for higher education and research concerns several of the research directors. They see the evolving situation as a major threat to United States research leadership within the timeframe of this study.

The lack of corporate funding places even more pressure on research. Currently, corporations “want to reduce their basic research expenditures and won’t give more money to universities.” This trend is expected to continue, according to the study participants. A few research directors criticized certain items in the scenarios, such as claiming in Scenario 3 that

U.S. research funding will drop 25 percent. One director offered that a 15 percent drop could be more likely and will still have the significantly negative impact described in this scenario. Another director commented that research funding will remain stable or possibly increase: "Giving up our research leadership is probably not going to happen. In the end, it's a national security issue." A third director disagreed with the notion that focusing on fewer research areas automatically will reduce competitiveness, claiming that universities in the United States can be highly competitive, global research leaders in certain Grand Challenges that really matter to the country and the world.

Comments on scenario 4: The commentary concentrated on how unlikely the scenario is; however, some disturbing elements could occur, such as the systemic decline of the U.S. economy and the concurrent rise of economies in the BRIC nations (Brazil, Russia, India, China) and other areas having economic potential such as southeast Asia and South Africa. Some of the more constructive comments addressed the possibility of universities moving away from research and toward education. The directors said these universities will still require robust research activities, claiming that one cannot just separate research from education so easily. "High-quality and successful higher education programs need quality research programs," said one research director. The participants agreed with the positive side of this scenario, which claims that national-level cyberlearning environments will rise rapidly and prominently in U.S. universities. But again, the need for research appeared in another research director's comments: "We can't be a skill-building agency if we are not researching. Classroom instruction won't make them (graduates) employable." Overall, the research directors described this scenario as severe: "However, with recent actions like the sequester, young people may not go into

research," and that will further reduce the country's ability to compete in research on a global scale, thereby making this scenario possible. One research director summed it up: "If this scenario happens, America will have lost its competitive edge and become obsolete."

Suggested Scenario Titles

Eight of the participating research directors responded to: "How would you title each scenario?" Their responses appear in Table 2.2. Three declined to offer any suggested titles. The titles that were offered for Scenario 1 illustrate hopefulness that research universities in the United States can retain their positions as world leaders by transforming to lead global research initiatives aimed at solving large, perplexing challenges that impact all of human society. Terms such as "nirvana," "aspiration," "enlightened," and "ambitious" are used to describe this research university. While one director felt this scenario is unattainable, titling it "bureaucratic social engineering," Scenario 1 is the favored scenario of nine participating research directors. Some even emphatically stated that this scenario must be their goal and that they have no choice. "If we don't reach Scenario 1, then it's over," declared one research director.

The titles created for Scenario 2 reflect the research directors' opinions that this scenario represents a less desirable, more isolated research university. Terms such as "silos," "constricted," and "targeted" illustrate the less collaborative, narrowing university that performs research only within its disciplinary boundaries. Other terms to describe Scenario 2 indicate concerns that universities under such a scenario would be disconnected from the transforming framework of internationally-based research. Phrases such as "heading toward the graveyard," "we don't get it," "trying to keep their heads above water," "monastic reflection," and "dependent on the individual PI" convey the participants' fears that in this scenario, the U.S.

research universities are not involved rather than participating and leading research in a robust and vigorous manner. Scenario 2 reflects a U.S. research university that is stagnant, not evolving in the same collaborative, global direction as other universities and research institutions.

Scenario 3 gained more favor with the research directors than Scenario 2, but it is still not their desired outcome. The phrases and terms used in the research directors' titles ("research partners," "knowledge miners," "focused," and "targeted") convey concerns that research universities would become role players internationally and not leaders across a broad spectrum of research topics. Other phrases (e.g., "U.S. in decline," "We need to learn to speak Chinese," and "Public research university excellence in decline") indicate that the research directors see this scenario as the beginning of a systemic decline in research for U.S. universities. While the scenario describes some active and important research partnerships between U.S. universities and those of other countries, clearly the research directors participating in this study do not wish to accept the role as "niche partner." They see their institutions as international leaders, and they express a strong desire to remain in this position.

Scenario 4 represents a future where Grand Challenge-level research moves overseas, and for all intents and purposes, does not take place in the United States. Instead, the university in this scenario focuses on teaching, learning, and retooling an American population needing employment in a truly global economy. The terms and phrases used to describe this scenario reflect the research directors' frustrations with it, essentially throwing their hands up and claiming that research in the United States is over. They leave little room for misinterpretation, using phrases like "U.S. gives up," "recipe for obsolescence," "the end of the public research university," "failing university," and "game over." Other phrases highlight the activities that will

fill the void—teaching and learning. Terms used to convey this include "the vocational model" and "teaching and learning university." As some research directors expressed, it is fine for a university to focus on teaching and learning, and several stated that this is their university's core mission. However, many directors believe a university cannot have great teaching and learning experiences without robust research activity and vice versa.

Table 2.2
Scenario titles suggested by research directors

Participants	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
1	Nirvana	Silos	U.S. in decline	U.S. gives up
2	U.S. continues to be global leader in fundamental R&D	Heading toward the graveyard (staying in a discipline)	We need to learn to speak Chinese	Rest in peace (end of the U.S. research university)
3	Global comprehensive research unit	Focused research leaders	Research partners	Teaching and learning university
4	Bureaucratic social engineering	Monastic reflection	Knowledge miners	Recipe for obsolescence
5	The aspiration	We don't get it	The beginning of the end	The vocational model
6	The penultimate public research university	Public research universities trying to keep their heads above water	Public research university excellence in decline	The end of the public research university
7	Enlightened university	Constricted university	Focused university	Failing university
8	Ambitious and successful	Targeted and dependent on the individual PI	Targeted, proactive portfolio	Game over
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A

Favored Scenario

Table 2.3 indicates the choice for "favored scenario" from among the four written for this study. It reports the number of research directors who favored each scenario in both Round 1 and Round 2. It also identifies three alternate scenarios, as described by one participant in each case. Nine participants chose Scenario 1 as the most robust and as a desirable aspiration for their universities.

Table 2.3
*Favored scenario selections**

Scenarios	**Number of participants selecting the scenario**
One: Thriving interdisciplinary research, solving global Grand Challenges	9
Two: Discipline-specific research, narrower research questions/narrowing university	0
Three: International research leadership, U.S. research centers partner in niches	0
Four: Focus is teaching and learning, Grand Challenge-related research moves overseas	0
A hybrid of Scenarios 1 and 2	1
No favored scenario selected	1
Alternate: • A threat is out there • Things remain the same • Virtuous competitive innovation system	
Total	11

*There were no changes in the participating research directors' favored scenario selections between Round 1 and Round 2 of the research interviews.

Comments on each scenario directors considered their most favored. Scenario 1 is viewed as the best position for a research university to occupy. Universities in this scenario have many resources of their own as well as access to unique resources available through their collaborators, funders, and governments. Participants thought that research universities in this scenario can determine their own futures with little disruption from outside forces. The variety of resources, infrastructures, expertise, laws, and policies favorable to research all combine to make this scenario the most favored.

None of the participants chose another scenario as their favored scenario. Most research directors see the second scenario as too narrow. It cannot support a broad enough group of research areas for major research universities to remain competitive in a global research ecosystem. They also anticipate problems if research predominately takes place within academic departments and disciplinary domains. Several expressed that solutions can be reached faster and addressed more thoroughly through interdisciplinary and/or transdisciplinary research.

Scenario 3 marks a decline in research leadership as the country's universities become niche players in internationally-based research initiatives. While the universities could be active, robust, and even pathbreaking in some areas, the directors, by and large, believe this scenario is unacceptable and to be avoided. Since World War II, the United States and its universities have led the world in research. The directors are not willing to give up that leadership.

Scenario 4 represents abject failure on the part of research universities, and the directors view this scenario as terrifying. A few believe it unrealistic; however, several can see certain elements (e.g., economic depression, sequester-like research budget cuts, and rising foreign economies) running amok and damaging the nation's research capabilities.

After reviewing the revised scenarios in the second round of interviews with the investigator, none of the research directors changed their choice of favored scenario, nor made any comments different from the first round.

Comments on what directors are doing to realize the favored scenario. Nearly all of the research directors are already using the Scenario 1 model as they transform specific areas of their own universities. For example, they are working to increase the number and diversity of partnerships. They envision working with new partners such as units of the federal government as well as new corporations and foreign entities, including foreign universities and corporations. One research director said, "There will be more teaming through agreements, MOUs [memorandums of understanding], etc., per new research initiative as well as portfolio-level research activity."

Several stated they are developing interdisciplinary research projects along with the required support services and infrastructures to make them successful. Another research director is exploring new transdisciplinary ideas to position his university "for the new futures that are coming," not all of which can be foreseen. Other universities represented by the study participants are globalizing their research programs. Their research directors are traveling the world, visiting other directors in a variety of European countries, the Middle East, India, Southeast Asia, China, and South America, and comparing research needs and interests to discover possibilities for collaboration. One university is developing research relationships within the European Union, India, Taiwan, and Singapore. A second university is increasing its international presence in China and Brazil and focusing on medical clinical research. A third is building relationships and a campus in India, creating this satellite site through support from one

of its large research institutes dedicated to applied science and technology research. In summary, all of these directors agree "the new nature of research is global."

In addition to focusing externally, each university is transforming internally to support internationally-based research. The directors often mentioned in the interviews a need to provide incentives for international research to open up global research channels. The study participants provided no specific successful approaches but thought that offering financial inducements and rewards for conducting research internationally is necessary. One university is revising some of its academic departments to promote a global focus. For example, this university has renamed some medical-related departments, calling them "Global Environmental Health" and "Global Health Systems and Tropical Diseases." These, among other such changes, will help position the university to research global medical challenges.

The directors recognize that cyberinfrastructure must be developed. A few specifically said that cyberinfrastructure improvements are required to enable global research operations. Some of the directors are seeking flexible, high-quality virtual environments to conduct collaborative research. Clearly, computationally-based research is on the rise in the emerging global research ecosystem. Other needs, such as improving or creating university offices to manage and interact with international and foreign regulatory environments, were also discussed.

Offices of international research administration are becoming more frequent, according to the study participants. One research director boldly claimed that the nature of the university must change to meet the challenges of the coming global research ecosystem. Specifically, he said universities should "do away with tenure lines. People get entrenched and don't change." In this new paradigm, universities need flexible infrastructures and organizational processes able to

transition quickly to meet research challenges and take advantage of opportunities afforded them. One research director summed up: “How do we engage the new world? By not burying our heads in the sand.” Most research directors are calling for their universities to be proactive as they rise to the challenges presented by global-scale, interdisciplinary, and transdisciplinary research.

Hindrances to Achieving the Favored Scenario

When asked what elements support or hinder achieving the favored scenario at his or her university, each research director dwelled on elements of hindrance. Most of these impediments can be categorized into eight principal areas:

- resistance to change by university personnel;
- resource constraints;
- public perceptions of education and research in public universities;
- political leadership;
- university organizational processes and culture;
- laws and regulations, especially in foreign countries and internationally;
- infrastructure, with an emphasis on cyberinfrastructure; and
- strategic planning.

Research directors expressed it is likely to take more than the 15-year period addressed by this study to surmount most of these obstacles. Yet, they remain hopeful that Scenario 1 is achievable.

Several research directors discussed the resistance of faculty, staff, and administrators alike to needed changes in how personnel are marshaled, deployed, and trained. They note that these personnel transitions are key to advancing education in general and research programs in

particular. One went so far as to assert this is the leading problem faced by research programs as they try to evolve. Others said this has been the leading impediment for many years.

The investigator asked a follow-up question: "How do you overcome this resistance?" Some directors had no answer; one immediately replied, "We need some people to retire." Still others talked more specifically about the need to change organizational culture. Those few participants who identified cultural change as the barrier expressed sentiments similar to one director who said, "Research universities will go extinct if they do not get to Scenario 1."

Resource constraints, specifically the lack of financial resources, were perhaps the most often mentioned barrier to the development of research programs. One participant summed this constraint up succinctly: "Dollars, pure and simple." Others saw the lack of finances as a pervasive problem far beyond university research, one affecting all aspects of university activity. Two of the public university research directors identified this as a particular problem for public universities because, according to them, they do not tend to have the larger research endowments leading private research universities have. These two participants also spoke specifically of the federal sequestration.[1] With the sequestration purported to be in effect until 2021 (as stated by the research directors), they claimed this will have a most deleterious effect on the nation's research programs, up to and including the "killing off a generation of researchers in the U.S. It will erode the research enterprise at a national level." They pointed to the sequestration as the kind of political and governmental action jeopardizing growth and international competitiveness of U.S. research universities.

[1] For information on the sequester, see U.S. Congressional Budget Office. (2013, March). *Final sequestration report for fiscal year 2013*. Retrieved from http://www.cbo.gov/sites/default/files/cbofiles/attachments/4402/Sequestration.pdf

The directors vigorously deliberated over the impact of public perceptions of education and research at public universities. One participant highlighted a dilemma he thinks public universities face regularly: “People question why a public university does something cool, but they never question it when Harvard or MIT [Massachusetts Institute of Technology] does something cool.” This opinion illustrates a particular hurdle encountered by public university administrators. These universities need to be viewed part of the public trust and as solvers of societal problems on behalf of the public that supports the institutions. However, this perspective seems in sharp contrast with a concern raised by another study participant: “Education is no longer perceived as a public good, but as a private benefit.” In a similar vein, another participant said, “Publics must be careful of their price points,” alluding to the cost-benefit to society of public universities. Overall, the study participants think that the public perception of the value of research value will continue to present challenges to public universities well into the foreseeable future, and especially throughout much of the 15-year period represented in this study.

Political support and the “marketing” of research benefits, especially to Congress, must be improved. Several research directors asserted this and admitted they must figure out how to describe to politicians and other government officials “what university research is all about and how it is good for the country.” As one research director stated, “They (Congress) need to have faith that investment in basic R&D means good things will come.” Another study participant said, “Once Congress is converted to the side of research, then we need strong political leadership from them. We especially need good science diplomacy between countries.” This statement reflects the need to think of U.S. university research within a global context, inherently recognizing success relies on engaging in research around the world, with other leading

researchers, universities, and governments. Research directors are calling for nothing less than the exercise of political will to advance research and support it. One research director, when referring to the governmental regulatory environment and how it should function, expressed a similar opinion differently. This director said the overall "regulatory environment should support research, and we need to use our political influence where possible toward this end." The directors recognize, too, that governmental regulatory systems themselves must be influenced as well as policy areas such as export control, international intellectual property law and policy, formal institutional review boards (IRBs), institutional animal care and use committees (IACUCs), and other regulatory oversight groups in governments and universities. Most of the research directors interviewed asserted the regulatory environment needs universal change. Some of the directors identified the need for broad, collaborative interinstitutional and international bodies that could provide review, oversight, and approval of research initiatives in an effort unify national bodies and streamline effort. According to one study participant, "U.S. research universities will need to possess and utilize knowledge of national-level law and business policies of foreign countries. MOUs will be needed to conduct research that meets foreign national laws." This research director discussed how some universities are developing international research administration programs to assist their principal investigators. Program personnel "possess the knowledge and capability to engage in research administration internationally on a very regular basis," this director notes. "Finance and compliance" are the issues of the day for this particular research director, and his observations accurately sum up the regulatory issues and challenges discussed by all of the research directors.

Organizational systems within U.S. research universities present another significant body of impediments identified by the study participants. Classic academic systems such as faculty tenure were discussed. While their abolition was not called for, the need to rethink and revise them was promoted. The necessity of better incentive systems to promote targeted research and collaborate with particular researchers was also identified and discussed. No specific alternatives to tenure or new reward systems were offered during the participant interviews, however. Other current difficulties were discussed as well. Most notable among these is the amount of control individual faculty members have over decisions concerning what they actually research. There is some truth to the statement offered by one participating research director that faculty are "not *directed* by the university, but are *a part* of the university." This research director disagreed with the key force and the most uncertain element in this study. His biggest objection being that "you can't tell faculty what to research" and that "universities don't do research, faculties do." This sentiment is reflected in the interviews regarding hindrances to research program development. One research director suggested that exploring the idea of jointly appointed faculty between universities and across international boundaries might provide a solution. In fact, such arrangements were described as a missing piece in university organizational systems. Essentially, this calls for the creation of international academic and research programs, according to this research director. Other university organizational systems deemed problematic included the organization of partnerships with both government and industry sectors. Some of the study participants talked about the inherent incongruence between a university's interest in basic research and what was labeled as the *parochial* nature of both governments' and industry's

interests. These directors concluded that universities need to learn how to work better with partner groups to meet all parties' research needs.

Four study participants brought up the need for new infrastructures, especially new cyberinfrastructures. Cyberinfrastructure refers to information technology, human resources and expertise, and the policies that make the cyberinfrastructure work. The directors referred to these new structures as multi-institutional, interdisciplinary, and international in design and deployment. Some participants highlighted the need for open digital data repositories at the institutional, national government, and international consortia level. Some universities are beginning to experiment at these levels currently, and the research directors foresee further repository development required around the world. These directors recognize that global availability of digital research data is important to advancing research, but they believe many research communities are not yet capitalizing on the technological capabilities afforded. They shared the opinion that within the 15-year period addressed by this study, open research data freely available on the World Wide Web will greatly advance a variety of research areas. In the interviews, they promoted the need for virtual research communities that would allow researchers to share data and information from any country or continent. These new cyberinfrastructures would enable universities to operate more effectively as new organizational systems, laws, policies, and protocols supporting international research are developed and implemented over the coming years.

The last hindrance to achieving Scenario 1 was an outdated or out-of-touch vision and a strategic plan. Research universities, they believe, must align their visions, strategic planning, and organizational development with their aspirations to collaborate in internationally-based

research. One research director articulated, “Universities need to define what they want to become, and first, they need to know who they are. Then they need to conduct strategic planning around this and put resources behind the new strategic initiatives.” When assessing a university’s leadership and management, alignment among vision, strategy, and organizational implementation is critical. If this alignment does not occur, the necessary resources will not be sought and the infrastructures and culture required to reach the university’s international research goals will not be developed.

Scenario Revisions

The investigator revised the first-round scenarios based upon the feedback from the research directors. Their comments largely pertained to individual scenarios, with only a small amount of commentary referring to all of them. The major changes made to each scenario are summarized below. The revisions illustrate the research directors’ perceptions regarding the believability of each scenario.

Scenario 1

This scenario now includes the possible consequences of government obligations to provide critical social services. The heavy cost burden on governments to ensure access to daily necessities such as clean water, efficient sewer systems, emergency services, roads, and medical care to ever larger or denser populations may curtail the amount of funding a nation can invest in research. India provides a leading example.

Governments, universities, private corporations, and private nonprofit research organizations will be engaged in the process of learning how to collaborate and fund research jointly, as opposed to having learned this already. Further, these entities are beginning to work

together through national and international boards to determine the nature and priority of funded research agendas. The research directors commented that learning how to collaborate and establish effective structures to implement these internationally is only just beginning; their approaches are will not yet mature.

The section on OA and IP policies was revised to describe a national OA policy that exempts materials stemming from patent- or trademark-pending or trade secret research or research already having received one of these designations. The scenario also was revised to clarify that private corporations tolerate the national OA policy as opposed to supporting it; they have concerns about it applying to types of research other than basic or fundamental.

Another scenario update was made to reflect that some of the more entrepreneurially inclined research centers are based in private organizations and not within universities. Also, high-performance computing cycles are not readily available; instead, their supply, while improved, remains a challenge. The first draft claimed that computing cycles are readily available.

The statement regarding where research groups publish their works was updated to say that they publish through a variety of conduits, including for-profit and nonprofit publishers, their own virtual research community sites, and other government- and university-managed research repositories. The first draft did not include for-profit and nonprofit publishers among the publishing options. Lastly, a revision was made to state that establishing and maintaining highly accomplished teams of researchers is a goal in this scenario, as opposed to constantly changing team composition.

Scenario 2

The revision illustrates that university scientists in the United States *occasionally* collaborate with engineers, business, and policy researchers, and sociologists to explore Grand Challenges, but not always, as the first scenario draft claimed. Additional detail is given regarding how research is more narrowly focused within disciplines. The revision explains this is because of the existence of conventional funding programs, discipline-based infrastructures (i.e., information technologies and facilities), and traditional research practices. The revised OA and IP policies section says that federal agencies have agreements with their international counterparts to support research development and the open sharing of information after an agreed upon 12-month embargo period from the date of publication; a timeframe was not stipulated in the first draft. The last revision still indicates that corporations want access to research, but is now more specific, saying that this access is to government-sponsored basic research and that corporations hesitate to share data. Instead, they move to protect applied research findings through IP actions so their competitors do not have access to their research results.

Scenario 3

The revision provides a specific instance of how and where research is growing: "China in particular has overbuilt its research facilities and has been recruiting talent from around the world for many years to realize its research capacity; it is now paying off." Further, a revision was made regarding the nature of the OA and IP policies; the national governments rising in research stature want to be seen as "world leaders in research, and, therefore, have adopted policies to ensure public access to their researchers' scholarly and scientific publications once

proper steps have been taken to protect IP via patents, trademarks, and other approaches." The investigator revised the amount of the U.S. government's drop in research funding from 25 to 15 percent. Some of the research directors felt 25 percent was too high and unrealistic. They said that a 15 percent drop is enough to experience the consequences described in the scenario and makes the scenario more believable. The revised statement on corporate involvement in research reads: "Corporations, which have long been a dedicated partner in funding university-based research, are looking to scale back their research investments. Their interests lie in funding highly directed, applied research that leads to rapid technology transfer and the commercialization of technologies, services, and products. Basic research is not their interest." Lastly, the influence of politics on research was added to this scenario, stating: "The Congress also has exercised its political will, reviewing and approving research project portfolios funded by the National Science Foundation."

Scenario 4

The investigator modified the statement about no U.S. universities being involved in Grand Challenge research: "There are still preeminent research universities in the United States, but they are much smaller in number (about twenty) and most are private institutions. Given these conditions and the subsequent lowering of U.S. research expenditures, fewer young people look to research and university employment as a viable career path." The revised scenario describes a class of "top twenty" research universities in the United States and how they adapt to the conditions present in this scenario.

Scenario Revisions – Concluding Remarks

Many adjustments to the four scenarios temper the "all or nothing" tone present in the first draft (see Table 1.6), making the final scenarios more moderate. The nature of the revisions come from research directors' comments directly. The scenarios in the revised form more accurately illustrate the evolving perspectives of research directors in U.S. universities, as they note that universities will still be in a developmental status in 15 years regarding how they will administer international research. Table 2.4 presents the final revised scenarios.

Table 2.4
Revised scenarios

Scenario 1

Thriving Interdisciplinary Research: Solving Global Grand Challenges

Global Context

There are many robust research initiatives thriving on a global scale. They are aimed at solving many Grand Challenges in research such as sustaining the environment (e.g., providing clean air and water), eradicating certain diseases, creating new biotechnologies, sustaining soils and agriculture, developing and sustaining renewable energy sources, and creating new information and communication technologies (ICTs) that rapidly evolve and reflect how individuals in a society work, entertain, and learn. A truly integrated global economy exists and demands some developments to improve societal conditions internationally as well as produce new goods and services that will serve as new economic engines. The global economy is healthy, yet is always looking for the next trend in goods, services, and technologies to sustain its growth. However, some nations do not invest in research as much as others. This is caused by the higher

burden of cost to provide social services to their larger or denser populations as compared to other countries. Governments, universities, private corporations, and private nonprofit research organizations are learning how to collaborate and fund research jointly to address the rising global challenges, although all parties recognize it will take many more years (well beyond 2028) to develop highly successful approaches to global research collaboration. They are beginning to work together through national and international boards to determine the nature and priority of funded research agendas.

Many of the nations involved in the research initiatives have laws and regulations requiring that government-funded research is open globally after a one-year period from the date of publication or other form of formal release of information and data. In most cases, unique or sensitive intellectual property (IP) is patented, trademarked, or protected by trade secret prior to publication and the national governments have processes that support these IP actions. Many (but not all) governments recognize that open access is important; it may spur on innovation rapidly since many more researchers and private citizens will be able to work with the information. Corporations are tolerant of the open access policy to government-funded *basic* research since they benefit from it as well; however, they continue to protect any IP produced from *applied* research they have funded or co-funded.

U.S. University-based Response

Translational research is the focus, where findings diffuse from basic research to practical applications quickly. For many years, university-based research has remained too compartmentalized, based on academic domains. However, many universities and national governments in Europe, North America, Asia, India, the Middle East, South America, Australia,

and New Zealand work together through interdisciplinary and transdisciplinary methods to optimize the diffusion. The world's leading research universities cultivate teams of researchers that contribute to these large-scale, internationally based research initiatives, many of which are funded for a decade at a time. University administrators direct most internal resources and policy development toward fostering flexible and agile research organizations that gather the most renowned researchers from needed disciplines. In addition, some of the more entrepreneurially inclined research centers are based in private organizations and not within a university. In either case, these organizations work through an elaborate global network of researchers, constantly seeking new initiatives and associated funding. The research groups collaborate internationally to respond to an agenda, apply for funding, conduct research, and spur the growth of the economies through private and public enterprises.

The universities, governments, corporations, and private non-profit research organizations collaborate in developing and managing robust virtual community-based ICTs. They provide the cyberinfrastructure required for the internationally connected university groups to collaborate, deliver research products, and work with private and public enterprises to translate findings into goods and services from which people, nations, and companies benefit. High-performance computing cycles are available and developed within international university- and government-based consortia, but they are in such high demand that the supply remains a challenge, although less so than in the past. The research groups publish their research products (e.g., data, notes, commentaries, audio-visual media, reports, and publications) through a variety of conduits, including for-profit and nonprofit publishers, their virtual research community sites, and other government- and university-managed research repositories. They also use their

universities' publishing services to produce, disseminate, and manage their research products. The mix of corporate, government, and university researchers is aimed at establishing and maintaining highly accomplished teams of researchers since research funding goes to the best collection of researchers for a particular project.

Scenario 2

Discipline-specific Research: Narrower Research Questions, Narrowing University

Global Context

While there are many international research agendas developed and underway, they tend to be focused within a disciplinary framework. For example, U.S. environmental scientists will collaborate occasionally with engineers, business and policy researchers, and sociologists to explore Grand Challenges such as clean air and water quality, but not always. Governments, universities, and corporations have some marked success with transcending their national and organizational boundaries to conduct pathbreaking research, yet there are limitations to the research. This is due to the existence of conventional funding programs, discipline-based infrastructures (including information technologies and facilities), and research practices that together tend to limit researchers to being engaged within their disciplines. These realities contribute to the narrower approaches to research. The global economy is healthy, yet is always looking for the next trend in products, services, and technologies to sustain its growth. The economy cycles up and down, and a contributing factor to this phenomenon is that new discoveries in science and technology do not develop quickly and consistently enough for the global economy to maintain an upward trajectory. Research funding is available, but there is not

enough of it, which constrains some Grand Challenge-level research initiatives. For a small group of research disciplines, such as the medical sciences and environmental sciences, the research is well funded and coordinated internationally among governments, corporations, universities, and private funding entities. Addressing Grand Challenges is the focus; however, it occurs only within a small set of disciplines.

Public policy, including laws, tend to be more developed in areas where the advancing academic fields are involved. For instance, policies regarding the degree of confidentiality and openness of research information are not applied across national governments, but rather occur at the agency level within a single national government. These agencies have agreements with their international counterparts to support research development and the open sharing of information after an agreed upon 12-month embargo period from the date of publication. Corporations have mixed reactions to this approach. While corporations want access to research (and they have it with government-sponsored basic research), they hesitate to share data. Instead, they move to protect applied research findings through IP actions so their competitors do not have access to their research results.

U.S. University-based Response

The universities have developed chiefly within their academic departments; hence, much of the resources, technology, and policy reinforce this arrangement. The research questions universities are able to address are narrow in scope. Therefore, they tend to develop highly successful departments in only a few areas since the university's resources are not leveraged across departments and colleges very well. Departments such as biotechnology/bioengineering, computer science and engineering, and crop/soil/water environmental sciences are among those

that have developed excellent platforms of researchers and infrastructures from which to compete for funding and collaborate with similar departments at leading research universities across the world. Many departments do not have the resources to develop the high-grade infrastructures and research capabilities needed to compete and collaborate at an international level. The individual university's reputation is built on only a highly select number of fields. The successful departments collaborate regularly with governments, corporations, non-profit research organizations, and other universities internationally. University and national research technologies are more aligned with the specific needs of a few fields, yet they have developed robust infrastructures that are comprised of Internet-based virtual research communities, repositories for research products, software production tools, and high-performance computing, which is developed at the university and national levels. The universities and departments publish their research publications through field-based publishers (for-profit and nonprofit), virtual communities, and other government- and university-managed research repositories. Much of the ICTs and related research services are concentrated within certain scientific domains.

Scenario 3

International Research Leadership: U.S. Research Centers Partner in Niches

Global Context

Several research areas critical to confronting Grand Challenges are being led by universities and governments in world regions such as far eastern Asia and India. Specifically, China is the research leader in information technology, agriculture, and biotechnology; India is a leader in information technology and agriculture; and countries such as France lead in biotechnology and Brazil in agriculture and biotechnology. China in particular has overbuilt its

research facilities and has been recruiting talent from around the world for many years to realize their research capacity; it is now paying off. Many of the nations that are leading in research have laws, regulations, and tax structures that provide great impetus for their universities to conduct innovative research. These national governments wish to be seen as world leaders in research, and therefore, have adopted policies to ensure public access to their researchers' scholarly and scientific publications, once proper steps have been taken to protect IP via patents, trademarks, and other approaches. They want other countries to see their leadership in research.

The faltering U.S. economic environment has been a major contributing factor to the rise of research leaders outside of the United States. The U.S. government's research funding has been shrinking consistently during the past 15 years, falling 15 percent during this period. At the same time, expensive U.S. government regulation and oversight of university-based research for the past 15 years has risen markedly. Many U.S. universities estimate this has added 10-15 percent to their overall research costs. Corporations, which have long been a dedicated partner in funding university-based research, are looking to scale back their research investments. Their interests lie in funding highly directed, applied research that leads to rapid commercialization of technologies, services, and products. Basic research is not their interest. Corporate-related taxes by U.S. states and the federal government have risen 12 percent during this period and, as a result, corporations have been withdrawing a portion of their research dollars to reduce their costs and maintain profits. The corporations' research dollars are focused tightly on specific, narrower applied research programs aimed at improving specific sectors of their product and service portfolios. They are looking for quicker and more targeted financial gains from research.

U.S. University-based Response

U.S. research universities have spent many years building entrepreneurial, interdisciplinary research centers; however, due to funding constraints, increased regulation, and regulatory costs, they are competitive in only certain areas of research. The U.S. Congress also has exercised its political will, reviewing and approving research project portfolios funded by the National Science Foundation. Consequently, many research portfolios of U.S. universities are no longer competitive with their international counterparts. They have had to retrench and focus on a small number of research areas where they can compete and lead globally. Most of these are in the medical and environmental research domains. Stem cell research is a prime example of where U.S. universities do not lead, but contribute significantly. Some leading U.S. biotechnology research centers partner with French universities, who dominate in this research field. Stem cell research is legal in France and well-funded by the French government and the European Commission; however, in the U.S. it is highly regulated with many federal legal restrictions and, subsequently, not well funded. Moreover, research centers at U.S. universities partner internationally in particular niche' areas with foreign universities that are leading the Grand Challenge research.

In order to collaborate internationally in selected areas such as medical, biotechnology, and environmental research, U.S. university research centers develop strong cyberinfrastructure so they can participate in virtual research teams spanning the globe. They possess top-flight scientific research facilities in the niche' areas and high-performance computing to keep pace with their international counterparts. While some funding comes from the U.S. universities and state and federal governments, interested corporations and private research organizations also

supply funding. However, funding for research also comes from foreign governments, universities, and corporations that are leading the research initiatives.

Scenario 4

Teaching and Student Learning is the Focus: Grand-Challenge-related Research Moves Overseas

Global Context

By 2028, U.S. unemployment stays steady between 10-13 percent. Several major industries and services have shifted their bases to China and Southeast Asia, India, Brazil, and, to a smaller extent, Russia. While corporations are concerned about U.S.-based employment, they see their consumer and employment markets growing internationally, and consequently, do not spearhead U.S. business investment as much as they have in past years. Their research investments are also shifting overseas, to the leading foreign research universities. The aforementioned countries, along with a select few in Europe (e.g., France, Germany, Great Britain, and Ireland), possess the world's leading research universities and related organizations. There are still preeminent research universities in the United States, but they are much smaller in number (about twenty) and most are private institutions. Given these conditions and the subsequent lowering of U.S. research expenditures, fewer young people in the United States look to research and university employment as a viable career path. Grand Challenge research initiatives clearly are shifting overseas, and only the most highly ranked U.S. research universities remain robustly involved in such research portfolios.

U.S. University-based Response

The top twenty U.S. research universities work strategically at maintaining their research leadership in specific fields. They realize they cannot be leading skill-building agencies if they

are not conducting significant research. Classroom instruction alone will not make their students employable.

The U.S.-based governments and many universities (especially those institutions below the top twenty) collaborate to invest in and improve degree programs and accelerate graduate rates. The objective is to increase Americans' employability, thereby keeping the U.S. involved in global economic growth. Consequently, many major U.S. universities have slowed their development of high-end, entrepreneurial research centers. Traditional academic departments lead as the prevailing university organizational structure. Research is occurring in U.S. universities below the top twenty institutions, but focuses much more on issues of local, state, and regional interest, and less on national or international interest.

Instead of developing cyberinfrastructure and services for research programs, U.S. universities and governments concentrate on developing *cyberlearning* systems, specifically virtual learning environments (VLEs). In addition, they focus on developing instructional content for the VLEs. The desired outcome is to improve graduation rates and have graduates enter the job market as quickly as possible. The universities want governments in the U.S. and other stakeholders to view them as the leading skill-building agencies in the new economy.

The universities understand that for the U.S. to reduce its long-term unemployment problem, they must graduate students more quickly while preparing them for the competitive international employment market. They also are under pressure from the U.S. federal and state governments to provide an affordable education and keep student debt low. In this environment, U.S.-based research in institutions ranked below the top twenty research universities focuses on improving state and local economies and supporting cultural interests; their research tends to

remain in the traditional academic departments. Only the uppermost echelon of U.S. universities participates in large-scale, internationally coordinated research.

Second-Round Responses

Five directors granted a follow-up interview with the investigator to respond to the revised scenarios. The other six participants responded by e-mail. The interviews were conducted and the e-mail messages were received during August 2013. Each participant was asked to consider the same seven questions posed in the first round of interviews in their responses. All of the participants read through the revised scenarios, and three made new comments, while the remaining eight directors stated they stood by their first round comments and had no additional responses. These eight participants stated that they liked the scenarios as currently revised. In addition, none of them offered any new scenario titles, nor did they change their selection of favored scenario. While most of the commentary supplied by the 11 research directors affirmed their stances from the first round scenarios, there was a small amount of unique commentary offered during the second round. This is provided below. Not all of the seven interview questions received responses in the second round.

Key Force

Additional responses tended to focus more on the specifics of the key force and how it will be manifested in Scenario 1. For instance, one director stated:

> A major driver of research direction is the interest of the funding agencies themselves, as expressed in position statements and funding opportunities. I am thinking specifically of the explicit interest in translational research and in transformative, interdisciplinary research as expressed by the NIH [National

> Institutes of Health]. The opportunity for support often drives the research direction of the researchers, especially toward collaborative, translational, interdisciplinary work.

Another director made a similar observation about the research funding entities' interest in setting the research direction. He referred to China to illustrate his point. Because China is a major funder of research, the university at which he works is "looking to China and the U.S. Department of Energy for large amounts of funds to conduct new energy research that is of interest, but particularly in China."

A third research director speculated how this scenario will play out and shared that "corporate R&D will become the applied R&D side of research at universities. Big foundations will do this, too." In all three of these observations, nations and corporations drive the research directions, as opposed to researchers' interests. Moreover, the research is translational, interdisciplinary, transdisciplinary, and applied, not basic or fundamental.

Main Element of Uncertainty

Only a few additional comments were shared regarding the element of uncertainty used in the study. While 10 of the directors affirmed a growing dichotomy between interdisciplinary research centers and academic departments, one director does not believe "the dichotomy is real. Both have a role in research; indeed, it is generally the same investigators who populate both. Faculty typically have a role in the traditional academic department and may identify a role in a center with overlapping interests. We certainly encourage this at my university."

As some directors did in their additional comments regarding Scenario 1, one director speculated how Scenario 2 may play out. He asked, "What's going to happen to the money that

drives the research enterprise?" He believes that in this scenario, the U.S. research universities are in marked decline as research institutions because their activities remain within disciplinary lines. This director openly and rhetorically wondered how the universities will use the monies they have been investing into research themselves when they are no longer competitive in the new, transdisciplinary, international research system.

Elements of Agreement or Disagreement

A few new comments were made about Scenarios 1 and 2, as well as a general comment about all the scenarios. Focusing on emergence of new approaches to collaborative research represented in Scenario 1, a research director posited that "translational research is certainly important, indeed vital, but it is not without risk to focus on it to the exclusion of basic research. The value of basic research might be lost in this scenario, and that would be a big mistake." Another observed that "the emphasis on a 'mix' of corporate, government, and university researchers seems likely to be an effective approach. The key is developing the right team of complementary expertise among individuals who can together articulate the key questions. The 'mix' as described is the most likely scenario to develop such a team." Regarding Scenario 2, one research director thought that it does not make "a compelling case for an international focus, as opposed to a widely collaborative research effort centered entirely in the U.S." Also, a general comment was shared that continues to illustrate the concern about the scenarios being too polarized: "It's not an 'all or none' among the United States research universities as the scenarios seem to tend toward. Instead, there will be 'the great sorting out' among research universities

with far fewer universities in the United States truly belonging in the R1 [Research I] classification."[2]

Steps for Achieving Favored Scenario

Providing more detail concerning how universities reach Scenario 1, one research director said, "Universities must pick specific, targeted areas of research and then make dedicated, strategic investments." For example, the director's own university recently achieved national certification status from the NIH for its cancer research institute. The director further shared that this certification demonstrates how universities and governments can partner to develop leading research capabilities and programs sanctioned by a base of experts at the national government level.

Hindrances to Preparing for Certain Scenarios and General Comments

One research director observed that the "renewed emphasis on teaching and student success by universities is an attempt to justify university budgets and has become politically popular. This will hinder the left-hand side scenarios, number (Scenarios) 1 and 3." One research director, in a second round interview, focused on the role of data and information by the end of the time the scenarios portray, 2028: "There is quite an information challenge: There will be 'infoglut' and more than ever before. Knowledge is ubiquitous by this time. How do we tell good information from bad information? This will be a major role of universities, that is, teaching people how to think critically."

[2] The Carnegie Foundation's former college and university classification system used "R1" as the designation for what the Foundation currently classifies as "Research – Very High" institutions. For more information, see the Carnegie Foundation at http://classifications.carnegiefoundation.org/

Conclusion

While the initial scenarios were drafted based on scenario studies, reports, and literature relating to the development of higher education and research, direct responses from the study participants and the subsequent scenario revisions document perspectives on the emerging global research paradigm from some of the leading research directors in the United States. These responses illuminate major hurdles to conducting Grand Challenge research in a global, internationally cooperative framework. However, universities are already successfully forming global collaborative teams, acquiring international funding and support, and navigating through complex national and international government regulations and policies. By engaging leading research directors in these discussions, the finished, revised scenarios provide researchers and research organizations with a series of timely and accurate globally-inclined scenarios. These research institutions can plan, prepare, allocate resources, alter policy, hire personnel, and implement operational directions utilizing the research program development scenarios produced in the current study.

Chapter 3 examines the characteristics of the global research paradigm. The structured interviews conducted with the participating research directors yield many opinions, data, and perspectives on numerous factors influencing globally-based Grand Challenge research, ranging from national and international economics, to national government funding priorities, and corporate, government, and university partnerships. The impacts of technology and culture on future research also are discussed. U.S. research universities, as the research directors point out, will need to organize themselves to maximize their research programs and interact with entities in other countries. The comprehensive treatment of these and many additional topics arising from

the interviews offer insights into the drivers shaping the future university research environment in the United States and elsewhere.

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Chapter 3

Research Directors' Discussions

During the first and second rounds of semi-structured interviews, the topics discussed fell into nine broad categories: (1) the international research platform, (2) national-level economics, (3) government regulation and politics, (4) population and social services, (5) partnerships, (6) entrepreneurial research center development, (7) future academic department roles, (8) technology, and (9) culture. Many of the comments regarding these topics were provided in Round One, and these helped the investigator revise the scenarios before sending them to the participating directors for the second round. The following distillation of the research directors' analyses and comments promotes an understanding of development of the current research programs in U.S. research universities and examines probable research directions during the 15-year period represented by the scenarios.

The International Research Platform

The emerging, international research environment was discussed at length. The directors addressed the development and importance of international research as well as the challenges such research presents. They also spoke of the economic context in which it will occur.

Development of Research Programs

Most of the study participants acknowledged the rising international environment within which research programs will be initiated, developed, and carried out. Within this new milieu, they observed that public–private research partnerships will proliferate and be seen as critical to the growing portfolios of research initiatives taking place at universities in the United States. In

fact, because of the economically driven context in which research occurs, research will increasingly be conducted within this framework. Most of the directors agreed that solving Grand Challenges through international cooperation and collaboration in research is critical. One participant stated that "these research problems are not U.S. problems, they are global problems." Another claimed, "International funding, initiation, and oversight are a must." One research director stated "we will see a lot more international cooperation on Grand Challenges." While all of the research directors agreed that research will become more international, two were skeptical about the ability of some universities to recognize the necessity for this global perspective. One stated, "There are varying national perspectives, and research will still be more nationally focused while working on Grand Challenges." While the development of research programs will take on a decidedly international composition, concerns about national centrism remain salient.

Challenges to Cultivating Internationally Based Programs

Throughout the interviews, the study participants described an expansive future of internationally composed research teams aspiring to solve large societal issues. Yet, they also admitted there are many challenges to achieving this goal. These include the following:

- **Lack of incentives.** Among the major challenges, researchers and universities may not pursue international research opportunities because they have few incentives to do so. No incentive programs to encourage international cooperation and collaboration in research have been developed by governments, international organizations, universities, or corporations. Research directors discussed this dilemma and the need to promote an evolution toward internationally based research teams and programs.

- **Focus on projects.** They described how the focus today is project-based, that is, granting agencies and organizations fund "projects," not "problems." They see a need for funders to transition to long-term funding research portfolios that address broad, Grand Challenge-level problems, such as long-term global environmental change. One research director pointed out that some organizations are forming research teams to solve large-scale problems, such as the Gates Foundation and its work on global and regional disease treatment.[1]
- **Lack of coherent regulations.** The directors highlighted the difficulties presented by international research, such as the lack of coherent government regulation among nations. In the United States, they said, ITAR (International Traffic in Arms Regulations)[2] and other forms of export control for tangible forms of knowledge raise issues. They see federal law as problematic because it impedes the sharing of knowledge between national borders, and they see a misalignment between U.S. laws and those of other countries, a situation that further restricts research collaboration. According to one director:

  > Universities will need knowledge of both national laws affecting the conduct of research as well as general knowledge of business policy in

[1] The Bill & Melinda Gates Foundation works worldwide to address issues of global health in developing countries, global development with a focus on hunger and poverty, and global policy and advocacy in which the Foundation seeks partnerships and policies that advances its mission. It also supports improvements in high school and post-secondary education in the United States (see http://www.gatesfoundation.org/).

[2] The U.S. Department of State's International Traffic in Arms regulations are part of Section 38 of the Arms Export Control Act (22 U.S.C. 2778). The regulations authorize the President of the United States to "control the export and import of defense articles and defense services." Further, the regulations state that "research funded by the United States government and specific access and dissemination controls protecting information resulting from the research are applicable." In other words, ITAR, regulates and restricts the flow of research information into and beyond the borders of the United States (see the ITAR regulations at the U.S. Department of State website, http://pmddtc.state.gov/regulations_laws/documents/official_itar/2013/ITAR_Part_120.pdf).

> a variety of countries. Operating in other countries, understanding the management and administration of processes and required regulations is massive.

A second director stated, "We will need contractual agreements to conduct research that meet national laws and policies. We will need to know those countries' laws. Adapting our management to these international environments is a big challenge." A third research director pointed to this problem and referenced an emerging European framework for research programs where United States-based universities can be contracted with and paid by European-based universities and governments.[3] This director sees that international public–private partnerships among corporations, universities, governments, and private research organizations are critical to the future of research program development.

- **Need for public support.** Public universities, in particular, will find the realm of winning public opinion over to support their research programs challenging as they seek to participate in international research initiatives. The research director of one of the public universities stated:

> We must do a better job of external outreach with our partners to our publics. If we don't, then private universities will take over research. Public support of public university research is critical. Even more pointedly, these publics who fund, support, and regulate public

[3] The European Union's Seventh Framework for Research Programme allows for universities outside of the EU to be involved with EU-based universities and funded for their participation in a given research initiative.

> universities need to also understand the rising imperative of conducting research via international, multi-institutional teams.

These sentiments underscore the importance of cultivating local and national support for global involvement in research.

In summary, the participating research directors asked two central questions: how do research directors bring together researchers to form the best teams across the world, and how do they foster internationally based research relationships? The directors described their aspirations for the future, which are consistent with Scenario 1, yet they are aware of the impediments to achieving this level of global research activity.

Economic Context of International Research

The rise of national-level economies and the development of a global economy in the late 20th century and early 21st century have given rise to factors that impact university research. This is especially true for university research conducted among multiple institutions and done so internationally, across several national borders.

Rise of national-level economies. The economic contextual discussions focused on emerging national economies outside of the United States. The directors recognized the growth of knowledge economies in other countries, particularly the BRIC nations (Brazil, Russia, India, and China), and one noted that South Africa is aspiring to join this list. Others talked about the African continent as the next great region of economic development. Africa will increasingly become electrified and have more modern roads and highways, cleaner drinking water, improved agricultural yields, and other infrastructure consistent with an emerging human society and economy in the early twenty-first century (Calderón & Servén, 2010). More so than the United

States, these regions will attract corporate investment to build new infrastructures, and applied and Grand Challenge-style research will be required to solve problems related to areas such as human and veterinary health, water and power supply, environmental management, and information and communications technology.

The situation and status of the Chinese economy drew comment from the participants as well. Several participants believe the economy and research universities in the United States are threatened by the rapid capitalization and overall robustness of the Chinese economy and research base. They often question how their universities might partner with the Chinese government, companies, and universities to engage in mutually beneficial research. Research into improving Chinese electrical power systems, which is a network of electrical components used to generate, deliver, and use electricity, is one Grand Challenge area where some research directors think U.S. universities could partner with Chinese universities because their national government is concerned about reliable, plentiful, and affordable power supply for its billions of people and rapidly emerging companies and public organizations (like universities). Two other research directors perceive China's economic data differently. They think that China is facing a potential backward step, due to overbuilding of city edifices and research facilities that are sitting unoccupied, as well as other rising problems, such as China's policy of currency manipulation and lack of legal controls involving intellectual property. In all of these cases, the research directors see the rise of international economies and their need for research to maintain their development as mostly a threat; however, they also see opportunities for research universities in the United States as they drive their research programs toward international competitiveness and collaboration.

Development of a global economy. Beyond national-level economies, there is a unified, global economy as well, one with no national boundaries. Several of the research directors stated that because of this, their universities will become more entrepreneurial and will increase their public–private partnerships, specifically with corporations and private research organizations. They said their universities follow developments in the global economy carefully. Recognizing the competitive nature of research and the critical need to form the best research teams, these research directors claimed this ability will be far more significant in the future. One of them said:

> Governments will come to realize that to solve their problems that researchers in a single university or country will not be able to solve them. They will need the best researchers, and they (these researchers) will be in different countries and in different universities.

The agricultural research needs of developing countries provide a good example. Such research would address not only the Grand Challenges of supplying healthy food to a large population but also the economics of food supply and the economic development of that region or country. Global economic development, societal problem solving, and the growth and development of research programs will go hand in hand, according to the participating research directors.

National-Level Economics

National economics in the United States are impacting university research funding negatively today and the participating research directors are concerned that this is the beginning of a long-term trend. They spoke of a lack of federal and corporate commitment to research now

and in the future as well as an upcoming loss of researchers and even entire universities as research institutions.

Lack of Federal and Corporate Commitment

After commenting on the international environment, the participating directors turned to a major domestic issue—the national economy. Several of them talked about how the United States has a history of over 50 years of federal investment in research and knowledge creation. "We are still in the lead in innovation by a large margin," said two directors. However, one director noted that "research activity as a percentage of U.S. Gross Domestic Product is falling way behind other countries." While the group agreed the United States is strongly in the lead, clear indicators force them to conclude that the nation's position is falling rapidly and should be cause for great concern. The critical question universities face, according to them, is the overall federal level of commitment to fundamental and Grand Challenge research funding. One director discussed the potential for a new model of federal investment in university research whereby federal agencies would invest directly in universities, cutting out or reducing grants and contracts processes. They would fund the universities directly much as state governments have been doing, which would represent a "complete restructure of how we invest in research universities." On the other end of the spectrum, another director articulated the "a threat is out there" alternate scenario, which describes how and why the federal government may abandon research funding altogether and what deleterious effects this will have on research universities (see Chapter 2 Alternate Scenario 1).

One director discussed the role of corporate investment on the U.S. economy and its effects on the national research ecosystem:

> U.S. corporations are sitting on a lot of cash, more than ever before. They are waiting for low-risk, high-return potential in knowledge creation activities. There is up to $2 trillion in private equity that could be invested in the economy but currently is not, due to this phenomenon.

This same director claimed that if the federal government would invest an additional $50 billion into research and development, then the United States could retain its global economic lead. According to the director, this equates to only 5 percent of current non-discretionary spending, which is largely military and entitlement programs spending. He concluded by saying, "So, we have the current ability and funds to achieve our own future knowledge security, and in fact, pay down the national debt very quickly also if we chose to do so."

Clearly, the participating research directors anticipate the possibility of different paths for receiving federal research funding. They see a current crossroads at which a decision will be made either leading to a new paradigm and a great future for university research in the United States or to more of the same, which includes more negative politics and public perceptions regarding federal research investments, an overwrought federal research regulatory system, and more long-term, injurious funding cuts.

Loss of Researchers and Universities

The effects of the U.S. budget sequestration of 2013 weigh heavily on the thoughts of research university administrators and the research directors participating in this study commented on it regularly. As a group, they concurred that the sequester will sharply reduce the size of an entire generation of researchers in all institutional settings (i.e., research universities, national laboratories, private research organizations, and corporations). "People will choose to

not go into research for their careers as a consequence," said one research director. Some of the directors also said that many researchers are looking for appointments outside of the United States, due to the sequester. Several research directors indicated this was an issue, especially with China recruiting leading researchers. In fact, the American Society for Biochemistry and Molecular Biology (ASBMB) surveyed about 4,000 researchers from a diverse group of scientific fields about the effects of the sequester on research funding and the research process itself. Approximately 18 percent of the respondents stated they are considering seeking research employment outside the United States (ASBMB, 2013). With aspects of the budget sequestration lasting until 2021, the research directors believe this will have generational, long-term, and permanently damaging effects on the U.S. research universities. A few directors predicted that the number of research universities in the United States could shrink dramatically given developing resource challenges. One of them claimed, "There are up to 500 [universities] that could lose their [Carnegie Foundation][4] research status. The U.S. could be down to as low as 100 [research universities] in this category."

Government Regulation and Politics

Government regulation has grown considerably over the past two decades, and it will continue to grow and impact research programs, according to the research directors. Because of this, they are concerned deeply about the current tone and long-term direction of the political environment in Washington, D.C., and the impact on government regulation and research

[4] The Carnegie Classification of Institutions of Higher Education is a system for classifying colleges and universities in the United States. It largely serves research purposes, enabling comparisons between education and research institutions. The system includes all accredited colleges and universities in the United States that are included in the National Center for Education Statistics' Integrated Postsecondary Education Data System.

funding. These concerns were discussed resoundingly during the investigator's interviews, especially when asked what factors support and/or hinder the development of the scenarios.

Political Control over Research Agendas

The future of federal legislative control and review of research funding decisions is of paramount concern, and current movements in this arena are causing further angst. For instance, Rep. Lamar Smith of Texas has introduced legislation called the High Quality Research Act to implement direct congressional review and approval of research projects slated for funding by the National Science Foundation (U.S. House of Representatives, 2013). One of the participating research directors claimed that the mid-term 2014 congressional elections will have a bearing on the outcome of this legislation, depending on whether there is a supportive U.S. Senate and President. Another director, sharing the concern, stated that the:

> Political agenda's impact on research direction and funding is a dangerous trend. More overt political control will impact areas such as climate change research and a variety of biological and medical research areas. We are already seeing the effects, such as the NSF's discontinuance of funding for social science research areas.

Given this trend, some research directors are calling for their universities to use political influence to moderate the ominous shape the political landscape is taking, fearing long-term and entrenched political control over research agendas.

Impact of Societal and Political Issues

Other major societal and political issues also can negatively impact the conduct of research and its funding now and in the future. "War has been very detrimental to research

program development. It reduces federal funds available for research and restricts international research relationships due to all sorts of new legal protections for the country like the International Traffic in Arms Regulation (ITAR)," expressed one research director. The past 10 years of war in the Gulf region has taught these research directors about the challenging effects of new war-guided laws that protect the national interest. They see a future ripe with the potential for more legislation like ITAR. As one research director observes, "Playing in the 'global sandbox' will be impeded by ITAR and export control. They will restrict and harm collaboration."

Effects of Political Gridlock

Political gridlock, with results like the U.S. budget sequestration of 2013, is another major concern. For these directors, a continued lack of cooperation among members of the U.S. Senate and House of Representatives could have a devastating impact on research. As one director put it,

> Congressional gridlock and the inability for the parties to compromise for the good of the country can and will damage research. We are living through this now with the budget sequestration. Too many politicians are focusing on making other politicians look bad, as opposed to solving problems.

Gridlock also is blamed for the inability of national governments to come together to form international regulation and policy affecting research. A lack of regulations regarding the handling and transporting of hazardous materials across national boundaries was given as a prime example. "Will this be regulated in a global collaborative?," asked a study participant. "The answer needs to be 'yes'," he declared.

Support for Open Access

At least one area of federal policy may bring some hoped for solutions. Government policies to mandate that the publications and data stemming from federally-sponsored research be freely and publicly available are being proposed. Many of the directors view this development as a necessary step in globalizing research because it is starting to show some government support for openly sharing research data and information around the world. Several of the participating research directors view open access development as necessary and presume it will be in place. Today the executive and legislative levels of the federal government are debating the body of open access policies under consideration. Within the federal government, however, some traction is being gained for them with the 2013 White House Office of Science Technology and Policy issuing an order requiring major granting agencies in the federal government to submit plans for facilitating open access to output of their sponsored research (U.S. Executive Office of the President, 2013). Also, the FASTR legislation [the Fair Access to Science and Technology Research Act, H.R. 708] introduced into Congress during 2013 is another indication of growing support for open access (OA) policies (Fair Access to Science and Technology Research Act, 2013).

Most of the directors do not see OA as their largest concern for conducting global research, but they do acknowledge it is one piece in the new global research puzzle. While the majority of the directors support the federal OA policies and view them as an important stage in developing a global research platform, two argue that these policies will be the least influential aspect of government regulation impacting research funding. They believe that policies regarding national research funding levels and economic stimulus leading to public-corporate research

initiatives will have a greater impact on research. Hence, they expressed neutrality and lean toward non-support of OA policies.

Population and Social Services

Three research directors discussed the societal and governmental imperative to invest financially in effective social services and public infrastructures as a significant factor impinging on federal research funding, and not only in the United States: "Demographic shifts of people in the U.S. and other countries are a major spur to the need for social service investments," offered a research director. Further, he stated:

> The U.S. population continues to shift toward major urban centers, resulting in the need to continue developing new urban services and infrastructure like police, fire, public transportation, schools, and medical facilities. At the very same time, the U.S.' infrastructure is aging, with much of its bridges, roads, water conduits, and other infrastructure being 50–100 years old and in dire need of attention.

Another director commented that "also, the dramatically rising costs of American healthcare during the past few decades is damaging the federal government's ability to maintain, let alone increase, research funding support." Others pointed to the large and consistently ongoing influx of legal and illegal immigrants into the United States who need healthcare, education, and job training. The United States is not the only country facing these kinds of challenges. One director observed that "India, for example, struggles with strengthening its research budgets because of the countries dense population and consequent need for comprehensive urban planning, new public infrastructures, and social services." Based upon the comments of a few research

directors, this appears to be a noteworthy impediment to national development in some countries. A similar impediment exists for the United States, and the participating research directors definitely foresee a growing negative impact on research funding unless something significant and nationwide can be done about the cost of social programs, especially healthcare since the federal government supports large medical programs such as Medicare, Medicaid, and the Affordable Care Act.

Partnerships

One response to the enormous funding challenges faced in the United States is to develop more targeted and specialized partnerships. These focus on the trio of university, corporations, and governmental units partnering on research initiatives.

Development of Corporate and Government Partnerships

According to one director, "Offices of research, especially the VPRs (vice provost/vice president for research), spend their time today aligning with federal interests with corporate interests." Another director echoed this sentiment, "The trio of government–university–industry is the arrangement we are looking to construct as frequently as possible." He further shared that "one day I expect the Feds to say that we have to always partner with corporations in our research."

While the federal government likes to partner universities and corporations in research as a method to improve the national economy, some of the study participants noted:

> Corporations are reducing their research and development divisions and are looking toward universities to carry out their R&D. However, the corporations

> by and large want control of the IP [intellectual property]. This area needs to be sorted out.

Further, they declared that corporate research cannot transition wholly to the universities without finances to support the research coming along with it. The question was raised, in the end, "Who is saving money on research?" It appears that both U.S. governments and corporations want to cut their research expenditures; however, university administrators, like those participating in this study, claim this is a shell game or a "robbing Peter to pay Paul" mentality. "The only way to reduce the cost of research and gain efficiencies is through conducting research on a global scale, finding and utilizing the very best researchers, and spreading the cost burden out widely."

The research directors do not view corporate investment in university-based research as a panacea. Some of them mentioned data and made statements such as "within universities there is a push to do more research with corporations, but for the 100 highest funded research institutions by the NSF, 4.4 percent of the research is with corporations. We are not sure how we move this percentage up." Another research director made a similar claim:

> Overall, corporate funding of university research is minor and currently stays at 5–6 percent now for many research universities. This is not expected to change. Corporate research interests are short term and they like to control the research. So, corporations don't have much impact currently; this won't change.

While corporate–university research partnerships provide new streams of revenue to fund research, the participants do not believe it to be the singular approach to solving the U.S. research funding problem.

Development of Public–Private Partnerships

Public–private partnerships will be a part of the new model of research support in the national and international economies. One research director referred to the formation of the Virginia Tech Carilion School of Medicine and Research Institute (VTCSOM&RI) as an example.[5] Announced in 2008 and opened in 2010, the new school and research institute is a public–private partnership between Virginia Tech and Carilion Clinic, a major health care provider and medical educator in Virginia. Other partners include the Commonwealth of Virginia, which is building the facilities and supplying grants to the partnership, as is the federal government though the National Institutes of Health (NIH) and NSF, both having awarded large research grants to the school and research institute during its young tenure.[6] The public–private partnership such as Virginia Tech-Carilion Clinic example is looked to as a speedy, nimble model through which research universities can gain significant amounts of funding and make fast progress in a research area.

Entrepreneurial Research Center Development

Many leading U.S. universities are home to interdisciplinary research centers. Through their evolution these centers are taking on new or increased roles. They are becoming the leading university unit for aggregating research funding, nurturing public–private research partnerships, and increasing the international nature of research, generating solutions to Grand Challenge

[5] Disclosure: This research director was not from Virginia Tech, which is the study investigator's employer.
[6] The VTC partners are embedded with one another; Carilion medical clinicians teach in doctoral degree programs and conduct research alongside and in teams with VTC Research Institute researchers and Virginia Tech researchers. The VTCSOM&RI is an independent corporate 501c(3) entity, managed by a corporate board of directors comprised of people from Carilion Clinic and Virginia Tech. The research teams are comprised of over 400 researchers conducting translational research in areas such as addiction research, cancer biology, computational biology, developmental and regenerative medicine, cardiovascular science and cardiology, infectious diseases, inflammation, neurobiology, cognitive neuroscience, and decision science.

problems and building the new, transdisciplinary basis upon which they will elevate a university's research competitiveness and solution-providing capabilities. One of the participating research directors summarized the history and purpose of research centers:

> Much research is interdisciplinary today, so we have research centers. These centers are growing in importance in areas such as Washington, D.C.; Silicon Valley, California; Research Triangle Park, North Carolina; and in other major urban centers with a research community because they can more easily leverage the growth of relationships with nearby government agencies and laboratories, as well as corporate and private research entities. But people have to put money into this approach, people meaning public, private, corporate, university. It's all about getting funding.

Research centers are recognized as necessities at research universities. Several of the research directors commented that "we need interdisciplinary and transdisciplinary approaches to solve problems. Grand Challenges can't be addressed by a single discipline." It was evident they recognize where research programs are headed when they commented that "the 'market pull' is to do more interdisciplinary work" and "these centers, among many things, help with increasing industry relationships."

The research center model posited in this study is entrepreneurial and interdisciplinary (see Table 2.4, scenarios 1 and 3). This suggests they will act autonomously and opportunistically to seek funding for conducting large-scale, Grand Challenge research that solves global problems. The research directors talked about the need for autonomy from the traditional and otherwise confining nature of their

universities; they and other their university administrators recognize their research centers must be quick, creative, and flexible when pursuing critical and far-reaching research opportunities. The interdisciplinary nature of many research centers is established. However, in the future, they will bring in disciplines that historically have not always been involved with the research center (e.g., certain areas of the social sciences, humanities like history and English, and the arts) and they will focus more on transdisciplinary methods.

Five of the participating research directors, in particular, spoke of transdisciplinary research and how groundbreaking it is, claiming, "transdisciplinary research will reign." They talked about new fields such as data visualization and the sustainability movement that would not exist today without transdisciplinary research. Being transdisciplinary refers to the creation of new disciplines and fields that span many disciplines. A new research and academic culture arises with a new vocabulary and new collaborative methods, thus transcending the disciplines involved in the research initiative at hand. "Transdisciplinary research will get people to solutions faster than the old silos or interdisciplinary work," claimed one research director, who also observed, "Transdisciplinary work increasingly is being fostered and supported by our newest research centers." This developmental path for research centers seems to be well set, with one research director saying:

> Universities won't go back to the "department alone" model. To grow, we need another model that supports transdisciplinary research. There will be fewer single PIs. We will be interacting with other nations like we do with

other (government) agencies, other PIs, etc. In this scenario, the national boundaries are starting to disappear and global problem solving through extensive, long-term portfolios of transdisciplinary research will begin to appear regularly on the research landscape.

The nature of the research center described in Scenario 1 of this study, which is purported to exist by 2028, will be entrepreneurial, interdisciplinary, and even more so, transdisciplinary (see Table 2.4). The centers will be problem-centric as opposed to project-centric, and the funding will foster this framework. Many of the participating directors said this paradigm provides a model for future research at their own universities.

The "new style" research center will not only be inside the university organization, but also will be growing in the private, nonprofit setting outside the university. One of the research directors articulated this when he said, "There will be three host settings of these centers, not just two. There will be university research centers and academic departments that support major research, but there will also be entrepreneurial interdisciplinary research centers that exist outside the university." He even went further to suggest it is possible for university-based research centers to become the centers of the past. He discussed how entrepreneurial, private research centers outside the university setting are growing. He offered The Wistar Institute in Philadelphia as a leading example.[7] Other such centers and institutes referred to by this director and a few others were the Stanford Research Institute, the Research Triangle centers, Georgia Tech Research Institute, Desert Research Institute, Battelle Memorial Institute, and the Howard

[7] Information on the Wistar Institute can be found at: http://www.wistar.org/.

Hughes Medical Institute.[8] Typically in these settings, researchers are not employed and managed in a tenure-track framework. Instead, they conduct research based on project contracts. This allows the private research center to move quickly toward new research opportunities, "staff up" quickly by hiring whom they need for a given research project or portfolio, and end their contracts when there is no longer enough interest and/or funding in a research area. The private, nonprofit research center may be a chief institution in the emerging global research paradigm.

Despite the exciting aspirations reflected by the majority of the director commentary, three directors regularly highlighted problems that need to be overcome if long-term success is to be achieved under the entrepreneurial interdisciplinary research center model. One articulated the dilemma this way:

> It's all about resources. Someone who wants a center wants resources. That's what they mean to say. However, there is no model for the sustainability for centers like there is for academic departments. A university might be able to pay for a couple (of) centers, but that's about it.

A second research director said:

> Entrepreneurial interdisciplinary research centers have a finite timespan. They are topic-driven and the topic can fizzle out. They have a different mission than departments. The departments have a mission related to instruction and

[8] For additional information, see: Stanford Research Institute, http://www.sri.com/; Research Triangle Park, http://www.rtp.org/; Georgia Tech Research Institute, http://www.gtri.gatech.edu/; Desert Research Institute, http://www.dri.edu/; Battelle Memorial Institute, http://www.battelle.org/; and Howard Hughes Medical Institute http://hhmi.org.

> the mentoring of students, and (they) conduct faculty development. Centers have research as their primary mission.

A third director observes:

> The centers are not part of the university governance process. They struggle for funds. Right now, departments as "tenure homes" are winning out. This dynamic between research centers and the university and how governance and tenure are carried out is very much going on. You can't currently have a tenure home in a center, and that may be a problem.

Two opinions challenging the ascendancy of the entrepreneurial interdisciplinary research center were offered. A common fear was expressed that such interdisciplinary centers may pose a threat to discipline-based research. One of the two critical research directors voiced his concerns: "We can't lose our disciplinary roots; we can't have too much interdisciplinarity." Another director questioned the need for entrepreneurial interdisciplinary research centers: "There is a difference between interdisciplinary activities vs. interdisciplinary centers. We don't need a center to work in an interdisciplinary way." While the majority of the directors endorse the up and coming new research centers, a couple of them state that not everyone is looking for research to be dominated by the new paradigm.

Future Academic Departments Roles

None of the research directors believe the academic departments will become the dominant framework for conducting research at U.S. research universities. However, most believe the departments will remain much the same as they are today, with similar levels of funding. Two of the directors said it is not an "either or" situation. They pointed out that

departments and centers can complement and advance one another. Another director described the matter this way: “Universities won’t give up traditional departments. They [departments] will be better on collaboration through transdisciplinary work.” However, this director posited, “Who drives and brokers the move to transdisciplinary work, this is the issue.” This statement and some of the ensuing discussion with this director indicates that the political power of the departments may wane if transdisciplinary research becomes a leading university driver and its proponents steer this driver, as opposed to the department heads doing so.

Some of the research directors see specific threats to the academic department. While they do not see them going away, they think some universities will move from this framework toward international campuses and online learning programs, which will weaken the position of the academic departments in the power base of the university. Essentially, the crux of the argument is that funds already resting with the departments may be diverted to these two competitors as they grow in certain universities. Also, any opportunities for the departments to gain new resources may be met with competing requests from the online learning programs and international campuses. The entrepreneurial interdisciplinary research center is not the only threat to the academic department. One of the directors explained that due to threats from centers, online programs, and international campuses, not all universities are embracing organizational change along the lines of Scenario 1 (see Table 2.4). He described a backlash at some universities where they are defending and protecting their departments from these threats and are reaffirming the academic department as the disciplinary home for their faculty members. The director said this is a curious development during a time when departmental boundaries are

disintegrating on their own as faculty participate with non-disciplinary colleagues in new centers, new campuses, and new educational programs.

Technology

Advances in information technology are changing the way research is conducted. Production, sharing, analysis, and visualization of data are all increasingly digital processes, and virtual environments to support these activities are emerging as a major force in global research activity. In addition, the public's demand for open and free web-based data and information is growing rapidly (Hey & Trefethen, 2005). The research directors discussed specifics regarding how technology not only enables global research but also provides a competitive edge to U.S. research universities seeking to remain leaders on the global stage.

While the directors do not deny the important role of technology in research, it was ranked as a lower priority when considering a potential key force or element of uncertainty in regards to the study's scenarios, and thus, they did not focus on it in the interviews. The vice provosts/presidents for research in this study tend to focus on issues of policy, regulation, contractual agreements, and funding sources and arrangements. Largely, they depend upon others to address technology needs and issues. Given this, two of the research directors specifically said that "technology is the least strong force" with which to be concerned. Another director said that technology is "not a strong force because we know that technology change is going to happen anyway." In the context of the scenarios, this means technology is not a good candidate to be the strongest element of uncertainty. In juxtaposition to this opinion, a third research director thinks somewhat differently about technology: "Technology is an important

factor. It can overcome fiscal and economic issues. Economics can't overcome technology. Also, technology can be disruptive."

Regardless of the ranking of technology as a force driving program transformation, all of the directors recognize the critical role it plays. Certain technological capabilities, especially related to digital data, are necessary for modern collaborative research to be undertaken. "Big data" and data visualization, analytics, sharing, management, mining, and discovery are all elements of technology applied in research that the directors discussed. While they talked about "big data" in general, the directors discussed in more pointed terms how new, high-level technologies maintain their competitiveness in research. Neuroscience research is offered as a good example. "A neuroscience research team needs an FMRI [functional magnetic resonance imaging equipment], without it you are not competitive." Nanotechnology research provides another example; without a cleanroom,[9] universities will not be competitive in nanotechnology. Several of the research directors emphatically stated they need better cyberinfrastructure and their universities must make the investment.

Some universities are offering data repositories. One research director even argued for institutional, national, and international data repositories to support academic and research programs. Also, as computational approaches to research continue to grow, some universities are developing faculty positions for individuals with informatics expertise to foster computational research in all major research areas. Among these areas are enviro-, geo-, veterinary medical-, bio-, hydro-, and policy-informatics. Only two research directors raised the need to create and manage virtual environments. They said such environments that enable researchers to work at a

[9] Cleanrooms are used to maintain extremely low levels of airborne pollutants, chemicals, and other particles, creating an environment required for certain forms of scientific research and manufacturing. For more information on cleanrooms, see cleanroom.net, the cleanroom industry news site.

geographic distance from the university, both within the United States and abroad, are necessary. While this need for virtual research environments was expressed, details for creating them were not provided.

A few of the research directors also highlighted some of the difficulties arising in computational research and informatics-based approaches. One of them described the dilemma: "The user interface between stewards of information and big data managers is problematic. Data analysts, data/information discovery experts, and data management specialists all talk differently now. They need to come together to coalesce and share vocabulary." His observation reflects the fragmented nature of cyberinfrastructure-related work, which often involves specialists from many areas (i.e., library, archival, and information sciences as well as high-performance computing and information technology and domain informatics).

Culture

An important cultural shift seems to be taking place in American society, and the research directors reflected on this during the interviews. Specifically, they addressed how cultural change impacts research decision making and prioritizing in American university, government, and corporate settings. Their comments focused on how little value Americans now place on experimentation and entrepreneurialism. They went on to explain how this shift is affecting the public perception of research and the research university. While they see a shift in American culture that does not bode well for university research programs, they recognize that shifts in university culture are necessary if U.S. researchers are going to engage in global research.

Shifts in American Culture

Perhaps the most ominous cultural change is an apparent shift in American culture away from new ideas and innovation, as observed by Denney (2011). All of the research directors commented directly about this, with one summing up the predicament well: "We are losing the American habit of risk-taking and visionary investing in research and innovation," while a second director says similarly that "the American freedom to pursue new ideas and the application of those ideas is being lost." A third director observes that "The country needs to have faith that investment in basic R&D means good things will come." Some of the directors reflected on the U.S.' former space exploration and military investments. These national investments in research were made without knowing precisely what the outcome would be or exactly how the discoveries would be used. Others talked about how American society is losing its "power to change," reflecting on Alex de Tocqueville's book authored in 1835, *Democracy in America* (de Tocqueville, trans. 2012), where the author discusses how ancient Chinese empires lost their supremacy because they lost their power to change based on exploration and innovation.

Loss of Public Support

The second, closely related, cultural shift the directors spoke about was the value people place on research. Every interviewed research director spoke about the shifting and worsening public perception of research and universities, and public universities in particular. A few directors stated that communicating the value of research to the public is as important as building international relationships. The directors strongly desire an improved public understanding of and appreciation for knowledge creation and how research leads to this new knowledge.

"Adequate public support for university research won't happen without it," claimed one director. As far as the once held perception that research and higher education are a public good, the research directors believe strongly that the "public good notion" is under attack and may be under attack even more so in the future. Many spoke about how these previously perceived public goods increasingly are thought of as private benefits to the individuals receiving the education or to the companies or other private entities benefitting from the research. One director observed that pharmaceutical companies and oil companies are identified as leading private entities that benefit from public research. Most of the directors view this "public perception problem" as a result of inadequate communication on the part of the universities. One of them said, "We need to find ways to communicate as effectively as we can on what research is all about to the public and to our congress people." The need to improve universities' abilities to market their societal value to a tax-paying public and their representatives is critical, or else much more financial support from the governments may be forfeit.

Needed Shifts in University Culture

Within the university, the research directors view a few aspects of organizational culture that they think need to evolve, or simply need to be revised, and the sooner the better. Faculty tenure was brought up several times in the interviews. The opinions on faculty tenure, from those who offered them, ranged from maintaining the tenure system in its current status due to the inherent difficulties in changing it, to rethinking and revising it to be much more complimentary to the evolving research ecosystem. Two directors expressed emphatically that the university must change on this issue; tenure must go away in order for the universities to be agile enough to pursue new and emerging portfolios of research. A third director focused on the need for cultural

change in universities and reflected on how difficult this is due to a preponderance of resistant university employees who will not embrace any sort of change. A fourth director concentrated on the organizational culture involving research specifically and said, "The key is developing entrepreneurialism in research," but later he asked rhetorically, "How can universities foster this cultural development?" While much of the focus on issues of culture in university research concludes that entrepreneurialism is needed and is most advantageous to universities, none of the research directors articulated particular methods by which to foster this culture.

One research director choose to focus on an element of culture within U.S. universities that is not present as widely in universities in other countries, especially in third world and emerging nations. This is the peer-review system in research and scholarship. For the director, this is a major element that separates the U.S. and some European, Australian, and New Zealand universities from much of the rest of the world. She said that researchers and research institutions "must value and promote the peer-review system, for it is the only system we have to independently critique and verify research." In addition, one researcher said, "Universities want students to understand foreign cultures, not just foreign languages." This research director reflected on previous commentary on working with governments, universities, and corporations in other countries and the need to navigate their cultural customs as well as their regulatory environments.

In the end, a larger, more philosophical question was asked: "How global a society do we want to become?" Both the complementary and the competitive nature of the relationship between national culture and interests and international partnerships are evident in this statement. While universities, especially public universities with their significant base of tax-supported

budgets, need to lead American society on international research issues, they must also follow the lead of public perception regarding how universities should conduct themselves in the global arena. As universities strive to reverse negative perceptions held by the American public, they also face resistance to changes within, the very changes these directors see as necessary to continue to remain global research leaders. These will be critical challenges going forward for research universities in the United States.

Conclusion

During these conversations in the semi-structured interviews, the complexities of university-based research program development for a worldwide stage became evident. It is clear most of these research directors have spent a great deal of time analyzing their experiences and the data they collect to understand the changing nature of research programs, particularly their economic, regulatory, and organizational contexts. The descriptions of these and the other related contexts in this chapter might lead to an improved understanding of the factors affecting the development of research programs. These descriptions also detail the challenges being posed to research universities in the United States, which are aspiring to be international leaders in team-based, problem-solving research on a worldwide scale. The investigations and discoveries provided in this chapter give research institutions an excellent view of the future trajectory of leading university research programs and the nature of the evolving ecosystem in which they operate.

Chapter 4 compares the current study's scenarios and the Organization for Economic Co-operation and Development's (OECD) 2030 higher education scenarios, which provide some focus on the nature of research development (OECD, 2009). The chapter focuses on the

similarities and differences between the two sets of scenarios. While the current study focuses on a group of research universities in the United States, the OECD's study is more expansive, collecting and analyzing data over a 20-year period from the 1980s to the 2000s and from universities spanning the 25-nation OECD member community, including the United States. The OECD scenarios describe differing futures of the global research ecosystem, while the current study's scenarios describe what may occur at the university institutional level in response to the evolution of this ecosystem. The current study's work serves as a test of the more expansive OECD study, focusing on how one nation's research universities are planning for and responding to global research development five years after the completion of the OECD study.

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Chapter 4

Comparing the OECD Scenarios of 2009 with the Current Study's Research Program Scenarios

Apart from the current study, only one other set of higher education scenarios focuses on the development of academic research over a multi-year period (i.e., of at least 15 years). These scenarios appear in the Organisation for Economic Co-operation and Development (OECD, 2009). In Chapter 5, "What is changing in academic research? Trends and prospects," Vincent-Lancrin (pp. 145–178), studied and documented the rise of academic research in OECD member countries over a span of two decades, from the 1980s to the 2000s (see Chapter 1 for the investigator's review of the study). Vincent-Lancrin's chapter appendix, *Future Scenarios for Academic Research* (pp. 173–178), contains the axes-driven scenarios he developed to examine the major forces and the most uncertain elements impacting academic research within the universities of OECD nations. The four scenarios are:

1. Open collaboration. Research is predominately government funded. It operates on an international scale and is highly collaborative between institutions and organizations. Knowledge created by the research initiatives is open and the research enterprise is very technological.
2. National interest promotion. Research is publicly funded and administered by the universities, which control the research process. Government advances a national perspective and its needs regarding research and education. Universities are

focused increasingly on the local and regional economy. Internationalization is a concept that governments turn away from.

3. International research marketplace. Universities compete internationally to conduct research for governments, corporations, and other organizations. They operate as revenue generating institutions and university research is funded from both public and private organizations. University revenues are increasing from the licensing of their research products. Corporations conduct a large portion of basic research.

4. New public management. Research is funded publicly and the governments manage research using a mix of public and private approaches. Universities are independent, yet they depend on public funds for research They have diversified their revenue sources, including foreign educational programs, deregulating tuition rates, patenting research products, and partnering with corporations.[1]

The two sets of research-based scenarios—the OECD 2009 set and the set posited in this study—both look at similar forces, such as whether research will tend to be more nationally or internationally conducted and how it will be managed, that is whether it will be governed within an institution or outside of it at a national or international level.

The investigator compares and contrasts the two sets of scenarios to determine how they may be used in conjunction with one another to understand better research program development in U.S. research universities over the next 15 years. From this examination, additional

[1] Further descriptions of the OECD scenarios are available in *Higher education to 2030 volume 2: Globalisation* (OECD, 2009, pp. 174-177).

probabilities for research program development in the United States can be considered, thus expanding beyond the institutional-level scope and strict findings of the current study.

Similarities and Differences

Major similarities and differences between the components of the OECD and research program scenarios become apparent when the scenario settings, axes and axis points, major forces, and scenario stories are compared. These chief similarities and differences are reviewed below.

Scenario Settings

The OECD 2009 scenarios and the scenarios of this study have different overall settings. However, because these settings are related, they are impacted by many of the same forces. The OECD scenarios are characterized by the type of research described in *Higher Education to 2030 Volume 2: Globalisation* (OECD, 2009), which reviews higher education institutions from 25 nations. These scenarios are set within national higher education systems to study to the extent to which these systems may or may not engage in research internationally. Specifically, the scenarios consider how these national, multi-institutional systems may manage their research initiatives and programs, that is whether public government management or free-market forces will predominate. Academic research in the OECD scenarios is shaped by certain forces:

> the increasing importance of knowledge; the growth of private funding and decline of government funding; the rise of competition from other sectors in basic research; the growing collaboration and competition at the national and international levels; the growing demand for accountability and transparency from governments and civil society; the new opportunities offered by

> technology progress; and the persistence of mass higher education systems (or continuing massification where it has not reached its peak). (Vincent-Lancrin, 2009, p. 173)

These external forces spur research programs in systems of higher education toward international collaboration. In this new global environment, national interests are considered within the context of an international research market, and both free-market and public-management constructs govern research. While private dollars are prominent in the research ecosystem, there is a new social contract, where public entities manage and monitor large-scale, international research programs, regardless of funding source (pp. 164–166).

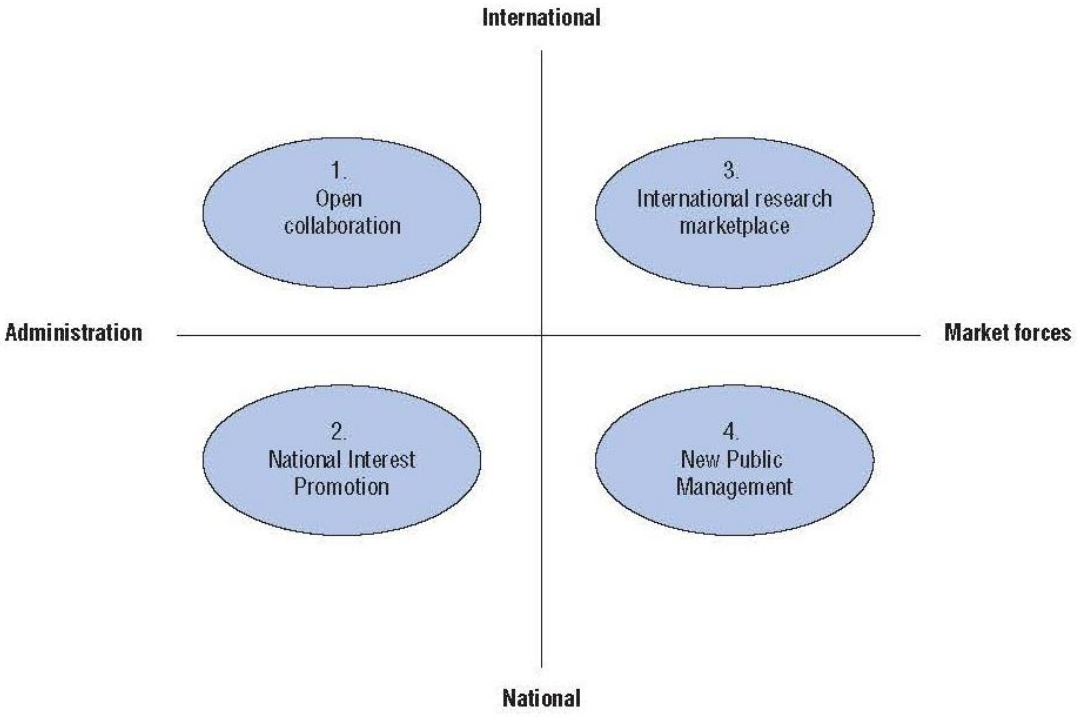
The setting for the research program scenarios is much different. While the OECD scenarios take place at the national and international level, this study's scenarios are set at the single university level within one country, the United States. Some of the same external forces are identified, but the scenarios examine how individual universities will respond to them. The scenarios also explore how the single institution may organize its research programs based upon whether it is internationally competitive in many research areas, contributes significantly to global research in a given interdisciplinary area, or participates primarily in research at the local or national level.

Axes and Axis Points

Although these two sets of scenarios are placed within quite different settings, the scenarios share much in common in terms of the key and major external forces examined. As a result, their axes and axis points, as shown in Figure 1.1, and Figure 4.1, share some similarities. Both scenario sets identify national and international economics, political issues and

governmental regulations, cultural perspectives on the value of research and research institutions, and technological advancements as major forces and a dynamic between national and international forces as the key driving force. A closer analysis of the similarities and differences between the axes and axis points will enhance understanding of the institutions and institutional systems represented and, in turn, improve understanding of how research universities will engage in international research.

Figure 4.1
OECD scenario axes



Note. Reprinted from *Higher education to 2030 volume 2: Globalisation* (p. 174), by the Organisation for Economic Co-operation and Development, 2009. Copyright 2009 by the Organisation for Economic Co-operation and Development. Reprinted with permission.

The vertical axes of key forces in both sets align; they are focused on international and national interests and activities. The horizontal axes, representing the most uncertain elements, do not align as well. However, generally, the left quadrant scenarios represent a somewhat more

open and collaborative environment among institutions (i.e., universities, governments, corporations, and private laboratories), while the right quadrant scenarios are somewhat more managed and controlled. In the case of the OECD scenarios, this heightened control in the right quadrant scenarios is because market forces predominate. Governments and government-related entities respond to the market forces by managing or controlling research activity, especially as it is conducted across national borders. In the corresponding research program scenarios, control is being exerted over research programs through traditional academic departments, where research is more localized and less interdisciplinary, transdisciplinary, and entrepreneurial.

One chief difference between the two scenario sets is whether their respective axes reflect external or internal factors as uncertain elements. The OECD scenarios utilize factors external to national systems of higher education as their most uncertain elements. Specifically, these are free market forces in the economy and society or large-scale, governmental management systems that will shape how university research will be initiated and conducted and how, and with whom, collaboration will occur. The most uncertain elements of the current study's scenarios are different. The factors used are internal to a single higher education institution; that is whether the single university will organize its research programs predominately in entrepreneurial research centers or in academic departments. In this regard, the scenario sets are dissimilar. One looks at forces outside the university that will shape its research programs; the other examines forces inside the university that will shape how its research programs are organized.

The scenarios are similar in their respective vertical axes, which lay out the key forces. Here, both sets of scenarios focus on external factors. In the case of the OECD scenarios, these factors center on whether the scenario is geared toward meeting international or national

interests. In the case of the research program scenarios, they center on whether a certain U.S. university's research programs are internationally competitive and, therefore, involved globally, are not internationally competitive and, consequently, more nationally or locally focused. The respective key force axes for both studies emphasize international activity on one end of the spectrum and national activity on the other. This illustrates that the OECD investigators and the investigator of this study, through their research, have concluded the national-international dynamic will likely be the key driving force, having the most impact on the organization and conduct of university-based research.

Major Forces

The two sets of scenarios also share similar major forces. Both studies examine economic, political, cultural, and technological forces and describe how these could affect the development of university-based research programs. Where the studies differ is mostly in how each major force is applied in a given scenario. Again, this difference stems from an external or internal focus, that is, looking at how forces affect a higher educational institution's behavior in the larger national or international realm or at how these forces drive a given institution to organize its research programs internally.

Economic. Economic factors are a major force present in both sets of scenarios. This force is most discussed in the OECD scenario "international research marketplace" and in the research program scenario "thriving interdisciplinary research." In both, economic interests drive research institutions to collaborate in Grand Challenge research to solve problems, such as how to provide clean water or a facet of healthcare in developing countries. The universities and the national governments described in the scenarios acknowledge that resolving such large societal

dilemmas not only improve human society but also result in innovative products, services, processes, and infrastructures that can positively impact a national or international segment of the economy. Similar interests across several nations, such as interest in developing new power systems like nuclear power plants, result in collaborative research to address a societal challenge. This research results in economic stimulation as a new technology is developed. While the OECD scenarios focus on impacts on national economies, the research program scenarios examine this as well as impacts at the individual university. However, in all of the scenarios, the benefits to national and local economies drive universities and national governments to collaborate with similarly interested institutions to create new resources and technologies.

Political. The political forces in both scenario studies are far-ranging. They include not only the power of a politician or party but also issues of governance, such as national legislation relating to research oversight and funding, government agency policies on research administration and research output, and governance and management of internationally conducted research initiatives. Both sets of scenarios discuss national governments and how they will evolve to leverage internationally composed research teams successfully for the betterment of their economies and societies. The research program scenarios illustrate how single universities may respond to federal and international mandates and laws regulating research administration, funding accountability, and access to research results. These issues are examined in the current study's scenario 1, "thriving interdisciplinary research," and 3, "international research leadership," and summaries of semi-structured interviews with research directors further expand upon the possible effects of government regulations (see Chapter 3 for more in-depth discussion). The OECD scenarios illustrate how governments and their systems of higher

education may respond to certain forces present in this broader political environment. For example, they examine such possibilities as public administration of inter-institutional research predominating (in the "national interest promotion" scenario) or international governments coordinating research (in its "open collaboration" scenario). These two OECD scenarios explore how these different approaches to program management would impact research within the higher education systems and at the national level. While both sets of scenarios examine the role of government regulation and oversight, only the research program scenarios investigate how government regulation and oversight impacts the organization and development of research programs within the individual university.

Cultural. Culture as it relates to research is also considered in the two sets of scenarios. The OECD scenarios point in a cursory way to the cultural effects of immigration, outsourcing research to foreigners, building national culture, and the overall de-funding of research programs. The two scenario sets also examine culture as reflected in public perceptions and beliefs regarding the value of higher education and research, especially research as performed at universities.

These latter cultural forces are discussed more thoroughly in the research program scenarios than in the OECD scenarios. This is because the research directors on the current study's Delphi panel spoke a good deal about the U.S. public's changing perception of the value of universities and research. Some of the directors are concerned that positive public perception is on the wane. This is at least, in part, because the general population sees private corporations as capitalizing on the results of publicly funded research programs while the public receives no discernible, tangible benefits, according to some of the research directors. Universities in the United States

definitely see their future success tied to public perception, which influences representation in government and, in turn, funding decisions that impact both public research and education.

Other cultural forces center on issues such as knowledge and information ownership and technology access. The OECD scenarios discuss the value of free and open knowledge to the public. They also articulate a concern in some OECD countries over the "digital divide" between developed and developing nations. These countries' representatives expressed opinions that the divide should be removed and that all people around the globe should be able to attain a certain threshold of access to the Internet and to digital tools. Others claimed that if their country is successful enough to develop a digital economy and the digital means to engage in various other activities, then this is a competitive advantage and this advantage should be maintained. The research program scenarios identify an increased level of support for providing and maintaining free information on the World Wide Web. They also address growing tensions over intellectual property (IP) rights in all of the scenarios; these tensions that stem from differing opinions on when those rights should be a public good or a privately held commodity. Essentially, society at large appears interested in openness and free information, but private corporations are interested in owning and licensing IP. This struggle is illustrated in different ways across the scenarios and is present in both sets.

Another cultural force, the wish to preserve and promote national culture, is discussed mainly in the OECD scenarios. In them, skepticism is occasionally expressed about whether the benefits of internationalization outweigh the possible price, which is a loss of national identity. Concerns are raised about how this identity is at times threatened by immigration and foreign influence. These scenarios describe how a nation's leading cultural voices—its journalists, media

personalities, and social scientists—will sometimes critique research projects with foreign entity involvement more critically and claim this involvement diminishes or overlooks certain relevant, national and cultural variables because the foreign researchers lack this cultural knowledge. They also raise concerns about foreigners and foreign companies conducting research of political and military interests to a country. Cultural forces as described in the two sets of scenarios illustrate the power of cultural beliefs and perspectives and their influence on publicly-supported research.

Technological. Both sets of scenarios discuss the transforming nature of technological advances on research and reflect an expectation that technology will increasingly play a significant role as universities compete and collaborate globally. However, they identify different technologies as the cause for such changes. Thus, while one set provides more detail on communications technologies used by individuals, the other elaborates on infrastructures to support educational systems and facilitate the entire research process. The major technologies examined are:

- Information and communications technologies (ICTs) used among researchers in single university and multi-institutional settings;
- Data centers, repositories, networks, and other related forms of technology infrastructure;
- Technology tools for data and information analysis and visualization; and
- Research instrumentation that generates digital research data.

To a certain extent, both sets of scenarios describe how technological innovations may improve research and change the way it is conducted. In the research program scenarios, the Delphi panelists commented frequently that current digital technologies have already rapidly and

irrevocably changed research processes, analysis, and, therefore, findings. In fact, they observed that science and scientific theory have become much more data driven due to new instrumentation, data centers, and analytical tools. The OECD scenarios specifically discuss how ICTs are fundamentally changing not only the way instructors and learners work but also the way researchers collaborate. These scenarios describe ICTs being used for communication to facilitate team interactions regardless of whether its members are conducting research from separate institutions, countries, or even continents.

Shaped by the panel of research directors, the research program scenarios are much more focused on the development of future cyberinfrastructure. Infrastructures such as data centers, high-performance computing centers, and digital data and scholarship repositories are identified in the research program scenarios as more advanced components of research cyberinfrastructure needed for universities to compete in the global environment. At the same time, coverage of ICTs in the research program scenarios is not as in depth. This is because the Delphi panelists were research directors as opposed to directors of research computing or chief information officers. If the latter were interviewed, perhaps there would be even more emphasis on technology and more detail of how technology might transform research. Together, both sets of scenarios predict an increasingly significant role for technologies as research moves to a multi-national and multi-institutional environment.

Scenario Stories

Comparing the scenarios' stories may yield further understanding of how research will be conducted in the future, both nationally and internationally. For ease of comparison, the scenario axes of both studies will be used as a framework for the discussion. Because the quadrants of the

scenario axes are numbered differently in the two studies, the quadrants will be referred to by position only, rather than by number: upper left quadrant (ULQ), lower left quadrant (LLQ), upper right quadrant (URQ), and lower right quadrant (LRQ). In the comparisons below, each quadrant represents two corresponding scenario stories, one from the OECD study and one from the current study:

- **upper left quadrant** ("open collaboration" and "thriving interdisciplinary research, solving global Grand Challenges");
- **lower left quadrant** ("national interest promotion" and "international research leadership, U.S. research centers partner in niches");
- **upper right quadrant** ("international research marketplace" and "discipline-specific research, narrower research questions/narrowing university"); and
- **lower right quadrant** ("new public management" and "focus is teaching/learning, Grand Challenge-related research moves overseas").

Upper left quadrant (ULQ). The two scenarios occupying the upper left quadrant—"open collaboration" and "thriving interdisciplinary research, solving global Grand Challenges"—are similar in virtually all respects, except that one portrays institutional systems while the other portrays individual institutions. (This difference is present in all of the scenario quadrant comparisons.) Both scenarios describe an environment in which research is largely publicly funded, but large infusions of private research investments from corporations and other private entities are present, as well. In this regard, the ULQ scenarios represent a mixed source of funds. Similarly, they also represent international scenarios where collaboration among universities, government laboratories, corporate research and development divisions, and private

laboratories is common. Both scenarios describe their environments as being driven by new technologies. They emphasize the recent advancements in communication technologies and how these provide the platforms used by researchers on different continents to conduct research. The technologies referred to foster direct communication via text and video as well as support the sharing of digital files. However, it is the research program scenario that, in addition, comments on developments in high-performance computing and other forms of cyberinfrastructure to conduct experiments and deliver research findings and products. Global networking is a key feature for both scenarios, not just between universities, but with other research partners such as government laboratories and private, corporate research facilities. Virtual research environments, or "virtual collaboratories," as they are called in the OECD scenarios, play a prominent role in research collaborations and research dissemination. Moreover, many nations are making large investments in research and its required cyberinfrastructure.

The research program scenario goes into more detail about research dissemination, explaining that research output will be available through myriad means, such as for-profit and nonprofit publishers, research-oriented virtual communities, and digital repositories operated by governments and universities. Through these means, research is available to the public in real time and in a quantity not experienced by previous generations. Society in general, and governments and universities, value free and open knowledge; both scenarios point to this as an important, developing cultural value. Given this, both scenario stories indicate tension between those who seek to protect copyrights and intellectual property (IP) and those who tend to regard research findings and products as a "public good" that should be available to all through open access. Private entities, like corporations, often reject the notion of public good, wanting to

maintain liberal laws that allow for much privatization of research findings, or at least the privatization of technologies they can develop and capitalize on in the marketplace. However, they yield to making basic research (not applied research) open to society, as described in the research program scenario. The OECD scenario, while not directly addressing this, is consistent with this approach to IP and research output, describing a similar call for open access to basic research. Because these issues are complex, with myriad economic implications for private, for-profit entities wishing to remain competitive, debate continues about managing IP. Even so, there is growing support for making many research findings open to a global society.

Lower left quadrant (LLQ). The scenarios in the lower left quadrant both reflect a withdrawal from international research, however, for differing reasons. The OECD scenario, "national interest promotion," describes more locally-focused research activity as universities strive to improve local and regional economies. This is in response to growing public skepticism of the value of internationalization of both education and research. Research is publicly funded and managed, and the universities with their faculties retain control and remain trusted members of society who "own" the research process. Given these characteristics, higher education and research institutions are under obligation to their supporting public to conduct research that serves society and the nation. In the OECD scenario, military-related research is on the rise as a manifestation of this growing national interest. A small number of leading universities remain highly active in international research, as some research areas require the best minds and a global approach. However, the emphasis in this scenario is on teaching more than research, and on developing the national economy and culture. International research efforts become the province of a group of elite research universities.

The research program scenario in the LLQ, called "international research leadership, U.S. research centers partner in niches," differs not in how it responds to the internationalization of research, but in its reasons for withdrawal. This scenario is not reflecting a country that necessarily wants to focus on national needs and desires, but rather on a nation retreating from the international scene simply because it cannot lead international research initiatives on the grand scale of the past. The U.S. focuses internally on the nation because of certain limitations impacting its universities' abilities to compete. The highly cyclical U.S. economy with its "peaks and valleys" (and especially its valleys) has been a major contributing factor to the rise of research leaders outside of the United States. The universities in the United States are not competitive due to government and corporate funding constraints, as well as increased regulation and the associated higher compliance costs. Because the country has not been able to compete and lead international research efforts, the development of its interdisciplinary infrastructures and research centers has been increasingly limited. Yet, this scenario describes how U.S. research universities will remain engaged in international research. The answer to this dilemma is through a small number of highly developed, interdisciplinary, entrepreneurial research centers in universities. In selected areas such as medical, biotechnology, and environmental research, U.S. university research centers remain internationally significant, recognized as important partners because they have developed strong cyberinfrastructures enabling them to work on international research teams virtually. The scenario also notes that some of these centers may not be based in universities but in private laboratories.

The two scenarios are similar, both reflecting a retreat from international research. However, in the OECD scenario, it is because of a growing interest in promoting the national

economy and culture. This represents a cultural retreat from internationalization, an active societal choice to retreat and focus nationally. In the research program scenario, the nation's ability to compete and acquire lead positions on large-scale, mega-funded international research initiatives has been lost. Instead, U.S. universities focus on being niche players and strong partners in certain areas of research. Withdrawal from the international research scene is not a choice, but the result of limited human and economic resources and a failure to continue developing the country's technologies and organizational platforms, through which the country could potentially lead the world. It is because of a lack of continued investment in research program infrastructure that the country is waning internationally, not because of an active choice and cultural preference.

Upper right quadrant (URQ). The scenarios in the upper right quadrant both describe an open market where research universities compete internationally for resources and the right to lead particular initiatives, but they differ in how they portray limitations in universities' abilities to compete. In the OECD scenario, "international research marketplace," universities compete internationally to conduct research as a service to the entity or entities funding the research, be they governments, corporations, or other public or private organizations. In this scenario, there are few external controls and universities compete openly and globally for research funding and for the privilege of being the lead institution for a research program. Public opinion is such that most people support universities bidding for research and working for any entity that can fund it. As this scenario develops, research universities limit teaching activities and sharp competition exists between universities to hire the best academic researchers available worldwide. There is some cultural backlash, such as concerns over foreigners conducting research of importance to a

national government or to a country's citizenry. The limitations are simple in this scenario: either a university can compete and win a contract, or it cannot. If universities from a certain country cannot compete for a prolonged period of time and consistently lose research business, then that country suffers economically and loses the capacity to grow and learn from the research innovations of its neighboring countries. The Western universities in this scenario experience a decline in their abilities to compete as universities in emerging countries like China and India become increasingly more adept at bidding for research contracts, leading international initiatives, and supplying well-trained, lower-cost research personnel.

The research program scenario in the URQ, "discipline-specific research, narrower research questions/narrowing university," is different from its corresponding OECD scenario. Here, U.S. universities also compete openly but they are limited, mostly because their research capabilities are concentrated within traditional academic departments. Just as universities in the OECD scenario may lose research funding and projects due to less-expensive, adequate-quality research capabilities in emerging countries, the universities in the research program scenario may lose research funding due to a similar inability to compete. However, this inability is because research is organized within antiquated departments and, therefore, overburdened with expense. The U.S. universities are stymied due to the country's adherence to conventional funding programs and older research practices. These are inherently discipline-based infrastructures, including information technology, and are not useful to other disciplines that are attempting to gain global competitiveness. Where other countries have developed research organizations that support many disciplines and cyberinfrastructures that can be used in interdisciplinary ways, the U.S. universities have stayed too focused on the discipline-based approach endemic of their

mature academic departments. In addition, due to the United States' decreasing international involvement, its economy remains more heavily localized and susceptible to local cycles. The marked lows in these economic cycles translate into interruptions in abundant research funding from sources within the country.

The two scenarios of this quadrant describe an environment of open international competition for research funding and leadership, unfettered by government over-regulation. However, one illustrates a country's drop in research leadership due to competition from emerging countries that are out-bidding them because they possess both newer research infrastructures as well as less costly, yet well-trained research professionals; the other illustrates a country that has not innovated enough, retaining its antiquated infrastructures and rendering its universities uncompetitive in the international research market.

Lower right quadrant (LRQ). The scenarios in the lower right quadrant are directly market driven, and they reflect negative international experiences in either the research market or in the economic markets. While they both are responding to these similar conditions, their responses are different. In the OECD scenario, "new public management," university-based research is largely publicly funded and a central public management approach is predominant (i.e., federal agencies, boards, or state-level entities directly govern and oversee research programs, as opposed to the university being the primary overseer). Market forces reign supreme, which means that universities are relatively independent and develop their own revenue streams quite autonomously. While depending on significant public investment, they seek funding and resources from businesses, other governments, and even foreign entities to support research. Government has deregulated much of its control over research in favor of allowing

market forces to predominate. By contrast, the public entities that oversee research and its funding insist on more financial accountability. Given these developments, the competition for research funding among U.S. universities has increased, and as a consequence, research funding has become more concentrated under the control of a smaller number of universities. In the OECD scenario, the universities within a nation compete more for limited research funding while attempting to diversify their revenue streams for both research and education. Moreover, research, and not teaching, still predominates.

In the research program scenario, "focus is teaching/learning, Grand Challenge-related research moves overseas," U.S. universities confront too many challenges, keeping them from focusing on large-scale, internationally-based research. They begin concentrating more on preparing the nation's citizens for a competitive and growing foreign employment market. In this scenario, research goes on, but it becomes the province of the U.S.'s top twenty universities, and these are mostly private. The universities below the top twenty focus their research endeavors on local and regional issues and much less on national or international research agendas. This development in research programming takes place because U.S. universities have simply lost out to more advanced research program development in countries like China, India, and Brazil and to certain regions such as Southeast Asia. Corporations invest in these countries because they see burgeoning, new consumer markets that attract employers and require infrastructure developments, many of which often necessitate funding new research initiatives. Because of these trends, U.S. universities focus more on education and place much less attention on how to retain research dollars. They foresee a future where U.S. citizens and program graduates will be employed in other countries. Therefore, for the U.S. to remain economically sound, it must

benefit from the development of these foreign markets through the sale of goods and services and employment for its citizens.

In both scenarios, the response to difficulties in the international research market is to shift focus to national-level research programs. This causes more intense competition among top universities for funding in one scenario. In the other scenario, universities no longer focus on research as their primary concern. Instead, they work alongside their governments to improve educational programs and prepare citizens and graduates for global employment markets.

Overlaying the OECD Scenarios onto the Research Program Scenarios for Further Research and Analysis

Since the research program scenarios are set at the single university level and the OECD scenarios are set at the multi-institutional, international level, the former scenarios can be "nested" inside the latter and used for planning purposes to generate potentially new understandings of how research may be conducted on a global scale. In other words, providing an international setting as described by the OECD scenarios and applying it to the institutional-level scenarios may produce additional knowledge about the future of research program development in national-level university settings. This approach may also serve as a method to produce hybrid scenarios from the two sets for further analysis and planning.

The scenarios could be nested in several ways. Examples are as follows:

- The "thriving interdisciplinary research, solving global Grand Challenges" scenario applied under the "open collaboration" scenario;
- The "international research leadership, U.S. research centers partner in niches" scenario applied under the "new public management" scenario;

- The “discipline-specific research, narrower research questions/narrowing university” scenario applied under the “international research marketplace” scenario; and
- The “focus is teaching/learning, Grand Challenge-related research moves overseas” scenario applied under the “national interest promotion” scenario.

Other combinations of scenarios could be posited, analyzed, and then described in a newly created scenario. While beyond the scope of this study, such an approach would build upon the previous research performed by the OECD and by the investigator of this study to expand upon current understandings of international research program development.

Conclusion

While the similarities between the scenarios—the key and major forces—of the OECD study and the current study may help corroborate the findings in both, the differences between them may actually be more helpful to library directors, research directors, university administrators and others involved in strategic planning and organizational development. These differences provide additional possibilities that might not necessarily have been considered in the narrower scope of the current study where select people are interviewed and one country is under examination. This may be, in part, because the OECD study looks at the larger systems and, in part, because it also studies other nations, thus, an understanding of certain aspects, especially the cultural ones, like the sense of national identity and the digital divide, may not have been considered much in a U.S. study. While planning in the United States will always be nationally centric, it will now be important in a global environment at least to take the perspectives of and developments in other countries under consideration. After all, they are also preparing for the

global environment, and in some cases, they will be partners, in others competitors. In cases where they are competitors, universities will need to consider issues such as the digital divide. Giving a basic level of access to everyone could have a huge impact on the ability of developing countries to compete. In turn, it could greatly affect U.S. universities' abilities to compete, making strong cyberinfrastructure development more important. The differences between the scenarios of the OECD study (2009) and the current study complement this investigator's findings and provide more for planners to consider.

In the next four chapters, the library case studies are presented. These case studies were developed through interviews with the library directors representing libraries from each of the four categories used to determine study participation: (1) public land grant university, non-American Association of Universities (AAU) member; (2) public land grant university, AAU member; (3) public university, non-land grant; and (4) private university. In each of these four instances, the director responds to only one scenario, Scenario 1 ("thriving interdisciplinary research, solving global Grand Challenges"), which was the one most favored by the research directors during the creation of the research program scenarios.

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Chapter 5

Library Case Development and Case A:

Public Land Grant Research University, Non-AAU Member

Case study research allows the investigator, and subsequently the case study readers, to understand organizational environments, contexts, and drivers and how they affect the organization as well as the individuals working within it through a comprehensive narrative description and examination (U.S. General Accounting Office, 1990). Before engaging in case study development, the investigator applied specific selection criteria to determine which institutions were invited to participate. First, the selected libraries are a part of the parent universities for which the vice provosts for research participated in Phase One (i.e., the scenario development and review phase). Second, each university library belongs to one of the four categories used in the study—public land grant, non-AAU member, public land grant AAU member, public non-land grant, and private. Table 1.3 lists 18 research universities from which the four participating universities/libraries were selected (one institution per category). In addition, the investigator and the dissertation committee combined their knowledge of each library and its director to determine which to invite for participation.

During July and August 2013, the investigator e-mailed the four library directors selected from the qualified list of universities, asking them to participate in producing one case study each, to be written by the investigator. All four agreed. The case study interviews were conducted via telephone between August and October 2013. Each director answered seven questions (see Table 1.8), posed by the investigator, who sent the questions in advance of the

telephone calls. The purpose of the questions was to elicit from the directors how their libraries would respond to the scenario most favored by the research directors in Phase One (see Table 2.3). Each library director reviewed only one of the four research program scenarios. This was the one most favored by the research directors, Scenario 1 "thriving interdisciplinary research, solving Grand Challenges." The directors were encouraged to share the scenario and interview questions with their associate deans or associate university librarians to gather feedback, and each director did so. Therefore, responses during the interviews were a compilation of each director's own responses as well as those of other people in leadership positions at her/his respective library. The four case studies were then compared to find similarities and differences in the libraries' responses to the scenario (see Chapter 9).

During the interviews, the investigator took notes on his computer and recorded the telephone conversations. The directors consented to the note-taking and recording in advance. In preparation for case study writing, the investigator listened to the recorded interviews and compared them to his notes, thereby corroborating the findings documented in these two sources. In addition, before drafting the case studies, the investigator asked each library director to review the interview notes pertaining to her/his interview to ensure consistency between the notes and the interview responses. By having two interactions with each director, having the directors gather responses from their associates, and by consulting both his notes and interview recordings while drafting the case studies, the investigator developed a methodological triangulation to corroborate the research findings (Yin, 2014). In addition, the investigator used a semistructured interview process (Wildemuth, 2009). He presented all questions in a consistent manner and

order with each participant and maintained a conversational style of questioning and responding throughout each interview (Rubin & Rubin, 1995).

Case A

Case A, a public land grant university located in the United States, is a member of the Association of Research Libraries (ARL), the Southeastern University Research Association (SURA), and the Association of Public and Land-grant Universities (APLU). It is not a member of the American Association of Universities (AAU). It provides services to over 250 undergraduate, graduate, and professional degree programs. This public land grant university is a co-educational institution founded in 1865. With 28,000 students, it is the largest university in its state and has the highest ranked research institution in its state. Its research expenditures are over $400 million per year. The university maintains 16 colleges with about 90 undergraduate degree programs, 100 master's degree programs, 60 doctoral programs, and four professional degree programs. The colleges are: agriculture, arts and sciences, business and economics, communication and information, dentistry, design, education, engineering, fine arts, health sciences, law, medicine, nursing, pharmacy, public health, and social work.

The university increasingly has stepped up its investments in research, and it aspires to become a top 20 public university, regarding its level of research expenditures. While the university does not maintain international campuses or research centers, it has many educational and research activities in other countries. Among them are educational initiatives in Guatemala and Ghana, health-care work in Israel and India, agricultural work in Southeast Asia, and business and engineering educational exchanges in Europe and Iraq. The university also provided its expertise to help establish two universities in Indonesia for the Indonesian

government. Its international activities are a mix of education, research, and service, with the latter including providing health care to areas such as Latin America, the Middle East, Central and Eastern Europe, and Southeast Asia. The university has aggregated funding from the Bill and Melinda Gates Foundation, the U.S. Department of Agriculture, the U.S. National Institutes of Health, the Asian Development Bank, and PEPFAR, which is the U.S. *President's Emergency Plan for AIDS Relief* program.

The university library system is comprised of 13 libraries, including the main library. The other 12 libraries address the following areas: agriculture, chemistry and physics, design, distance learning, education, law, fine arts, medicine, sciences, engineering, special collections, and a library storage facility. The library system's annual budget is $21 million. It employs 190 people and maintains an $11 million library collections budget. The system holds over 3.5 million volumes in print, film, and digital form. No specialized library programs exist to support the university's international initiatives; however, the library employs an international programs coordinator who assists university members. Moreover, the library provides its core library services to university personnel regardless of their location. The library is well known, particularly for its extensive special collections of rare and primary documentary sources, specializing in documents, photographs, oral histories, and audio/visual materials that document the state's society and culture. These collections include public policy materials, which document how the state's leading citizens have contributed to public policy formation at the state and national level.

On August 27, 2013, the investigator interviewed the library director via telephone. The director shared the questions with the libraries' associate university librarians and gathered their reactions and feedback prior to the phone interview.

Future Directions

In addition to well-known forms of secondary literature (scholarship) and primary resources to support research (archival collections), the library, heeding the past 15 years of discussion on the importance of managing digital research data, sees this as the next big challenge. All of the major government-based granting agencies and most of the private organizations and foundations with grant programs have adopted data access and management requirements to openly share data with the goal of improving and accelerating research. Principal investigators are expected to adhere strictly to compliance requirements but many of them need services and support to comply with granting agency policies. However, there are many leading research universities that still need to develop the institutional capacity to manage research data, especially in cases where no government- or discipline-based data repository exists. University libraries in general have responded to this need, and the Case A library has made significant strides, developing a repository to preserve and provide access to university researchers' digital research data.

Although significant resources have been applied to building the university's data repository and affiliated services, this effort has not been undertaken without controversy. In fact, there is marked and consistent pressure from the university on the library to continue contributing in a leading way to undergraduate student education. Examples of such support include providing modern, technology-rich learning spaces for group and individual study

activity; updated library instruction programs; literacy programs in visual communication and multimedia production; and production zones that include an array of 3-D printers, plotter-printers, digital scanners, and the loaning of laptop computers, e-readers, tablets, and other mobile recording and computing devices, including the mass-marketed Google Glass, which is now priced at $499.00 (as of 2028).

The activities described above require the majority of the library's resources. Hence, significant tension exists in the library between the proponents of student education and those of digital research services. The scientific/medical areas of research are a particular source of this tension because their computing and data services needs are so profound and expensive. The library, which possesses well-established funding sources to support student learning, has been working for several years to generate funding sources for the new digital research services. This work has yielded limited results; the governmental mandates for data access and management have been largely unfunded mandates, leaving it up to the universities to figure out how to fund policy compliance. The size and robustness of the digital research services developed and offered by the library are directly proportional to the amount of funding made available for the library's digital research services. Since the digital research services are brand new, the library hesitates to re-direct existing library budgets to them and seeks new funds from the university administration. The Administration has given the library some modest budget increases to initiate data repository services, but does not allocate resources for any additional digital research services.

Services

While the library focuses on undergraduate student education and instruction, in terms of research, it focuses on scholarly products and primary resources, such as books, journals, conference papers, technical reports, business and organizational records, personal papers, photographic and moving image materials, and, more recently, digital research data from scholarly and scientific research. These contemporary, digitally produced datasets are the next big "product type" for the library to concentrate on collecting, managing, providing access to, and preserving. The library sees this work as highly complementary to its historical role as the curator of scholarly and research-related information. The library does not endeavor to engage as partners in production processes in scholarly communication, such as supporting the technologies used to produce research data or scholarly journals or conference proceedings; however some better endowed libraries are working in this area. Providing an infrastructure and service platform for new approaches to research are viewed by the library director as too expensive and taxing for this library. Therefore, it does not engage in co-designing a research program's production processes with respect to data management, technical/design/service support for virtual research environments, or processes for production and dissemination of scholarly content such as journals, books, proceedings, and websites. The library sees the need to assist the university's researchers in meeting the data management requirements that are now *sine qua non* with almost every granting agency and organization worldwide.

The library has spent many years focusing on the details of sustaining digital objects. Some of these details include learning about the characteristics of digital file formats and how to document them, leveraging unique identifier systems for author and document identification

(e.g., ORCID identifiers for authors and digital object identifiers [or DOIs] for documents), and determining metadata schemas and local practices for generating metadata per digital object. The metadata work is in depth, involving the technical, administrative, descriptive, and contextual information needed for the long-term management of the university's intellectual output in digital form. The library takes great pride in the detailed level of digital curation in which it operates. While the library provides a highly regarded general collection, it is well known across the state for its special collections. The digital curation work is an extension of the library's special collections work, and data work is even referred to as "the new special collections" in many of the library's plans and reports. The focus on research data requires the library to become more involved in the beginning of research projects; however, the library's leadership, management, and employees see this as a means to an end. The focus remains on managing scholarly and research *products* as opposed to shifting the library's focus onto scholarly and research *processes*.

In order to collect research data, the library has worked for several years to integrate its subject librarians onto as many of the faculty's grant-sponsored research teams as it can. The subject librarians focus on recommending metadata needs and generating the metadata that serves the data sharing and access agenda, as prescribed by most of the granting agencies and organizations with which the university works. The library has made some marked progress in this regard. A few of the subject librarians are now co-appointed between the library and the colleges or schools. The leading example of this arrangement is between the library and the medical school, where the subject librarian is relied upon for both in-depth knowledge about

medical information resources and the research data management plans at the project level and metadata creation for sharing and access purposes.

Other employees, based in the library's information technology and digital initiatives department (IT&DI), apply their technology- and curation-based knowledge as they work with the digital objects further to create or auto-generate additional metadata (to document the technological characteristics of the materials) and administrative and preservation information (to document who has managed the objects and in which systems, as well as what steps have been taken to ensure their long-term accessibility, such as generating additional versions in open standard-based digital file formats). The subject librarians with the most data management knowledge work comfortably with the technology and IT&DI curatorial employees to ensure that the digital objects being collected are well documented, are kept in open file formats, have proper unique identifiers associated with them, and are easily accessible and well preserved in the library's digital repository.

Beyond the library's almost singular focus on the technical aspects of research data management, it also provides some ancillary services to augment this role. These complementary services involve promoting open access to research data as well as maintaining data producer rights and providing copyright research and assistance. The subject librarians and the technology and curation personnel hold campus events to raise awareness of the presumed benefits to accelerating research processes and improving findings through the open sharing of data. Also, because data rights are complicated, the subject librarians advise faculty researchers on how to retain their rights to the data they produce while sharing it openly. They also assist with copyright-related concerns when data from outside sources are incorporated into the datasets the

faculty and researchers produce and analyze. The library has not yet hired a rights manager due to funding shortages; however, the approach of utilizing the skills of other library personnel allows the library to support researchers with basic knowledge and advice.

Infrastructures

Two major aspects of modern infrastructure for many organizations, including those at university libraries, are the physical facilities and information technologies. This case study examines and describes how these two infrastructures at the model library will evolve to respond to the favored scenario.

Facilities. The library director acknowledged that many top university libraries have been designing research commons spaces for their researchers. These spaces are set up for small research team collaboration, both in person and via high-performance live telecommunications, which provide the required visualization technology and analytical software tools necessary to complete data analyses. Given the library's extensive investments in undergraduate student-focused learning spaces, the library director feels that these spaces can be leveraged for faculty-level research space needs. The library does not have the space available, nor does it have the resources needed, to develop cutting-edge, technology-enhanced research spaces. The director acknowledges that many of the university's major research centers and institutes have developed research spaces specifically designed to support their research teams. These teams look to the library to manage the final intellectual outputs of their research endeavors and assist in data management planning to ensure they meet any granting entity's requirements for data access and management, as opposed to providing them with physical workspace.

Technologies. Technology is evolving rapidly at this library. The high demand for faster processing speeds, wider network bandwidth, and larger online storage space all led the library to partner with the university's information technology (IT) division. When talking about library technology, the library director asserts the critical need for the library-IT partnership. He describes the accomplishments stemming from consistent partner meetings held for several years now and the technical infrastructure developing because of joint planning. Further, the director does not see the library becoming a "hard-driven" IT operation; the library looks to the IT division for that. However, he says the library will be equal partners with IT, and one party will not be subservient to the other. He recalls when the library reported to IT about 15 years ago and how the organizational structure did not work well for the library. In addition, the library director states, "We have to be able to talk to IT," reflecting the need for a library culture that fosters communication and understanding between the two entities. In this scheme, the library concentrates on developing metadata, selecting and converting file formats, and providing online access to the digital materials. It also partners with other university libraries to develop and maintain distributed, inter-institutionally based digital preservation services. Moreover, library personnel frequently converse with their IT counterparts regarding server management, server-side issues with digital asset management, network port selection, and security management for the inter-institutional digital preservation network. The IT division, according to the director, does the "heavy technology lifting" for the library.

Types of Scholarly and Research Content

The library director foresees the scholarly and research content the library curates will remain essentially the same, except there will be an expansion of digital research data to collect

from the university's researchers. In addition to describing the services, technology, and library's role regarding research data management, the director discussed how the library successfully identifies and collects these data. The answer is a tripartite relationship among the library director, the chief information officer (CIO), and the vice president for research. This is the "three-legged stool" required to establish a university-based research data management program. The library provides metadata and access to research data; the CIO delivers the "big IT" required to store, process, and render research data available; and the vice president for research delivers research data, information policies, and funding to move forward with this overarching program. However, in this university, there are not enough resources to go around. The library director notes that the three-partner approach emphasizes searching for and storing data; it does not focus on aspects of use, interpretation, analysis, and visualization of data. With resources being fairly tight, the library decided long ago to concentrate on the basics of data management, leaving use, analysis, and visualization capabilities up to the individual research centers and researchers. According to Soehner, Steeves, and Ward (2010), this is becoming a common approach.

Organizational Development: Culture, Structure, and Skills

Regarding the library's organizational culture and structure and the skill sets required to deliver certain services, the library has concentrated on developing relationships with other university departments and offices. Library personnel have long believed that to be involved in new research programs, the most important relationships to build are with the provost, vice president for research, the CIO, and the vice president for budget and finance. Relationships with academic deans and research center directors also are viewed as critical, otherwise colleges and centers would not work with the library on research data management services. The library

administration is resolute that it must be involved vigorously in research infrastructure and services conversations within the university. Hence, the library focuses on relationship development with the major stakeholding offices in the university's administration.

As for skill sets, the library director called for "better educated science librarians. Not only do librarians need to show students how to find things, but they also need to be strong in the subject matter and in data management work." The director has been working to develop more co-appointed librarian positions, where the librarian is one-part information professional and one-part co-researcher and data manager on research teams, as described by Devare and Steinhart (2006) and Jaguszewski and Williams (2013). The director openly questioned, "Can we turn the corner and see these hybrid positions as predominant in the library?" After many years, the library leadership team has made progress, but is clearly looking for more hybrid subject-intensive positions to be created.

With respect to the library's culture and structure, the director does not see its rather classical organizational structure, or the existing, decades-long library culture, as an impediment. Instead, the director and his leadership team see these as valuable stabilizing elements. This is not to say the team does not recognize shortcomings in the existing structure and culture. However, with an IT&DI department evolving to handle an ever-growing amount of digital research data, the library leadership team is concerned more with resources, relationships, and acquiring or training personnel to focus on the dual role of library instruction and data management.

Leadership and Management

The library's approach to leadership and management will not be impacted greatly as the university's research programs transition. For instance, as mentioned previously, leadership in the IT area is oriented outside of the library. The leadership team inside the library, which consists of the library director and four associate university librarians, believes it has made good progress on establishing base level IT positions within the library. Other than the subject librarians, library units have little to do with the new research services. The leadership style emphasizes a service-oriented leadership, meaning that employees focus on serving clients while their leaders concentrate on removing barriers so employees can work and achieve their goals (Edvinsson, 1992; Grönfeldt, Grönfeldt, & Strother, 2006). When discussing the library's role in the new research paradigm, the library leadership team asserts that the library must continue to bring new, added value to the research environment. Further, they claimed that the library must always be ready for the major changes that continue to come. The library director, concerned about the library's readiness for new research-oriented challenges, stated, "We (the library profession) are not a good 'what-if thinking' profession." The library director clarified that he meant the profession struggles with planning and developing strategies based on possible scenarios. Further, he ruminated about the background of future library directors, "Those with historical training and little technology training may be sent to public libraries." Given this acknowledgement, the director can see a need for some targeted changes in the library's culture, and he will work closely with his leadership team to effect these changes.

Developing University Contexts

The university has made great strides, with its leading research centers achieving national recognition through various federal government-based certification programs and through participation in global research endeavors. Two of these centers, in medicine and energy research, have been partnering with universities in China as well as with the Chinese federal government. These concentrated efforts to gain national recognition by a select group of the university's research centers have spurred the library to build its data repository and seek co-appointments for a few select subject librarians. The driver for the library to move in this direction, as seen by the library leadership team, is one of survival. This traditionally undergraduate, education-focused university, for the past 15 years, has been "making waves" in the global research arena, and the library has had to step up and provide data-related solutions to support this successful research activity as needs evolve. The library leadership team realized that the library must be relevant in a shifting university landscape and must bring new value to the academic enterprise, wherever it goes. Given these conditions, the library began granting higher salaries to its leading IT&DI personnel as well as to selected subject librarians. As an incentive, the library administration decided to give all grant overhead dollars back directly to the librarians who generated the grants. The competitive compensation is based on performance and success in establishing the new service paradigm.

Partnerships outside the University

Given that the library has invested deeply in its data repository, it has developed partnerships outside the university to augment and grow this core service. Most notably, the library some years ago joined a regional digital preservation network. The preservation

consortium allows for replicated storage at a number of different universities as well as regular automated monitoring of the digital content, making sure that it remains accessible and unchanged in any way. The library also is a member of a software foundation that manages and maintains the software platform upon which its repository is built. The foundation coordinates community-driven software development and keeps the repository platform secure and functional as new requirements become evident within the community of institutions using it. In addition, the library is active in two communities of practice, the Digital Library Federation and the National Digital Stewardship Alliance. These professional consortia afford the library's employees who are involved with research data management the opportunity to interact with and learn from similar employees from other university libraries. These modest collaborative investments allow the library to maintain its repository technology and keep its employees up to date with the latest digital curation approaches.

Conclusion

The organizational model of focusing narrowly on developing a digital data repository with complementary rights assistance services and on research team-based metadata work has served this particular library well. While not providing as expansive a base of services as its more well-endowed counterparts, this public land grant university library developed a cadre of highly skilled technology and digital curation professionals as well as subject librarians who could partner with researchers and provide data management support to research teams. The library leadership team's focus on developing in-depth relationships to create data management infrastructures with the CIO and the vice president for research demonstrates an ability to prioritize, apply available resources, and develop working scenarios in partnership with other

stakeholding offices to succeed in the foundational role of information management within the global research paradigm. Where the library leadership team knew their organization could not take on the robust research and curation technology profile required, the team sought and won over the CIO's office to provide the platform so that the library could focus on collecting, metadata, access, and preservation. The office of research as well as college deans and the research centers work with the libraries not only to manage their significant data to meet granting entities' data management requirements but also provide worldwide access to datasets.

The library has chosen, based on its resources and partnerships, to support the university's international and multi-institutional team-based research represented by this study's favored scenario through its new core service, the research data repository. The repository is a three-pronged service: Subject librarians assist researchers with the early aspects of managing research data and its metadata in the active research phase, repository technologists design and maintain the repository while data curators manage the datasets, and the subject librarians assist researchers with any rights-related issues as well. With limited resources, the library through its partnership with the IT division and the research office are meeting a foundational need of the internationally-based research teams by providing a research data management service via the repository. The library also is remaining consistent with its leadership team's perspective on the role of the library, which is to serve as the university organization that manages scholarly and research collections. Moreover, research datasets are being added to the other collections of scholarly and research materials the library holds. Through this approach, the library is aligning itself with how research is being conducted in the favored scenario by meeting a core need of the research teams.

In the next chapter, Case B illustrates a more diverse set of services and organizational directions taken by the library of a larger AAU member public land grant university. In this case, the library develops a shared vision and collaborates on joint programs with the university's information technology division to support the broad set of services and infrastructures future researchers will need in the global research ecosystem.

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Chapter 6

Case B: Public Land Grant Research University, AAU Member

Case B, a public land grant university and member of the American Association of Universities (AAU) located in the United States, is a member of the Association of Research Libraries (ARL), Southeastern University Research Association (SURA) and the Association of Public and Land-grant Universities (APLU). The university, the largest public university in its state, was founded in 1856. The university serves about 37,000 students in 100 undergraduate and 120 graduate programs. The general university endowment is worth $1.2 billion. Its research expenditures are over $750 million per year. There are 12 colleges: agriculture and natural resources, architecture, arts and humanities, behavioral and social sciences, business, computer and mathematical sciences, education, engineering, information studies, journalism, public health, and public policy.

The university manages a robust research portfolio and develops many significant partnerships with government agencies and corporations within the United States and internationally. About 15 years ago, the university opened a 200-acre research park, which still hosts university-corporate research collaborations. Current research initiatives being conducted in these state-of-the-art facilities concentrate on bioscience, medical science, and environmental and climate research. The university also maintains strong and growing research relationships with 10 major federal agencies. The university-government research partnerships specialize in areas of climate change, cyber security, terrorism, human diseases, and space science. Global research engagements have resulted in several ongoing research partnerships with universities

and corporations in other countries. As a result of work by enterprising research directors, the university has established research programs in several European Union countries, India, Taiwan, and Singapore. The university manages one of the world's largest particle physics cyclotrons and also leads an international research effort on the transmission of human and animal forms of influenza. In addition, the university partners with a national-level cancer research institute, and together they support 3,000 researchers.

The university library system is comprised of eight libraries. They include the main library and an undergraduate library, as well as libraries for architecture, arts (visual and performing), chemistry and physical sciences, East Asian studies, engineering, and special collections. The system has an annual budget of $29 million, employs over 200 people, and maintains a $12 million library collections budget. It holds over 4 million volumes in print, film, and digital form. While there are no specialized library programs to support the university's international initiatives, library services are available to university members regardless of location. The library supports the undergraduate and graduate degrees offered by the university and provides access to print collections, databases, a wide variety of digital resources, and special collections. The major special collections pertain to radio and television broadcasting in the United States, East Asian history and culture, the history of performing arts, and national and state politics and public policy.

On September 10, 2013, the investigator interviewed the library director via telephone. The director shared the questions with the libraries' associate university librarians and gathered their reactions and feedback prior to the telephone interview.

Future Directions

The leadership team envisions the library as a provider of critical cyberinfrastructure (i.e., technology, expertise, and policies) to the university's research enterprise. This is achieved through a highly collaborative integration between itself and the university information technology (IT) division. The library has developed a shared vision with and formed teams with IT to address specific needs regarding e-Research support, such as data management, virtual research environment hosting, and digital content production. The library leadership team acknowledges that past library organizational cultures hindered technological and collaborative advancements. Therefore, the leadership team has concentrated on activities to help build a culture supporting employee inquisitiveness and exploration, as well as rapid service development and changes in organizational direction. The resulting library program, therefore, consists of services focusing on information/data management, electronic records management, active partnerships with university researchers during research projects, open content production and publishing, and cyberinfrastructure development. The library has yet to develop spaces for collaborative research projects; instead, it has well-developed, undergraduate-level learning spaces to support undergraduate research activities.

The libraries' information professionals and staff are becoming skilled at many technical processes and specialized in overseeing content production and the sharing, preserving, and utilizing of digital forms of research data, including digital scholarship, university electronic records, and other various types of digital multimedia typically used in both research and teaching/learning environments.

Services

Library staff spent approximately two years interviewing researchers in the university's research centers to understand their work better. Specifically, they wanted to know how research was being conducted as well as how it would be conducted in the near future. Once this effort was complete, the library leadership team, coordinated by the AD-IT, determined the areas where the library could partner with researchers and research units. The interviewing and assessment was spearheaded by the library's associate dean for information technology (AD-IT), who conducted most of the interviews himself. Subsequently, the library began hiring the right employees and initiating the right services. Much time and effort were expended to create procedures for these services.

As a result, the library services' portfolio for research engagement focuses on providing technology tools and developing partnered research relationships. In short, the library built a modern, networked cyberinfrastructure of hardware, software, expertise, and policies to undergird and assist in delivering research success. The library services are focused on data and information production—providing the tools, training, and consulting services that support researchers who are adopting new research approaches through computational, digital, and web-enabled means. The library regularly tests new software products, systems, and services and brings its findings to the attention of researchers. The research community is pleased as it sees the library taking on this unexpected role. Library employees realize they must think about new, creative technologies to determine their potential academic significance. As described by Marcum and George (2010), library personnel are becoming applied researchers, investigating the modern e-Research paradigm to discover how services and technologies can be developed

and deployed to support internationally based research projects. The library has become a willing partner in the experimentation and production of new research methods, and it supports these efforts with an evolving cyberinfrastructure.

During the early phases of cyberinfrastructure and services development, library managerial leaders and employees all asked the question, "As we become so technology-centric, how do we differentiate ourselves from the university's IT division?" For them, the answer was clear: the library's relationship with its information producers and users. Further, they needed to determine when the library should provide a service and when some other department should. Library personnel realized they would lose their relationships with researchers in the future if they did not learn more about new approaches to conduct and report research today. For decades, this library's employees have worked alongside university faculty, assisting them with course instruction by identifying quality information resources and helping them with rights issues, publishing, and information management through institutional repository services. In more recent years, the library has been taking its service platform to the next level, leveraging its existing faculty relationships and working with the faculty in new, data- and information-centric ways. Many libraries, and this library in particular, have for many years cultivated one-on-one relationships among faculty, librarians, and other library employees, who together as co-workers advance teaching, learning, and research through the application of technology, information, and data. The focus on relationship-building and its visible benefits signify its growing importance; this has perhaps become the library's most important ability.

While supporting and engaging in new research methods with university faculty and students via the provision of training, tools, and platforms, library employees also understand

they play an important role in teaching and learning. To fulfill this role, the director states that the library needs more individualized relationships and partnerships with faculty. She believes that the library's decades-long approach to instructional support, where librarians spend a lot of time in group sessions teaching students how to find library resources, is no longer time well spent. While this activity continues, they are seeking to free up this time so that librarians and library staff can engage in other teaching and learning-related activities. They support blended courses comprised of both face-to-face and virtual learning components, and they teach how to use online software tools in these courses to communicate, collaborate, and complete assignments. Some librarians teach not only about software tools but also research methods and techniques, multimedia design, and visual communication concepts.

The library also supports the development of open educational resources (OER) and open scholarship and publishing via the World Wide Web. It has, for many years, promoted open access approaches, including the technical and content development of OER. The library director and her associate deans see that resources made available due to open access enhance teaching and learning as well as research activities, and recognize that in the end, research cannot be separated completely from learning. By developing and providing open content development, the managerial leaders believe they are contributing to achieving the university's aspiration to provide affordable, accessible higher education in many locations around the world. Many of the world's top universities are trending in this direction, as Caswell, Henson, Jensen, and Wiley (2008) notes. The library has declared that it will engage in publishing and developing scholarly, scientific, creative, and educational open content.

Infrastructures

As with Case A, this case study describes how two major aspects of modern infrastructure, physical facilities and information technologies, will evolve to respond to the favored scenario.

Facilities

Certain spaces within the library have been transformed into modern learning and collaboration zones. These spaces provide a variety of things for many people. Most are open, airy, and designed for group work. They allow users to move furniture, change lighting, and bring in the hard technologies needed. Walls are moveable, as well. Both open areas and enclosed rooms are equipped with multiple, large digital monitors, and some host large visualization walls. Many types of computing hardware and software are present and change rapidly depending on the requests of members of the university community. While these zones appeal to students searching for locations to engage in course projects, the library director questioned how the library is going to promote these "space-related services" to faculty. Although many student-oriented learning spaces in its main and branch libraries could serve faculty as well, the library leadership team has yet to determine how to encourage the faculty to use them. The director admitted that the libraries' major facilities are accommodating changes in research and learning approaches practiced largely by students and only somewhat by faculty.

Technologies

Library employees realize how crucial information technology has become to the suite of services they provide faculty and students. Many university libraries still struggle to establish an adequate technology platform to support technology-based research and learning. This is largely

due to lack of funds and critical expertise within the library. However, the library director years ago made a two-fold decision: (1) library technology will increasingly become research technology managed by the library, and (2) the library must and will collaborate with the university IT division in a deeply embedded, integrated way. She said that entrepreneurial research needs a support system. She also observed that library technical services tend to become outsourced to a vendor vended and included with published content while the library at the same time shifts its technical resources toward research data management services.

Through the years, increased interaction between the library and IT has become necessary. Recognizing the benefits of a strong relationship, the library director and the university's chief information officer (CIO) look for opportunities to bring their two organizational cultures together. This has led to several IT/library management-team retreats. The director and CIO desire to progress the relationship and remove the "us vs. them" mentality that persists despite frequent collaboration. They work together with the intent of developing a shared vision and see each other as true partners striving to accomplish the same thing. The goal is technology-enhanced and enabled research, teaching, and learning, with an emphasis on digital curation and digital content development. Their change-management goal is to have their management teams become true partners, working on the same programs and services as opposed to sharing a project. As the partnership progresses, IT will recognize which responsibilities should be shouldered by the library. The director noted, "The library brings relationships; IT brings infrastructure. Both have expertise that we need to share; both sides do infrastructure and content."

Types of Scholarly and Research Content

Regarding new types of content, the library director quickly observed that the print collection has ceased growing. The only physical collections that continue to grow are the special collections. Print literatures from countries and publishers still unable to publish their works electronically are small in number, and the library staff quickly scans and makes these works available through an online repository. For many years, the director has been hopeful about the promise of open access publishing and repositories and their related national-level policies and legislation, as well as university-level policies and the policies of international research boards. Given the growth in open content, the library uses a different collection development model than in years past, taking responsibility for sustaining certain subject areas of open content. The library now spends more time on teaching and research partnerships. The "collections thrust" is to collect, organize, and sustain content for the future, as it is already openly available today once produced and published through open access methods. In this predominately open scholarship paradigm, the library director observed that privacy in research is all but gone: "Privacy—you can forget it," she said.

Certain genres of information collections now receive much more attention. The library has become involved in the university's electronic records management activities, operating the records management unit, which includes managing the university's electronic records. On a policy level, the library has become proficient through many years of experience scheduling the retention and destruction of both electronic records and digital research datasets. The director shared that "electronic records are essentially a dataset and can be managed as such, are legally important, and must be sustained for public accountability purposes. The same can be said for

research data. Electronic record content is becoming huge." Digitizing print- and film-based materials are still a big operation in the library, focusing increasingly on hard to find foreign materials. The library is involved in the management of the HathiTrust, now 20 years old, as well as DPN (the Digital Preservation Network), which preserves both scanned and born-digital content. Scientific data over the past 15 years has grown exponentially in importance and continues to remain significant.[1] Many of the library's core services and technologies are geared toward the production, use, and management of digital data. This serves two critically important aspects of research: (1) to make scientific predictions based on the research performed and (2) to support the reliability and reproducibility of the research findings, thus corroborating scientific predictions. Given these two cornerstones of successful research, the library has made data management a main priority.

Organizational Development: Culture, Structure, and Skills

The library's managerial leaders of this university have seen many changes, and they have a well-developed vision for the library's future. The library leadership team envisions an organizational culture that supports rapid response to new strategic initiatives and opportunities; de-emphasizes hierarchical structure; and emphasizes the building of relationships, soft skills, and progressive attitudes. Library employees need to be comfortable with moving quickly in new directions, and they need to possess a broader view of what the work is, and then adopt a new model of working. This is necessary so that the library can take a much more entrepreneurial approach, generating ideas, piloting them, and then seeing the money come in to support the initiatives past the pilot phase. In the past, the library had an idea (or was given an idea) for a

[1] More information about the HathiTrust can be found at http://hathitrust.org and about DPN – the Digital Preservation Network at http://dpn.org.

new service, sought funding to bring it about, honed it until it had been perfected, then offered the service to the university community. The library director acknowledges that the traditional process takes too long and that funding is no longer allocated in this way at the university. The entrepreneurial or "start-up" approach is needed now.

The library's organizational structure should not matter, according to the director. The structure focuses on supporting business processes like financial and human resource management. "The actual work we do doesn't need siloed library departments," she said. Unfortunately, the library still struggles with the siloed view of its work. The director and her leadership team have been working to break down both cultural and organizational barriers. They have created many work groups with employees from several departments, providing funding for them and empowering library employees to engage in problem solving with university partners, such as researchers and IT. In the end, the director knows she must remain intent on hiring a group of people without the old expectations about library units, budgets, and how neither of them can change. In fact, she stated her belief that "the incoming experience of newly hired library personnel will not mean a whole lot. Relationships are based on constructive attitudes and people skills, and these abilities will be critical now, and even more so in the future." The library employees are rethinking what a collection is, what research services are, and how they will collaborate within the library and with partners to advance the university's research portfolio. The organizational culture, structure, and skills need to be elements of infrastructure that support the new entrepreneurial library. Lastly, all library employees must contribute to establishing credibility with the university community. "We are establishing a new role for ourselves," the director said. She continued, "To us, we are doing the same things, but expressed in a new way.

That's how we see ourselves. However, our faculty sees this as all brand new territory for the library. We must establish credibility."

Leadership and Management

The library director and her associate deans see two major challenges, (1) getting employees to see the library differently, and (2) determining how to reward them once they do. These managerial leaders are developing a library culture where employees adopting new and successful approaches are given public recognition through awards and certificates. In addition, the employees need to know their ideas are heard and at least seriously considered, whenever possible. The library director and associate deans understand this. They talk about finding the doers in the library. "Doers move up," the library director says. "We need to invest in the people who step up and show us something. We must give them nourishment so they can bloom." This approach is similar to the process described by Fernández-Aráoz, Groysberg, and Nohria (2011). In this process, those employees with high potential to succeed and advance in the employing organization are identified, developed, and retained. The director explains that this as an individualized process, one that focuses on cultivating an employee's capabilities rather than on reorganizing an entire department or creating another type of work unit. She also describes the library's well-designed mentoring programs for newer and younger information professionals. These programs reinforce new work perspectives and skills by handing down the library's culture and emphasizing the vision to a new generation of librarians. Increasingly, librarians are members of the millennial generation whose values and approaches to work are different from previous generations. As noted by Meister and Willyerd (2010), the Millennials, much more so than their predecessors, tend to value lateral forms of collaboration within the organization, with

members of units outside their own, and they prefer communicating through a multitude of technological means. Succession planning is tried in a small number of libraries and, as documented by Groves (2007), is viewed as an investment in growing and sustaining the new cultures, attitudes, and skills that make work organizations like libraries successful in achieving their new initiatives, such as providing information and data services in the new global e-Research paradigm. Throughout this evolution in culture, structure, and skill-building, developing credibility within the university community must be a main goal. They know without it, they will not be seen as capable partners for the IT division, and researchers and administrators will not trust them to deliver on the library's new services.

Developing University Contexts

The university has made significant investments in developing its own research centers, which have become leaders on a national and international scale, devoted to specific areas such as health, climate, and computing. It has also established long-term research partnerships with the federal government, universities in other countries, and U.S. and foreign corporations. In particular, its collaborative research programs in India and Singapore are noteworthy and are frequently mentioned by other research directors as leading examples of global research influencing their own research programs. These program development initiatives have served as drivers as the library grows and evolves its research-related services.

The library believes it needs to engage in organizational transformation; otherwise it will be rendered irrelevant to the university's research enterprise within no more than 10 years. It has addressed how to partner with other units, provide incentives for organizational transformation, and break down barriers in order to align itself with the university's trajectory for research

program development. The library leadership team decided some years ago that library employees must work together in a flatter organization, inside the library and with external partners, because it is difficult to predict with any certainty how research will be conducted in another 15 years. The library must be ready to transition based on external change. Its leadership team sees that the most challenging barriers reside within the library itself. "The library's internal educational task is on us. We also have barriers such as our own mentality and a lack of expectations from others, especially from the users," stated the library director. The library emphasizes partnerships of many types inside and outside of the university. It also attempts to be a fluid organization, one that can move quickly in a new direction in response to changes in the university environment. The leadership team sees this ability as critical if the library is to support the information, communication, and data components of large-scale research.

Partnerships outside the University

This technologically advanced library, in close cooperation with its IT partners, collaborates in several consortially-based organizations, including some involved in digital preservation and access, collaborative virtual research environments, digital data networks, and e-Publishing cooperatives. As described above, the library is active in managing the HathiTrust, the world's leading digital repository of scanned secondary publications, and DPN, a network created to preserve all manner of digital objects. It also has participated in developing a new consortium to create an internationally collaborative virtual research environment supporting current research projects, mostly involved in the life sciences. In addition, the library is engaged in DataONE, a global data preservation and access network for environmental data (specifically, climate research for its university) as well as a regional library publishing cooperative that

produces e-Journals, e-Conference proceedings, e-Books, and websites for the member libraries and their universities. Moreover, the library has the resources to invest and participate in many large and significant cooperative organizations. The library's employees benefit greatly because many of them are actively part of the professional communities that are now advancing the role of libraries in major research universities. They contribute to and learn from many colleagues at other libraries across the country and sometimes internationally. These major consortial investments aid in fostering the library's marked advancement in areas like repositories, publishing, preservation, data curation, metadata, virtually conducted research, and the dynamics of virtual research teams.

Conclusion

This library's organizational model, characterized by library–IT collaboration, data/information management services, and open content production, is at the middle of an emerging spectrum of research university library models. While not as robust as a model with a large cadre of library-based technologists, information/data scientists, and information/data managers, this model provides for a far more rich and diverse set of research services than a data repository-centric model. This library recognizes there are many other ways of adding value to the research enterprise than focusing on collecting new scholarly products (i.e., data) alone. The emphasis placed on e-Records and the production of open scholarship and OER, in addition to assisting with curating research data, illustrates that this library has a wide vision and works toward realizing it. The transformational approach espoused by its leadership team has helped the library achieve many of its goals. In addition, this library model takes a different approach to working with university IT. It is more than the library director, CIO, and vice president for

research attempting to figure out "what to do with all this data." In the best-case scenario, this library's approach leads to data becoming a project worked on jointly between the two entities. While they are not yet embedding themselves in one another's units, they have been developing a shared vision and perceive e-Research engagement as an equally shared program. The model for this case study does not possess the resources of a large private research university library, which often works without direct partnering with university IT to develop cyberinfrastructure and technology-intensive services. Therefore, the library attempts to achieve a similar vision through a deeply developed collaborative culture.

The library supports the university's international and multi-institutional team-based research, as illustrated in the most favored scenario, through several partnerships and new e-Research services. The new services center on producing open, digital content as well as sharing and preserving of digital research data, digital scholarship, multimedia in both research and teaching/learning activities, and managing the university's electronic records. More specifically, the library provides research data and digital scholarship management services centering on a scholarship and data repository as well as technologies, consulting, and technical production support in regards to open content development and electronic records management. Library employees also are serving on research teams, assisting mostly with data management and virtual research environment communication and software tools.

The library has achieved this portfolio of services, consulting, and technology infrastructure through collaborative partnerships with the university's IT division, with which several library employees are integrated with IT division employees on teams that address these service areas. The joint cyberinfrastructure development and management efforts have served the

university well in the international, multi-institutional research team setting as described in the favored scenario. Without the integrated work with IT, the library would be limited significantly in its ability to meet the data and information needs of the international research teams. This approach represents an expansive set of services in which the library partakes in a variety of activities centered in the university's interdisciplinary and transdisciplinary research programs.

The library's evolution in this direction is reflective of its newly developed organizational culture, which values experimentation and being open to new opportunities to work with researchers. This library focuses much more on research and scholarship processes and determining how to be a partner in them, as opposed to focusing solely on the collection of end products of these processes. To this end, the library views its role as an information and data partner to researchers in the full cycle of research activity, starting with project creation and initiation to project execution and completion. Through this approach, the library aligns itself with how research is being conducted in the favored scenario by meeting a variety of information and data process- and product-related needs prevalent with research teams operating in the global research environment.

In the next chapter, Case C illustrates a more elementary approach to new services and organizational shifts by a mid-sized library of a public research university (non-land grant). In this case, the library finds the university's IT division to have a foreign culture from its own, so much so that they are rarely able to work together. Consequently, the library works closely with the university's research office to identify and make the case for the technologies, services, and infrastructures the university's researchers will need to support their initiatives in the broader, global research environment.

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Chapter 7

Case C: Public Research University, Non-Land Grant

Case C is a public non-land grant research university located in the United States. It is a member of the Southeastern University Research Alliance (SURA), the Association of Research Libraries (ARL), and a member of the Association of Public and Land-grant Universities (APLU). It provides services to over 300 undergraduate, graduate, and professional degree programs. This university is the second largest public university in its state. Founded in 1851, the university serves over 41,000 students in more than 170 graduate, 120 undergraduate, and 10 professional degree programs. The university's endowment is worth $750 million. Its research expenditures are $275 million per year and have grown about 20 percent each of the past three years. There are 17 schools and colleges: applied studies; arts and sciences; business; communication and information; criminology and criminal justice; education; engineering; a graduate school; human sciences; law; medicine; motion picture arts; music; nursing; social sciences and public policy; social work; and visual arts, theatre, and dance. The university is a comprehensive, co-educational institution serving the educational needs and interests of the citizens of its state and has developed beyond its historical roots to become the only teacher's college in the state.

The university maintains a medium-sized research portfolio when compared with other leading U.S. research universities. However, its portfolio has been growing in recent years. Two university laboratories, in high-energy physics and in advanced energy systems, have become international leaders in their fields. Over the past ten years, these labs have received about $100

million in research funding support from the National Science Foundation, the U.S. Department of Defense, and the U.S. Department of Energy. Both of these laboratories employ about 300 people. The high-energy physics laboratory collaborates as a partner in high-energy physics research with the European Organization for Nuclear Research (CERN) in Switzerland, home of the Large Hadron Collider. In addition, the university research programs lead nationally in fields such as chemistry, communication sciences, criminology, ecology and evolutionary biology, materials science and engineering, meteorology, political science, and psychology. It is also a leading university in applied research in national security and defense, focusing on energy and power systems. Its research portfolio is concentrated in the environmental sciences, specializing in air and water quality. University researchers partner with some notable U.S. national laboratories in all of these research areas. The university is seeking new partnerships with both U.S. and foreign universities as well as government-operated and major private laboratories.

The university library system is comprised of eight libraries. They include the main library and libraries for communication and information, engineering, law, medicine, music, politics and public policy, and science. The libraries' annual budget is $18 million; it employs about 165 people and maintains a $9 million library collections budget. The libraries hold about 3 million volumes in print, film, and digital formats. In support of the university's internationally based programs, the library operates branches in Panama, Switzerland, and the United Kingdom. Other than these small-scale international locations, the libraries do not offer any specialized programs that support the university's international initiatives. Library services such as interlibrary loan are available to all members of the university community irrespective of their current location, as long as there is a local library with which the university's library can work.

The library's special collections focus on Latin American records and papers and state-level politicians' papers in support of the political and public policy research of the region.

On October 4, 2013, the investigator interviewed the library director via telephone. The library director shared the questions with the libraries' associate deans and gathered their reactions and feedback prior to the telephone interview.

Future Directions

The university library has transitioned many of its subject librarians into scholarly communication experts. They advise faculty and students on copyright, author rights, use of digital and institutional repositories, and how and where to publish to maximize the impact of their works. The library's scholarly communication librarian and the repository librarian help to build the scholarly communication program and assist in training and updating the subject librarians' knowledge and skills. The library director believes that, while this progress has been good and desired, the library has reached a plateau. She and her associate deans see the library becoming more involved with digital research data by offering new services. She plans to build a new digital data repository and work in concert with the university's relatively new data center. Together, they will provide for the long-term management of digital data, building processes for transferring datasets from the data center to the library. The library can apply its scholarly communication expertise to research data management issues and advise researchers on how to share their data most effectively, and under which terms and conditions. Managing the accessibility of research data and assisting researchers to comply with granting agencies' data management policies will be the next step for the library in this developing role.

Services

With 17 colleges and schools, the library's responsibilities are many and its resources are spread thinly. There is a strong ongoing emphasis on undergraduate education. Therefore, the library has maintained a corps of subject librarians who specialize in instructional services for undergraduate students. Development of undergraduate learning spaces in two of its campus libraries has helped to change student perceptions somewhat. They now view the library not only as a maintainer of traditional collections, but also as a provider of content production technology and related services. Unfortunately, the library has experienced long-standing difficulties in attempting to partner with the information technology (IT) division, which has made it difficult for the library to establish planned technology-based services for supporting the university's growing international and e-Research initiatives. Given these challenges, the library is honing its ability to provide advice and information about managing and disseminating research data during the scholarly communication cycle, that is, during creation, dissemination, and preservation of scholarship. The library has provided an institutional repository for the past ten years to hold the scholarly reports, papers, and articles produced by the university's faculty. It is a modest, yet reasonably successful, service because many subject librarians recruit content from the faculty for placement in the institutional repository. However, developing additional data and information services based on cutting edge digital data centers and emerging virtual research platforms remains elusive for the library.

The principal thrust of the library's change-management agenda over the past decade has been to educate subject librarians on scholarly communication issues and encourage and provide incentives to them to engage with faculty on these subjects. Specifically, these issues concern

using digital repository services, retaining and managing the faculty's intellectual property rights, and using open access methods and web-based publishing to further the reach and impact of the faculty's scholarship. For many years, the library's leadership team, comprised of the library director and three associate deans, have felt that their librarians cannot adequately advise faculty because they do not possess enough knowledge of these areas to speak with authority and expertise. Several years ago, the library hired a scholarly communication librarian as well as a repository librarian to work with faculty and to train the subject librarians in these areas. The library has wanted to hire an intellectual property rights librarian but has lacked the funds and opportunity to do so. The library's leadership team has known for some time that it needs to move beyond the "one person equals a program" approach; however, it simply has not been able to do so due to funding constraints. The library also has needed to keep most of its subject librarians focused on undergraduate learning, as opposed to converting some of these positions into e-Research, e-Publishing, and digital curation services. Fortunately, only a small amount of attrition has occurred over the years so that most of the subject librarians gained many years of experience and became experts on changes in digital scholarly communication. They specialize in promoting and incorporating open access publishing methods, which are used to ensure unfettered, "paywall-free" use of knowledge. They also concentrate on analyzing the impact of the scholarship of the faculty to whom they are assigned on research initiatives conducted within their university as well as at other universities around the world.

Infrastructures

Two major aspects of modern infrastructure at the library, its physical facilities and information technologies, are changing to support collaborative research and new technological

needs. This case study examines how these two infrastructures are evolving at the model library in an attempt to respond to the favored scenario identified by the research directors and describes the challenges encountered.

Facilities

In the past ten years, the university library has made incremental progress converting library spaces for learning and research. The library leaders have managed to clear print collections from two floors of their main library and the science library and renovate them into learning spaces for undergraduates. The volumes have been moved to a library storage facility outfitted with the latest high-density compact storage. The main library houses a commons area for research called the "scholars' commons," which is restricted to faculty use. It provides both quiet reading space and laptop and desktop workstations with specialized software for text and data analysis, statistical software, and geographic information systems (GIS) processing software. There is also a group corner in the scholars' commons to support faculty conversations regarding research projects. The scholars' commons seats about 30 faculty members.

Technologies

Many of the library's changes in technology have taken place in the undergraduate learning spaces and in the scholars' commons. Technologies such as large digital monitors and touch screens, 3-D and plotter printers, and a wide array of software tools for textual and numeric analysis, model building, multimedia production, geospatial representation, and data visualization are widely available in these spaces. The library also loans an array of hardware to students in its undergraduate learning commons, including laptop computers, tablets, digital cameras, video camcorders, digital audio recorders, and more. The library, in its role of

technology provider, has made much progress, and the students rate the library highly on meeting their course assignment and research project needs.

Regarding large-scale technologies to serve as a base for new cyberinfrastructure for e-Research, the library has been hard pressed to make progress. Largely, this is because of an organizational culture clash between the library and the university IT division and their inability to collaborate, along with the library's lack of an appropriate budget for the technology and technologists required to operate in this milieu. The library director described the IT division as a highly centralized business process unit driven almost solely by the goal of achieving financial efficiency for the university through control of IT costs. "They work very differently and don't seem too interested in working with us," declared the director. The director believes the IT division does not see research technology needs as an enterprise-wide concern but instead views new technology methods in research as largely experimental and, therefore, highly expensive. However, the IT division acknowledges the need for research computing. At the urging of the vice president for research, the IT division has established a data center and a new high-performance computing cluster in recent years. Otherwise, the IT division provides much of its research computing services through technology partnerships, such as with the Internet 2 Consortium and the regional IT network organization. The IT division uses the Internet 2 Consortium's Net Plus services regularly. Despite the differences existing between IT and the library, the library director knows they must support one another to develop an effective campus-level cyberinfrastructure, with the library performing curation of digital functions and IT providing server and network infrastructure, as articulated by Lynch (2008).

Given this relative lack of progress on cyberinfrastructure, a few years ago, the library director began working directly with the university's office of research and, specifically, with the vice president for research. The office of research has successfully communicated with the IT division about the need for a data center for storage purposes and a small-scale, high-performance computing (HPC) cluster. Significant progress has been made on these initiatives, developing them from initial establishment to intermediate-level computing operations upon which the university's researchers can rely. For the library director, the next step is to work through the vice president for research to begin looking at how finalized research datasets held in the data center can be migrated to the library's digital repository for preservation, permanent access, and linkage to the research publications they support in scholarly journal articles. The library director hopes to be working closely with the data center and HPC managers and has been working with the vice president for research to establish a series of meetings between them and the university's CIO, data center manager, and HPC manager. She stated that "they know Big Data processing, but they don't know research data curation; together we can perform important e-Research services for the university." Such an arrangement would mark a significant change in how the library contributes to research initiatives, as it has not yet partnered with another university unit in this manner.

Types of Scholarly and Research Content

When asked about new forms of research content that will be curated by the library, the director resoundingly replied, "Research data, we will collect it and work with it to make it accessible." The library director envisions librarians working collaboratively alongside researchers on research projects; however, they have yet to do this in a consistent way. In her

comments about working with research data, the library director concentrated on the library's role to render datasets available to researchers. She feels this is the niche her library can fulfill through broad promotional and outreach efforts as well as by promoting specific datasets held in the library's digital repository. Open access approaches to make data accessible appeal to the director, as well. She supports open data policies at the institutional and granting agency levels as well as federal legislation that enhance the shareability of research data, stating, "This needs to be about public access and solving societal problems, not about the database owners and their business needs."

Regarding published scholarship, the director shared that it will continue to be published primarily in digital form. Yet, she sees one important change on the horizon. The director identified the need for national-level licenses to e-journals, databases, and other published scholarship. She described how other countries such as Canada (Groen, 2000) and the United Kingdom operate this way and save their universities a lot of money through national licensing. She is not sure why this has not occurred in the United States, but she actively agitates for it among her colleagues. Specifically, she has spoken with the Association of Research Libraries and library services groups like Lyrasis,[1] organizations that have piloted national-level, e-Book licensing in the past. She urges them to revise their past efforts and reconstitute their licensing work. The director predicted that the various regional groups that bring many libraries together, such as the Orbis Cascade group in the Pacific Northwest, the Greater Western Library Alliance (GWLA), and the Association of Southeastern Research Libraries (ASERL),[2] could become

[1] More information about Lyrasis, a library services cooperative, is available at http://www.lyrasis.org.
[2] More information can be found on the Orbis Cascade Alliance at http://www.orbiscascade.org/, GWLA at http://www.gwla.org/, and ASERL at http://www.aserl.org.

significant players in national-level licensing initiatives for uniform, nationwide access to digital scholarship. Further, the director articulated that if a library-related entity could take over this licensing function, then individual libraries and their employees could focus on the promotion and use of the scholarship in current and future research projects, as opposed to the contractual negotiations that take place at every library.

Organizational Development: Culture, Structure, and Skills

The director and her associate deans have worked to develop an organizational culture that is flexible, based upon the opportunities available to the library. Subject librarians, who must constantly learn about and support changes in the scholarly communications cycle, must be allowed to try new activities, fail, and learn from them. The library leadership team has supported this approach to professional growth. Working with their employees, the leaders and managers have made good progress in getting away from an organizational culture where they "talk a lot, but don't do anything until they know they are guaranteed to be successful," as described by the library director. She notes the only way to move away from this culture has been to support employees when they try something new. The library leaders and managers then encourage employees to apply lessons learned from failed efforts to the next new activity. They are careful to guide this employee-initiated experimentation and learning so that employees do not become too frustrated or discouraged by experiencing too much failure at one time.[3] The library director does not see a pressing need to revise the organizational structure of the library, but rather to support librarians and staff experimenting with new activities. If possible, she would also like to acquire new resources for a few key e-Research, service-related positions in areas

[3] Heifetz and Laurie (1997) refer to in their work on adaptive leadership where leaders and managers are regulating the amount of distress employees are exposed to as the organization attempts to transform itself.

such as e-Publishing and rights consulting and a few technologists with experience in data repository work.

The library director said her leadership team has been asserting that they must change "the cultural way we see our work. We work in an uncertain, shifting environment, and we will miss some important opportunities if we don't change this." As previously identified, her team has aspirations of moving beyond the library's scholarly communications program into new areas, such as partnering with data centers to curate research data. Luce (2008) examined this type of partnering and other related roles in the e-Research environment; many of these new roles are being considered by the library director and her leadership team. They desire this activity to be ongoing rather than occasional, becoming a core library program. They talk about the disconnect between their plans and the library's current capabilities. The library leadership team knows it must align positions with necessary skills to move into new research services. The members see a limit to collections-based activities and a shift to a more outward focus. According to the director, they are asking, "What are people doing out there on campus?" They discuss how the library's services will continue to be more about the scholarship process, not just about managing the final products. To do so, they acknowledge the library needs an infusion of new people with new skills. The leadership team also recognizes the need for people outside of librarianship to "help us decide what we're going to be doing." Team members articulate a need for added perspectives from outsiders, such as management experts, researchers, research policy administrators, resource allocators, and technology leaders. "This will aid us in understanding both the hard and soft skills we need to bring into the library," said the director.

Leadership and Management

While the leadership team has successfully transformed certain aspects of library culture and developed a skill base to promote and provide advice on open, web-enabled, scholarly communication, organizational challenges remain. Some employees have yet to adopt the new library culture. For instance, the associate deans and managers face ongoing difficulties with the library's human resource (HR) officer. When attempting to change an existing, vacant position to fit the needs of the changing library, the associate deans regularly hear the HR officer say: "That position is in the collective bargaining unit," or "This position is 'that way' for a reason." She is often vague about the reason after such a comment. The associate deans described the HR officer as being very strict about policies. The director notes, "It's very important to get buy-in on the new organizational culture and services from people in important positions such as an HR officer. Otherwise, they actively resist and prevent important changes from happening." The director knows that transmitting the new organizational culture from leaders to followers, as described by Schein (2010), is critical if the library is to complete its transformation. Her leadership team speaks together about this dilemma frequently with the hope of adopting a common understanding about the library's internal challenges and then devising approaches to resolve them. They know there is a danger that employees reporting directly underneath the senior leadership will "keep things the same" if they don't comprehend the library's new directions and services and the work behaviors and values needed to support them. The leadership team discusses how to get employees throughout the library to embrace their vision. The director said, however, her associate deans see that the decisions they make and their own

work behaviors, when in clear view of the library employees, are beginning to change their organization's culture.

Developing University Contexts

The university is about to embark on a new seven-year capital campaign with a fundraising goal of $1.5 billion. The institution is striving to update buildings and erect key facilities to support the university's growth in scientific and engineering research. The university has a goal of becoming a top 25 public university in research and expects the capital campaign to help with the physical facilities and high-technology equipment required to reach this status. The library is involved in the campaign and is looking for capital support to construct a new library building designed specifically for the interplay of technology, information, and student learning. They also are looking to build the library's endowments, which will help to fund a few positions for the new, next-generation data repository service they aspire to create to support the university's growing research activities. Another developing trend is internationally offered distance education. With three major satellite locations in other countries, the university has established a successful online learning program, and university leaders plan to expand on this platform. In response, the library is seeking resources and funding for new technologies and for two new specialized librarian positions. These librarians will be responsible for designing and supporting course-based student research projects at a distance. The library's future growth plans focus on technology-intensive infrastructure and service positions that will help provide the university with cyberinfrastructure-enabled teaching, learning, and research.

Partnerships outside the University

The library has a modest history of consortial involvement with other libraries, and it sees more similar relationships on its horizon. For many years, the library has had associations with regional library consortia involved in purchasing and licensing library materials and promoting resource sharing between members. This, of course, is a typical consortial experience for most libraries. However, this library has developed relationships beyond these conventional associations. About ten years ago, the library joined a regional digital preservation network to preserve the library's institutional repository content. The experience with this network has helped the library learn how to collaborate with other library partners in newer cyberinfrastructure-based programs and services. Several years ago, the library also joined a coalition of libraries involved in library publishing services, mostly as a way for their librarians to be engaged in a community of libraries that are providing such services; this university library has not developed these services yet. These early and modest consortial relationships have offered the learning opportunities required for this library to take its next steps toward establishing the infrastructure and services necessary in the new e-Research paradigm.

With the library's interest in curating and repositing the university's research data of long-term value and with the recent establishment and advancement of the university's data center, the library has been investigating how other libraries and universities work together consortially to manage data. It has examined how some of these consortial data centers and services work, such as the National Snow and Ice Data Center (NSIDC) and the Sustainable Environment Actionable Data (SEAD) consortium.[4] With the university's concentration on

[4] More information on the NSIDC can be found at http://nsidc.org/ and on SEAD at http://sead-data.net/.

environmental science research, the library has expressed interest in collaborating with and using the services of data consortiums. The library is also interested in taking this interest one step further. Through the planned discussions among the library director, vice president for research, and the CIO, the director plans to discuss the need for a new hybrid organization at the university, one that focuses on an integrated approach to data curation, data storage, and high-end data processing and visualization. While this may seem like a large leap for the library, the absence of any university unit taking on this responsibility presents a good opportunity for the library, the office of research, and the IT division to form a partnership. However, the director understands that this potential collaboration must be nurtured among the units, as observed by researchers like Vangen and Huxham (2003), who further assert that trust must be built and cultivated through inter-organizational interactions and collaborations. The director is convinced that the university's data-centric research programs would benefit greatly from this new organization, and she believes it is possible to garner the necessary funding if these three major units can develop a specific plan. Consequently, the university and the library could then leverage outside partnerships, like consortial data service centers, to great advantage. In fact, the library leadership team feels such a development is required to utilize these partnerships meaningfully.

Conclusion

This library's organizational model is defined by building internal capacity to advise university researchers regarding the scholarly communications cycle and by supporting changes within this cycle. While it is taking many years to gain the resources to progress beyond this plateau, the library hopes to move into research data management services, with a specialization

in making datasets accessible to researchers around the world. The model practiced here may not be as robust as some other library e-Research service models; however, the director notes that their approach has made the best use of existing people and resources while arguing the case for partnering with other university units, like the office of research and the IT division, to manage new digital information resources such as digital research data. In the meantime, the library's leadership team has worked to develop an organizational culture that values learning about areas related to conventional library work, such as open access models, web-based publishing, repository services, and copyright in the context of creating scholarship and other forms of research information.

With the university's recent growth in areas such as high-energy physics, power and energy systems, and certain environmental sciences, the library's leadership team feels it is ready to contribute to these highly visible developments in the research portfolio by assisting with aspects of managing and rendering accessible the resulting research data. The library, however, must find a way to acquire the resources to hire people in new positions, such as systems engineers, software programmers, a data repository manager, and a data curation specialist, if the library expects to engage actively in these e-Research initiatives. The director feels encouraged that the upcoming conversations among herself, the vice president for research, and the CIO will result in a concrete plan for overarching research data management services, complete with budget projections required to support the new research work. The library does not possess the resources of some of its larger library counterparts. Therefore, it has developed the organization as far as it can and is now readying itself to achieve a broader e-Research services vision through

a new partnership among key university units while leveraging outside consortial data services for further infrastructure support and service capacity.

With its limited capabilities and capacities, the library supports the university's international and multi-institutional team-based research, as illustrated in this study's favored scenario, through its scholarly communications program. It emphasizes consulting services where librarians inform and educate faculty members on how best to publishing in the digital, web-enabled environment, how to use repository services of varying kinds, and how to retain their rights in the works they produce. Undergirding this effort is the library's digital institutional repository, for which the librarians collect scholarship from faculty and promote the service. Unable to develop enough of their own technology expertise and resources, coupled with the inability to partner with the university IT division, the repository and the scholarly communication program are all the library is able to offer to the university's growing number of internationally-composed research teams. Given the library's aspirations and recent conversations with the research office to do more, it is hoping to expand its e-Research services to include a new data repository to enhance access to the university's unique research datasets. The scholarly communication program is the library's main offering to research teams and it confirms the library's view of its future direction, which is that of a consultant and educator on how research products can be created and disseminated in an increasingly open, networked, and global research ecosystem. Through this approach, the library is aligning itself with how research is being conducted in the favored scenario the best it can, which is by meeting some of the informational and training needs of the research teams.

In the next chapter, Case D illustrates a far-ranging and robust approach to e-Research infrastructure and services achieved by a private AAU-member university library. In this case, the library has a large cadre of technologists and information specialists. Together they have created an advanced cyberinfrastructure that supports virtual communication in online, international research environments; multiple repositories for data and research publications; e-Publishing services, tools, and application platforms; and a variety of digital content creation services, training, and other forms of support. These new, specialized information professionals have expertise in information science, information management, research design and processes, software programming, and virtual team management. They not only manage content created in expansive, internationally-composed research teams, but given their expertise, they also engage in designing research projects alongside the investigators and senior personnel involved in the research projects. Moreover, they are research project co-leaders. The library also has disseminated its research engagement activities across all of the major library departments and libraries so that the majority of library employees have a role in e-Research services, as opposed to keeping this type of work bound to one specialized unit. This library model is the best developed and most advanced of the four case models examined in the current study.

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Chapter 8

Case D: Private Research University

Case D is a private research university located in the United States. It is a member of the Southeastern University Research Association (SURA), the Association of Research Libraries (ARL), and the American Association of Universities (AAU). The private university was founded in the mid-1800s and benefitted from a large endowment established by the founding trustees of the university, who were leading capitalists in the American economy in the late 1800s and early 1900s. The general university endowment is worth $9 billion. Its research expenditures are over $1.5 billion per year, the fifth largest for a university in the United States. The university has a graduate school and colleges of architecture, business, computing, engineering, environmental sciences and studies, medicine, law, liberal arts and sciences, and public policy. Many of its undergraduate and graduate degree programs are ranked within the top 10 in the United States, with some selected programs within the top five (e.g., medicine is ranked third in the nation). Specializing in cancer research as well as on heart-related diseases, the university is a worldwide leader in biomedical research and environmental research focusing on climate-, air-, and water-based concerns. The university has an expansive research agenda, with a growing global health and related clinical practices portfolio on every major continent.

The library system is comprised of a main library facility with nine branch and school libraries, and it maintains diverse collections and services: undergraduate library and learning commons, visual and performing arts and film, music, special collections, law, business,

medical, environmental sciences, and a marine science research center. The library has a $40 million annual budget with 300 employees and a $20 million library collections budget. The system holds over 6 million volumes in print, film, and digital form. It has a rich repository of special collections, documenting a variety of major themes in U.S. history, English literature, medical history, and natural history and science from the 18th, 19th, and 20th centuries. The library coordinates with the university's research centers, some of which are co-located in Argentina, Brazil, China, Costa Rica, Egypt, France, Germany, India, Ireland, Singapore, and South Africa. There are also international campuses delivering educational programs in Brazil, China, and India. New campuses are being planned for Singapore and the United Arab Emirates. The library involves employees from its many branch and school libraries and departments, ranging from public services and general and special collections to technical services, information technology, and digital initiatives, in the new global e-Research environment.

On August 20, 2013, the investigator interviewed the library director via telephone. The director shared the questions with the library's associate university librarians and gathered their reactions and feedback prior to the investigator's telephone interview.

Future Directions

The library has worked diligently to become a deeply integrated partner in all aspects of research, including the creation, dissemination, use, and preservation of data, information, and knowledge. This involves working with research information of all kinds, such as secondary information generated during research projects like e-mail, team discussion forums, live chat, and meeting minutes and notes, as well as data annotations and research notebooks. In addition, the library creates a comprehensive technical environment for research teams, curating digital

research objects of many kinds, offering virtual research environments for collaboration and communication, training researchers how to effectively use software tools available in the technical environment, and providing rights administration and consulting services. Further, the library's new information professionals, who are knowledgeable about information science methods, research processes, and technology configuration, partner with researchers in managing aspects of research projects.

Services

The director believes the service profile of the library will need to continue to focus on how to serve research teams. The library is responding to a scenario where multinational, inter-institutionally comprised teams are conducting Grand Challenge research that is well funded by government and industry. The university's research administration supports the grant proposal writing process and assists with identifying the top researchers to serve on these leading research teams. The library becomes involved in the team-building process either through the research centers and researchers as they push the project forward via the proposal process or through the university's office of research, which ensures that repositories are identified, data management plans are finalized, and other virtual research services are retained (e.g., virtual community space to share research notes, annotate preliminary research findings, upload datasets and analytical information, and support communication channels such as e-mail, discussion lists, synchronous audio/video calls, and asynchronous video sharing).

Library personnel involved in research teams have specific roles, such as executing data management plans, providing metadata, bringing knowledge of discipline-based ontologies, and offering expertise and training regarding virtual services and digital tools. In addition, the library

personnel on the team identify problems or challenges during the research process that are information-/data-centric or technological in nature and work to provide solutions. They view these challenges as opportunities to leverage their expertise and their unique access to resources resident in the library and in other university units to problem solve for the team. The special access these librarians have allows them to aid the team in a myriad of ways, from arranging for allocations of compute cycles from the high-performance computing center to gaining rights management assistance from the rights expert in the library.

As Pfeffer (2010) described, some libraries have developed a base of power within their respective universities by demonstrating their expertise and cultivating successful relationships with other university units, like high-performance computing centers. A library can then use this power to advantage to develop services and expertise further and to become acknowledged throughout the parent university as the lead problem-solving unit for international research initiatives conducted virtually. This library has developed such power-based relationships, as described above, among its university researchers as well as with their research partners at other universities.

Fulfilling a more traditional role, this library still manages scholarly and research products generated by the research teams. However, it also finds information and externally produced datasets and locate researchers who are not necessarily affiliated with the university but who possess expertise needed by the teams. When appropriate, they also contribute by releasing project information to interested parties in the broader research community.

The library director sees that these new roles are much more active than older, more traditional librarian roles. In this more sophisticated role, librarians ask how they can help

research teams with information and data management, services, tools, and technologies. The library director said, "While we are beginning to experiment with these kinds of services and relationships today, in 15 years, we expect this approach to be the core research service offered by the library; it will be quite ubiquitous and common." The director further mused that "this will be the role of our library, but I suppose it depends upon a library's specific university context and is dependent on the university's leadership and where they see the library fitting in to this emerging research paradigm." While dependent on its university leadership, the library leadership team has put much effort into gaining the attention and respect of university leaders and altering their perspectives and expectations regarding library work.[1] This has allowed the library to change, grow, and become involved in new areas.

Infrastructures

Two major aspects of modern infrastructure for many organizations, including those at university libraries, are the physical facilities and information technologies. This case study examines and describes how these two infrastructures at the model library will evolve to respond to the favored scenario.

Facilities

The library director envisions a "deeper engagement in research support" as a result of the direction in which university research programs are moving. This deeper engagement, according to the director, involves the physical library spaces as well as the digital repositories and related digital production services. She articulated the need for research commons throughout the university and said that the main library and the other school and branch libraries

[1] The group composed of the library director and her five associate university librarians defines the library's leadership.

should participate in developing and managing these. After acknowledging this, the conversation turned toward reference services. The director shared that "reference questions are not the same anymore." They are not strictly about finding an article or book to complete a course paper. In fact, their librarians rarely receive this type of request anymore. Instead, students and faculty want to know if digital tools are available and how to use them. These tools are needed to analyze and visualize information resources and datasets and to create multimedia, web sites, databases, engineering plans and drawings, presentations, and other similar output. Geospatial tools and services are also frequently requested as geospatial capabilities are becoming necessary in various disciplines, including engineering, medicine, business, humanities, and many others. These tools and services need to be available in the research commons, and some of them need to be more generally available in the various libraries. The director summed up: "We need our spaces to reflect the kinds of work our students and faculty are doing and, in particular, the students because they are the people who use the library facilities the most." She went on to reaffirm that "libraries must support research teams—both higher skilled faculty research teams as well as graduate and undergraduate student research teams who are learning about the act of research."

Technologies

When the conversation turned to information technologies and how they will evolve, the library director quickly responded, "We need robust repository services. We need people with the savviness to work with scholars. We also need cyberinfrastructure savviness. Then, we need to go out there and figure out where the library can play an important role." She sees two types of technologists in university research libraries: (1) those who build new IT infrastructures or

platforms on which researchers conduct work and (2) those who work on teams with researchers and contribute by manipulating technologies for the good of the project. The library will be the host for a variety of repositories, including separate project- and program-specific ones. These infrastructures will contain the output of multi-institutional and international research teams. This library is becoming a leader in developing new software and services to support researchers located in teams around the world who need technology platforms and tools to communicate and process data virtually. The library has also been involved in new, vast data curation networks in medical and environmental research, advancing the technologies and services used in those areas. It has taken the past 15 years to erect these cyberinfrastructures, and many necessary adjustments have been made to institutional and administrative frameworks, as articulated by David (2004). The library always has multiple technology initiatives ongoing at once and does well to advance them with support from a committed base of partnering libraries at other leading institutions.

Types of Scholarly and Research Content

Primarily, the new type of content being managed by the library is scholarly and research output produced by research teams. Given the international make-up of these teams, the library will continue to manage content from some team initiatives, but not all. In many instances, where their university researchers are on teams with researchers from other universities, repository and virtual research services will often be provided by a partnering institution. The director recalls that this feels like the cooperative library collection development arrangements of past years, but instead focuses on the cooperative deployment of virtual research services, including designating repository locations and associated services per research team, project, or program. Managing

scholarly and research content in a cooperative approach like this requires memorandums of understanding (MOUs) between the institutions represented by the research teams. This is because most institutions want access to research output during live projects, to archived sets of output after the project's close, and to the data in cases where the lead institution providing the virtual services discontinues management and maintenance of the content for any unspecified reason (i.e., institutions may ask for succession rights to archive the content, if needed). The templates for these MOUs have been reviewed and signed off on by the university's legal counsel, who also reviews MOUs on a case-by-case basis when any special stipulations have been added.

Organizational Development: Culture, Structure, and Skills

The private university library is cultivating a diversity of skills and a certain mindset among its employees, imbuing them with the confidence needed to work alongside researchers. To support university research initiatives, the library will continue to need employees highly skilled in methods associated with information science and best practices regarding information management and communication. These information professionals will also need to be well versed in the subject matter in which their partnering researchers work, typically holding a master's degree in a related field, and some will possess PhD degrees. These information professionals will be skilled research managers who "hold their own" when working with research center-based, faculty researchers. Another critical skill area will be software programming knowledge, enough to configure and manipulate tools and platforms as needed for the research project or program. Moreover, these professionals will be active research content managers and research team virtual environment specialists—possessing the ability to support

team communications within this environment and modify software tools at the code level when necessary.

Some library employees will be technologists outright. They will be in-depth specialists in areas such as systems architecture and engineering, software design and architecture, software development and programming (coders), software application management, web interface design, information architecture and usability, and web programming. Many of these services will take place in the Cloud; therefore, they will need to possess abundant experience with these activities in a cloud-based setting. The relationship being cultivated at this university, between the new library information professional, or informaticist, and the team of interdisciplinary researchers, is reminiscent of the earlier call for medical informaticists to build alliances with chief information officers to advance the science of medical care (Spackman, Elert, & Beck, 1993).

Beyond skills, information professionals will have a different mindset from those in many libraries today. They will no longer be traditional passive librarians, waiting for the public to come to them. The new information professionals will be self-assured, knowing their skills and abilities equip them to interact with researchers. Therefore, they will act as independent agents on the library's behalf, actively seeking opportunities to contribute to research initiatives. At this library, they have already proven they can be partners. They are highly educated and assertive. The role of the library is expanding beyond what many at the university expect or believe possible, although knowledge of the library's capabilities is improving. The new information professionals understand this and are confident of the library's support.

The library's organizational structure is described as *lateral* as opposed to *hierarchical*, avoiding the classic departmental organizational chart model of traditional libraries. As a result, team-based work is more prevalent and, perhaps, more productive as individuals work more directly with other employees and units. Just as information professionals serve on research teams, information and technology professionals work on teams within the library to create complex and comprehensive stacks of IT infrastructure with cloud-based virtual services and operating systems, middleware, software-based platforms and tools, content reuse and exchange protocols, layers of metadata, and tools for moving, analyzing, visualizing, and annotating research content. These "systems teams" are already interacting with the information professionals in addition to other members of research teams, and they understand the need to continue developing the capabilities of the virtual research systems offered by the library.

As library services evolved beyond traditional collections management and reference-based support, the library leadership team had to make a decision regarding organizational structure. Would their new information professionals be specialists residing in a specific unit of the library, thus creating a stand-alone unit focused only on research endeavors, or would they and the university be best served by a model where this work is shared across units? With its ample budgetary resources, the leadership team chose the latter, resulting in research engagement throughout its library units. The director expressed that she hated to see research collaboration become the province of a special library unit only. She and her leadership team made the conscious decision to identify meaningful roles in this model for as many library units as possible. She visualized the library organizational chart as fluid rather than hierarchical, where people move across the organization with ease to perform work and collaborate with fellow

library employees. Having achieved their objective in 15 years, this library provides a model of robust cyberinfrastructure, one replete with dedicated technologists and a new type of information professional who specializes in information management, communication, research management, and relationship-building. The library has many of these professionals ready to join international research teams, utilize the library's technical environment, and work closely with library technologists.

Leadership and Management

The library's approach to leadership and management focuses on developing employee independence by delegating power, duties, and decision making to the new information professionals, the IT managers, and the library technologists. The breadth and scope of the new responsibilities are vast, as are the opportunities to engage in teams and contribute to advancing research. Given this environment, the library's leadership team, knows they must empower the people who work directly with the researchers. Broad strategic plans are built jointly between the library leadership team and its employees. Implementation plans are developed by library middle management and their employees and are reviewed and monitored by the leadership team along with middle management. In a supporting style, the library leaders and managers provide visible support for the library's directions and employee activities through positive reinforcement given verbally in library-wide gatherings, through one-on-one conversations, and in departmental, committee, and work group meetings. Moreover, the library managers allocate time for conversations with employees and monitoring of work to reinforce organizational strategies and directions and oversee plan implementations.[2] This supportive style is also characterized by a

[2] Blanchard (1985) describes this approach to management as a supporting style of management.

low level of direction from managers. Conversations with employees provide feedback on current work and confidence in subsequent actions. Because the employees understand the library's strategic directions and implementation plans, this verbal support is enough direction from management to confirm the appropriateness of employee activities.

One challenge the library faced during its early organizational transition was a tendency by some to embrace tradition. Several employees would regularly say, "We have never done that before." They had reputations as naysayers among the library's leaders. When discussing which services the library would discontinue, the leaders and managers knew they needed input on the activities being targeted from those actually doing the work, those who were closest to the library's users. The managers also knew they could not criticize everything that came before, that is, the library's functions and services and how they were performed. They knew they must somehow link the library's past way of doing things to the newly emerging services, infrastructures, and processes. These simple approaches helped them lead the library through a significant paradigm shift to achieve their organizational goals and objectives.

In this university library, the transition from traditional services to research engagement and support is, for all intents and purposes, complete. The transformation led by the library director has been sought actively during the past 15 years, and the library leadership team has also evolved, whereby they are communicating a clear vision, socializing the needed work approaches and values, and building trust while emphasizing their leadership strengths among themselves and the employees.[3] The library's leaders also focus on positive, clear, and credible communications between library leaders, middle management, and employees to adjust, as

[3] The library director's story of leading the library through its transformation is similar to the transformational leadership approach described by Bennis and Nanus (1985).

needed, to environmental conditions in the university and international research teams.[4] Everyone in the library is much more focused on events and environments outside the library, that is, in the university, in the research teams, and in the broader global research ecosystem. The conversations between the library leadership team and employees center on these external environments as opposed to the library's internal one. At the same time, the library organization has been transformed. This has occurred largely as a result of the arrival of many new employees over the past 10 years, the cultivation of new skills and perspectives, and the affirmation provided by the university's administration, which allocated the necessary resources to change the library into an organization capable of supporting the university's e-Research needs. This model library concentrates on being an embedded research partner, collaborator, problem solver, and activator in the global research milieu.

Developing University Contexts

The library's globally integrated parent university is engaged actively with international research teams and organizations, think tanks, private research centers, international and national-level repository organizations and virtual research environments, data centers, and government laboratories. The librarians/information professionals are integrated into this multi-institutional, interdisciplinary environment and have moved beyond conducting literature searches to shaping plans for data and information curation and international plans for communication and partnership. The library's international and area studies librarians and staff contribute regularly to these plans. With the university moving rapidly into the burgeoning global research ecosystem, the library—from its leadership to its employees—understands that

[4] The library leaders' communication style is consistent with authentic leadership theory as described by Avolio and Gardner (2005).

the driver for organizational transition is survival. As the library director says, “If we didn’t change, we would be left in the dust and relegated to a tertiary role.” However, this library made the transition successfully, offering timely and critical value-added services, resources, and expertise to its university’s international research programs and resulting in the professional satisfaction of the library leaders, managers, and employees.

Partnerships outside the University

The library has been involved in an impressive number of consortia and cooperatives to create technology infrastructure necessary for highly collaborative international research. Many institutions are beginning to comprehend the complex infrastructure requirements for research on this global scale. Some of the consortia the library has joined, including a few they have helped to found, develop software platforms for data curation and repository services. Other consortia in which it participates are embedded in certain interdisciplinary areas, such as neuroscience, and these develop and manage large-scale, international virtual research environments supporting research collaboration and communication, as well as data and scholarship repositories to collect and manage the research data and information produced. The library also interacts with national-level data centers that specialize in certain interdisciplinary areas such as biomedical technology and environmental sciences research. Well-established cooperatives among university libraries and IT divisions support the dissemination of findings through online, open-access journals, databases, and repositories. Other cooperatives provide for long-term preservation of digital research objects through distributed networks, with nodes nationally and internationally maintained. Through this well-developed network of consortia and cooperatives, this leading research library provides its university with a vast array of services and infrastructures to foster

global, digitally-centric research, including a number of digital repositories, digital preservation networks, data curation consortia, e-Publishing cooperatives, virtual research environments and communities, and access to entities that develop and steward original software platforms and tools to foster all of these activities. The library's efforts help the university maintain its worldwide leadership in a number of research areas.

Conclusion

This library's organizational model (i.e., to maintain a large group of technology specialists and information professionals skilled in information science and management, research processes, research management, light-duty software programming, and virtual research environments) makes for a robust research-partnering library. Further, the library involves many library units in research engagement, including its reference/research support, cataloging/metadata, and IT areas. It also provides place-based services (i.e., learning and research commons areas located in the main library and major school and branch libraries). Its funding, early initiative, and leadership allow it to perform much technology-specific e-Research and broader cyberinfrastructure work on behalf of researchers. As a result, the library has attracted enough support that it has not had to concern itself with forging a strong relationship with the university's IT division, except in areas such as information security and network management and processing cycles for live, computationally-based research, where researchers require mass amounts of high-performance computing cycles. The major library–IT relationship lies within the library as the library's own technologists follow IT-produced policies on network security and management and transfer digital content between research computing and the library. The office of research, research centers, and the leading PIs regularly have the new

information professionals and library leaders in their midst, working on current project support and advancing new components of cyberinfrastructure. This is a library that has successfully embedded itself in the research initiatives at its own university as well as those of many other institutions.

The library is supporting the university's international and multi-institutional team-based research, as illustrated in this study's favored scenario, through several extra-university partnerships engaged in technology development and management and a robust set of e-Research services. The library employs many highly skilled technology developers, who have erected an advanced technology infrastructure, and a team of data and information specialists, who have cutting-edge information and technology management skills and serve on many research teams. The large capacity of human resource expertise allows the library to grow and be recognized as a leader at the university in supporting the new global research environment and its emerging data and information challenges.

The software technologies used in the library's rich cyberinfrastructure environment have been developed by the library with several other leading universities and their data centers, research centers, libraries, and IT divisions to meet the needs of researchers who are working together at a global scale. The technologies could not have been developed without this rich, well endowed set of partnering institutions coming together. The capabilities produced have served the university very well and makes it an outstanding and leading institution in the global research community. The library's approach aids the university in achieving its goal of being a dominant, global leader in internationally coordinated research as described in the favored scenario.

The library's evolution illustrates the successful development of the (1) desired organizational culture and (2) extensive resources to build advanced technologies and hire the leading personnel required. It is a culture where technologists and information/data managers see themselves as being on par with the researchers as team members, making important contributions to research initiatives that enable the teams to achieve their goals. The library is aligning itself with how research is being conducted in the favored scenario. Its approaches are very innovative and advanced and are desired highly by its world-leading parent university and its leading research partners around the world.

In the next chapter, the investigator compares the four library case studies. He examines general similarities and differences between the libraries overall, as well as within the main areas considered in the cases: vision and role of the library, services, facilities, technologies, types of scholarly and research content, organizational development, leadership and management, developing university contexts, and partnerships outside the university. The comparisons will yield further understanding of the issues being faced by libraries in research universities in the United States and will illuminate the trends that are developing as they grow and evolve to meet the needs of researchers and research administrators in the global e-Research ecosystem, as expressed in the most favored scenario.

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Chapter 9

Comparison of the Library Case Studies

Comparing the four library case studies provides a better understanding of the services, infrastructures, and human and financial resources that are allowing libraries to engage in the emerging international research environment. In each case, the library's leadership team has made it a goal to foster some level of organizational transition following a particular strategic direction adopted by the organization. The extent of change this approach effects varies from case to case, yet all of the libraries are evolving. For instance, each library, due to user expectations and preferences is developing technology infrastructures and services, or at least planning to do so. Therefore, some of these libraries are already procuring new technologies, hiring tech-savvy personnel, and establishing partnerships that will enable them to support e-Research, while the others are seeking partnerships and funding that will allow them to remain relevant participants in their universities' research initiatives. These libraries differ primarily in their technology infrastructures and financial resources, which is consistent with what Lynch (2008) anticipated and wrote about five years ago. In the end, a library's ability to reach its goals regarding research program support relates directly to the robustness of its technology, the abundance of its financial resources, and the successfulness of its leaders fostering collaborative partnerships and organizational cultures that facilitate necessary organizational change.

Similarities and Differences

The major similarities and differences among the four library cases become apparent when the case study sections are compared. To provide a framework for this comparison, the

same eight areas used to describe and examine each library (Cases A–D) in Chapters 5–8 are explored. These are: future directions, services, infrastructures (facilities and technologies), types of scholarly and research content, organizational development (culture, structure, and skills), leadership and management, developing university contexts, and partnerships outside the university. The similarities and differences in these principal areas are discussed.

Future Directions

Three of the four libraries in the case studies are managing new products generated from research, providing technologies that support research processes, and two of them are managing online virtual environments. Digital research data are the leading new research product that all of them must curate. Historically, libraries have collected primary resources, like records, papers, and research data, predominately in analog form. These activities are the rich tradition of archives and special collections units in university libraries. Today, these same libraries are infrastructures, services, and areas of expertise to manage, use, preserve, and share digital research data. This activity is at the core of the new, global research ecosystem. Many libraries are also collecting a new form of scholarship, that is, "digital-born." This includes data and communications[1] generated during the digital research process as opposed to only the data and results published upon project completion. Examples of these are websites, virtual communities, and social media platforms. Increasingly, libraries are collecting and, in some cases, even producing scholarly and instructional open content.

While many of these activities may seem like simply new approaches to a traditional collecting role, libraries are also providing technologies and services that support the modern

[1] "Communications" in this context means online communications among researchers working through a virtual research environment. Among the communications to curate include posts to internal blogs and wikis, forum posts, e-mail, chat and instant messaging, and annotations on research findings and data.

research process itself. The libraries in these case studies provide workflow support and technologies for producing e-Journals, e-Books, e-Conference proceedings, databases, websites, virtual research environments, and multimedia. Through these services, the libraries are integrating themselves into the research process as the new scholarly products are being produced. Some of the libraries are designing and supporting virtual research environments as well as creating technology solutions for data analysis and visualization. These libraries are transcending their traditional roles of collection and production support. They are evolving and becoming cyberinfrastructure creators, managers, and consultants. As libraries embrace these roles, a new type of library is emerging. They are becoming knowledge production and communications partners.

Each of the four libraries has moderately different plans for future services, infrastructures, and personnel. Case A has focused solely on expanding into research data management. This library is experiencing some resistance as it moves into digital research services. Case B library, while emphasizing research data management, is also actively engaged in producing open content like multimedia and other instructional materials, as well as journals, reports, papers, books, and proceedings. The library also is focusing on electronic management of research project administration records. In partnership with its university's information technology (IT) division, it is emerging as a provider of critical cyberinfrastructure for research initiatives. Case C library is transitioning its subject librarians into positions as scholarly communication liaisons who advise researchers on repository use, web-based approaches to publishing, and intellectual property rights retention. This library is the lowest funded of the four, and it provides all of its own technology support and infrastructure. It does not, as yet,

partner with other university units or with external organizations to address technology issues. However, it has aspirations to establish a data repository service. The future plans of Case D library are the most expansive among the four. This library shares similarities with Cawthorne's research-intensive model library (2013, pp. 102–104). It has worked consistently to become a partner in many aspects of research. It supports many types of published and unpublished information resources generated from research activity. The library also develops software, technology infrastructures, and virtual research environments and pioneers new services to support its university's international research endeavors. Over the years, it has hired new technologists and information management professionals to work on these and other services. All of the libraries have "change agendas" to create new infrastructures and services and cultivate new organizational cultures and employee expertise. However, the libraries are evolving slightly differently in each of these areas as a result of different leadership and management approaches and overall library goals.

Services

The services being developed by the four case study libraries can be grouped into four categories: (1) managing scholarly and research products in final form, (2) managing scholarly and research processes by providing technologies and related support, (3) consulting and providing information, particularly on scholarly communications issues, and (4) partnering in research initiatives by providing solutions related to information, data, and technology issues or serving as research project managers.

Traditionally, libraries manage the *products* of research, such as books, journal articles, research reports, and conference proceedings. Case study libraries are extending these services to

include management of research data. While one library struggles to establish its research data management services and has not yet done so (Case C), the other three already provide these as core services. Still others, such as Case D library, have moved beyond research data management and are managing communications (e.g., e-mail and discussion lists) in virtual research environments. The Case B and D libraries also manage the virtual research environment itself, which is composed of websites and social media tools for communicating, annotating, file sharing, meeting live, and other related tools for personal interaction and information sharing and analysis. Managing the information products stemming from research activities remains a core service of all of these libraries, albeit the scope of collection and information types collected varies across the cases.

Some of the libraries have expanded beyond managing *products* to managing *processes*. To create research products, certain technologies and support services must be present "behind the scenes." These technologies enable workflows, both electronic and non-electronic. Some examples are software tools to support the creation of academic journals and conference proceedings, books, multimedia, audio/video, websites, virtual community sites, written papers and reports, digital exhibits, and more. Processes to aid the production of research-based information have become core information services at Case B and D libraries. The capacity to perform these services requires adequate technological expertise to manage the necessary applications and the content they generate. These libraries must retain employees who are proficient in operating the relevant software as well as have the ability to train and support researchers using the technologies. These two libraries have developed the capabilities necessary to engage in the *process as service* model for information services. The other two case libraries

have not developed this service model; however, given their statements during the interviews they would like to do so if resources are available. Instead, Case A has focused its limited resources and abilities on generating a research data repository service; Case C, with even tighter constraints, has strengthened and emphasized its scholarly communications consulting program.

Case B and D libraries have become partners with researchers in their research initiatives by providing technology solutions. Both stand out from Case A and C libraries in this regard. These libraries analyze the needs of their researchers to identify and provide possible solutions for their information- and technology-related challenges. Although Case D library has made more progress, with library personnel fulfilling specific roles on research teams on a regular basis, the leadership teams of both libraries recognize that understanding university researchers' activities and challenges is critical. They feel that, without such knowledge, their services would soon become irrelevant; with such knowledge, the libraries can evolve to become recognized throughout their respective universities as lead problem-solving units and strong research partners. Case A and C libraries have not been able to make such an investment, mostly due to a lack of resources to conduct thorough researcher assessments and analyses. In fact, Case A library, after an analysis of researcher needs, questioned its role: Is the point of the work of university libraries to create new university-wide research services, or is it to be open and flexible, seeking targeted opportunities to engage in research initiatives to make the most of their limited funding and resources? Currently, Case B and D libraries support research, in part, through informatics work, where they apply information technology and methods associated with information science to a variety of interdisciplinary research challenges to solve them and aid researchers' abilities to generate meaningful findings.

Infrastructures: Facilities and Technologies

All four libraries are developing their infrastructures—facilities and technologies—to support the research services they are establishing. Most of the libraries are renovating their spaces to facilitate teaching and learning. These spaces are now prevalent in libraries around the world, even more so than when the trend was first identified by Brown and Long (2006). While this effort is ongoing and generally provides study locations and resources to undergraduate students, researchers can make use of such spaces, as well. Case D library has developed what it calls research commons in its main and branch libraries. These commons contain individual and group study areas and technologies specifically for researchers. While the library acknowledges that the university's research centers have developed their own such spaces, it recognizes researchers sometimes prefer to read and study outside of their laboratories. They seek a change of environment and sometimes need the type of technology supplied in these areas for data analysis and visualization purposes. The other three case study libraries have not developed spaces specifically for faculty-level research activity. Instead, their focus has been on student learning. However, these types of spaces can support student research. Technologies for display, analysis, and manipulation of information are typically provided. The software tools, though, are of a general nature and are not always the more specific tools faculty use for analyses. Thus, there appears to be a difference, perceived at least, between research spaces for students and those for faculty.

The technology infrastructures are different at each of the four case study libraries. In fact, the varied approaches to technology reflect the future directions being taken. In Case A, the library is partnered actively with the university information technology (IT) division to provide

computer processing, network bandwidth, and storage capacity for its research data repository service. In Case B, the university library and IT division are collaborative, having integrated some of their programs. This has resulted in additional services well beyond the data repository represented in Case A. Case C library "goes it alone" and, as a result, has not moved forward with services such as data repositories, virtual research environments, and e-Publishing programs. Case D, a well-funded library, largely "goes it alone" within the university. However, it is not alone. It has well-developed technology partnerships outside the university, enabling it to create new software applications, hardware/software architectures, and technology-based services for its researchers. It works with the university's high-performance computing center (HPC) to ensure the availability of needed computing cycles for the research initiatives in which it is involved and to transfer research data to the university library. Otherwise, this library's robust technology is largely due to strong external relationships with libraries as well as data centers and research computing units. In any of the cases, the chosen pathway for creating new research information infrastructures and services is technology partnership whether within a university or among a university and external partners. The differing approaches to technology infrastructure represented among the four case studies may be the most significant factor impacting each library's future services, programs, and overall directions.

Types of Scholarly and Research Content

The collections of the libraries will continue to grow, with conventional published materials and primary resources remaining at the base of their holdings. Such work is a process of accruing materials as opposed to replacing or ending the collection of certain kinds of content. While all of the libraries recognize the necessity of expanding into extensive research data

collecting, one of the libraries is not yet able to perform this work. There are many drivers affecting which research datasets are collected and rendered accessible, ranging from granting organizations' data access and preservation policies to university policies, citizen-based advocacy organizations such as patients' rights groups, and the wishes of researchers themselves. Research data as a library collection figure prominently in the future of these libraries. The director of Case B library also discussed the importance of electronic records and recordkeeping services for both research programs and university administration. Perhaps those university libraries that already maintain an active records management program may expand into this area. Two of the libraries (Cases B and D) have been developing virtual research environments for international research teams. They expect to collect and archive the online communications within these environments as part of the record and to curate information generated during these significant, large-scale research initiatives. As posited by Luce (2008), some of the case libraries see support of new forms of information as an important component of their current as well as future portfolio of services. This may include hosting social media and virtual community sites, blogs, wikis, and other web-based forms of communications as well as managing the content created and communicated within them.

Organizational Development: Culture, Structure, and Skills

While some aspects of organizational development are similar among the libraries, two of them are cultivating a much different culture among their employees to become more directly involved in research. During the interviews, all of the libraries' leaders expressed similar views regarding the type of culture needed to support modern research initiatives successfully. Like Awan and Mahmood (2010), each director recognizes that leadership, organizational culture, and

employee involvement are all contributing factors that must be integrated if a library's programs and services are going to advance. They all see the need for a library culture that supports viewing the portfolio of work performed by libraries differently from past portfolios, is flexible where library employees learn new skills and approaches in the midst of a new project or program, and promotes their working as colleagues alongside researchers as opposed to being a service provider to researchers. The directors from the libraries with the most extensive research-related information services (Cases B and D) describe their organizational cultures as being exploratory and experimental. These libraries study their parent university's researchers. Their employees see themselves as full partners on research projects, engaging directly with faculty and leading in areas pertaining to information science. They no longer work in a more traditional environment where library employees are deferential to faculty, following their lead, or where they wait for users to come to them with questions. They are empowered by the more experimental culture to investigate solutions for research processes, and they are encouraged by management to make recommendations and decisions regarding a project's approaches to information and technology. In Case A and C libraries, organizational culture is considered less important. Their directors both see a need to work closely with researchers and desire to develop similar cultural aspects as the other two libraries. However, their focus is to serve either as managers of research information products or as consultants on repository use and retention of copyrights and intellectual property. They are not engaged in analyzing information and data or in finding solutions for technology challenges encountered in research projects. Case A and C libraries are trying to solve different problems and provide different services than Case B and D

libraries. The latter are more concerned about research processes and environments, while the former are more concerned about research products.

When asked about organizational structure, all of the directors said they had to decide how involved each library unit would be in e-Research. In other words, they had to determine whether to establish a specialized e-Research services unit, diffuse e-Research activities and associated work perspectives and values throughout library units, or create a hybrid of the two by combining these approaches. Once again, the directors of Case B and D libraries shared similar views. They both wanted to achieve as flat an organizational structure as possible. According to Case D library director, the library "does not need much structure, except to support business processes such as financial and human resources. We are moving to teams and work groups." Her goal, which is nearly achieved, is to spread the new e-Research work across as many library units as feasible. Case B library director commented that the organizational structure "should foster and support things that need to happen in the library and for the university." This director believes there should be a formal organizational structure only when needed. Otherwise, it should be kept flat and flexible. The library directors in Cases A and C felt similarly about a flat, effective organizational structure; however, they opt to maintain their classic library departments. They both articulated that this classic structure can be leveraged to engage in new activities. Essentially their approach is to transition the activities within an existing library department as opposed to creating new work units. Most of the libraries see e-Research activities being conducted within two to three library units, such as the information technology/digital initiatives department and the information services department. Librarians in these units will serve on research teams or assist with rights issues and repository usage. Case D library director

spoke specifically of diffusing this work across library departments and branch libraries. Case B library director hinted at a similar approach during her interview, but she did not emphasize this organizational structure to the same extent.

The skills required for the libraries to provide e-Research services are similar. All of the library directors commented frequently about the attitudes and soft skills required and discussed their growing importance to the success of their libraries. For all of them, relationship-building skills are becoming critical so that library employees can work successfully with researchers and research administrators. Case B library director claimed this is one of the areas where the library excels and brings added value to research services, distinguishing it from the university's information technology division, which does not have similar relationships with researchers. In fact, all of the directors highlighted communication and team-building skills, emphasizing that the employees must work well in teams within the library, between the library and university units, and with partners external to the university. In addition, Case B and D library directors spoke about the importance of having employees who take initiative and possess the willingness to assess, explore, and identify new areas where the library can bring value to the services and products that support global research. These two libraries are consistently looking for new ways to engage in faculty research initiatives. All of the library directors also discussed the hard skills required. Specifically, they identified the need for technology skills such as software development and programming, server and network administration, data and information management, and web design and development. Most of the directors need personnel who can do more than one thing well. This is illustrated most clearly in Case D, where the library employees have software programming skills and a good working knowledge of the research fields of given

projects, as well as the ability to manage research data and other information assets and communicate clearly and effectively.

Leadership and Management

The leadership and management methods of the case study libraries are similar because they are all aimed at transitioning the libraries so they can develop and maintain new e-Research services. All four directors noted that previous organizational culture at their respective libraries was not conducive to success in the emerging global research ecosystem. As noted by Blessing and Hrycaj (2013), the need for cultural change is acknowledged at many academic libraries. These four were certainly no exception. Seeking transformation, the directors have developed specific strategies to change library culture. Each library has experienced varying results, but all have made progress. One management method common to all of the libraries is to promote transparent behavior, including communication, by the library leadership team and all employees. The libraries' leaders also practice a service-oriented style of leadership, concentrating on removing barriers experienced by employees so they can complete work efficiently and achieve their objectives. In addition, the leaders promote a service-oriented perspective among the employees, one that centers on serving researchers and other clients effectively. Some of the library directors speak about challenges they encountered when old organizational cultures needed to be replaced. In one case, librarians were preoccupied with how to retain their faculty status rather than how to use them to gain entry into faculty research projects so they could participate and determine how to best serve research needs.

Beyond these similar aspects, however, the libraries' leaders do have some different approaches to leadership and management. In part, these differences stem from unique

challenges and resource constraints at some of the libraries that have resulted in more conservative organizational visions and service goals. The library management in Case A practices a leadership style that promotes positive and open communication. Primarily through this communication, the leaders have developed a library that concentrates on research program needs and looks for major changes in them. In addition, they are striving to become a library that anticipates possible emerging situations and responds to them; however, they admit they do not yet have this capability.

Case B library's approach to leadership and management concentrates on changing employee perspectives regarding the library and its programs and services. Its leaders recognize that library personnel must first think differently about their work if they are to transition into the less traditional roles necessary to provide relevant e-Research support. This library has a well-developed employee recognition program to acknowledge those that learn new skills and take on new job duties. The goal of the library leadership team has been to transform the library into an organization that explores new opportunities alongside researchers, acting as both research partners and service providers. This goal has been achieved. As a result of changed perspectives and employee willingness to take on new roles, Case B library has now created various content production, information management, and technology solution services.

Case C library has concentrated on organizational and cultural change as well. Although the library encountered challenges, it achieved the goal of establishing a successful scholarly communications program. The challenges have revolved around the HR officer and a few influential employees not recognizing and accepting the need for new roles and positions. However, the behavior of the library's leadership team, expressed through its strategic planning,

decisions, and public conversations, has begun to effect and change the perspectives of these few individuals. Case C library continues to have aspirations to move beyond its scholarly communications program to managing new forms of scholarship and research information through a digital repository service that supports content types like digital numeric data, image and spatial data, as well as forms of digital multimedia. They anticipate partnering with the university's data center and the office of research to achieve this goal eventually.

The leadership team of Case D library has had the most ambitious transformation goals of all. It has concentrated on identifying and developing those employees who can advance the library and help reach its goals. Once these employees are identified, the management approach has been relatively "hands-off," delegating program authority and decision making to the new information professionals, the IT managers, and the library technologists. Using a supportive management style, library leaders provide employees with verbal confirmation of current actions and, thus, imbue them with confidence in subsequent ones. This feedback reinforces the library's goals as the employees work to accomplish them. The leadership team of Case D has served the library well, involving employees from many of the library units in the new research services, as opposed to having employees concentrated in a single specialized unit. Important new services have been generated from this organizational environment, such as offering and supporting virtual research environments for international research teams in which the university's faculty are involved as well as providing information- and data-related technology solutions for them.

While organizational transformation is taking place in all four libraries, each library's leadership team has a somewhat different management approach to achieve this transformation. In addition, the aspirations are directly related to the resources and expertise possessed by the

library. In instances like Case C library, the resources available and the expertise in e-Research services and cyberinfrastructure are inadequate and limited. Therefore, its leadership team's organizational goals, while significant, are more modest. This library has achieved its first goal of developing a scholarly communication program that disseminates information to and consults on related issues with researchers. At the opposite end of the spectrum, Case D library, with its wealth of resources and large number of skilled professionals, has much more ambitious goals such as inter-institutional technology development and virtual research environment management and, for the most part, achieves them.

Developing University Contexts

The leaders are transforming the case study libraries because they perceive a threat to their relevance in the university research enterprise. This threat arises from the continuous change taking place at universities in response to various external drivers. The leaders suspect that if universities continue to change in significant ways, eventually their libraries will be out of sync and, therefore, no longer relevant. The concern over relevancy is influencing how the libraries align with and support the universities' research programs and develop value-added services. Perhaps the major force driving all of these libraries to evolve is the establishment at their respective universities of large entrepreneurial research centers. New research centers are leading both national and international initiatives and garnering large budgets, infrastructures, numbers of personnel, and are quite often internationally engaged. The Association of Research Libraries 2030 scenarios (2010) reflect this development as well by identifying internationally conducted research as a major factor impacting research university libraries.

Within the context of the research presented in this study, some of the case study libraries are working with large entrepreneurial research centers. For instance, Case B library works with a center at its university that employs approximately 3,000 researchers. Such large centers typically have long-term partnerships with federal agencies, private research organizations, think tanks, corporations, and many foreign and domestic universities. Research centers of this magnitude are reshaping the university landscape in the United States. For the libraries to remain relevant in this new research center-dominated environment, the directors from the case libraries believe they must transition to meet the ever-changing information, communications, and technology needs of these centers.

Other drivers are specific to individual libraries. University C's library, for instance, will soon be conducting a capital campaign. This university is looking to attract private developers to construct new and upgrade existing buildings, especially those that support the science and engineering fields. In addition, it has set a goal of becoming a top 25 public university in research, and it hopes the funds raised in the capital campaign will propel it to this status. Such a high-priority initiative at a university has its impacts on the library, as well. In this case, the library is determining how it will become more relevant to the science and engineering fields and also how it will contribute to this important resource development initiative so that it can reap its share of the benefits. Case C library has another driver impacting its future direction. Its university built three foreign campuses and established a large and well-reputed distance education program through these sites. The university plans to create research programs at these foreign locations, utilizing the faculty members that are already based at each one. Given this

development, the library is identifying ways to engage in these new overseas research programs so that it can begin to participate in the international research arena.

Case D library has a unique driver of its own. Its university is deeply involved in collaborative, internationally based work with many other research-oriented educational institutions, corporate organizations, and government units. This is a university that plays a key role in the global research ecosystem, leading many international research teams in areas of great significance to the university. Consequently, the university's library knew it must transform and address the needs of these large-scale, internationally composed research initiatives. While the other three universities and their libraries are striving to reach similar statuses in the global research environment, the library in Case D has more fully evolved its e-Research services. It and its university already represent what well-funded, internationally oriented universities and libraries will look like in the future.

Partnerships outside the University

All of the libraries are engaged in formal communities of practice and at least one technology-based network, while only a few of the libraries are involved in software and virtual research environment development. To varying degrees, all four libraries have formed partnerships with entities outside of their universities, primarily with other university libraries, to enhance their own capacities and capabilities and expand their access to expertise. According to Walters (2008), this is a common way for university libraries to extend their services when human or financial resources are limited. With these partners, the libraries participate in activities such as digital preservation, repository services, and e-Publishing. They also collaborate to establish and maintain virtual research environments, create research data

networks, develop and maintain software, and establish standards for all of these areas. Both Case B and D libraries are involved with distributed data networks like the DataONE or SEAD initiatives. They offer and maintain well-developed research data management services. The libraries in Cases A and C are not involved in research data networks, albeit the library in Case A is heavily involved in research data management via its data repository service. This library has developed its information technology, digital initiatives, and subject-centric employees, in part, by joining organizations that support communities of practice, like the Digital Library Federation. Case C library participates in a regional digital preservation network as a way to preserve its institutional repository content. It is also a member of an organization that supports a community of practice regarding library e-Publishing services.

The university libraries in cases B and D are deeply involved in consortia that develop cyberinfrastructure tools and standards to support international research initiatives. Both of these libraries are engaged actively with global research teams, and library employees participate as team members. However, Case D library is the only one involved in developing technologies and inter-institutional services that, combined, create virtual research environments and data consulting services. This library also works with professional organizations other than university libraries. For instance, for data network and virtual research environment activities, it collaborates with university and government data centers, information technology divisions, and leading research centers. While all four libraries engage in partnerships outside the university, the types of partners and activities differ, either emphasizing the development of data networks, virtual environments, software, and standards, or the development of and participation in

communities of practice where employees learn about emerging information services that support international research and scholarly production.

Conclusion

Throughout the interviewing and case-study development process, the leaders of the four libraries acknowledged the importance of providing value-added services that support Grand Challenge research conducted on an international and multi-institutional scale. The directors believe that offering such services is the best way for their libraries to remain relevant in their rapidly evolving university environments. Consequently, providing these services helps them attract resources and build relationships with university and external partners. These partnerships enable them to develop new technologies and infrastructures and allow employees to acquire job-related knowledge and skills. In turn, these resources and skills enhance the libraries' research-related contributions. For the directors, successfully producing new technology-centric and consulting-based information services has confirmed these beliefs. The four libraries are making progress, albeit the nature and extent of the progress is different in each case. The libraries' leadership team in each case, has discovered and utilizes productive tactics to advance organizational transformation, such as inter-institutional partnerships, intra-university partnerships, and approaches to leadership that foster self-examination with the library organization, which leads to producing new library perspectives and work cultures on the part of the employees. All are transforming to meet the varied needs of their universities' researchers, and some are becoming embedded in the research process itself, often participating as equal partners alongside research faculty.

To provide the robust library services required for supporting global research initiatives, a library must possess new and relevant infrastructures, resources, and expertise. The extent of research support services at any given library will always be dependent upon available technology, finances, and employee skills and aptitudes, as well as upon the ability of its leaders to combine these resources and cultivate an organizational culture that attracts partners who can help create such services. In one case, the library with the fewest resources does not have substantive technology partners. However, through membership in a regional digital preservation network, it has been able to preserve its institutional repository content. Two of the others, with more resources, partner frequently with their university IT divisions to develop both technology infrastructures and services utilized by their respective university's researchers. The leaders of these libraries see the benefit and seize collaborative opportunities that result in expanded services. These partnerships benefit the libraries in that they are able to construct and maintain technologies together that they otherwise would struggle to do solely on their own. The fourth, with the best resources, partners little within its university but collaborates a great deal with other universities and libraries to develop and manage new technologies and maintain associated services. Case study (D) illustrates how financial abundance can allow a library to cultivate a more experimental, risk-taking culture because the financial consequences of mistakes are not as important to them as they would be to the other case libraries.

While the financial resources available are an obvious factor contributing to each library's effective engagement in supporting global research through information and data services, it is the approach to developing and providing technology that differentiates them. Libraries can gain access to more resources through strong technology partnerships, be they

internal partners, such as IT divisions or offices of research, or external partners, such as data centers, libraries, government units, and other universities. Those libraries that collaborate with others clearly are in a better position to provide new e-Research services, transform organizationally, and engage productively with their university and others worldwide. Some of the libraries in these cases are illustrating successful paths to supporting large-scale, international research and may become models to be studied by other libraries and universities interested in achieving the same positive results.

In the next chapter, the investigator comments on the study's major points, looking at some issues that are germane to the entire study, then keys in on aspects of importance for universities and their research programs, and then their libraries. In particular, the investigator reviews the value of combining the scenario and case study creation methods to ascertain a realistic and useful view of the future for planning exercises in an organization like a university library. Next will be a discussion of the implications of the study's findings for U.S. research universities and their evolution as well as how information policy as depicted and described in the study may impact research and scholarship and the organizational actors involved – universities, governments, publishers, and libraries.

Turning to libraries, the chapter will continue with a review of the impact of the evolving U.S. research university, international cooperation and globalism in research, and their effect on U.S. university libraries. Specific aspects that will be reviewed include: leadership and organizational transformation, organizational culture, technology and the emerging cyberinfrastructure, and resource availability and inter-institutional and international partnerships. The chapter will end with a review and discussion of further research needing to be

conducted to better understand the evolution of research universities and their libraries in the global research ecosystem. As this understanding evolves and improves, it is likely that researchers working on this topic will comprehend better the broader socio-economic contexts and systems that are impacting the United States and the Western world in general.

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Chapter 10

Conclusion and Further Research

As the nature of knowledge creation and production through research evolves, U.S. research universities and their libraries are transforming to remain relevant in the new global research environment. The findings of the current study demonstrate that financial and budgetary activities, leadership and management, organizational culture, employee training and incentive programs, technologies, and legal and policy frameworks must be altered as a way to achieve this transformation. Conducting scenario studies is one useful qualitative research approach to understand how U.S. research universities and their libraries will change in each of these areas. However, new scenarios are needed because few existing ones have identified the key forces and drivers affecting research program development. The exceptions are the Organisation for Economic Co-operation and Development (OECD) scenarios for academic research (2009) and those of the current study. In addition, only the current study specifically describes how U.S. research universities will respond to such drivers and how their libraries will, in turn, transition to support them as they engage in Grand Challenge research conducted on a global scale.

Previous scenario studies focused primarily on how higher educational systems, usually at a national or multi-national level within a region, must contribute to a nation's or region's economic development. The role of universities within this context is to train the highly skilled workers needed to transform an economy. Thus, the motivation for conducting such studies is ultimately to improve student learning and economies by assessing a particular higher educational system's effectiveness in transferring knowledge to the students and, consequently,

integrating them into the workforce. Therefore, learning is the focus. To plan for how universities, and libraries in particular, will serve the needs of global research endeavors, more studies are required.

Using the case study method in conjunction with the scenario development process, helps researchers and other interested persons understand how institutions like universities will respond to the scenarios. The semi-structured interview process can elicit questions, comments, and perspectives about scenarios not previously considered during initial scenario development. These new perspectives can be incorporated into a case study, further illuminating how study participants interpret the scenarios as their implications are considered. Hence, scenario-based case study development extends the usefulness of scenarios, creating a view of how single institutions can develop strategies to succeed in various future environments and providing *real world* feedback about the likelihood of the scenarios themselves.

In the current study, the investigator modified this approach to elicit feedback from library directors on only one of the scenarios, the one most favored by the research directors. This allowed for a more practical way to conduct in-depth exploration of the most likely scenario, resulting in more complete findings directly applicable to current and emerging university and library settings. According to the research directors, the other scenarios posited in this study are less likely to occur and are less desirable, therefore, U.S. research universities are spending less time and energy planning for them. Hence, the library directors were asked to focus on and respond to the favored scenario only.

Study Implications

The findings of the study suggest that there are many important implications for both U.S. research universities and the libraries. At the university level, there are repercussions in areas like technologies used in research as well as for the composition of research teams, the management of research programs, and in relation to sources of research funding. At the library level, there are ramifications for the leadership teams and how they lead as well as the overall imperative of organization transformation and changes in organizational culture. There are also consequences in regards to the resources needed by libraries to enable the transformation, including partnerships with external entities to develop and maintain technologies and manage services.

Implications for U.S. Research Universities

Four main areas will increasingly present challenges for universities as they strive to participate in the emerging global research environment:

1. New, unforeseen digital processes and technologies used in research, including the next generation of virtual research environments, virtual communication, scientific instrumentation, and technology infrastructures;
2. Increasingly diverse research teams, involving more team members from various disciplines and locations and from differing international and institutional cultures;
3. More multi-institutional and international research programs, creating associated legal, policy, and procedural complexities; and
4. Newly emerging funding models, developing to procure resources specifically for internationally based Grand Challenge research.

Each of these will have considerable impacts on a university's organization, priorities, funding streams, technologies, and, consequently, research programs.

Technologies. The scenarios and case studies all strongly indicate continued, rapidly evolving development of Internet-ready digital technology. These technologies will increase society's capacity to perform research and will likely transform how it is conducted, especially within the science, technology, engineering, and medical (STEM) fields. In particular, STEM researchers in the past 20 years have seen rapid development of digital scientific instrumentation and burgeoning growth in the digital data generated as a result of its use (Hey, Tansley, & Tolle, 2009). The emergence of new and improved scientific instrumentation is ongoing, and such advances are expected to continue at a swift pace. During the past 10 years, researchers have also seen a quickly developing virtual research environment with new platforms, software tools, and Web-enabled live communication. Here, too, there are no signs of a slowdown (Walters, 2014). More recently, researchers have experienced the rise of new digital data networks, data centers, access portals, and digital preservation systems that are all part of the modern technology infrastructures and services becoming increasingly available. Largely, these are developed and maintained by universities and government units and, thus, continued expansion is possible, as indicated by some of the research and library directors involved in the current study. By the year 2028—the year focused upon in the scenarios of this study—the technology environment in which researchers work will become even more integral to the research process as the tools, platforms, and networks utilized become far more robust.

Research teams. The team-based approach to research holds promise for solving Grand Challenges. However, the complexities of this approach will inevitably present problems. Today,

universities are witnessing an increase in large teams of researchers, both within and across disciplines, as research initiatives address more perplexing and broader issues. The participating research directors believe this trend will continue and the composition and size of research teams will continue to expand. The mere size of these teams affects many areas of research, making it necessary to address workflow, leadership, and communications issues, among many others. Related challenges universities will be facing will stem from the differing backgrounds of researchers. Given that teams in Grand Challenge research increasingly will be composed of people from a growing number of nations, institutions, ethnicities, and cultures, with varying beliefs and motivations, there will be many diversity issues to surmount. Universities must consider how they will both respect these differences and acculturate researchers who come from many different disciplines and have their own national and institutional ways of administering and conducting research. While large, interdisciplinary research teams are currently in vogue, the research directors indicated that their size and scale will increase exponentially, making the management of research an even more arduous task than it is today. Managing program expectations, communications, interpersonal relations, and research outputs and outcomes will be increasingly challenging, and universities and their research administrators will be evolving their universities to better accommodate these differences.

Research programs. A related area that will impact U.S. research universities will be the multi-institutional and international composition of research programs. A team's make up will present various legal, policy, and procedural challenges when performing research and research administration on a global scale. As discussed by the research directors, a certain amount of harmonizing will be necessary in the overall regulatory environment to reconcile differences in

national laws as well as government- and institutional-level policies. While this work has begun, the current study shows that much more is required to streamline research administration procedures and make performing research across national boundaries more efficient.

One particular area of law and policy, that is, information and data policies themselves, will need attention. Many countries, particularly within the European Union, have adopted national laws and policies to make the products of research sponsored by public agencies open to the public. In addition, some private granting organizations require open access to research output. The United States is beginning to adopt similar policies and is considering national legislation on these matters. During the timeframe covered by the scenarios, it is possible that the United States will follow the lead of these other countries and adopt some laws or policies that call for open access to information and data generated from publicly-funded research. In fact, this process is currently underway (U.S. Executive Office of the President, 2013). Obviously, such information and data policies will impact how research university libraries acquire, manage, and disseminate scholarly and research information. Governments and universities may need to form international entities to facilitate and manage internationally based research programs. The goals would be to make the regulatory environment efficient across national borders, to allocate funding, and to perform oversight activities for global research programs. Because research university libraries handle information produced from internationally managed research initiatives, they may need to be subject to such international bodies. Research directors are beginning to recognize that many issues must be addressed over the next fifteen years for global-scale research to be regulated efficiently.

Research funding. Along with new regulatory bodies, new funding and financial management models for internationally based Grand Challenge research may need to be established, as well. Funding will need to be aggregated from many sources for large-scale, international research to be carried out. International bodies that oversee research initiatives could also aggregate and allocate funding and serve as the financial auditors of these programs. Regardless of the financial management methods utilized in the future, research directors participating in the current study see the need for new models to aggregate, allocate, and manage funding on a global scale. It is likely that universities, national governments, and international bodies will work together on this issue to improve the financial accountability and effectiveness of international research programs.

Implications for U.S. research universities abound as they transform to remain not only relevant but vital as world leaders in research. The participating research directors do not anticipate this transformation will be complete by 2028 because many complexities must be resolved. Issues of law and regulation and process and procedure must be decided, and international-level research program agreements must be reached. Internationally-savvy research administrative teams must be organized, and comprehensive cyberinfrastructures must be designed and built. Such transitions are only beginning, but they indicate that U.S. research universities recognize it is imperative to organize for global research. The move toward entrepreneurial, interdisciplinary, and transdisciplinary research centers is at the foundation of this transformation. During this study's interviews, it became clear that the university administrators feel threatened by a concomitant historical drop in research funding resulting from the sequester and the development of research capacities and infrastructures in countries like

China. Although U.S. research leadership is at stake, the research directors feel positive that establishing research centers; preparing for internationally composed research initiatives; and developing the ability to partner with governments, corporations, universities, and private research organizations, both foreign and domestic, puts them in a good position to succeed regardless of future developments.

Implications for U.S. Research University Libraries

The transformation of the U.S. research university is causing the transformation of the research university library. The study's findings, as embodied in the scenarios, illustrate the changes in organizational development taking place at universities. Further evidence of this is present in the library case studies, which reflect how the libraries are responding as they attempt to remain not only relevant but vital to the university's rapidly evolving research programs. The case studies explain how the libraries intend to be involved in a variety of activities supporting research. These include managing new scholarly and research outputs; supporting digital research and scholarship processes; solving research problems as research team members; acting as consultants on data, communication, and technology issues; and developing and managing new technologies through external partnerships.

Currently, only one of the case libraries is engaged in all of these areas, while the others are involved in some of them to varying degrees. Each library's ability to engage in these activities, and to what extent it does so, results from factors such as the leadership and culture present at the university and library and the resources available, particularly funding, technology, and expertise. The combination of effective leadership and sufficient resources at one of the libraries has allowed it to proactively support its university's global research initiatives.

Leadership, culture, and organizational transformation. Each of the four library directors represented in the cases lead their respective libraries with the intent to transition them. Thus far, they have all experienced success to varying degrees. While their leadership approaches are not always the same, their goals are similar. Most of the directors discussed the need to change organizational culture to create the libraries they envision. They view cultural issues as impeding organizational transformation; therefore, their leadership approaches are designed to effect the cultural evolutions they seek. The directors sense that if they can change library culture, then transforming library services, infrastructures, and skills will follow. Each director understands that, in the end, the vision itself is meaningless if the library employees do not adopt it. They are the ones who must possess the proper values, perspectives, and skills if the library is to engage in the services, processes, and partnerships each director wishes to establish.

Some of the directors use their unique positions to discuss the external changes they see occurring, both beyond the university and within it, with their staff. As discussed by Heifetz, Grashow, and Linsky (2009), these leaders are "getting on the balcony," viewing what is coming and attempting to bring others in the library onto the balcony so they can see, as well. Through one-on-one conversations and group discussions, some of the directors articulate what is on the horizon. Next, these directors try to create a sense of urgency, as described by Kotter (1996), stressing how everyone in the library must come together to respond to the changing landscape. The library directors acknowledge that external change is real and is already beginning to impact their libraries. They work diligently to get the library employees to understand the changing environment, see that their own response and transition is urgently needed, and recognize that they must work together as one organization to achieve the library's transformation goals.

The directors use a variety of techniques to generate buy-in from library staff. Some of them concentrate on discussions with their associate deans/associate university librarians (ADs/AULs). This is to ensure that these members of the library leadership understand and accept the need for transformation. The directors also want the leaders to co-design action steps to begin moving the library toward the organization it needs to become. Heifetz, Grashow, and Linsky (2009) discuss this phenomenon as "creating the guiding coalition," whereby the leadership team, comprised of the library director and the ADs/AULs, comes together, agrees on the organizational vision and strategy, and guides the library in achieving its new goals.

Some of the library directors are moving beyond establishing a guiding coalition and are quickly involving library employees in the new strategic directions. First, as discussed in the interviews, a few of the directors spend time "communicating the change vision," as Kotter (1996) calls it, with the library employees. They know they must do this to move the employees to action, and in the desired direction. They are attempting to "inspire a shared vision," as described by Kouzes and Posner (2006), across all sectors of the university library. Once communicated, the leadership empowers the employees, assigns them new tasks, visibly supports those employees who adopt the new strategy, and ensures that these particular employees have secure positions within the organization.

Through the change management process, the library directors and the leadership teams, especially in the Case B and D libraries, are not just trying to transition; they are attempting to establish a cycle of strategic development in their libraries. In other words, they evaluate external environments frequently and consistently for changes, share these changes with the library staff, and then respond by implementing an internal change management plan. This is an ongoing

process. Because of the rapidly evolving research university environment, the library must become very skilled at environmental assessments and initiating strategic change cycles on a continual basis. In fact, they may need to enact such cycles more frequently and quickly as the global research environment transforms and the university transitions to keep pace with the external environment and the opportunities it affords. Increasingly, research university libraries are mirroring other service industries; they must assess, identify, and respond to external factors or face irrelevancy and subsequent decreases in funding.

Resources and partnerships. Any organization attempting to transform needs resources. The case study libraries all face challenges as they attempt to free up previously allocated financial resources and redirect them to support new strategic directions. A similar process must be undertaken regarding the library's human resources. Leaders must view the abilities and aptitudes of individual employees as resources, redirect these individuals to different roles, and allocate the time necessary for them to acquire additional skills and become competent with new duties. The emerging global research environment is creating a rapidly growing demand for new library skills and expertise. Oftentimes, the required expertise relate to technologies used in research and scholarship or to data and information management and software programming. Sometimes, the ability to train research personnel how to use certain technologies and manage data is also required. The libraries will not be able to move quickly enough in this new environment by hiring new personnel alone; existing employees will need to develop new skills. This means that the library's leadership must cultivate an organizational culture that values the acquisition of new skills and rewards employees when they do so. Even more importantly, these employees will need to put new skills into practice as quickly as possible on behalf of the

research teams and projects the library serves. The library will not be able to move in new directions at a leisurely pace; if it does, then other units and professionals with information technology and instructional expertise will provide needed services to researchers, leaving the library with a diminished role.

The leadership must determine which currently available resources, both human and financial, to redirect and apply to new strategies and how to acquire resources not yet available, including both necessary technologies and the human expertise to achieve new organizational goals. Library directors may not be able to procure all of the needed resources on their own, so they look to relationships within the university when assessment of external environments indicates a need for new organizational directions. For instance, they often rely on the university administration and sometimes the provost to redirect, at least temporarily, undesignated financial resources so necessary changes can be initiated. The library director may also look to the university's chief information officer (CIO) for assistance with technology transitions.

In fact, technology investments may be critical as the global research environment continues to evolve. Over the past 10 years, this emerging environment has already called for new technologies, resulting in the inception of institutional repositories, virtual research environments, and social media communication tools. Technologies and services presently unforeseen will be requested, and libraries must find the means to supply them. Therefore, most research university libraries would benefit from establishing technology and service development partnerships inside and outside of their universities as soon as possible. Those libraries that have engaged in technology development and shared service models are already experiencing early success in the global research environment by providing services to research teams in areas such

as research data management, virtual research environments, and technology deployment. Developing trust between institutions and a shared vision through such partnerships could prove critical to libraries looking to be embedded in digital research processes and on large-scale, inter-institutional research teams.

Further Research

Scenario-based methods can be used to extend the research findings presented in this study and expand the available knowledge relating to the development of universities involved in global research. For instance, there are other participants than research directors in the university environment who influence the shape of research programs and their capabilities; the perspectives of these participants bear examination and can be included in new scenario studies. In addition, other scenario-based approaches that can be used to examine other institutional settings and how universities might progress or falter in the new global environment.

Conducting Follow-up Studies with Other Participants in Global Research

Additional scenario studies are needed to further understand the development of research universities and libraries in the global research environment. Specifically, there are other university-based actors than the research directors alone. Involving these other actors, such as library directors, chief information officers (CIOs), and research computing directors, may yield new perspectives on globally-oriented research program development in universities.

Library directors. The current study produced scenarios describing research program development in U.S. research universities. One of the unique aspects of this phase of the study was to derive scenarios based upon input from leading research administrators at the universities, usually vice presidents or vice provosts for research (VPRs). Subsequently, their favored

scenario was used to create case studies with input from the four library directors at the same universities. Therefore, the library directors read and responded to only the scenario most favored by the participating research directors; they did not read all four scenarios. By asking the library directors to respond to the remaining three, researchers might gain additional insights into how libraries may respond to and plan for some of the forces and drivers, and combinations thereof, identified in the research program scenarios. While the same forces and drivers are present in all scenarios, they manifest themselves differently in each. Hence, libraries may respond to them differently.

Additional research to elicit the thoughts and opinions of the library directors as they consider the nature and extent of research program development in U.S. universities and the external forces affecting them might also produce new insights. The library directors did not participate in the interviews that led to the current study's scenarios. Involving these directors, who represent the four categories of research institutions present in this study, could yield noteworthy perspectives on the international development of team-based research, especially regarding the information and data-related policies, services, and technology infrastructures being created to support them. In addition, involving their library associate deans/associate university librarians (ADs/AULs), as was done in the case study development phase, could potentially yield new perspectives. The ADs/AULs are responsible for developing and implementing major programs at their respective libraries and for collaborating with the library directors to foster organizational development and cultural change. Their insights, based on their experiences, could enlighten researchers as they examine the programmatic changes libraries are

undergoing and how those changes influence the composition and development of team-based international research.

Library directors and library specialists in areas such as research data management and intellectual property rights work with the university's VPRs and their offices of research, assisting on aspects of information and data policy. In particular, these policies help regulate the openness of information and data, the scheduling of retention periods, and the acceptable conditions and methods under which data will be shared, when not under a completely open policy. The library directors and their teams are a great source of knowledge about the services and technologies, especially the software and repository architectures, that need to be provided to research teams to facilitate and execute research and foster new discoveries. Involving library directors and their leadership teams in scenario creation might provide added insights on the future direction and shape of scholarly publishing and information dissemination. Such a study could focus on aforementioned areas, such as how data and information policies at the institutional, governmental, and inter-institutional/inter-governmental levels will affect scholarly publishing. Which information is shared and how may be determined, or at least influenced, by the emerging information policies needed to coordinate research globally. As new ways of conducting research and generating and disseminating information develop, they, too, will impact scholarly publishing.

Chief information officers and research computing directors. Another important university leadership position is the chief information officer (CIO). Frequently, the CIO is a vice president in the university, reporting to a university president, provost, or a vice president for business and finance. The individual in this position is placed highly within many research

university organizations and fulfills many responsibilities that impact research. The CIOs often oversee the information technology divisions, which are composed of areas such as high-performance computing, research computing, systems and network administration, information security, enterprise systems, telecommunications, and some relevant applications management. In addition, directors of research computing, perhaps the IT administrator closest to the CIO, also could provide valuable qualitative data and perspectives on IT in the global research environment. Involving the research computing director in scenario development would be analogous to involving the associate deans/associate university librarians. The research computing director is the "front line" administrator leading and managing the personnel meeting certain IT needs of researchers and research teams. Their perspectives might give researchers an improved understanding of some of the policy, resource-related, skill-based, and operational issues that must be considered while developing and managing the global research environment's cyberinfrastructure.

In the Digital Age, where research is advanced through the generation and sharing of large amounts of digital data, enabled by cutting edge cyberinfrastructure, and conducted through virtual research and communication environments, the CIO and the IT division are core to successful participation in global research initiatives. Eliciting, documenting, and analyzing the perspectives of CIOs as they consider the aforementioned areas and their relationship to internationally composed research might provide new understandings. The university's vice president/provost for research, while potentially involved in these IT-intensive issues, does not typically possess the in-depth knowledge or experience related to the complexities of large-scale computing and networking. To improve the understanding of where research on the global stage

is heading, we need the best understanding possible of its technology-related components; therefore, conducting a scenario study with CIOs using a Delphi panel interview process might provide a clearer depiction of U.S. research program development.

Developing Scenarios Using Additional Approaches

Additional scenario development approaches could be used to elicit new understandings of educational research institutions. For instance, new insights might be provided by conducting scenario studies similar to this one with universities in other countries, combining some of the OECD's system-level scenarios (2009) with the institutional-level scenarios of this study, conducting a scenario study to understand what might cause U.S. research universities to drop in research-intensity rankings, or examining how they might advance their educational programs.

Universities in other countries. The current study produced scenarios and case studies based on individual universities within the United States. The methods of this study could be applied to a sample of universities located in another country. This might be especially fruitful to conduct in countries that maintain universities that do not follow a "western-style" approach to higher education. Perhaps countries outside of North America and Europe, such as China, might produce research findings that are qualitatively different, thus producing scenarios and case studies distinct from Western nations. Such a research project would help determine whether higher education institutions of China are experiencing the same drivers and forces as their western counterparts and, consequently, whether the nature and extent of their growth is similar or different, and why. Future studies could be conducted with universities in countries such as South Africa, Malaysia, and the United Kingdom or for countries in the European Union, all of which have completed national-level scenario studies, as reviewed in this study (Chapter 1,

literature review section), but not scenario studies at the institutional level. Such institutional-level studies could benefit the country in question. Its government officials, higher education administrators, and others interested in research would see how individual universities might respond to certain drivers and forces, which, in turn, would affect the larger higher education and research system.

Multi-level scenarios. As discussed in Chapter 4, not all scenario studies of higher education are the same. In fact, they are not always designed to address the same level within the socioeconomic system examined. This is true of the OECD scenarios on academic research (2009) and the current study's research program scenarios. The former focuses on national or regional (e.g., a group of nations) systems of higher education and the latter presents scenarios at the individual institutional level within one nation. Therefore, it is possible to overlay scenarios from these two sets. The scenario combinations posited in Chapter 4 could be used to generate new scenarios that capture dynamics at both the national and institutional levels. Such an approach has the potential to yield more comprehensive multi-level scenarios, which, in turn, may produce more complete responses from those people using the scenarios for planning and research purposes. Another approach might be to use this multi-level scenario method to create original scenarios (not by using existing scenarios, such as the OECD and current study scenarios). Generating new scenarios at varying levels and overlaying them to create different combinations are extensions of the original scenario method and could be useful to understand the development of universities at institutional, national, and multi-national levels. There are no studies produced through this multi-level scenario method, and future studies of research program development at universities might benefit from experimenting with this approach.

The "great sorting out" of research universities. Some of the research directors in this study discussed a "great sorting out" of U.S. research universities, meaning that many currently classified by the Carnegie Foundation as "Research – Very High" institutions will not have this status in the future due to factors reducing research funding and expenditures in the United States. One director suggested that while there are currently 400 research universities in the U.S., this number could possibly shrink to approximately 100 if factors like the sequester continue for many years. New scenario studies could identify the major drivers and key forces that might cause leading research universities in the United States to lose their research institutional status. While many of these drivers and forces might be similar to those considered in the current study, how they play out to reduce research capacity and programming in the United States is not within the scope of this study. Further, a new scenario study could examine more closely what a particular university's research programming might look like once it has been diminished, which fields may be emphasized, which ones may not be, and what happens to international research partnerships in an institutional setting where research plays a lesser role. The study could also look at the remaining research universities and describe the nature and extent of their research programming in an environment where far fewer research universities exist. It could ascertain whether U.S. research universities will still be global research leaders or niche partners with foreign universities and what the institutional ramifications within the United States will be if they are no longer leaders. The current milieu described by the participating research directors indicates a future with far fewer U.S. research universities. How this weakening process will occur would be of interest to researchers and certainly warrants further investigation.

Development of educational programs. Further research can be conducted in regards to the advancement of educational programs in U.S. research universities. The procedures used in this study (see Chapter 1) can be applied to examining Scenario 4, "Teaching and student learning is the focus: Grand Challenge-related research moves overseas." In this scenario, U.S. research universities do not compete well for global research initiatives and turn toward improving educational programs to prepare U.S. citizens and their university graduates for a global employment market. Scenario 4 suggests that state and federal governments and universities in the United States will establish benchmarks for universities in developing globally-leading educational programs.

Among the collaborative developments of universities and governments are cyberlearning systems that link the best instructors with students across the country, both synchronously and asynchronously. While the scenario centers on advancing online, distributed learning and improving the employability of U.S. citizens, it does not address which degree programs the universities will develop further to enhance employability. Future scenario studies could focus on three programmatic aspects: (1) designing the delivery of education via nationwide virtual approaches, (2) examining which subject areas should be developed to improve the integration of U.S. citizens and the nation's university graduates into the global employment market, thus improving the national economy, and (3) exploring the expectations of university educational programs from the perspectives of policy makers and funders such as state governments. Research into the development of the subject degree areas could necessitate additional research on global economic development to understand economic growth and the projected skill areas needed from future workers. Once these scenarios are created, a new study

could pull them together with the current scenarios and examine the development of universities from both the research and education perspectives.

Examining Global Research Management and Funding

During the scenario development process, several research directors spoke about the need for new international bodies involved in initiating and overseeing research programming aimed at solving global problems. They also spoke about the need to move research funding away from the individual project level to a more coordinated research portfolio funding approach that is intended to advance research discoveries in a strategic way to solve Grand Challenge problems.

International bodies. The research directors who participated in this study see a need for new international entities to facilitate, initiate, review, and oversee global research initiatives. Scenario studies that explore the roles of and needs for such bodies could aid national governments, universities, corporations, and private research organizations as they work to establish the systems needed for future governance of international research. Such studies could seek to define the aspects of research program management needing international governance. Core concerns such as how financial allocations are determined and how matters of financial management and accountability are addressed could be examined. Other concerns, such as how to ensure technology interoperability and establish standards that facilitate international research, might also be areas to investigate.

Determining the best methods for organizing such international bodies will also require further research. Considerations will include how nations will be represented and how the bodies will be governed. Will these organizations be affiliated with and governed by an entity such as the United Nations via its UNESCO arm or through another organization such as the OECD?

Would these bodies function better as stand-alone groups governed through an independent, member-represented board? In addition, research is needed to comprehend the complexities involved in reconciling laws and regulations of the various nations participating regularly on international research teams. Research into these legal and regulatory systems could help to advance them. Once similarities and differences in these laws and regulations are understood, new international regulations may need to be promulgated to foster the growth and problem-solving capacity of international research teams.

Portfolio funding. Some of the research directors interviewed in the current study commented that most research funded by government agencies is project funded. In the future, these directors suggested, research will need to be funded at the portfolio level. A portfolio of research may be comprised of several research projects, perhaps conducted sequentially, to solve a Grand Challenge problem, such as how to supply adequate, sustainable clean water in northern Africa. The directors claimed sequential research projects are often necessary to resolve a Grand Challenge and said determining the nature of all research projects in advance of conducting them is impossible. They emphasized a need to leave research portfolios somewhat open ended so that projects can be designed in real time as findings from ongoing research are determined, analyzed, comprehended, and then utilized to design the next project. It is likely that solving such Grand Challenges will require a large-scale, international approach. Therefore, the goal is to move Grand Challenge research away from project-based to portfolio-based funding, making this the mainstream approach in the international research environment. A scenario study could involve interviewing leading principal investigators who conduct Grand Challenge research and program officers at grant-issuing institutions to understand better how funding for portfolios

could be allocated. In addition, further research could ascertain how best to establish a research portfolio creation process.

Conclusion

U.S. research universities are transforming to maintain their leadership positions in a research environment that is drastically changing. They are experiencing this transformation process because many current research problems such as food security, human health, and power generation and sustainability are not national problems, they are global problems. In these and other instances, new knowledge must be created, produced, and disseminated for human societies to ameliorate these challenges; it can be the research universities that take the lead and create this new knowledge. In addition, U.S. research universities are responding to the development of a global economy, competition being presented by countries like China, and the rise of other national economies in developing countries. This emerging and rapidly evolving milieu requires abundant resources and the best minds in the world to solve sweeping societal problems. University leaders foresee a future where research is portfolio-based, internationally composed, internationally funded and managed, and inherently interdisciplinary. Research will also be increasingly heterogeneous, involving many types of institutions and giving rise to an increasing number of government–university–corporate–private partnerships. The universities are devising strategies to maintain relevance by generating value-added services to support the research process within this burgeoning global environment.

Research programs at U.S. universities are facing a future dominated by international research teams, which may be initiated, funded, governed, and monitored by new international bodies. Challenges to carrying out research in this way abound, raising questions such as how to

integrate different national legal systems and policies for activities like management and transport of hazardous materials, how to ensure financial accountability, and how to respect and resolve organizational and cultural differences between researchers of varying disciplines, institutions, nations, and ethnicities. While many difficulties and impediments to international research require attention, the concerted effort worldwide to move toward it is undeniable.

Libraries, too, are transitioning. The goal is to remain not only relevant but vital to their universities by increasingly providing valuable services that support international, Grand Challenge research. They are managing new forms of scholarship and research information, supporting digital research and scholarship processes, producing content, working as partners on research teams, consulting on research projects, and developing new technologies. As a way to expand their capabilities, research university libraries are partnering more than ever before with multi-institutional networks that create new technologies and offer the technology-intensive services desired by international research teams. The library leaders participating in this study clearly are dedicated to transforming organizational culture. In doing so, each hopes to foster an environment where employees focus less on maintaining collections and more on providing services that solve research problems related to information, data, communication, and technology issues. If U.S. research university libraries can align their own goals with the rapidly changing ones of their parent institutions, and can achieve them, perhaps they can not only remain relevant but also become integral partners in global research endeavors.

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APPENDIX A

Informed Consent Form

I volunteer to participate in a dissertation research project being conducted by Tyler Walters, a PhD student from Simons College Graduate School of Library and Information Science. The project is:

The Future of Knowledge Creation and Production in University Research Programs and Their Impact on University Libraries

I understand that the project is designed to gather data and narratives regarding potential futures for research programs in U.S. research universities as well as for the university libraries serving them.

1. My participation in this project is voluntary. I understand that I will not be paid or compensated in any way for my participation. I may withdraw and discontinue participation at any time without penalty.

2. I understand that most interviewees will find the process interesting and thought provoking. If, however, I feel uncomfortable in any way during the follow up interview session, I have the right to decline to answer any question or to end the interview.

3. Participants will have the opportunity to ask questions of the investigator about the study, specifically about any risks they perceive. In response, all necessary steps to reduce those risks will be taken.

4. Participation involves responding to questions during two interviews conducted by the researcher. Each interview will last approximately 60 minutes. It will be recorded and notes will be written during this time. Transcript and interview summaries will be created from the interview recordings. The recordings, transcripts, interview summaries, and notes taken by the investigator during the interviews will remain closed and in the possession of the investigator only. The investigator will destroy all research data (recordings, transcripts, summaries, and notes) within one year of publishing the results of the study.

5. I understand that the researcher will not identify my institution or me by name in any reports using information obtained from the interviews and that my confidentiality as a participant in this study will remain secure. All published materials will use anonymized and aggregated data only; they will not contain any references to specific institutions or individuals.

6. I understand that this research has been reviewed and approved by the Institutional Review Board of Simmons College.

7. I have read and understand the explanation provided. I have had all my questions answered to my satisfaction and I voluntarily agree to participate in this study.

8. I have been given a copy of this consent form.

_____	_____	_____
Signature	Date	Printed Name
_____	_____	_____Tyler Walters_____
Signature (Investigator)	Date	Printed Name (Investigator)

For further information please contact Tyler Walters at _____.

If you have questions about the research or your rights as a participant, you should contact the Simmons College Human Protections Administrator in the Office of Sponsored Programs at _____ or Dr. Peter Hernon of Simmons College at _____.

APPENDIX B

Letter of Invitation to Participate Sent to Research Directors

Dear _____,

My name is Tyler Walters and I am the Dean of University Libraries, Virginia Tech. I am also a PhD candidate conducting a research project as part of my dissertation research at Simmons College Graduate School of Library and Information Science on managerial leadership in the information professions. The project is a scenario planning study entitled:

The Future of Knowledge Creation and Production in University Research Programs and Their Effect on University Libraries

You are one of twelve experts I am inviting to participate in the first phase of the study. This is an anonymous study; your confidentiality is assured. As a group, you represent research directors (typically vice presidents / provosts for research or a major research administrator designated by you) in major U.S. research universities. I will ask you or your designate to review the four scenarios that pertain to research program development and respond to eight questions. The scenarios and background information are contained in a brief document that I will send, should you or your designate consent to participate. I will conduct an interview to gather the responses. I expect the interview to take no more than one hour. Once I complete the interviews with each of the twelve research directors, I will update the scenarios based upon the participants' input. A second brief round will be conducted, using the same questions and participants to respond to the newly updated scenarios. You or your designate's input from this second round will be collected via telephone interview. The interview is anticipated to last no more than 30 minutes. Then, I will analyze the qualitative data collected and produce final research scenarios that will be used in my dissertation research. The resulting scenarios will help shape a better understanding of how experts view the future development of research programs in major U.S. research universities.

The second phase of my research involves developing case studies of university libraries, based upon library deans' responses and reactions to this research project's research program scenarios. Your university library may be invited to participate in the development of these case studies. I am happy to address any questions you may have and would like to thank you for considering being a participant in this research project.

Please reply to this email by _____, 2013 and let me know if you or your designate will or will not be participating. If you are participating, I will send the informed consent form, the brief scenarios, and questions. Then, we will establish a time for our interview.

Thank you for your consideration.

APPENDIX C

Letter of Invitation to Participate Sent to Library Directors

Dear _____,

I am writing to ask for your assistance with my dissertation research. I have sent the email (below) to _____, your VP for Research, asking for participation in my study. Dr. _____ (the VP for Research) can also designate another research administrator to participate. In short, I have written four scenarios describing how research program development in major U.S. research universities may occur in 15 years (2028). I need VPRs/designates to read the scenarios and answer eight questions I will put to them. I would like to interview them face to face, if possible. The second phase of my research will be to have four library deans respond and react to the finished scenarios and describe how they expect to see their libraries arrayed with services, infrastructures, etc. to meet these scenarios. You and your library may make it onto my final for library case study development (and the end product will be kept anonymous, as well as the institutions who participate in responding to my research program scenarios). My sample population is based on a cross section of SURA and ARL institutions, further subdivided by 1) public land grant, 2) public land grant and AAU member, 3) public [non-land grant], and 4) private. I have twelve institutions in total I am trying to involve in my research. Your university is on my list. I would be happy to send you the draft scenarios and questions as well, if you're interested in helping me. Mostly, I would like your help in trying to figure out the best way to gain VPR consent to participate. Again, the VPR can designate someone else to participate.

In case you're wondering, my research differs from the ARL 2030 Scenarios project significantly. The ARL scenarios look at how a fictional individual researcher responds and works in the new environments based in the scenarios. My study looks at some different environmental drivers, but specifically looks at how research universities at the institutional level will respond in the scenarios with regard to research program development. The second phase of my research then builds university library case studies focusing on services and infrastructures. The ARL project did not produce any library case studies.

Thank you for any assistance you can provide. Please let me know what thoughts or questions you have. I'm happy to call you and follow up at your convenience.

Best,

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