# The New Academic Library—Building Institutional Repositories to Support Changing Scholarly and Research Processes

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**Introduction**

How will academic libraries look in the future? What types of information will they contain? What resources will be accessed through them, and what services will they provide? While many externally produced information resources can be licensed and purchased, there can be no doubt that a growing number of academic libraries are also collecting, organizing, and disseminating the intellectual output of their parent institutions. This body of campus-born work stems from both learning and research programs; it is voluminous and diverse and needs to be managed well for the long-term. To meet the challenge, institutional repositories (IRs), where these items are held, organized, and accessed, are proliferating at a great rate. As of November 2006, there were 764 institutional repositories registered worldwide in the Registry of Open Access Repositories.[1] Almost all of this growth has taken place over the past five years. In fact, the rate of growth has been so explosive that in the December 2, 2006, SPARC Open Access Newsletter, Peter Suber predicts that in 2007 "[institutional repositories] will soon be a new fact of life for universities, like libraries or web sites, and the discussion will shift from their utility to the best practices for filling them."[2]

Suber goes on to write about the diversity of materials in repositories:

> I'm tempted to predict a continuing tension between the narrow conception of institutional repositories (to provide OA for eprints) and the broad conception of IRs (to provide OA for all kinds of digital content, from eprints to courseware, conference webcasts, student work, digitized library collections, administrative records, and so on, with at least as much attention on preservation as access). But I have to predict that the broad conception will prevail.

Institutional repositories (IRs) contain an abundance of faculty-generated pre-prints and post-prints, conference proceedings, technical papers, research reports, white papers, theses and dissertations, and other text-based forms of scholarly works. There are, however, newer, more complex, and extremely diverse forms of intellectual output being generated. These include data sets derived from research; learning and complex multimedia objects used in instruction, simulations, visualizations, and other forms of digital models; and audio/

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video webcasts of conferences, lectures, and symposia. A cyberinfrastructure of people, technology, and policies will be necessary to manage, preserve, and provide access to these products. Library services will come to the fore to support the creation and use of this digital material in new and different ways. This paper will explore these developments, reflecting upon their current application as well as future potentialities in universities. The planning and experiences of the Georgia Institute of Technology will be drawn upon as an example.

## The Content of Institutional Repositories

For generations libraries have focused primarily on two things: their users and their collections. While the digital world has changed the nature of much of today's intellectual output, this fundamental focus remains. To better understand why we need repositories, and how we need them to function, we must focus on the contemporary processes of academic research, learning, and communication. Only then can we identify the resulting tangible intellectual outputs and, thus, create and maintain comprehensive collections. We must also examine these outputs carefully to determine how to make them function well within the new digital object management framework. Without this functionality, digital library collections provide very little value to the user.

A university's digital intellectual output includes a diverse body of items, such as:

- annual reports,
- computer programs,
- conference papers,
- data sets,
- learning/complex objects (digitally captured courses, multimedia simulations/visualizations, captured notes of faculty and students, etc.),
- lecture series materials,
- models,
- pre-prints/post-prints,
- proceedings,
- research reports,
- simulations/visualizations,
- technical reports and working papers,
- web pages, and
- white papers.

Libraries increasingly will build information systems to organize, preserve, and provide access to these kinds of resources. The four major categories of output that will be reviewed are:

1. faculty and researchers' scholarly communications (i.e., pre-/post-prints, journal articles, conference papers, research reports, technical papers, etc.)
2. student intellectual output,
3. learning objects and other multimedia-based works, and
4. digital research data sets

This group of information resources goes markedly beyond standard scholarly writing, even in digital form. Academic libraries are beginning to address a plethora of scholarly and research resources created by their faculty and students. While these resources pose new challenges, they also present new opportunities. Libraries extending their capabilities to organize these new resources, make them widely accessible, and preserve them for future use are becoming integral to academic knowledge dissemination processes.[3]

## Faculty and Researchers' Scholarly Communications

Published scholarly communications—books, pre- and post-prints of journal articles, conference proceedings, technical papers, and research reports—are examples of traditional content familiar to all librarians. These make up the bulk of IR content today. Librarians building IRs for their campuses naturally think about how to ingest their researchers' scholarly content into the repository. However, the original scheme of author self-submission has not been successful in all cases. The reasons may be attributed to many factors, however, one contributing factor seems clear: research and scholarly communications processes have changed drastically over the past several years. To understand and adapt to these changes, librarians must examine how scholars and researchers are producing their works and ask if the library can provide services to assist them in these production and ingestion processes.

While librarians have been concerned primarily with formal modes of scholarly communication, informal modes are developing rapidly and, in some cases, replacing traditional methods. Some of these originate within virtual research environments and include blogs, wikis, listservs, and other social software content. Collecting these conversational and, at times, transactional elements of the research process will grow in importance as libraries seek to capture the essence of scholarly debate and disciplinary development. Those engaged in IR-building will do well to study this rising informal mode of scholarly communication and begin designing solutions for capturing and providing additional access to these resources. The institutional repository can be a central tool in approaching the challenge of organizing and accessing

both formal and informal scholarly communications that will be created, transmitted, and maintained in myriad digital forms.

Many librarians developing IRs are doing just that. They are becoming proactive by assisting faculty as they produce scholarly work. Hence, services to create and collect the abovementioned content are on the rise. These range from collaborations to produce electronic journals, frequently with open access content, to the digital production of conference proceedings and the digital capture of lectures, symposia, and conference sessions. While these "scholarly communications services" have existed for some time, librarians are beginning to tie these services to the IR. More specifically, librarians and IR staff are supporting technical production processes and hosting the final intellectual output of scholarly conferences. The role of the IR is to serve as "home" to the conference's host web site by providing a place where the conference's scholarly output is organized and rendered searchable and accessible. The IR framework also supplies the necessary functions and procedures to assure long-term preservation. Libraries are beginning to use their IRs in a similar way to support production of open access electronic journals. The journal's production process is amended to include hosting the journal issue and articles within the IR. The journal issues are organized, made accessible, and steps toward digital preservation are taken all by using the IR system. The digital capture of scholarly oral presentations is treated in much the same way; the IR is host to the digital audio/video files and a web site or page can be built to highlight the specific scholarly event. Librarians are exploring ways to make effective links between their IRs and other information-producing and -capturing processes.

Creative methods for collecting digital intellectual output and managing it in the IR are materializing. All of this activity highlights a crucial element for this work to be successful—library-faculty partnerships.[4] Libraries cannot deliver these services unless college and university faculty want them and will participate in them. Submitting a pre-print to an IR, publishing an open access journal, recording a campus lecture series, and hosting digital content from a scholarly conference all require faculty to initiate, participate, and "buy in" to the service in question. Cultivating long-term, consistent, and collaborative partnerships with faculty is the bedrock upon which libraries will continue to transform themselves into high-value hubs of digital information services.

**Student Intellectual Output**

Student research is growing in validity and often relates to research projects conducted by faculty. In particular, Georgia Tech has focused on growing undergraduate research output with programs like the Summer Undergraduate Research Experience, Undergraduate Research Scholars Program, and the President's Undergraduate Research Award. Currently, there are more than twenty undergraduate research programs in addition to those at the graduate level.

In response, the library at Georgia Tech has extended a core of repository-related services to students, beginning with a variation on the graduate-level electronic theses and dissertations program. The library, in partnership with the Undergraduate Research Office, is instituting a repository program for an electronic workflow supporting the review, approval, and dissemination of "senior theses," better known as the Undergraduate Research Option. This program stems from the rapid increase in undergraduate research programs, scholarships, awards, and international research initiatives. The undergraduate theses are managed through the use of the ETD-db software developed by Virginia Tech for the Networked Digital Library of Theses and Dissertations and, once submitted and approved, are mapped to Georgia Tech's SMARTech institutional repository, powered by the DSpace software.

Georgia Tech is involved in other student-related repository projects as well. The library, the Undergraduate Research Office, and the School of Literature, Communication, and Culture, along with a group of interested students, are investigating the creation of a student-managed journal of undergraduate research, with the library supporting the technical workflows (using OJS, the Open Journal Systems software), providing web-based dissemination and acting as the repository for its content. In addition, the *Technique*, GT's student newspaper, is produced through a partnership of the Student Publications Board, the GT Office of Information Technology (OIT), and the library. Today, the *Technique* is dynamically generated via an SQL database hosted on an OIT server. The library hosts the web version of the paper, as well as its static XML, PDF, and image files, and provides for its long-term management all via SMARTech. The staff of the library's Archives Department oversees this project while working closely with the Library's Digital Initiatives Department. There are other repository services supplied to support student activities, such as the digital capture of student research and creative works on display in the library's East Com-

mons, a group-oriented learning and social space within the library complex. There is also potential to record student lectures and events; however, this has not yet occurred. Because there are more students than faculty on any given campus, adapting repository services to serve them will likely become commonplace at many universities.

## Learning Objects and Other Multimedia-based Works

Many libraries are incorporating the aforementioned traditional faculty and student outputs into IRs already. However, there are less traditional intellectual products from research and learning processes that need to be addressed. For example, learning objects are proliferating on many campuses and are some of the most challenging types of digital output to manage in a repository. They can be defined as "modular digital resources, uniquely identified and metatagged, that can be used to support learning."[5] Generally, instructors design learning objects to support class-related instruction for the purposes of illustrating, demonstrating, or simulating principles or conditions. David A. Wiley further states, "The main idea of 'learning objects' is to break educational content down into small chunks that can be reused in various learning environments. . . ."[6]

The Wisconsin Online Resource Center characterizes learning objects as follows[7]:

> Learning objects are a new way of thinking about learning content — Learning objects are much smaller chunks of learning than courses, modules, or units. Interactive objects typically range from 2 minutes to 15 minutes for completion.

The Center further explains that these objects:

• are self-contained—each learning object can be taken independently;

• are reusable—a single learning object may be used in multiple contexts;

• can be aggregated—learning objects can be grouped into larger collections of content, including traditional course designs; and

• are searchable—every learning object has descriptive information allowing it to be retrieved easily.

These types of digital objects are technically quite different from the static text and image files that so typically populate today's IRs. Furthermore, learning objects must be interoperable with course management systems and other virtual, collaborative learning environments. The authors' and users' needs can differ from those when accessing traditional IR content. Learning objects will be revised frequently, even from semester to semester, as faculty upgrade, replace information, and update objects to reflect their latest approach to teaching a particular principle or idea. While many IRs are open to the public, some have levels of restriction. Learning object repositories will need to establish well-defined access control. Faculty may want access to their learning objects limited to the university community, to a certain set of colleagues in their discipline, or open only to the students in their classes. Clearly, learning objects require different management criteria as well as some new repository functionality.

Why should libraries be concerned about managing learning objects? First, they represent the digital intellectual output of a university's faculty and instructors. Second, they are increasingly used in newer, technology-enhanced forms of teaching and learning. Third, as they become more prevalent, librarians will find these kinds of multimedia objects either embedded or linked to more traditional forms of scholarly communications. In any case, librarians need to learn how to manage these objects because they will increasingly find themselves involved with them.

At Georgia Tech, the library is embarking on designing a media and learning object repository for a few chief reasons. Student intellectual output is increasingly multimedia. The library, in its learning space known as the Library West Commons, hosts a multimedia center. This is where students have access to training and assistance while creating multimedia objects for their class assignments and research. Faculty are assigning more classwork that requires multimedia authoring skills, and, as a result, the work of this center and student output are both growing at an accelerated pace. Georgia Tech is also migrating courseware from WebCT Campus Edition to the open source, community-driven learning and collaboration software, Sakai. This monumental move provides the opportunity to build a more responsive infrastructure, manage learning content better, and provide new content-related services to faculty and students.

Other major campus trends also involve multimedia authoring and distance learning use of learning objects. The GT School of Electrical and Computer Engineering, Digital Media Laboratory (ECE DML), is embarking on an initiative to create easy-to-use multimedia authoring tools overlaid on Macromedia Flash,

which is GT's primary software for multimedia authoring. The DML anticipates that by making learning object creation easier for faculty, objects will proliferate and a learning object repository will become necessary. We are already seeing this increase. GT's Distance Learning and Professional Education (DLPE) operation is seeking a change from the policy of discarding learning materials at the end of each semester (a policy in place since the 1970s) to an open-ended policy allowing the faculty/creators of learning objects to store, revise, and reuse them for future distance learning course needs. The three units—ECE DML, library, and DLPE—are keenly interested in working together to solidify this infrastructure for learning object management and reuse. Libraries can play a significant role in their academic institutions' virtual learning strategies by organizing and managing access to digital learning objects.

## Digital Research Data Sets

One more major class of digital-born intellectual output at colleges and universities is digital data sets generated from modern research processes. Much of this comes from the science, social science, engineering, and medical disciplines. The kinds of data typically encountered are geospatial data, social science/economic statistical and observational data, biological data, astronomical data, nuclear physics data, and genomic and protein data. From a library perspective, digital data is of interest as a resource to be managed if it is a primary source that must be made available to support current and advance future research and/or if it can be considered an extension of scholarly publications, e.g., raw, digital data accompanying journal articles and technical papers. Creators and users of such data commonly require particular policies and systems functionalities for depositing it into a repository and for searching, presenting, and manipulating it. Some academic libraries are involved in these uses and managerial aspects of data sets; however, extending the operational capacity of libraries to incorporate the full range of digital research data management is a very challenging agenda.[8]

Among the challenges libraries face are the lack of clear policies, the need for data curation tools and interoperable technologies, and the need for changes in organizational culture and technical infrastructure. Because of the expense involved and the enormity of the challenge, libraries will be required to educate the campus on the need for, and benefits of, actively curating digital data. Universities will need to establish programs and incentives that promote digital data curation as an integral part of research projects, thus shaping university culture. Policy can serve as this initial catalyst. Granting agencies such as the National Science Foundation (NSF) and the National Institute of Health are implementing data access and management policies that may drive universities in this direction. In response, universities will need to make a commitment to the public use, reuse, and maintenance of digital data.

Pragmatics dictate that not all data can be sustained. Therefore, universities also need clear criteria for selecting which sets of digital data become long-term university responsibilities. Libraries can contribute to the selection process by adapting archival appraisal theory as well as other parameters to judge which research materials are worthy of long-term accessibility. This combination of policymaking, educating, promoting, cultural engineering, and selection criteria-building will become essential when creating digital data curation programs. Libraries can assist with developing and implementing this agenda and become equal partners with scientists, advanced technologists, and policymakers. New partnerships and services will need to be established. They may take on a discipline-based alignment, such as several universities with keen interests in the biosciences and bioinformatics forming a consortium to provide data curation services for their home institutions' related data sets.

In addition to changing cultures and implementing policies, much work remains to improve technology integration and build reliable data curation tools. Data does not reside in just one information system; therefore, integration between systems is critical. Universities have research data residing in many applications such as databases (commercial and open), digital asset management systems, content management systems, and repositories. Consequently, curating this data may include moving it from one system to another, linking it between systems, and possibly migrating it to a central system. The exact future architecture is undetermined, and many universities and consortia may take divergent paths. Regardless, data curators will need tools for data and metadata extraction, database emulation, and data provenance tracking (to document the origin, use, and reuse of data and tend to the digital preservation of data sets). Libraries increasingly will assist in promoting further development of data curation technologies as well as standards and technical protocols to ensure interoperability and data migration.

If progress in terms of policy, culture, and technology occurs, then libraries may become a partner in

devising an infrastructure for long-term digital data curation and preservation. It is certainly within the mission of academic libraries to preserve such intellectual products. The policy, cultural, technical, and economic challenges that lie ahead, however, are enormous. Libraries in partnership with other libraries, with high-performance computing centers, and with data creators and aggregators will need to invest significant amounts of time, energy, and money to provide some initial solutions. We are beginning to see such major investments. Therefore, librarians involved in the world of repository development and services should watch these advances very closely in what may be the largest challenge in the repository movement today. This is an opportunity to reinvent libraries for the better as we face inherently new challenges in managing complex research objects such as data sets.

**Cyberinfrastructure for Managing Intellectual Content**

Given the perplexity and diversity of digital intellectual content being produced, librarians, archivists, scholars, and researchers need a common, modern cyberinfrastructure to manage it and foster its utilization. Fran Berman, Director of the San Diego Supercomputer Center at UC San Diego, defines "cyberinfrastructure" as the "coordinated aggregate of software, hardware, and other technologies, as well as human expertise, required to support current and future discoveries in science and engineering. The challenge of cyberinfrastructure is to integrate relevant and often disparate resources to provide a useful, usable, and enabling framework for research and discovery characterized by broad access and "end-to-end" coordination."[9] Cyberinfrastructure emphasizes not only technology, but policy and people to form a well integrated whole, fostering scholars' and researchers' participation in communities that advance knowledge and learning.[10]

The Georgia Tech Library and Information Center has been developing two key components to enhance cyberinfrastructure efforts at Georgia Tech, repositories and digital preservation networks. One of the unique features of Georgia Tech's repository development is its SMARTech IR. It was designed to be the central repository for campus-born intellectual content. From here, searching technologies and digital preservation activities can be applied in global ways while achieving optimal content access and ease of use and ensuring availability to digital items as information systems change over time. After selecting those campus information systems that contained intellectual output, library personnel began to meet with the departments responsible for those systems to discuss establishing automated transfers of information to SMARTech. A classic example of this kind of integration effort is the now common transfer of electronic theses and dissertations into an IR. The body of research reports existing in the office of sponsored programs (OSP) information systems provides another example. Many researchers obtain grants from public and private entities and must submit reports documenting research status or final research results. The OSP manages these electronic documents and sends them to the appropriate granting agencies. Publicly accessible OSP final project reports are being transferred into the SMARTech repository in a pilot program to test and further develop this transfer and ingest process. There are many other information systems that contain digital intellectual output, including student portfolio systems and academic units' web-based applications used to disseminate information to university officers and the media. Efforts such as these to embed the IR into the research document handling systems of the larger university will help to "institutionalize" the IR and make it an indispensable element of cyberinfrastructure for all fields represented at a university.

A solid cyberinfrastructure must also facilitate the preservation of digital intellectual output. Hence, in 2004, the Georgia Tech Library contributed to the co-founding of the MetaArchive Cooperative[11] to construct a distributed digital preservation network. In 1996, RLG with its Report of the Task Force on Archiving of Digital Information, framed the challenge of managing digital information resources: "If we are effectively to preserve for future generations the…corpus of information in digital form that represents our cultural record, we need… to commit ourselves technically, legally, economically, and organizationally to the full dimensions of the task."[12] By 2002, the GT Library moved assertively toward managing licensed electronic resources and campus-generated digital intellectual output, working aggressively to address the usability of digital information resources over time and across new technologies. The MetaArchive Preservation Network is a result of this interest in "born digital" preservation and is an essential cornerstone to building a workable cyberinfrastructure.[13]

Georgia Tech and the Emory University Libraries co-founded the MetaArchive Cooperative, with Emory as the lead institution and Auburn University, Florida State University, University of Louisville, and Virginia Tech as the other partners. In 2004, the Cooperative was

awarded one of eight original digital preservation partnerships in the Library of Congress' National Digital Information and Infrastructure Preservation Program. It has successfully implemented the MetaArchive Preservation Network, a distributed digital preservation network technology based on the LOCKSS (Lots of Copies Keep Stuff Safe) software, and is the first LOCKSS Private Network (LPN). A network of geographically and institutionally diverse digital repositories adhering to best practices, such as those set forth in RLG's Trusted Digital Repositories: Attributes and Responsibilities and the Reference Model for an Open Archival Information System, greatly reduces the threats to the existence of digital intellectual content.[14] In short, replicating digital content at the same institution only renders this content vulnerable to natural and manmade disasters as well as to the idiosyncrasies of the institution's technical infrastructure. Using the LOCKSS software system, a leading software for distributed digital replication, the MetaArchive Cooperative established the MetaArchive Preservation Network, a distributed means for replicating and preserving digital archives.[15] This network supplies the geographic and institutional dispersal and diversity needed to protect and preserve each institution's digital intellectual output. There are other LPNs such as the Association of Southeastern Research Libraries electronic theses and dissertation preservation network, the second LOCKSS Private Network in existence. More are being planned and built in the U.S., the U.K., and South Africa. Working to achieve the enduring usability of digital intellectual output through cooperative interactions with leading national and international institutions and organizations will benefit all college and research libraries—big and small—as they strive to address this keystone of cyberinfrastructure known as digital preservation.

## Conclusion

More then ever before, libraries are involved in managing very diverse digital information resources. Commercial full-text databases, e-journals, e-books, prepublished scholarly writings in digital form, digital learning objects, multimedia works, student research output, digital research data sets, and other intellectual products are being propagated at an astonishing rate. To organize, make easily accessible, and preserve this content, libraries must partner with other technology professionals, other types of information professionals, as well as scholars and researchers to design and build the cyberinfrastructure of tomorrow. This cyberinfrastructure will need to effectively deliver this content and provide digital services that allow academicians to share, utilize, manipulate, and disseminate a significant amount of intellectual output. Librarians will participate in this cyberinfrastructure-building phase and, hence, will change forever the way libraries function and provide services. In turn, the old perceptions of academic libraries will fade. They will be perceived as flexible and indispensable hubs of communications tools facilitating the exchange of ideas, the enhancement of learning, and the preservation of information generated during academic and research processes.

## Notes

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