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Erin Baucom
University of Montana, Missoula

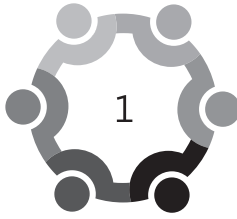## Let us know how access to this document benefits you.

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Digital objects are composed of bitstreams, sequences of 1's and 0's, which require specific software (and in some cases hardware) to make the content understandable to human users. Digital objects, like word processing documents, digital images, websites, e-mails, datasets and so much more, are fragile, easy to modify, and susceptible to bit rot (loss or reordering parts of the bitstream) and obsolescence. Digital preservation is a combination of policies and workflows that dictate the active management of digital objects to ensure their continued authenticity and meaningful access over time. Obsolescence is one of the unending battles that digital preservationists fight. File formats are continually updated, hardware consistently replaced, and software abandoned. One common strategy to combat obsolescence is to migrate older digital objects into new formats. To keep these digital objects available for future users, long-term digital preservation is essential.

For as long as there have been digital objects, there have been archivists and records managers planning for the preservation of said objects. These efforts

were done alone or in small groups, and they focused on very specific records or small groups of record formats. It wasn't until the explosion of personal computer use and the Internet in the 1990s, and the ensuing exponential increase in the number and types of digital objects, that major steps were taken toward a comprehensive and collaborative approach to digital preservation. This chapter presents the history of digital preservation through a small selection of milestones. These milestones were chosen due to the impact they had on the preservation landscape through the development of policies, resources, and tools. Included in this historical account are a range of landmark reports, the development of international standards, projects that produced resources and tools for digital preservation, and the copyright laws that shape the choices made by professionals who are engaged in determining how digital objects are preserved and accessed. This chapter is just a small glance at the hard work done in the last few decades to advocate for and preserve digital objects for future generations.

Background

When considering digital preservation before the 1990s, it is important to understand that the computing systems generating electronic records were initially limited in scope. Many of these systems were created to process large datasets or to automate processes. In the beginning of the nineteenth century, punch cards were used to automate a series of textile patterns created by knitting machines during the weaving process.[1] Computing machines adopted the use of punch cards for data processing in the 1880s and continued with this system well into the next century. Vacuum tube technology was introduced in the late 1940s, and this vastly increased the power of these processing systems. At the same time, the capabilities of these machines were expanded beyond sorting functions into complex mathematics. Electronic calculating machines were improved upon and reduced in size through the 1950s, culminating in the development of the first digital computers that would resemble something today's consumer might recognize. However, the 1950s machines were still primarily used to process and analyze datasets.[2] This data was preserved on magnetic tape, which researchers could access by running the data through one of a series of complementary statistical software packages. This implies that the data files were software-independent, while still being dependent on the hardware needed to run the tapes.[3]

As computing diversified, so too did the types of electronic records generated. Ronald Zweig wrote in 1993 about his concerns with the then-current preservation strategy of backing up electronic records with printed paper copies. Too many records were not being printed because they were considered to be the internal documents of corporations, government bodies, and other organizations. As a historian who at the time specialized in Jewish history during and immediately after World War II, Zweig did most of his research with internal documents that would be lost under the preservation model popular with institutions in the 1990s.[4] Zweig was just one of many researchers pointing out that a more comprehensive effort, driven by policy and supported by government, was needed to keep these digital objects available for future researchers.[5] This swell of support for digital preservation led to one of the best-known reports on what the future of the preservation of digital information should entail.

Preserving Digital Information: Report of the Task Force on Archiving of Digital Information

In 1994 the Commission on Preservation and Access (CPA) and the Research Libraries Group (RLG) charged a new task force to identify the impediments to the long-term preservation of electronic records and to make recommendations for resolving those issues. The task force was also charged with providing general recommendations that resulted from their work investigating current practices in digital object preservation. Finally, task force members were asked to provide an alternative to what the charge called "technology refreshing." The recommendation was that technology refreshing—that is, moving digital objects from old storage media to new versions of the same media—be replaced by migration; that is, moving digital objects to new software and hardware environments on a regular schedule. In 1996 the final report from the task force, entitled "Preserving Digital Information," identified two major recommendations for the preservation of digital information: the need to engage content creators in the digital archiving process, and the need for a network of trusted and certified digital archives.[6]

The first recommendation required content creators to help archivists and records managers preserve the interconnected attributes of digital objects, specifically "content, fixity, reference, provenance, and context,"[7] throughout what has become known as the "life cycle" of the digital object. This illuminates one of the differences in how archivists work with paper records versus electronic

records. While this process of early intervention had been and continues to be an essential best practice for records managers, it was rare that an archivist would interact with a content creator before the end of the active life of the records donated, or indeed before the records were even created. This need to collaborate with donors so early in the life cycle of the records was a paradigm shift for many.

The second recommendation introduced the need for a certification program for digital archives so that these repositories could be trusted to store and provide long-term access to digital objects for future researchers. This emphasis on certification recognized the limits imposed on preservation by copyright law and tried to proactively address them. Certified repositories would have the authority and responsibility to save digital objects that were in jeopardy even if the repository did not originally own the intellectual property rights to these objects. This emphasis on certification led to the idea of Trusted Digital Repositories.[8]

Open Archival Information System Reference Model

In 1990, at the request of the International Standards Organization (ISO), the Consultative Committee for Space Data Systems (CCSDS) started "developing formal standards for the long-term storage of digital data generated from space missions."[9] The result was the Open Archival Information System (OAIS) Reference Model. The first draft of this model was released in 1997, and the final draft was approved by the ISO in 2002, updated in 2012, and is currently listed as ISO 14721:2012.[10]

The OAIS model was developed as an abstract reference model so that the implementation of the model by an archival repository could be customized to meet the needs of specific user groups. OAIS was the first to describe the concept of an archival package which includes the digital objects and their accompanying "reference information, context information, provenance information, fixity information, and access information" as described by metadata. The OAIS Reference Model has become a common language that is widely understood by digital preservation practitioners who come from a variety of professional backgrounds. OAIS also became the starting point for future-focused projects such as the creation of repositories, assessing existing repositories, creating new metadata schemas, and standardizing the metadata that are unique to digital objects.[11]

RLG-OCLC Report
Trusted Digital Repositories: Attributes and Responsibilities

In 2000, following the CPA-RLG's "Preserving Digital Information" report and the development of the OAIS Reference Model, the Research Libraries Group partnered with the Online Computer Library Center (OCLC) on a collaboration to lay out the attributes required of a Trusted Digital Repository.[12] The working group's report was titled *Trusted Digital Repositories: Attributes and Responsibilities* (2002). This report defined a Trusted Digital Repository (TDR) as "one whose mission is to provide reliable, long-term access to managed digital resources to its designated community, now and in the future."[13] Along with this definition were the basic requirements needed to support such a repository, including "OAIS compliance, administrative responsibility, organizational viability, financial sustainability, technological and procedural suitability, system security, and procedural accountability."[14]

The report provided several recommendations to accompany this definition of an ideal Trusted Digital Repository. These recommendations included a continued push for certification programs for digital archives, an emphasis on collaboration between institutions when creating these repositories and other digital preservation services, unique identifiers for digital objects, the acknowledgment of the interplay between digital preservation and intellectual property rights, what metadata is required to preserve and access digital objects, and how to automate as much of the generation of this metadata as possible. All of these recommendations were broad, with no specific technical solutions suggested. The report reinforced the need for a common understanding of what the certification of digital repositories would mean, and emphasized the need for metadata that would be specialized for digital preservation requirements.[15] After all of this conceptual work, digital preservation moved towards standardized practical solutions for all of the problems identified by these reports.

Trustworthy Repositories Audit and Certification Checklist

In 2003, the Research Library Group created a joint task force with the National Archives and Records Administration (NARA) to develop specific criteria that would "facilitate the certification of digital repositories," as defined by the report on Trusted Digital Repositories.[16] The task force's preliminary efforts

were turned over to a collaboration between the Research Library Group and the Center for Research Libraries (CRL) for testing in 2005. The result of this testing, the Trustworthy Repositories Audit and Certification Checklist (TRAC), was published in 2007. TRAC was later used as the basis for ISO Standard 16363 concerning the audit and certification of Trustworthy Digital Repositories.[17]

The creators of the checklist required auditors to be aware of the uniqueness of each digital repository and each institution within which the repository sits. This reinforced the conclusion of the developers of the OAIS Reference Model that flexibility in repository development is essential. TRAC was meant to be useful for as many different digital repositories as possible. The checklist was not just meant for auditing an existing repository, but also to help guide the creation of new repositories and to support the extension of the capabilities of current repositories. In support of these efforts, TRAC "recognize[s] standards and best practices relevant to the community of the repository, as well as those of the information management and security industries as a whole."[18]

Digital Preservation Network

Preservation storage for digital objects that conforms to OAIS and TDR standards is often beyond the reach of institutions with limited resources. The Digital Preservation Network (DPN) was founded in 2012 in the United States with a starting membership of sixty institutions as a collaborative use of technology, expertise, and financial resources to create a robust and enduring digital preservation service. The DPN, a nonprofit membership model organization, was careful to first agree upon legal agreements pertaining to the collaboration, with an eye toward what would happen to material deposited by an institution that may later become defunct. This model ensures that all data deposited, regardless of the original owner, will be available to users in the future. Membership in the DPN is available to any U.S. organization that is interested in the long-term preservation of its digital content and is willing to participate fully in the effort by providing, at a minimum, feedback on the creation and maintenance of the network.[19]

The DPN has been set up as a series of nodes which specialize in ingest and replication. The ingest nodes focus solely on the tasks of receiving content into the network. The replication nodes provide authenticity and repair services for data stored in the network. The nodes are geographically dispersed and operate on a diversity of hardware and software platforms. After extensive

testing, the system began ingests in 2016. The network is currently focusing on relatively small ingest caps of 5 terabytes per member per year (members can purchase additional storage as needed). The system has been built to scale up as the resources of the network grow. Members of the DPN exponentially increase their preservation capabilities when using this system, as opposed to what they could do with the same resources in a home-grown repository.[20]

International Research on Permanent Authentic Records in Electronic Systems

Working in parallel to and beyond the creation of the OAIS Reference Model, the *Trusted Digital Repositories* report, and TRAC, was the International Research on Permanent Authentic Records in Electronic Systems (InterPARES). InterPARES is a series of international collaborative projects that have been conducted since 1994. Originally, the UBC Project was undertaken at the University of British Columbia in partnership with the U.S. Department of Defense (DoD) and ran from 1994 to 1997. The UBC Project focused on how to maintain the authenticity of electronic records during the active part of the digital object life cycle. This first partnership resulted in the DoD Standard 5015.2 for record-keeping systems.[21]

InterPARES has gone through a series of four iterations, each building on the results of the preceding project. InterPARES one through three focused on research into defining what an authentic electronic record is, determining how to preserve these digital objects, working with content producers and industry to develop a shared understanding of the needs of digital objects, creating workflows for archives with limited resources, and devising training resources for professionals who would implement these workflows.[22] The current project, InterPARES Trust, focuses on extending research and international collaboration on preserving digital objects that are housed on the Internet.[23] The international reach, collaborative nature, and continued financial support of the project is what makes InterPARES so unique. It is one of the few collaborative projects that has been sustainably funded since 1994.

Preservation Metadata: Implementation Strategies

In response to the recommendations from countless reports that work be done to improve the capture of the unique metadata that are needed for the

preservation of digital objects, several projects were launched across the globe. One of these projects was the development of PREMIS (PREservation Metadata Implementation Strategies). The OCLC and RLG sponsored a working group from 2003 to 2005 that produced the "PREMIS Data Dictionary for Preservation Metadata," which focuses on the metadata needed when digital objects are stored in repositories. This data dictionary became an international standard. The Library of Congress maintains the schema for representing PREMIS in XML.

Ideally, a repository would automatically generate the metadata for each digital object without the intercession of the creator of the content or the archivists maintaining the object in the repository. The metadata is supposed to ensure that the digital objects can be accessed by users of the repository, that the objects are not altered (maliciously or otherwise), and that all authorized changes to the objects are recorded.[24] This metadata specifically addresses the archival concerns of authenticity and fixity which directly correspond to the trustworthiness of digital repositories.

PRONOM

In contrast, the PRONOM project focused on the metadata that is needed to understand the file formats of digital objects. This understanding is essential for digital preservation efforts, and it directly relates to the concept of access. In 2002, the Digital Preservation Department of the UK National Archives developed PRONOM, an online registry of file formats and software products that support identifying the technical metadata associated with each file format. PRONOM was originally an internal resource of the UK National Archives, but it has since become an open international resource and is on version 6.2.[25]

According to the National Archives website, "PRONOM is more than just a database of technical information. It is intended to encompass a range of tools and services to support digital preservation functions such as preservation risk assessment, migration pathway planning, object identification and validation, and metadata extraction."[26] PRONOM and the associated tools and international projects that resulted from it allow institutions to perform vital digital preservation tasks without expending a portion of their limited resources to obtain and validate the technical metadata of the varied digital objects in their collections every time a new file type or updated file format is introduced.[27] Knowing the specific file type and file format of a digital object allows digital preservationists to address the unique preservation requirements

of each digital object, and it eases the migration or emulation of these objects so that users can have access to them now and in the future.

National Library of Australia: Preserving Access to Digital Information

In an effort to provide a centralized and collaborative environment in support of digital preservation, the National Library of Australia initiated the Preserving Access to Digital Information (PADI) initiative. The project ran from 1996 to 2010, and it partnered with other similar projects in Europe. The initiative wanted to advertise strategies and guidelines developed by its representative institutions for the preservation of and access to digital objects to all of the cultural heritage institutions in Australia. This active outreach effort necessitated the creation of a website that allowed institutions to connect to each other in order to share knowledge and tools.[28]

The development of the PADI website and the project's outcomes were made possible by a cooperative efforts of libraries, archives, and museums across Australia. This initiative was a landmark in digital preservation history because it represented how the collaborative efforts of many different types of cultural institutions could result in equal access to digital preservation resources. This initiative was a model for similar projects in the future.[29]

Electronic Resource Preservation and Access Network

In a setup akin to and in partnership with PADI, the European Commission funded the Electronic Resource Preservation and Access Network (ERPANET) in 2001. ERPANET was an international collaboration meant to develop a set of centralized resources that "make accessible tools, knowledge, and experience"[30] for all the organizations that are involved in digital preservation. The goals of the project were to raise the awareness of the complexities of digital preservation, provide information and current research about digital preservation, provide training, promote collaboration, and lobby software producers to include digital preservation functionality in their products. The project's website was last updated in 2007.[31] The ERPANET project was revolutionary because it actively lobbied software developers to consider incorporating digital preservation principles into updates of their existing software and all

their new software going forward. The project also laid the infrastructure for continued collaboration in research and the implementation of digital preservation strategies across Europe.

Digital Preservation Europe

Using the infrastructure created by the ERPANET project, Digital Preservation Europe (DPE) campaigned for digital preservation across the globe from 2006 to 2009. DPE was a consortium of European institutions that shared their digital preservation expertise and resources and brokered collaborative partnerships under the brand We Preserve. DPE produced toolkits for self-auditing digital repositories, unique identifier services, a shared research agenda, and an exchange program. We Preserve also created marketing videos through a cartoon series documenting the exploits of Team Digital Preservation. This cartoon series was one of the first efforts that introduced digital preservation to lay audiences. This innovative approach to explaining the foundational concepts of digital preservation helped expand outreach beyond the cultural heritage sector.[32]

Open Preservation Foundation

The Open Preservation Foundation started as the Preservation and Long-Term Access Through Networked Services Project (PLANETS). It was a four-year project, from 2006 to 2010, funded by the European Union to develop standards-based, evidence-based, interoperable digital preservation services. The project brought together the expertise of national libraries and archives, research universities, and technology companies throughout Europe.[33]

In 2010 the Open Preservation Foundation (OPF) became a not-for-profit organization that was created to sustain the results of the PLANETS Project. It uses a membership model to fund its continued operations. Members have unlimited access to all OPF resources and have the responsibility to help determine the direction of the OPF's continued research and development efforts. Nonmembers can still access the tools, trainings, and events provided by the OPF, but they must pay a fee for software support. Without the OPF, the open source tools developed during the PLANETS Project would become obsolete very quickly. Many institutions with limited resources depend on open source tools to perform digital preservation tasks and would therefore have to either

shift resources to buy proprietary versions of these tools, or have to modify their digital preservation workflows to a less robust standard.[34]

National Digital Information Infrastructure and Preservation Program

The United States took a slightly different approach to Europe when developing a digital preservation infrastructure. In December 2000, the U.S. Congress appropriated $100 million for the Library of Congress (LOC) to create the National Digital Information Infrastructure and Preservation Program (NDIIPP). Following this mandate, the LOC worked from 2000 to 2003 to develop a plan to implement the program, which Congress later approved. In 2004 the LOC started funding proposals geared toward encouraging public/private partnerships to build the distributed infrastructure, tools, and services necessary for digital preservation. The program also focuses on capturing, preserving, and providing access to digital objects.[35] This effort is a quintessential representation of the common understanding shared by digital preservation practitioners that one should use the tools available to preserve at-risk digital objects before they are lost forever, while at the same time striving to develop better tools and strategies for the future.

National Digital Stewardship Alliance

As part of NDIIPP, the National Digital Stewardship Alliance (NDSA) was started in 2010 using a model similar to PADI and ERPANET. The NDIIPP helped the NDSA for the first four years with administrative support and leadership. Currently, the NDSA is housed within the Digital Library Federation at the Council on Library and Information Resources. The mission of the NDSA consortium is to focus on the preservation of the United States' digital resources. There are over 210 members in the consortium, with an emphasis on diversity in institutional focus and funding type. The NDSA does not require dues, only that the members share their expertise in digital stewardship.[36]

By working together and sharing resources and expertise, members of the NDSA produce guidance about digital preservation through reports, briefings, demos, and webinars. The NDSA also organizes meetings and professional development events. The focus on collaboration, stewardship, inclusiveness, and exchange allows smaller institutions to move forward with digital preservation

efforts without straining their limited resources. Importantly, products developed by the NDSA are available for all to access regardless of membership status.[37]

Digital Preservation Coalition

The Digital Preservation Coalition (DPC) provides a different model for efforts similar to those conducted by the NDSA. The DPC was established in 2002 as a not-for-profit company in the United Kingdom. Because it does not have governmental backing, the DPC is sustained by membership subscriptions. The members work together to create long-term access to digital content and to raise awareness in Europe about the value of digital preservation and its challenges. The DPC focuses on providing the context-based solutions that meet the unique requirements of each digital collection. To achieve this, the DPC focuses on developing the skills of the workers who provide digital preservation services. What is unique about this organization among the many mentioned in this chapter is that the DPC provides services only to its members. However, the DPC does provide free access to the reports and handbooks created during the course of its work.[38] One such publication, the *Digital Preservation Handbook,*[39] is in its second edition and is one of the foundational readings in a digital preservation practitioner's library.

UNESCO/PERSIST

In an effort to create a unified understanding of the need for digital preservation for the entire international community, UNESCO published its Charter for the Preservation of the Digital Heritage in 2003. This charter recognized the fragility of digital objects and the immediate need to produce policies and strategies for these endangered digital heritage materials. As a first step, the National Library of Australia prepared digital preservation guidelines to accompany this charter and the subsequent regional workshops held to promote digital preservation among UNESCO members. However, efforts seemed to stall there. In 2012, at the UNESCO Memory of the World Program Conference, it was reemphasized with new urgency that a concentrated, unified international effort for the preservation of and access to digital heritage be made. This led to the creation of the PERSIST program in 2013.[40]

The PERSIST project is a subprogram of the UNESCO Memory of the World Program that began in 1992. This program was created to preserve the world's documentary heritage, make this heritage universally accessible, and raise awareness of the importance of our documentary heritage. Access to our documentary heritage is facilitated through the digitization of documents, and awareness is raised through a registry of heritage.[41] In partnership with the International Council on Archives and the International Federation of Library Associations and Institutions, UNESCO raises awareness of digital preservation through three working groups: policy, technology and content, and best practices. These three groups working in concert will develop systems, policies, and best practices that can be used by each UNESCO member at the local and national level according to its own laws and cultural needs to preserve the digital artifacts of its history.[42]

Internet Archive

Along with the standards, policies, and tools developed to shepherd digital files through their life cycles, similar work was being done to preserve the Internet itself. One of the first efforts toward archiving the Internet began in 1996 when the Internet Archive (IA) was founded by Brewster Kahle. In the beginning, the IA tried to capture as much of the Internet as possible, prioritizing what it believed to be what was most at risk or most important. Today, the IA has multiple channels through which web pages are captured: the subscription service Archive-It, which allows individual users to request that the IA archive a certain web page or series of web pages; internal capture priorities developed within the IA; and a user tool that allows users to add to the archive themselves.[43]

The IA has since expanded to become a library that provides "Universal Access to All Knowledge";[44] this library now preserves digital versions of books (those published before 1923 can be downloaded, and those still in copyright may be borrowed), audio recordings, videos, images, and software programs. The IA's efforts are supported by donations, grants, and providing for-fee services while encouraging individual users to upload their own content to it.[45]

One of the services that the Internet Archive provides is Archive-It. The Archive-It service was launched in 2006 as an international subscription service that helps organizations create archival collections of web content. The collections are full-text searchable and are stored in the IA's data centers.[46] The IA

has made great efforts to provide accessible content to users who are visual- or hearing-impaired, leading the way in the accessibility of digital collections.[47]

International Internet Preservation Consortium

Due to differing copyright laws, Europe developed its own Internet preservation model spearheaded by the National Library of France, along with twelve other institutions. They created the International Internet Preservation Consortium (IIPC) in 2003. The IIPC is an effort to share the resources to "acquire, preserve, and make accessible knowledge and information from the Internet for future generations everywhere, promoting global exchange and international relations."[48] For the first three years, only the original thirteen members were able to participate. Now membership is open to all cultural heritage institutions, and the IIPC currently has members from forty-five countries. The IIPC works to develop its own tools and standards to create an international Internet archive similar to the work of the IA, but with a focus solely on creating and preserving web pages.[49]

WIPO Copyright Treaty

Simultaneous with the work being done to preserve the many new types of digital content appearing in the 1990s came a need to modify existing copyright law. In 1996 the WIPO Copyright Treaty (WCT) was created to address, among other things, the rights of computer program and database creators as part of the Berne Convention. One of the key specifications of the WCT that directly affects how digital objects are preserved was the mandate that the digital rights management (DRM) and encryption measures put in place by creators be protected. Some DRM software interferes with the metadata extraction tools used during the stabilization of digital objects. DRM software can also interfere with migration processes and the tools used to provide users with access to digital content. Encryption necessitates the preservation of the keys used to decrypt the content, which are easily lost. However, as an international treaty, the WCT explicitly includes language that allows member nations to create limitations and exceptions to the treaty so that it may conform to national law. This ability to allow nations to create exceptions and limitations is essential to digital preservation efforts. The enforcement of the treaty began in 2002.[50]

Digital Millennium Copyright Act

In an effort to conform U.S. copyright law to the WCT, the U.S. Congress passed the Digital Millennium Copyright Act (DMCA) in 1998, with an enforcement date of 2000. The DMCA requires that DRM technology be respected unless an exemption is granted for preservation purposes; limits the infringement liability of online service providers; and "expressly permits authorized institutions to make up to three digital preservation copies of an eligible copyrighted work."[51] While this law aligns the United States with international copyright standards, it does increase the burden on U.S. institutions to request exemptions and more strictly define fair use when preserving and providing access to digital collections.[52]

Conclusion

Digital preservation has come a long way since 1994. There are now international standards, formal and de facto, for many of the essential digital preservation tasks and for digital archival repositories. Institutional support has increased, and administrations have acknowledged the importance of preserving digital objects as part of their cultural heritage missions. Most importantly, the milestones presented in this chapter reinforce the need for collaborations between institutions and across nations when undertaking the task of preserving digital objects. None of the past or future work done by tool and policy creators, report writers, and digital preservation professionals was done in a vacuum, and all future efforts in digital preservation will build upon the work of the past. Having all of this information openly available helps institutions carefully choose how to expend their increasingly limited resources to create or improve their digital preservation programs, thus ensuring that the digital objects which record our cultural and intellectual heritage are saved for future generations.

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