Preserving digital materials: confronting tomorrow's problems today

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Abstract

There is investment on a very large scale in creating digital cultural material, and as the quantity grows, problems of preservation are becoming more apparent. Digital materials are different from physical materials, in particular because their content can only be delivered by computer processing. Their preservation is difficult and complex. Policies are needed on what to preserve for the long term. Solutions are required to practical and technical issues that include cataloguing digital materials, dealing with technical obsolescence and the physical deterioration of media, and to problems of authenticity. First step strategies are reviewed. Overarching contextual factors discussed include vulnerability, political context, value, and ownership. The large amount of work on digital preservation worldwide is outlined. It is concluded that although it is difficult to envisage digital materials surviving for millennia as physical objects and collections have done, the internet itself may constitute a new context that will enable at least some of them to do so.

Introduction

"Digital materials, regardless of whether they are created initially in digital form or converted to digital form, are threatened by technology obsolescence and physical deterioration."
– Research Libraries Group

There is an enormous amount of investment in digital material, and very large quantities are being produced, much of which is economically and socially significant. A proportion of this is cultural material including images, sound, text, research data, and catalogues of collections. Materials such as works of art and music are also being created in digital form only, as 'born digital' objects with no physical existence, while other digital materials such as computer games are being increasingly considered as having cultural value.

Much of this digital cultural material is ephemeral, but a substantial proportion has long-term value, and museums, archives and libraries – 'memory institutions' – are increasingly faced with the need to preserve it. This preservation is complex and difficult, but there is a great deal of work focused on understanding and developing the means to preserve it, being done both in the UK and internationally.

There are two major aspects to the preservation of digital materials: the practical and technological challenges that are within the control of the owning organisation, and the political and organisational context that is not. Because of the seeming need to understand computer processing technology in depth for digital preservation, many conservators might think it outside their remit. However, this article will show that, as with physical objects, the most important factor for successful preservation of digital materials is the ability to analyse problems from a preservation viewpoint. This article then is not a manual for digital preservation; rather, it aims to raise awareness among conservation practitioners of this increasingly important area.

Digital materials and digital preservation

Much digital material consists of representations of physical objects such as images, documents, or of recordings of real performances of music. Other digital material is known as 'born digital' – for example, works of art or digital music that are created solely in digital form. Increasingly, scholarly journals are published only digitally.

Digital materials are different from previous comparable media. Films, records, audio tapes and books are all physical media, and each carries a different kind of content: images or sound or words to be comprehended. 'Digital materials', the term used in this article, are generic: their content ranges from images and sound to data and electronic text that can be analysed. Their use to convey touch is quite well established, and even smell is being explored. Digital materials are all similar, whatever kind of sensory content they represent. They consist fundamentally of binary states (on/off, positive/negative charge, etc.) stored on physical media. But though simple at this level, they are very complex, because to re-create the content they represent it is necessary to use a computer to process the physical binary states electronically as digits (hence the term 'digital'). Eventually the content is re-created, as light waves, sound waves, pressure or scent molecules that can be perceived as text, image, sound, physical touch or smell.

Because digital materials are basically made up of simple binary physical states, they can be copied perfectly and stored on a whole range of different physical media – hard disks, optical media such as CD ROMs, magnetic tapes, electronic chips – a range which is constantly being extended. The computing systems needed to process the electronic data and deliver the content are an interaction of complex physical devices (hardware), and processing instructions (software). The rate at which this digital electronic technology is evolving means that to preserve digital materials, it is not sufficient to consider only the physical storage of the material, the means of processing the data to re-create the content must also be tackled. While it would be feasible to make a special machine to play a film, record, or tape stored on an old analogue format, the re-creation of an obsolete computer together with its software programs is a far more complex matter.

Furthermore, while small damages to physical objects over time may not be important, in the case of the digital materials they might well be catastrophic. These materials usually have to be 'bit perfect' – every binary state has to be present and correct – in order to be usable. Conceivably a process of digital restoration could be applied, but this could only work for the data representing the content, not for that relating to its processing.

Digital databases are a particular type of digital material. Here, individual building blocks of data are stored in such a way that they can be assembled and presented in many different ways, or analysed and synthesised to produce new information. Not only must the data be preserved, so must information about the structure of the storage. The usefulness of a database often depends on its compatibility with the software used to create and manage its structure.

Much work on digital preservation is in progress (see the websites listed later). For example, in the UK, some of the major users and creators of digital materials such as the British Library and university research libraries have established the DPC (Digital Preservation Coalition). There is also considerable literature, much of which is on line. A useful summary of the issues surrounding digital preservation is to be found in Moving Theory into Practice: Digital Imaging for Libraries and Archives (Kenney and Rieger 2000). The DPC's Handbook, Preservation Management of Digital Materials (Jones and Beagrie 2001), and its accompanying website, provide an authoritative overview of problems and practicalities. The CAMiLEON project (see Websites: CAMiLEON project), which is also tackling these issues, has provided a discussion paper that illustrates many of the difficult decisions that have to be taken (Wheatley 2001). Useful insights from a conservator, focusing on the peculiar nature of digital materials and the concepts of distinguishing content from medium, are provided by Howel (2001).

Practical and Technical issues

The three main components of digital materials have very different life spans: binary data can last forever, but software usually lasts for decades, and hardware often becomes obsolete after only a few years. While data can exist independently of the computer systems that deliver its content, as computer technology evolves, the data may no longer be accessible because of incompatible formats and technology.As a result, there are a number of practical issues that are within the control of an organisation that must be addressed if the digital material it owns is to be preserved.

Policies for preservation

The preservation of digital materials depends on a continuing pro-active process: passive preservation alone, or benign neglect, will not suffice. Preservation strategies (preventive conservation) for physical objects normally seek to establish an environment that will halt or slow down their deterioration so as to reduce the need for interventive treatment. Although this requires specification, implementation, monitoring and adjustment, a degree of failure does not usually result in catastrophic loss. However, if digital materials were simply stored on a recommended medium and kept in a suitable environment, in years or decades hence, because of the comparatively short life spans of software and hardware, they would become inaccessible. Action, which inevitably incurs cost, is needed.

Moreover, many digital materials are not created simply to be stored: most are actively used in research, interpretation, collections management, or commercially as with digital images. They are more like historic working objects in this respect. However, many organisations have ceased to run such objects in part because of cost. Where digital materials to be preserved are on a large scale, the continuing planned action and procedures to manage these processes is very costly in terms of staff, equipment and finance (Besser and Yamashita 1998).

In order to keep costs manageable, the amount of digital material to be preserved needs to be as low as possible. Hence policies on what is to be preserved are essential. For this, digital materials can usefully be designated for short term, medium term, or long term preservation (Jones and Beagrie 2001: 4.2). Short term materials might include the equivalents of printed visitor information – and this might well be easier to preserve in printed form. Medium term materials might, for example, be exhibits created for the web, which might not need to be preserved for any longer than physical galleries and exhibitions need be. On the other hand, the meticulously assembled data in a collection database which maintained accountability for the collections and embodied the knowledge of staff across a whole museum, would be an example of material requiring permanent preservation. Policies are needed not only on which digital materials require long term preservation, but also to establish the necessary procedures and processes and to provide the requisite resources.

Actions needed
At, or close to the time digital material is created, a decision needs to be made as to whether it is of long term, medium term, or short term value. This will dictate the subsequent plan of action for preservation of the material, and is comparable to the decisions needed when a working physical object is acquired, and to making a conservation and maintenance plan for it (Paine 1994, 5.12).
Short term digital materials will need little subsequent action. For preservation for the medium term, materials require day-to-day management as well as backup to make sure they remain accessible for as long as required. Plans for the preservation of materials for the long term require careful attention to a number of factors. These include the standards adopted in creating them, which storage media to use, how frequently backup copies are made that can be used in case the primary version is lost or damaged, formats for the data, and to the strategy for ensuring that the data can continue to be processed by software and hardware as computer systems evolve (see below).

Retrieval and identification

Just as for physical objects, to record their identity and significance within a collection, information about digital materials needs to be collected and attached to them. This identification information is stored electronically, and is known as 'metadata' because it is data about data (Kenney and Reiger 1999: Ch5). It is arguably even more important to record information about digital materials than about physical objects. Many (though not all) physical objects can be recognised by visual inspection and matched to their catalogue or inventory description. Similarly, it might be possible in some cases to open and recognize an unlabelled and uncaptioned file containing a digital object. However, there can be vast quantities of such files (is this not a useful point?). On top of this there is an extra dimension to digital as opposed to physical objects: that is the possibility of retrieving the 'objects' themselves by electronic searches. This is normally only possible if metadata are attached to the files. Once again it is the ability to process digital materials using computers that makes the difference.

Actions needed
Digital materials should be adequately catalogued at the time they are created. Before embarking on a substantial digitisation project, the metadata scheme needs to be carefully worked out. Normally this will be based on the Dublin Core. This is a set of information headings, agreed internationally, that form an adequate basic metadata record for any cultural item. Dublin Core headings include a title, the creator, the subject, a description of the content, the publisher, and so on. Although these do not provide a full description of the digital material, consistent use of the Dublin Core headings across different collections will mean that different digital 'collections' are at least catalogued in comparable ways (see Websites: Dublin Core Metadata Initiative).

The process of cataloguing the digital materials as they are created may well be the slowest part of a project. This mirrors the experience of adding physical objects to collections, where information about the provenance and significance of the object (its catalogue information, or metadata) is being perceived as ever more important, and documentation is consequently more and more time consuming.

Technological obsolescence

"To access the data we need the originating software. To run the software we need the operating system it was

designed to run on. To run this operating software we need the hardware it was designed to run on."
– British Library Research Report, 1996

Rapid obsolescence is a consequence of rapid technical development. Both software and hardware evolve (Jones and Beagrie 2001: 2.2). The result may be that digital materials cannot be processed by new computer systems, and hence that the content is lost.

Some important kinds of digital materials are particularly vulnerable to technical obsolescence, especially those that are highly interactive, such as computer games, which of their nature depend on highly specific computer systems. Some museums, such as the Design Museum, are beginning to collect computer games, designating them for permanent preservation, and so are beginning to address these challenges. On the other hand, some of the people who created the earliest web exhibits are resigned to their creations becoming inaccessible to most people, because the software and hardware in general use can no longer deal with the exhibits. This, however, is little different from physical exhibitions, which are normally removed from a museum without trace. Perhaps web exhibits might be compared to live arts performances, where part of the appeal is the evanescence of the event.

Although the loss of digital materials of short-term value may not be a problem, the loss of others can be very regrettable. Although analogue, the BBC's Domesday videodisks give a striking example of the problems of technical obsolescence. The BBC commemorated the thousandth anniversary of the compilation of the Domesday Book itself by commissioning records of every parish in England from local schools. Two analogue videodisks were produced to provide a twentieth century version of Domesday. Yet videodisk technology was never widely adopted and was in practice used only for a few years. Fifteen years after they were made, only a few Domesday Disks survive, with even fewer of the machines that can deliver the content. The way forward is to convert the content from analogue to digital, something which is fortunately being attempted alongside the USA/UK CAMiLEON project (Wheatley 2001).

Actions needed
First, to ease problems of obsolescence, the design templates and means of presenting data can be treated differently to the data itself. The former can be considered short term, while the data is designated long term for preservation.

Secondly, technical standards which are already internationally accepted and in common use should be adopted. For example, there are internationally recognised standard formats for images, text, sound and other media (Jones and Beagrie 2001: 5.2). It will be easier and less costly in the future to convert digital materials for use on new database software and hardware if they comply with these standards.

In the case of images, it may be more cost effective in the long run to retain an archive of physical photographic images alongside the digital files. This is because the cost of re-scanning the photographs for use in new computer systems may prove less than converting the digital files to new generations of technology. The preservation of photographic materials, though difficult, is well understood, and initial layout to make a physical photograph at the same time as a digital one is low. However, there will be the added costs of cataloguing and maintaining a physical film archive as well as the digital materials.

Further options for ensuring that digital materials remain usable are discussed in Jones and Beagrie 2001: 4.3 and in Wheatley 2001. There are two main approaches. The first is emulation, where software is written to enable a particular type of computer to behave and look like a different type of machine and to run software specific to the other computer. A commonplace example of emulation is the software that can be run on Macintosh computers so that they work like Windows machines. Some of the advantages claimed for emulation are that original digital productions can look and feel the same as they did originally, and that the original data and software do not have to be re-written or digitally manipulated, and are therefore more nearly authentic (Rothenberg 1998; Wheatley 2001).

The second approach is migration: the conversion of the digital material into a new format that can be run on new generation software and new machines. Thus digital materials are transferred from one generation of technology to the next. Migration preserves the information content of the digital material but does not necessarily result in an exact digital replica, nor in the original features of display and appearance. The latter may be important, for example in the case of computer games (Wheatley 2001).

It is often said that the most effective way of preserving digital materials is to keep using them. In this way small upgrades or modifications are made as software and hardware evolves to ensure that the digital material remains usable, and any problems become apparent and can be addressed immediately.

All these solutions, however, raise questions of authenticity (see below).

Physical deterioration

Storage media for digital materials are physically not very durable. They are composite, being made of a number of different materials such as synthetic resins, metals, and carrier media. The different materials have different requirements for preservation and can adversely affect each other.

Jones and Beagrie (2001: Fig.7 p.130) cite predictions of 30 years life span for CD ROMs, if stored in optimum conditions (25% RH and 100C) and 75 years for CD/DVD disks. But different claims are made for the longevity of the various digital storage media. This may be because longevity is affected not just by the use or storage environment, but by the particular manufacturing specification and manufacturer. Digital media may also suffer scratches, breakage and so on. More inherently durable media are being developed, but it is clearly hard to manufacture materials that last anywhere near as long as those used historically, such as vellum and rag paper, that have survived for centuries often in less than optimum conditions.

Actions needed
It will almost certainly be necessary to adopt ongoing media reformatting. In this, data are copied from an existing storage medium to a new one in order to circumvent the problems of both technical obsolescence and data being lost due to deterioration of the storage media.

Media reformatting of personal files by individuals may not be thought of as particularly problematic. However, when it is applied to the digital materials of an organization, it becomes extremely onerous. For example, even though the reformatting CD ROMs can partially be automated, where there are any quantity of them the task becomes enormous. Also, if the CD ROMs are an un-used archive, the organisation needs some means of monitoring the disks to make sure they are reformatted before they start to deteriorate. Thus, even the apparently comparatively straightforward business of media reformatting at appropriate intervals requires thought-out policies, procedures and resources, both financial and staff.

Maintaining authenticity

Authenticity means that digital material is what it purports to be. Authentication is the process that would attempt to establish the degree of authenticity (Jones and Beagrie 2001: 2.2).

The concept of authenticity is difficult to apply to digital materials, since of their nature they require processing which means they are digitally manipulated, often re-saved in a different form, and that it is good practice to make multiple copies. The very ease with which digital materials can be altered makes it even more important to users that they have some assurance that the digital resource is actually what it is described as. This is crucial to maintaining the trustworthiness of an electronic record, and especially to ensuring that a `born digital' object is the same as it was when it was first created.

Digital materials, especially cultural ones, have a market value. For example, already art curators are collecting work in what they see as a highly influential and popular medium – that is, computer games – and artists and composers are creating original works in digital media. The economic value of digital cultural materials is also attested by the level of investment by commercial picture libraries in digitising their images. As long ago as 1995 the Wall Street Journal (23.1.95) reported that acquisition of digital reproduction rights was already one of most important new art markets in Europe.

It would be comparatively easy for digital fakes to be created, especially as passages of computer code can be cut and pasted from one file to another. It is common for website designers to re-use parts of existing website designs in ones that they are creating. Again, a dealer might claim that a digital image in their possession was the only record of a destroyed or vanished physical object such as a painting. Such an image, if authentic, might well have considerable commercial value, but in fact it might be an edited copy of an image of an existing object. A digital record of an entire non-existent collection could be faked in this way.

The process of preserving digital materials by media migration inevitably results in changes to the way that their content is represented. Howell (2001) argues that it is the information, i.e. the data, we should be concerned about, not their representation. But is the message entirely independent of the medium? Is it unimportant that something that purports to have been created in the year 1996 is, in 2096, actually nothing of the sort? Even if emulation is used to enable the digital material to be run on the original software, there will be subtle differences (Wheatley 2001). However, this applies to physical objects as well; few historic objects appear the same today as they did originally.

Actions needed
Watermarking can be used, in which digital identification data are inserted into digital material, normally to protect copyright and ownership. Digital watermarks are invisible or inaudible to users, but the watermarking software can identify them. Ironically, because watermarks often make the digital material impossible to copy, they can make preservation more difficult. Digital materials, including databases such as museum collections management systems, usually require the author and subsequent editors of data to be recorded. It can be very important to know the originator of a piece of information (Museum Documentation Association 1997). The security implications of allowing anyone to alter records are obvious: was that teapot silver, or silver plate? was the medal copper alloy or gold?

Documentation, as much on paper as digitally, may be the principle means of assuring authenticity for digital materials just as it is for physical ones.

Broader contextual issues

The factors described above that affect the preservation of digital materials are difficult, but not impossible, to deal with: they are all within the control of the organisation that holds the material, and they relate to the foreseeable future. But what of broader influences? Benarie introduced the idea of analysing the physical, political and social factors which enable the long term survival of cultural materials (Benarie 1987). Might these factors have the same effect on the survival of digital cultural materials as they do on physical objects?

It can be seen that physical properties of objects such as bulk and strength (as in a building), or being made from durable materials, can aid survival. Digital materials do not have these beneficial characteristics. Also, physical objects may be deposited in climatic environments such as sealed tombs or caves, that fortuously lead to their preservation over a very long period. A stable physical environment such as these are not sufficient for the preservation of digital materials: active management to avoid the problems of the technical obsolescence of hardware and software is also needed.

Political stability is an important factor in the survival of physical objects. Many are vulnerable to destruction deliberate or otherwise during civil unrest or war. In some respects, digital materials could be likewise vulnerable: computers might well become political targets, and most digital materials require clean, stable environmental conditions. However, in other respects they may be less vulnerable: controversial digital materials may be less easily identified, and they are not made of valuable reusable materials.

Ownership also influences survival. When a physical object is created, it has a greater chance of surviving if it is highly valued, since it is likely to be prized by its owner as denoting wealth or high social class. For digital materials, this value usually arises from the advantage the information they contain gives the owner. It is thought unlikely that this particular value will persist because the information will lose its currency or uniqueness. In the long term, both physical and digital materials have a higher chance of surviving if they belong to a large permanent organisation such as a government, a religious organization, or a memory institution, because it is usually important to such institutions to maintain records of their transactions and their history. Many important digital materials are indeed created by such institutions. On the other hand, such ownership can make them targets for destruction during political unrest as discussed above.

It is concluded that digital materials only benefit from a limited number of the broader factors which are conducive to the survival of physical objects. However, there are other over-arching factors which will benefit digital materials but not physical objects. One is their obscure nature, meaning that specific items are not easy to seize in times of conflict. Another could be the internet. In a sense digital materials exist not in the physical world, but in the context of the pervasive digital electronic communications medium, the internet. The very nature of the internet, where damage to any one part is inconsequential for the operation of the whole, argues that important materials will survive. Communication is so rapid and effective that a threat to important digital cultural materials would be communicated almost instantly, enabling evasive action to be taken. The ability to make multiple perfect copies which can be quickly sent to and stored in many different places would enhance their chances of survival.

This relatively un-planned survival could be envisaged as analogous to the passive preservation of physical objects in a sealed tomb or cave.

International collaboration

The issues and importance of preserving digital materials are being recognised, and this is the focus for a great deal of international effort. A number of projects have been funded to investigate the issues of preserving the enormous amount of digital materials for education and cultural purposes in which governments such as the UK, the USA, Canada and Australia, have invested heavily. National libraries are being particularly active. Most of these projects involve international collaboration but there are other initiatives being undertaken to archive material of specifically national significance, for instance by the National Library of Australia. The Appendix to this article gives details of the organisations and projects involved and their websites.

Conclusion

It can be seen that one of the most important factors for successful preservation of digital materials is the analysis of the problems in ways very familiar to conservators used to dealing with physical objects. Many people today see the present as “one of those times in history when humanity transforms from one type of human society to another ... with technology as the catalyst” (Hillis 1997). In times of change, conservation becomes more important than ever, and practitioners have much to offer from their experience and skills.

From such an analysis, a number of factors have become clear. Among these is the need for appropriate preservation policies and resources which address problems of retrieval, technical obsolescence, physical deterioration, and authenticity. For each of these problems, it has been possible to suggest a course of action which an owning organization can follow. However, only some of the broader contextual issues that benefit the survival of physical objects are relevant to digital materials. Thus, while they too benefit from being owned by powerful, permanent institutions, their preservation by chance is improbable. Nevertheless, there is much national and international work in hand on digital preservation.

While it is suggested here that the internet could in fact constitute a special context that might lead to the unplanned survival of some digital cultural material, in general, a pro-active approach to preservation is crucial. JG Ballard, in his science fiction story, The Time Tombs, imagines the operations of desert tomb robbers a couple of millennia hence (Ballard 1980, 19-34). The robbers are not searching for gold and silver; the treasures are tapes that, when the tomb is disturbed, will create a virtual reality image of the buried person. They are the virtual equivalents of the well-known burial portraits from Roman Egypt. Furthermore, in the story, the tapes have a high market value. If such a story were a reality it is conceivable that tapes (and the entombed hardware) could survive, just as physical objects in Egyptian tombs have done. But it is highly unlikely that such survivals from the dawn of the Information Age would remain accessible as they had not been subject to continuous active preservation measures.

A note of scepticism has been sounded throughout this article about the chances of digital materials surviving in the very long term. But perhaps this is too pessimistic. First, there is the special nature of the internet, as yet barely understood. The internet is the sum of the resources, effort and intentions of every individual that uses it. Many people will be interested in and committed to the survival of digital materials. For example, in 1996 two individuals recognised that the world wide web was an evanescent medium, and founded the Internet Archive in order to permanently preserve important materials from it. Its historic archive, the Wayback Machine, can be accessed by anyone, using an ordinary browser (see Websites: the Internet Archive). Then, paralleling the popular interest in keeping physical working objects in running order, there is the thriving community of people making software to emulate early games machines so that they can continue to run their favourite Atari computer games. Many people are willing to go to considerable lengths to decipher and re-create operating systems for long deceased machines – from all of 50 years ago!

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References

Ballard, J.G. 1980. The Time Tombs. In: *The Venus Hunters*. London: Granada Books, pp 19-34.

Benarie, M. 1987. *European Cultural Heritage: Newsletter on Research*. Vol 1 no.4, October, p 7.

Besser, H. and Yamashita, R. 1998. *The cost of digital image distribution. The social and economic implications of the production, distribution and usage of image data*. Report produced by the School of Information Management & Systems, UC Berkeley. Museum Education & Site Licence Project. Marina de Rey: Getty Information Institute / Mellon Foundation.
Also online: http://sunsite.berkeley.edu/Imaging/Databases/1998mellon/

Hillis, W.D., 1997. A Time of Transition \ the human connection. *Communications of the Association for Computing Machinery*, Vol. 40, No. 2. Also online: http://www.longnow.org/about/articles/ArtHuman.html

Jones M and Beagrie N. 2001. *Preservation management of digital materials*. London: British Library.
Also online: http://www.dpconline.org/

Keene S. 1998. *Digital collections: museums and the information age*. Oxford: Butterworth-Heinemann.
Accompanying website: http://www.suzannekeene.info

Keene S. 2002. *Managing conservation in museums*. 2nd edn. Oxford: Butterworth-Heinemann.

Howell A. 2001. Preserving information in a digital age. What's the difference? *The Paper Conservator* 25, 133-50.

Kenney, A.R., Rieger, O.Y. (eds.), 2000. *Moving Theory into Practice: Digital Imaging for Libraries and Archives*. Mountain View, CA: Research Libraries Group.
Accompanying website: http://www.library.cornell.edu/preservation/tutorial/

Museum Documentation Association 1997. *SPECTRUM: The UK Museum Documentation Standard*. 2 edn. Cambridge: Museum Documentation Association.

Paine, C., (ed). 1994. *Standards in the Museum Care of Collections: Larger and working objects*. London: Museums and Galleries Commission.

Rothenberg J. 1998. *Avoiding technological quicksand: finding a viable technical foundation for digital preservation*. Washington DC: Council on Library and Information Resources / European Commission on Preservation and Access.
Also online: http://www.clir.org/pubs/reports/rothenberg/contents.html

Wheatley, P. 2001. Migration – a CAMiLEON discussion paper *Ariadne*. Issue 29.
Also online: http://www.ariadne.ac.uk/issue29/camileon/intro.html

Websites

CAMiLEON project
A partnership between the Universities of Leeds and Michigan, investigating particularly the feasibility and implications of migrating digital materials from one system to another, and of developing emulations.
http://www.si.umich.edu/CAMILEON/

CEDARS project
An electronic libraries project that has been broadly investigating issues around digital preservation.
http://www.leeds.ac.uk/cedars/

Digital Library Federation

Good links and information on this topic, from this USA organisation.
http://www.diglib.org/preserve.htm

Digital Preservation Coalition
The DPC is a partnership of major information organisations in the UK, including the British Library, the Public Record Office, University Research Libraries, and many other similar organisations.
http://www.jisc.ac.uk/dner/preservation/prescoalition.html

The Domesday Disks
Finney, A., 1988, 1996 and 2002. Domesday – the Domesday Project.
http://www.atsf.co.uk/dottext/domesday.html

Dublin Core Metadata Initiative
http://dublincore.org/

The Internet Archive
http://www.archive.org

PADI (Preserving Access to Digital Information)
From the National Library of Australia. Subject gateway with excellent links to this topic.
http://www.nla.gov.au/padi/

PANDORA
Preserving and Accessing Networked Documentary Resources of Australia. A project to create a digital archive of important material relevant to Australia, in just the same way as a national library does for printed material.
http://pandora.nla.gov.au/

Research Libraries Group (RLG)
Work on the implications for libraries of on line information. See report: Digital preservation needs and requirements in RLG member institutions.
http://www.rlg.org

Appendix: International work on digital preservation

The UK has been a leader in creating on line resources for culture, education and learning. In particular, the university community has made very large investments through the Joint Information Systems Committee (JISC). From 1998 – 2002 the CEDARS project investigated these issues. Recently the Digital Preservation Coalition (DPC) has been formed, as a partnership of major UK information organisations, including the British Library, the Public Record Office, large university research libraries, and other similar organisations. Both these and CEDARS have valuable information on their websites, and the DPC has published a handbook which reviews problems and solutions in greater depth and detail.

Other digital preservation initiatives in Europe include ERPANET, a network of the European Commission, that aims to establish a virtual clearinghouse and knowledge-base on state-of-the-art developments in digital preservation. Focusing on the areas of cultural heritage and scientific objects, it will facilitate the transfer of expertise, information, best practice and skills development among individuals and institutions.

In the USA, the Digital Library Federation website has a good description of work in the US. The National Digital Information Infrastructure Preservation Program is funded by Congress to take an overview of these issues. It is commissioning a survey of national preservation initiatives and holding stakeholders' meetings. The Digital Library Federation itself is tackling the very difficult issues of electronic scholarly journals (unlike journals in print form the subscribing library does not physically possess the volumes, and is reliant on the publisher for maintaining them as an archive). The Federation has published a number of reports.

Other USA organisations working in this field include the Council for Library and Information Resources (CLIR), which maintains an overview. The CLIR has published a report on a national strategy for digital preservation. Foundations that have a presence in digitised material, particularly the Mellon Foundation, are also funding work on digital preservation (e.g. Besser and Yamashita 1998).

PADI (Preserving Access to Digital Information) is operated by the National Library of Australia. It aims to provide mechanisms for preservation, through encouraging strategies and guidelines, and promoting relevant activities, and through providing an informative website and discussion forum. Again from the National Library of Australia, PANDORA (Preserving and Accessing Networked Documentary Resources of Australia) was set up in 1996 in recognition of the increasing importance for national life, scholarship and culture of the electronic resources on the internet. PANDORA captures and archives material of significance to Australia and Australians.

Most of these projects include international collaborations. The Research Libraries Group (RLG) has as its members national libraries and archives and many of the leading universities and knowledge organisations throughout the world. It has a dedicated project, PRESERV, working on digital preservation. A recently established joint UK / USA project is CAMiLEON; the partners are the University of Leeds and the University of Michigan.