Preserving Moving Pictures and Sound

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Foreword

The Digital Preservation Coalition (DPC) is an advocate and catalyst for digital preservation, ensuring our members can deliver resilient long-term access to digital content and services. It is a not-for-profit membership organization whose primary objective is to raise awareness of the importance of the preservation of digital material and the attendant strategic, cultural and technological issues. It supports its members through knowledge exchange, capacity building, assurance, advocacy and partnership. The DPC's vision is to make our digital memory accessible tomorrow.

The *DPC Technology Watch Reports* identify, delineate, monitor and address topics that have a major bearing on ensuring our collected digital memory will be available tomorrow. They provide an advanced introduction in order to support those charged with ensuring a robust digital memory, and they are of general interest to a wide and international audience with interests in computing, information management, collections management and technology. The reports are commissioned after consultation among DPC members about shared priorities and challenges; they are commissioned from experts; and they are thoroughly scrutinized by peers before being released. The authors are asked to provide reports that are informed, current, concise and balanced; that lower the barriers to participation in digital preservation; and that they are of wide utility. The reports are a distinctive and lasting contribution to the dissemination of good practice in digital preservation.

This report was written by Richard Wright, a specialist in audiovisual preservation and formerly technology manager of the BBC archives. The report is published by the DPC in association with Charles Beagrie Ltd. Neil Beagrie, Director of Consultancy at Charles Beagrie Ltd, was commissioned to act as principal investigator for, and managing editor of, this Series in 2011. He has been further supported by an Editorial Board drawn from DPC members and peer reviewers who comment on text prior to release: William Kilbride (Chair), Neil Beagrie (Managing Editor), Janet Delve (University of Portsmouth), Sarah Higgins (University of Aberystwyth), Tim Keefe (Trinity College Dublin), Andrew McHugh (University of Glasgow) and Dave Thompson (Wellcome Library).

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Abstract

This report is for anyone with responsibility for collections of sound or moving image content and an interest in preservation of that content. New content is born digital, analogue audio and video need digitization to survive and film requires digitization for access. Consequently, digital preservation will be relevant over time to all these areas. The report concentrates on digitization, encoding, file formats and wrappers, use of compression, obsolescence and what to do about the particular digital preservation problems of sound and moving images.

Executive Summary

The status and technology needs of moving picture and sound materials will be examined. The scope of the report includes analogue material on physical carriers such as film, audiotape and videotape (and so stored on shelves); digital material on physical carriers such as CD, DVD, digital videotape and digital audio tape (also stored on shelves); and finally, digital content in files and so held on some form of mass storage. While the focus is on professional collections in institutions, companies or other organizations, the information will be relevant to personal holdings.

The audiovisual domain is unique in that digitization is routinely critical to preservation. Audiovisual digitization for preservation is so pervasive that the two words have come to be used interchangeably – an issue which this report seeks to clarify. Audio and video need digitization for the very survival of their content, owing to the obsolescence of playback equipment and decay and damage of physical items, whether analogue or digital. The basic technology issue for collections of moving images and sound is the necessity to digitize all content currently sitting on shelves. Film on shelves can be conserved (unless it is already deteriorating), but still needs digitization to provide access.

Moving image and sound content is at great risk. Surveys (such as Klein and de Lusenet, 2008, p.125) have shown that 74 per cent of professional collections are small: 5,000 hours or less. Such collections have a huge challenge if their holdings are to be digitized. About 85 per cent of sound and moving image content is still analogue, and in 2005 almost 100 per cent was still on shelves rather than being in files on mass storage (Section 4.1). Finally, surveys have shown (Section 3.2) that in universities there is a major problem of material that is scattered, unidentified, undocumented and not under any form of preservation plan. The quoted surveys are from Europe and North America because there is no survey of the situation in the UK, in itself a cause for concern.

The next technology issue is moving digital content from carriers (such as CD and DVD, digital videotape, DAT and minidisc) into files. This digital to digital 'ripping' of content is an area of digital preservation unique to the audiovisual world, and has unsolved problems of control of errors in the ripping and transfer process (Section 4.2).

The final technology area is digital preservation of the content within the files that result from digitization or ripping, and the files that are born digital. While much of this preservation has problems and solutions in common with other content, there is a specific problem of preserving the quality of the digitized signal that is again unique to audiovisual content. Managing quality through cycles of lossy encoding, decoding and reformatting is one major digital preservation challenge for audiovisual files (Section 5.3). The other issue is managing embedded metadata (Section 5.2.1).

This report describes the techniques needed for preservation planning, digitization and digital preservation of audiovisual content. Standard and emerging technologies in audio, video and film digitization are described. The implications for small collections are addressed (Section 8).

A vital issue in preservation is access: motivation and funding for digitization purely for preservation purposes is difficult, if not impossible. There is great public, institutional and educational interest in the audiovisual record of the twentieth century. Creating access (Section 7) to that record is the key to obtaining the support needed for the digitization and preservation of the content.

1. Introduction

The landscape for 'moving pictures and sound' is complicated:

physically, there are large differences between audio, video and film recordings. The formats and record/playback equipment are completely separate; the digitization procedures are different; the digital files have different wrapper formats and metadata (with some overlaps); and the storage requirements differ, with video taking roughly 100 times as much storage per second of material as does audio, and high resolution digital film taking roughly 10 times more storage than video;

culturally and economically, there are significant preservation and curation differences between collections from:

- **commercial media industries** – music, cinema and commercial broadcasting where preservation needs a commercial justification, a business case;
- **public bodies** – public service broadcasting, academic collections and heritage institutions such as national museums, libraries and film institutes where preservation needs a cultural heritage justification, though increasingly this sector also needs a business case;
- **technical areas** such as medicine, geology and surveillance, where recordings of images or of seismic events are raw data, kept as medical records or for reprocessing; and
- **other –** a wide range of independent collections, ranging from individual efforts to material gathered by non-profit specialist institutions (for example, steam engine clubs or ethnological research) that do not fall into any of the above categories, though their material may eventually end up being donated to a public collection.

Within the landscape is a range of technologies including engineering, computing, Internet technology, archiving, media management, museum collections management, curation, preservation, access, knowledge management and resource discovery.

Audiovisual archives are young institutions with (relatively) young content: no major collection predates the twentieth century. While the BBC had a formal, catalogued gramophone collection that began around 1930, the formal television archive only dates from 1972. The British Film Institute was founded in 1933, and the British Library Sound Archive was founded (as the British Institute of Recorded Sound) in 1955, though both have much older material in their collections. The Imperial War Museum in London (one of the first institutions to collect film) was founded in 1919.

These collections hold the sound, image and moving image recordings from a technology less than 200 years old: photography from the 1830s, sound recordings from the 1880s and motion picture film from the 1890s. The twentieth century brought audio and videotape formats, and then digital media: CD, DVD, DAT tape and minidisc. The proliferation of formats and consequent obsolescence of those being replaced is a major problem in preservation of audio and video media. The complexity of sound and moving image media cannot be ignored and should not be oversimplified: audiovisual content requires specialist knowledge.

2. Basic Concepts and Terminology

Audiovisual recordings are surrogate reality. The technology allows the listener and viewer to get a sensation of what a situation sounded and looked like, but the technology actually only captures the sequence of light patterns or sound pressures acting on the recording instrument (camera, microphone). These patterns (for film) and signals (for video and audio) are more like data than like artefacts. The preservation requirement is not to keep the original recording media, but to keep the data, the information, recovered from that media.

2.1. Stages in sound and moving image digital preservation

For sound and moving image preservation, the following stages in the overall process need to be kept clear:

- **signal**: the audio from a microphone, the video signal coming out of a video camera. These signals have physical properties (bandwidth; dynamic range) that can be defined and measured. The quality of a recording and the success or failure of any process of copying, digitization or preservation can be reduced (in large part) to how well that process maintains these two physical properties of the original signal;
- **recording of a signal onto a carrier** (also called support, physical medium or recording format). For a century, the methods of capturing a signal were tied to the carrier of the signal: a wax cylinder, film reel or videotape. Digital technology produces recordings that are independent of carriers. Carrier independence is liberation: discs, tapes and films deteriorate or get damaged. Born digital recordings are liberated from these carrier-based problems, leading to a desire to liberate analogue recordings by digitization;
- **digitization**: analogue recordings can be played back and recorded onto a new carrier, or digitized and so released from carrier dependence. Digitization has to ensure that the digital version has the same bandwidth and dynamic range as the original, to capture the original quality; and
- **digital preservation of the digital representation of a signal**, meaning preserving the numbers, but also preserving the technology needed to decode (render) the numbers. Audiovisual content has a particular problem. The coding of the signal can be a compromise, not actually capturing the full signal, but instead losing some of it (lossy encoding) to get a more compact representation, thus reducing storage and transmission costs. Unfortunately coders/decoders (codecs) go out of use, and are replaced by newer technology. The file format holding the coded signal, the wrapper, is also subject to obsolescence. The failure and obsolescence of storage technology and the obsolescence of encode/decode methods and wrapper formats are major digital preservation problems for audiovisual content.

2.2. The three kinds of audiovisual recordings

Sound and moving image recordings can be divided into three technical groups:

1. analogue recordings: vinyl discs, magnetic audio tape, VHS and U-matic videotape and film are all analogue technology. The recording medium (the carrier) is an integral part of every analogue recording system;
2. digital recordings on dedicated physical carriers: audio CDs, minidiscs; video DVDs, DV tape. These are recordings that use numbers to represent the sound or moving image, but as with analogue recording, there is a specific medium or carrier (and its associated read/write technology) that is an integral part of the recording method; and
3. digital recordings that exist as files on digital storage. Modern equipment can record sound and moving image representations directly into the device's memory, at which point the recordings are files and have an existence that is independent of any particular storage media.

The recordings described in point 2 are not files. Specific technology and workflow is needed to move such recording into files. For CDs and DVDs either the individual sounds or video clips are ripped from the original carrier, or a special file is created that is meant to be an exact image (clone) of the data on the CD or DVD. For minidisc and for digital videotape the technology needed has complications, described in Section 4.2.

2.3. Complexities of the video signal

An audio signal is a simple concept, easily represented on a graph as sound pressure vs time. Video is a signal representing the scanning of an image. The signal repeats as successive images are scanned: 30 per second in countries with 60 Hz mains electricity, and 25 per second where the mains frequency is 50 Hz. The signal is more complex than for audio. Each number (for a digital video signal) gives information about some point in a two-dimensional image, but which point requires a starting point and synchronization. An audio signal does not have synchronization issues: if some of the waveform or numbers are lost, the remainder make perfectly clear audio. If some of a video signal is lost, the playback system 'does not know where it is' and cannot make a sensible image until it can get information showing where an image scan starts.

In consequence, a video signal is a complicated waveform: a combination of image information and synchronization information showing the start of every image, and the start of every scan line in an image. A basic preservation problem for video is that any loss of signal in playback can cause loss of synchronization information and failure to form proper images. Individual lines can be lost, whole images can be corrupted because information is misinterpreted, and a whole sequence of many seconds or minutes can be corrupted and suffer from various kinds of instability ranging from minor shakes to total loss of picture.

Synchronization makes video playback more challenging than audio playback. Any attempt to play video carriers for preservation purposes requires special equipment that analyzes the video signal, keeps it in synch if at all possible, and actively regenerates a stable signal on output, despite having an unstable and incomplete signal on input – a time base corrector (TBC)**.** The technology is built into professional videotape players, and there are also standalone TBCs. Additional equipment may be needed: a filter to remove noise that would compromise a digitization process, a time code generator. All of these issues, and others such as proper setup of the playback machine, colour decoding and processing; proper capture of an interlaced video signal, make video playback (for preservation) a professional technical issue.

3. Preservation Issues for Sound and Moving Picture Content

This section reviews what is needed, and what is missing, in order to preserve moving pictures and sound.

3.1. Conservation and preservation: best practice

Conservation, preservation and digitization are related terms. This document uses the following definition:

Preservation is the totality of the steps necessary to ensure the permanent accessibility – forever – of an audiovisual document with the maximum integrity.
(Edmondson, 2004, p.20)

'Maximum integrity' means keeping the full quality of the audio and video, as set out in detail in Edmondson (2004, Section 6.4.6: 'As far as possible, the new preservation copy should be an exact replica of the original: the content should not be modified in any way'). Audiovisual archives are in a difficult position. Generally, they simply cannot keep their original artefacts for very long because of the factors of obsolescence, damage and decay (see next section). A format can become obsolete in a decade. Therefore they are continually making new master copies. In an analogue world they made new analogue masters. With the disappearance of analogue technology they now are literally forced to digitize, and the result of the digitization is a new master copy. There is also digitization just for access, and commonly digitization serves both purposes.

Audiovisual archives have a basic principle: a new master will contain as much of the quality of the original as is technically feasible, hence Edmondson's phrase 'maximum integrity'. Introducing a reduction in quality simply to save time or money or storage space is not supported by the Edmondson definition of preservation, which is also the agreed definition of the major audiovisual archive associations FIAT-IFTA (1996), IASA (2005) and AMIA (code of ethics, undated) as well as UNESCO and CCAAA (joint publishers of Edmondson, 2004).

Within preservation there are two broad categories: conservation and preservation actions. Preservation actions are interventions, and conservation is what is going on all the rest of the time. Digitization is just one type of preservation action. A file format migration (from an obsolete file format to a current format) would be another preservation action.

Conservation addresses prevention or delay of deterioration and damage. Conservation does not prevent obsolescence, which for audio and video is the main driver for migration from old carriers (formats) to new ones. A preservation action is an intervention taken when conservation is not enough. The typical case is making a transfer (migration) to produce a 'new master'.

Since about 1980, the range of possible preservation actions has expanded to include the option of digitizing content, making a transfer from analogue to digital. As discussed in Section 2.1, there are advantages in digitization as a migration preservation action. It:

- liberates the content from the carrier;
- (potentially) removes the problem of loss of quality whenever making a migration;
- allows production of access copies cheaply and quickly; and
- (potentially) enables all the access possibilities of Internet technology.

Conservation of analogue content can be divided into the following concerns.

- packaging, handling and shelving (storing): the immediate environment of a physical item;
- environmental conditions: essentially control of temperature and humidity, and the stability of that control, but also protection from anything harmful in the environment, such as dust, pollutants, magnetic fields, excess light or infrared and ultraviolet radiation;
- protecting the masters; and
- condition monitoring.

Physical conservation is described in detail in the PrestoSpace (2006) wiki.

3.2. Understanding the problem

The physical risks are well documented. Presto (2001) found (in a study covering four million hours of content) that 70 per cent of the audio, video and film was at immediate risk from obsolescence of formats and equipment, tape decay and damage to carriers.

A major preservation risk facing sound and moving pictures is lack of awareness, where an organization does not know the quantity, value, condition of, and risks to, its holdings, or understand the solutions and funding opportunities that may be available.

An organization may not have:

- a full inventory of its audiovisual holdings;
- documentation (cataloguing) for the holdings;
- playback equipment for all the various formats;
- technical skills for maintaining and operating all the equipment it does have;
- staff with specialist knowledge of audiovisual content;
- a collection strategy for moving picture and sound content, tied to an overall institutional strategy;
- a preservation plan for dealing with the risks facing the collection, and for developing the use and access that can realize the potential value of the materials; and
- adequate staffing and budget.

Evidence for this view comes from surveys from the Presto series of projects (Presto 2001, PrestoSpace 2004) and other major surveys including:

- TAPE's survey of 374 European audiovisual collections. Two thirds had no preservation programme (Klijn and de Lusenet, 2008, p.133);
- a thorough survey of a single major university (Indiana), tracking down all the sound and moving image content in all departments, and finding 600,000 hours, most of which was not being actively cared for in any fashion (Casey, 2009); and
- *The National Recorded Sound Preservation Study* (Bamberger and Brylawski, 2010) commissioned by the US Library of Congress in 2006. This study of audio collections in the USA reviewed previous work and undertook new work covering public sector institutions holding an estimated 46 million sound recordings. Among their conclusions: 'few institutions know the full extent of their holdings or their physical condition' (p.3); 'Few institutions have the facilities, playback hardware, and staff resources to preserve recordings' (p.4). Major sections of the report deal with the need for preservation education (pp.99–107), and the complicated 'conundrum' of preservation, access and copyright (pp.108–137).

4. Moving Into the File-Based World

4.1. Digitization of analogue material

Sound and moving picture collections are largely analogue. The TAPE (Klein and de Lusenet, 2008, pp.126, 128 and 131) study of 374 European collections gives detailed results on 19 million hours of film, audio and video, with 85 per cent of audio, 82 per cent of video and 96 per cent of film being held in analogue formats. Digital formats accounted for 3 million hours out of the 19 million (16 per cent). Most of the digital content was on dedicated carriers (audio CD, video DVD, DAT and MD audio formats, digital videotape formats) and not in files. The trend of course is toward more files and fewer physical holdings, but as of 2006 (when the TAPE results were collected) there were many tens of millions of hours of audiovisual content in formal collections in Europe, with negligible amounts held as files.

There are only three ways to preserve analogue content:

- conserve the originals;
- make copies of the originals, using the same or similar technology (dubbing analogue content onto new analogue carriers); and
- move the content onto new technology.

Keeping the originals is a basic principle of archiving (Edmondson, 2004, p.37) but does not solve the main preservation problems of obsolescence, decay and damage. In consequence, archives periodically make new masters, on the same technology (dubbing an old audio tape to a new one; making a print of a film) or on new technology (making a CD from an audio tape, digitizing a film).

For three decades for audio, and for at least two decades for video, archives have been digitizing their content. Regarding technology and the purpose of a *Technology Watch Report*, the technical problems are not the digitization itself. The problem areas are:

- successful playback of the originals, in order to get an optimal signal to digitize;
- standards: what compression level, encoding method and file format to use; and
- efficiency: digitizing the existing analogue materials fast enough and economically enough to cope with the size and urgency of the problem.

Playback of audiovisual carriers: there are two main problems for playback of all analogue media: 1) lack of equipment, spares, calibration materials and experienced operators; and 2) condition of the originals, which may be fragile or already damaged or decayed.

There is a particular problem for tape, common to audio and videotape (and also common to both analogue and digital tape, including data tape): sticky shed. This is the shedding of the oxide coating of the tape during playback, leading to clogging of the playback head and resultant loss of signal. Initially the signal loss is usually brief and intermittent, but eventually the playback machine can jam completely.

4.1.1. Audio digitization

While the standards for digitization of audio are well established, and fully documented in IASA-TC 04 (IASA, 2009; see Section 6), one remaining issue for audio tape is whether to increase the complexity of the digitization to also capture bias frequency. That information can be used to correct for any errors or distortions in the time domain, such as the wow associated with a cyclical variation in transport speed regulation, a common problem in analogue audio technology. The Clarity™ service (Howarth and Wolfe, 2004) from Plangent Processes can correct such problems, but only on an original recording (because it relies on the bias signal of the original recording). There is alternative technology from Cedar and Cube-Tec (two leading providers of audio restoration) that can (in some cases) correct for temporal distortions without use of the bias signal. A sensible way forward would be to use conventional digitization, but where an original audiotape recording can be identified, that original should be saved just in case someone in the future deems it worthwhile to capture the bias for timing correction. As a general issue of best practice, original analogue media should be saved wherever there are doubts about the quality of digitization.

4.1.2. Video digitization

For video, the major problems are:

- as for audio: equipment, operators, fragile and decaying media; sticky shed;
- as for all magnetic tape formats: head wear, head life, head replacement;
- time base correction (TBC): video has a synchrony problem, mentioned in Section 2.3. Equipment for older formats may not include TBC circuitry, or their performance may be poor compared to modern equipment. The result is a need to combine playback on old equipment with use of the latest TBC equipment to get the best result;
- dropouts and concealment: videotape playback equipment produces a continuous signal for real time recording (or viewing or transmission), and so the equipment continues to run whether or not it is reading usable data from the videotape. Simple equipment displays blank lines; more complex equipment repeats preceding lines (or entire frames) to replace the otherwise blank lines, a process known as concealment. Generally, there is no way to know what part of the digital signal has been generated by concealment; and
- colour decoding: many videotape formats mix the colour information with the brightness signal, creating *composite video* which needs to be decoded to be saved as a standard SDI (Serial Digital Interface) component digital video signal. There are different kinds of colour decoder, of varying quality. The best equipment for PAL (the UK composite colour system) decoding (Easterbrook, 2008) is not commercially available; eventually there should be software decoding that will outperform current hardware.

Because of TBC and dropout, the output of the playback process is not necessarily the same as the signal on the tape. Generally there is no way to measure the differences because of the internal processing to recover from, and conceal, errors. Emerging technology (Houpert, 2011) bypasses this processing, instead directly digitizing the signal from the playback head and doing all further processing in software. This approach is a breakthrough. The software can provide a complete log of errors and subsequent recovery or concealment.

Nevertheless, 'the better is the enemy of the good' (Voltaire, 1772). The urgency for audio and videotape is to digitize adequately as soon as possible, because the playback machines are already disappearing. The essential question is whether the content can be captured to the standard that audiovisual archivists have always used when making a new master – no perceptible impairments, no loss of sound and image quality.

Recommendations for digitization of videotape:

- analogue videotape formats (and obsolete digital formats such as D1, D3, D5) should be digitized NOW, using professional equipment and procedures. Current digital videotape formats (such the DV family, Digibeta) should, where possible, await developments in digital to digital transfers;
- if the original is composite, save the composite if possible and decode using the best available colour decoder in order to also save as component (the SDI standard); and
- if during any videotape transfer using conventional equipment, playback problems are encountered and cannot be resolved, conservation of the original videotape should be ensured so that the direct capture method (Houpert, 2011) can be applied if deemed appropriate.

4.1.3. Film digitization

Film can potentially be kept for centuries if stored under sufficiently cold and dry conditions (Niseen *et al*., 2002), but film that is already undergoing chemical decay, or needs digital restoration or needs digital access copies, requires digitization . Film digitization has the following issues:

- high cost and low speed of datacine equipment, though this is an area of rapid change with a range of new equipment appearing and costs dropping;
- difficulties scanning film that is warped or shrunken, has damaged perforations or has weak or lumpy splices;
- loss of resolution scanning 12:9 aspect ratio film on equipment designed for a 16:9 aspect ratio (the modern standard in television);
- special processing for dealing with scratches (wet gate; infrared scanning);
- adjusting scanning parameters for every different shot in a film (grading);
- the complexity of some forms of archive film. These are often spread over many reels, sometimes on pairs of reels, one with even numbered shots, one with odd numbered shots; and
- a range of problems recovering the audio from film soundtracks.

A very recent and thorough guide to film digitization is *Film Scanning Considerations* (de Smet and Triemstra, 2011) from the Dutch National Institute of Sound and Vision.

Standards for digitization are presented in Section 6.

4.1.4. Efficient digitization

Large amounts of analogue content are being digitized, with much more remaining (Wright, 2010, pp.7–8). This digitization effort has focused on an efficient process, the *preservation factory* approach (PrestoSpace, 2005).

The basic requirements for efficient digitization are:

- a collection level approach: making a budget for efficient digitization of a collection, rather than just looking at the time and cost of digitizing individual items;
- enough material to set up an industrialized workflow (typically at least 1,000 items in a single format or category according to the IASA guideline (2009, Ch 9)); and
- division of labour: with enough content, the work can be divided into tasks (equipment operation, metadata, logistics of moving and labelling material) with consequent increase in efficiency (Smith, 1776).

In general, a small collection cannot set up a preservation factory, but larger institutions and private companies have set up highly efficient workflows. Industry has also developed high efficiency workstations: NOA and Cube-Tec Quadriga workstations run four simultaneous audio digitizations; Front Porch produce the SAMMA line of robotic systems for video digitization.

There are automated methods for detecting audio and video problems. Automatic monitoring is built into the Quadriga, NOA and SAMMA systems (and other commercial products), but these methods produce extensive logs of issues and potential faults that have to be manually reviewed. Automatic detection of impairments has been developed for video and film restoration technology, but again the detection only flags potential problems that have to be manually reviewed. There is a need for effective integration of signal processing technology with human checking in order to produce a really efficient method of quality control within a preservation factory approach. In the US, the National Archives (NARA) are currently reviewing digitization and quality control methods for audiovisual materials, and will produce public results in 2012 (Murray, 2011).

4.2. Digital but not files: migration from digital carriers

Generally. archive material is either not digital and on shelves (such as books) or it is digital, as files on some kind of storage (electronic documents or scans of book pages stored as TIFF or JPEG files). The audiovisual world has something else to worry about: digital content that is not in files:

- audio on audio CD, minidisc or DAT tape;
- specialist digital audio formats from the 1980s which stored audio on videotape; and
- video on DVD or on digital videotape, such as Digibeta or the prosumer DV formats.

'Digital content not in files' is a problem unique to audiovisual content, and so will be examined in some detail. In an attempt to uphold archive principles and save the bits, three cases occur:

- the bits are not available (to the external world): minidisc, Digibeta;
- the bits are available, and a clone can be made: CD, DVD, DAT, DV; and
- the bits are available, but a clone is *not* made because it cannot be used.

Case 1: the bits are not available (to the external world) and the data is decoded during playback; examples are minidisc and Digibeta. On playback, the bits from the recording media are internally decoded by electronics within the playback device, and then a standard, uncompressed, signal is presented to the outside world. For a massive project, an archive could attempt to modify equipment to expose the encoded bits, and thus keep the original, but there would be no standard software for playing such files. Rather than create files that have an immediate preservation problem, standard practice is to accept the inability to recover the original data.

Case 2: the bits are available, and a clone is made: CD, DVD, DAT and DV tape. This case is easy to justify, as it follows a main archive principle – preserve the artefact. There are complications:

- playback errors compromise the clone*:* the data coming out is in general NOT identical to the bits on the tape, because of playback errors and concealment (Rice and Lacinak, 2009; Rice and Elnabli, 2010);
- suitability of the clone for digital preservation: for video, there is an 8:1 size difference between uncompressed and DV coding, which could be economically significant. Therefore, as an instance of temporary archiving (see Section 6), just the DV could be saved until such time as DV is at risk of becoming unusable. Then an uncompressed new master could be made, and stored much more cheaply than at present;
- workflow requiring an unencoded signal: automatic checking in a digital archive workflow may not work on the encoding data. Video checking may need an uncompressed signal rather than a DV signal. In such a case, making the required signal has to be added to the workflow, which means quality checking is not operating on the *artefact* being saved.

The fact that CD, DVD and DV material can be cloned using consumer equipment is an attractive prospect for digital preservation, except for the problem of the unknown degree of uncorrected errors embedded in the material. Best practice would require use of professional playback equipment for two reasons: 1) to have the best chance of correct playback; and 2) to have information from the playback device about error rates.

Case 3: the bits are available, but a clone is *not* made: this is the case for the BBC's D3 preservation project (Ingex Archive, 2009). The problem is that the format is composite PAL, not component. New use of the content, whether for editing or for broadcast, requires a component signal, so the BBC included PAL decoding in the workflow, and saved the result of that decoding, not the direct output from the D3 playback.

Conclusions for preservation of digital data not in files:

- most situations will be Case 1 or Case 2;
- if the bits are available for bit preservation (Case 2) then making a clone (a file that holds those bits) is the best route, using equipment that provides information on errors so that quality control can ensure a clone really is a clone;
- generally Case 1 produces an uncompressed signal, so best practice is to save that signal as is, without recompressing; and
- Case 3: engineers argue about what to do about colour decoding (going from composite to component). If the particular composite format is obsolete (as with D3) then there is a case for not saving the artefact, and instead decoding to component.

4.3. Born digital material

The basic issue for born digital material is digital preservation, discussed in Section 5. However, before digital content (audiovisual or otherwise) enters a digital repository or formal digital preservation process, there is one fundamental decision to be made: accepting the input file as is, or converting to a preferred or common format (often called normalization). There are various considerations:

- a common format simplifies repository management, but archive principles require keeping the original file, the artefact;
- selecting a standard format: as will be discussed in Section 6, the eventual goal is uncompressed data in a widely supported open standard. For audio the standard format is Broadcast WAV, with sampling at 96 kHz with nominal 24 bit samples. For video the standard digital representation of a digital video waveform is the ITU Rec. 601 standard stored in an MXF (or possibly MOV or AVI) wrapper; and
- metadata mapping: when more than one kind of file comes into a repository, there is the immediate issue of potential metadata differences and incompatibility, also discussed in Section 6. Relevant metadata from all the possible file types has to be harvested and mapped (to a common vocabulary) if it is to be of any use for running the repository, such as making a catalogue of content.

5. Digital preservation

This section covers digital preservation technology for content arising from the three different paths just described: digitized from analogue, migrated from digital carriers, and born digital.There is a fundamental problem with the direction of technology: newer technology holds more (for the same price) but does not last as long as the technology it replaces.

Table 1: The Trend in Storage (Wright, 2009)

Medium	Storage density, bits/cm²	Life, years
Stone	10	10,000
Paper	10^4	1,000
Film	10^7	100
Disc	10^{10}	10

A basic issue in digital preservation for all forms of data is that there still has to be something physical to hold the data. Digitization breaks the link between content and specific carriers, but there still has to be the equivalent of a carrier. As Table 1 indicates, modern storage has a short lifetime. Future technology is not likely to last longer than current hard drive and data tape lifetimes.

In Section 3.1, the distinction was made between conservation (which should be happening all the time) and preservation actions (specific interventions of finite duration). The same terminology can be applied to files. They need continuous care, whether called curation, maintenance or conservation.

If technology were stable, continuous care would suffice. However, digital technology changes rapidly – investment in computer equipment is usually amortized over three years. New versions of software may appear every few months. Entirely new products (smart phones, tablet computers, e-book readers) appear, with new requirements for audiovisual access. Obsolescence of old technology and requirements of new technology force audiovisual archives to change what they are doing and move to something else, by taking preservation actions.

5.1. Preservation actions

The two basic kinds of preservation action are: 1) changing the audiovisual content within a collection; 2) changing the system that holds the collection.

If changing the audiovisual content is the action taken, the change could take place when a file enters a system, or while it is being held within a system. The first is commonly called normalization, where the concern is that all the content, particularly the embedded metadata, makes the jump from input to normalized file. Tools to help metadata normalization of audiovisual content are available (PrestoPRIME, 2011a).

The reason for changing content when it is already in a system is obsolescence – the encoding or wrapping no longer serves its purpose. If a system holds access proxies (as well as master files), this problem would be expected to occur because of the rapid change of access technology. One way to cope with obsolescence is to maintain software that renders the encoding, despite some form of general obsolescence. If the software is itself maintainable indefinitely through some form of a universal machine, the file itself need never be changed. This approach to preservation has been pursued by the Multivalent Browser (Phelps and Wilensky, 2001). Multivalent is being updated to work on professional video formats as part of the PrestoPRIME project.

For master material a strong position can be taken. If the content is uncompressed, there should never be a need to change the actual numbers that make up the content. This statement has proven true for uncompressed audio for the 20-year life of the WAV format. Further, audio that was digitally sampled in the 1960s can go straight into a WAV format, with no change to the numbers.

The master material that will need to be changed is compressed material, and the change will be motivated by obsolescence of the compression. Compression for master audio material is already an obsolete approach, so we can predict that all compression for master files of moving picture and sound will become obsolete within one to two decades.

It may be decided to change the system that holds the content. The goal of the ISO Open Archival Information System Reference Model (OAIS) approach to digital preservation is a system that survives its own changes, because all levels from storage media through networks and servers and up to applications and access technology are subject to continuous change, as are staff, management and entire host institutions (CCSDS 2002).

There is nothing about this pervasive risk that is specific to sound and moving pictures, except for the fact discussed in Section 5.2.2 that audiovisual content tends to be in media asset management systems, which generally have no specific OAIS functionality.

5.2. Digital conservation

There are four main factors in a programme of conservation, whether analogue or digital:

- packaging, handling and storing;
- environmental conditions;
- protecting the masters; and
- condition monitoring.

These were the headings used in Section 3.1 for analogue conservation. The following description is about digital conservation (curation), using the same headings as for analogue content, in hope that archivists will see that though digital preservation is indeed a new world with new problems, it is not entirely new. The basic concerns of handling, environment, protection and monitoring remain, but problems, precautions and methods of remediation manifest in new ways.

5.2.1. Packaging

The basic package in the digital world is the file, and files in common computer systems are stored in folders. Effective management of a large number of files begins with file and folder naming conventions, and control of any actions that can change file names or locations. These issues are common to the management and preservation of all kinds of files, and so are not discussed here.

One reason for naming conventions is to prevent two files having the same name, which brings up the issue of identifiers. Unfortunately as in so many metadata areas, there is confusion rather than a unique type of unique identifier. The International Standard Audiovisual Number (ISAN) is an ISO standard dating from 2002, but the cost of registering has limited its use. The cinema and broadcast industry developed the Unique Material Identifier (UMID), an SMPTE standard. The Broadcast Wave Format has a place for an identifier which is called the Universal Source Identifier (USID), and the UMID has been used as a USID. The Audio Engineering Society (AES) produced the standard for streamed (rather than file-based) audio, AES-3, and that was specifically designed to hold a UMID or a Universally Unique Identifier (UUID, another ISO standard). The Federal Agency Digitization Guidelines Initiative (FADGI) in the USA is 'a collaborative effort by federal agencies to define common guidelines, methods, and practices for digitizing historical content'. FADGI started in 2007 and has a very useful website (FADGI, 2007). The current confused situation regarding unique identifiers could be improved if interested parties would work with FADGI, or follow their guidelines.

Wrappers: File formats for audiovisual content are complex, and so have come to be called wrappers, as they include video, multiple channels of audio, technical metadata such as timecode, time-based metadata such as subtitles, and finally conventional metadata (which may refer to the whole object or may be linked to specific timecodes). There is some consensus on use of the MXF wrapper for professional content (digital cinema, broadcasting, US Library of Congress) but the Apple MOV format (Quicktime) and the Microsoft AVI format are better known in smaller institutions. MXF is a SMPTE standard; MOV and AVI are proprietary, but they are licence-free and well documented and supported. There are technical issues with MOV and AVI: the AVI wrapper is particularly poor at handling timecode.

Diverse wrappers lead to incompatibility. The convergence on the Broadcast WAV format for audio archiving means virtually all digital audio collections are compatible. The use of different video formats means that the embedded metadata may not be compatible. Building a collection from diverse formats requires the interpretation of multiple kinds of metadata. As standard digital library technology uses metadata harvesting as part of ingest, the use of multiple wrapper formats complicates the ingest stage for any digital collection. PrestoPRIME (2011a) has helpful technology to map metadata of several types to a common language, and to convert from one to another.

Complex objects and information packages: the one general standard for digital preservation is the Open Archival Information System Reference Model (OAIS). OAIS is a general model and so will not be described here, except to say that a basic feature of it is the information package. Material going into a digital preservation system is organized as a Submission Information Package (SIP). This kind of package is meant to contain everything relevant to the use and preservation of the object: a complete object, plus provenance, rights, any information needed to use (render) the object, and any information relevant to digital preservation of the object. The question for audiovisual content is simply this: can a wrapper be an SIP?

The standard information package in the digital library world is the Metadata Encoding and Transmission Standard (METS). Unfortunately, METS was not found to be used for audiovisual content in any of the US government departments surveyed by FADGI. There have been four projects which implement OAIS (to some degree) for audiovisual content; three have used METS – Caspar (Lamb, Prandoni and Davidson, 2010), PDPTV (Rubin, 2010) and PrestoPRIME (Addis *et al*., 2011). The fourth, EDCine (Nowak *et al*. 2007) did use a wrapper as the SIP, the MXF format. EDCine did not attempt to put anything in the SIP which MXF was not already capable of carrying.

For those archives that do want to make a single package from diverse kinds of information, there is a range of competing approaches:

- folder-based: a folder/directory is used to contain the items making up the object. This approach is only possible if the device on which the package is to be stored has a file system that offers folders. This approach is not possible on Linear Tape Open (LTO) data tape without using the Linear Tape File System (LTFS);
- index-file only: the package consists purely of an 'index' or metadata file. This describes the package and its contents with links to the location of the content files; and
- composite: the package consists of a single file which contains all the package details, metadata and content files, similar to a ZIP or TAR file.

Examples of folder-based approaches are:

- BagIt, a very simple approach developed by the Library of Congress, and widely used;
- DPP (digital program package), developed by the Japanese national broadcaster NHK working with IBM, and formalized by the Japanese Association of Radio Industries and Businesses as TR-B31 (ARIB, 2011). The DPP is a candidate for the SMPTE Archive Exchange Format (AXF) standard.

The main example of the index-file approach is METS, already mentioned.

Examples of the composite approach are:

- MPEG-A PA-AF: a detailed proposal from the influential MPEG group of standards, but with no information on take-up;
- Front Porch Digital AXF: a proprietary format that is not the SMPTE AXF, but which the company is proposing to SMPTE (in competition with the NHK DPP) as a candidate for the SMPTE AXF standard.

There is a confusing range of options for a package for audiovisual content that is larger than a single wrapper. The PrestoCentre in cooperation with FADGI will provide updated information. Those archives that can already use METS need not wait; others may wish to see if a consensus emerges.

5.2.2. Handling

One form of handling is when an object is moved. The moving of digital objects actually involves recreating the bits on some other storage location. This is an active process, and so it could go wrong. The basic way to test the process is to use a fixity check, which requires:

- creating a key from a file known to be good;
- keeping that key separate from the file (though it can also be kept inside the file); and

- checking that key against the same key recreated from a copy or any other subsequent use of the file. If the keys match, the files match (to within a certain probability, which can be made as high as needed by increasing the complexity of the key) and so the file is good. The handling (moving to new storage; making a copy for someone in another place, or even just reading the information back from storage) has been successful.

Making a fixity check is a well-defined concept in digital preservation. Calculation of fixity has to be noted and guaranteed to happen, at the right time. Checking the fixity is a related action that also has to be guaranteed to happen. Formal repositories and digital preservation systems (discussed next) ensure that fixity calculation and checking do indeed take place at just those times and places necessary to ensure against incorrect versions of a file, or a corrupt file.

A more general form of handling is the overall management of a collection of files. A small collection may have no formal management technology, but then every operation on the collection is manual, uncontrolled, probably unrecorded and possibly irreversible. This form of non-management is very familiar to us, as it is how most people deal with the files on their personal computers – but the approach is the antithesis of a designed, controlled and documented method of file management. This topic is relevant to audiovisual collections because many are just beginning to adopt formal technology for managing files, and their first choice tends to be a Media Asset Management (MAM) system, because such systems were designed to support audiovisual content. Unfortunately, MAM systems are not a subset of Trusted Digital Repositories, Digital Libraries or Digital Preservation Systems. The audiovisual world and the digital library world tend to use quite different technologies for managing a collection of files. The consequence is that while digital library collections have been developing a path from collection management to trusted repositories to digital preservation systems, audiovisual collections have tended to be on a separate path.

The practical consequence is that the tools and systems in common use in digital libraries are unknown in the audiovisual world. Conversely, when audiovisual collections do try to use digital library or repository tools, they often fail: MXF is not recognized by the standard digital library tools JHOVE and PRONOM/DROID or any digital library metadata extractor.

5.2.3. Storing

Storage is a major issue in digital preservation, being the physical reality of a digital collection. For most aspects of storage, audiovisual files are just like any other files. However, there are two issues that do specifically affect moving picture and sound files: 1) use of compression; and 2) very large individual files.

Storage costs have been reducing in a consistent way since 1970, with the result that for audio collections there is complete acceptance of the principle that the master copy should be uncompressed. Video is 200 or more times as big, per hour, as audio. High Definition video can add roughly another factor of ten, and film can add another factor of ten. Storage costs reduce by roughly a factor of ten every five to ten years, so the arguments about use of compression in video can be expected to run for at least another decade, and a decade beyond that for digitized film.

The modelling of storage costs is not a simple issue (see PrestoPRIME 2011b for modelling tools). When making a decision about use of compression to reduce cost of storage, one should at least also include an estimate of the initial cost of compressing the data (software or hardware plus computing time) plus an ongoing cost, for as long as compression is used, of the software or hardware plus computing time to decode the data whenever the file is used. These costs are then compared not just against the current cost of storage, but the ongoing costs should be compared to the reduced costs of future storage.

Moving picture files can be very large: an hour of standard definition video, uncompressed, is about 100 gigabytes. If an error in one frame renders the file unreadable, that is a very disproportionate loss. The probability of such an error also goes up in direct proportion to file size. For both these reasons, it would be advantageous for audiovisual content to be stored in such a way that it did not attract failure. One method is to break a file down into many smaller files, and indeed this approach is used in digital cinema production where the standard production format is essentially one file per frame, with a folder as the package for a whole film.

More sophisticated audiovisual file management, product name MServe, has been developed by IT Innovation (University of Southampton). MServe is in use in the commercial media industry as an upgrade to the Sohonet service that links 200 London media companies (Postmark, www.it-innovation.soton.ac.uk/projects/postmark). PrestoPRIME has technical information and tools (Phillips, 2010) about detailed management of contracted (outsourced) storage, with particular reference to storage of audiovisual content.

5.2.4. Environmental conditions

In the physical world, the environment is temperature and humidity control, fire prevention and a good roof. For files on mass storage the issue is the *social, political and economic* environment, the funding and management of this invisible archive. Digital libraries have developed the concept of a *trusted digital repository*, and have gone further to develop checklists of what needs to be in place to gain the trust of users of such a repository. The standard checklist is TRAC (Dale and Ambacher, 2007) and an ISO standard is forthcoming (CCSDS, 2011).

5.2.5. Protecting the masters

In shelf-based archives, proxies or viewing/listening copies were essential to minimize use of precious and fragile masters. A digital archive can make as many master copies as it can store, but still may find that none are suitable for particular access purposes. In consequence, proxies are still an issue in digital archives, but for new reasons. The master file for video will be very large; impossibly large for web access, and possibly too large for efficient access over local networks.

Digital audiovisual archives need to have *viewing proxies,* usually of two sorts: 1) medium quality for internal professional access; and 2) low quality for web access. As bandwidth increases, the definitions of low and medium change, leading to the need to periodically upgrade proxies. An efficient approach to proxy generation has three levels:

- master;
- mezzanine: the most efficient coding for generating new proxies; and
- viewing proxies (of one or more quality levels).

The EDCine project (Nowak *et al*., 2007) used lossless JPEG2000 (in an MXF wrapper) for the master, and a high quality lossy JPEG2000 encoding for the mezzanine. Lossy JPEG2000 supports efficient coding of the distribution format required for digital cinema.

Protecting the masters as a conservation issue reduces to preserving the bits, keeping the original digital content without change. When a file has to be migrated to something new, that is a preservation action, and the risk then is loss of audiovisual quality. Maintaining quality despite change is the topic of Section 5.3.

Preserving the bits is a pervasive issue in digital preservation, requiring everything from secure storage media to a secure operating budget. Moving picture and sound files have the same bit preservation requirements as other files, with one exception: the use of compression. Compression can be used on any kind of file, but compression has particular significance for audiovisual content: 1) compression is widely used; 2) compression greatly affects resistance to small corruptions in a file (bit rot); 3) audiovisual content produces such large files that bit rot becomes a real concern.

Uncompressed audio and video is highly redundant, and loss of one bit in a file (providing it is in the audio or image area of the file, not in the metadata and control area) is insignificant. With compression, an altered bit changes a number that is a parameter in a calculation, not just one pixel or one sound sample. The calculation could apply to a whole image, and so the effect of the loss is magnified. Heydegger (2008) found that a one-bit error in a compressed file could affect 10^5 bits or more or render the whole file unreadable, depending upon the type of compression.

5.2.6. Condition monitoring

In the analogue world, shelves had to be checked to see that stock was all present and accounted for, and in good condition. There was technology such as A-D Strips that could monitor for acetic acid. In our new world, storage media (which have many properties in common with analogue audio and video media) also deteriorate and are subject to failure. The greatest risk is the overall complexity of computer systems and the rapid obsolescence of these systems at all levels.

For outsourced storage, condition monitoring is someone else's task, but the archive has the difficult problem of ensuring quality from a distance, controlled by a service level agreement. The technology for monitoring what is happening at various levels includes:

- technology built into storage media hardware for measuring errors and anticipating (and hopefully preventing) media failure;
- storage management software that monitors performance and errors, again anticipating problems in order to prevent failures; and
- processes within storage management software that periodically test content to check that it is readable and correct (scrubbing).

All this management costs money and time. For in-house storage, somebody in charge needs to understand at least the three levels of condition monitoring just mentioned. For outsourced storage, it is useful to know enough to understand the costs of managed storage, and what is gained by investment in these various technologies. PrestoPRIME (2011b) has a storage management tool that investigates costs versus benefits of storage options, including showing the results (and the differential costs) of scrubbing (file checking) at various time intervals.

5.3. Maintaining quality

Audiovisual files hold a signal or an image, and so have a quality dimension that has no equivalent in text files. Digital Preservation projects (Planets, 2010) provide guidance for optimizing the preservation of whole ranges of significant properties, but audiovisual content also has purely technical dimensions. For audio, the significant property is signal fidelity as measured by bandwidth and dynamic range. For video and film, image quality is ultimately subjective, but there has been work, over decades, on objective measurements that estimate perceived visual quality.

Automation of audiovisual quality control was mentioned as part of digitization (Section 4.1.4) but such tools could have an important role in digital preservation, providing their performance is improved so that false alarm rates are no longer a problem. There is PrestoPRIME technology for automatic detection of disruptions in video (Schallauer, Fassold, Winter and Bailer, 2009)

Apart from unrecoverable errors, the only process that could reduce quality is compression, or successive applications of compression. A primary quality control strategy in the digital preservation of audiovisual content is the complete avoidance of repeated application (cascading) of compression. In the analogue world when archives were forced to make a new master, there would be an inevitable generation loss. In the digital world it should be possible to make perfect copies, but compression interferes. If a master file is compressed in one lossy way and then migrated to a different type of lossy compressed file, there is a decode–recode cycle that also produces additional loss, the digital equivalent of a generation loss. However, for cycles of lossy compression there is an invidious problem. There may be no perceptible effect until finally there is major breakdown, in contrast with the gradual losses from migrations of analogue content.

The best strategy is to avoid lossy compression in master material and avoid multiple uses of compression. If master material is already compressed using a lossy method, then the next step in the life of that material should be a move to a lossless encoding, to break the cycle of repeated applications of compression which would just move content lower and lower in quality.

6. Standards

6.1. Audio

The full guideline for audio is IASA (2009), and for video the three major audiovisual professional organizations (IASA, FIAT, AMIA) are currently co-operating on the production of a full guide to video preservation, IASA TC-06 (in preparation; publication expected end 2012).

Audio should be sampled at a minimum rate of 48 kHz, with 96 kHz being strongly recommended. Nominal 24-bit sampling is recommended (19 to 21 true bits, depending upon equipment used). Audio should be placed, uncompressed, in a Broadcast Wave Format version of the WAV file. Broadcast WAV files can be played by any application that can play standard WAV files, so use of the Broadcast WAV file format should simply add information, not add problems. Major brands of audio workstation (NOA, Cube-Tec Quadriga) support the Broadcast WAV format.

6.2. Video

The standard digital representation for video is ITU Recommendation 601, sometimes referred to as SDI. Digitization should be at 10 bits per sample, with a 4:2:2 allocation of samples to the three dimensions of a colour signal. ITU Recommendation 601 has been the standard for digital video in broadcasting since 1984.

There are many different kinds of video:

- standard definition (SD) and high definition (HD);
- monochrome or colour;
- composite or component colour video; and
- three incompatible versions of composite video:
    - PAL (UK and Commonwealth countries);
    - NTSC (North America, Japan and many other countries); and
    - SECAM (France and some francophone countries).

There are also various kinds of HD video, mainly either 720 or 1080 vertical lines, either progressive or interlaced, and at various frame rates. Explanation of all these technical issues is beyond the scope of this *Technology Watch Report*, but *JISC Digital Media* (2009) gives a basic explanation.

Ideally video would be stored uncompressed in a professional, open standard wrapper. MXF is recommended, but MOV and AVI are also used. AVI cannot be used on professional broadcast video with embedded timecode, or the timecode will be lost. Lossless compression is also used in major audiovisual archives, specifically JPEG 2000. Lossy compression is best avoided, but could be tolerated as a Temporary Archiving compromise as discussed in Section 6.3. Currently, it is very difficult to transport or store uncompressed or even lossless compressed high definition video, so Temporary Archiving is forced upon us for HD.

There is a genuine problem for video. The data rate of 200 Mb/s is about 70 times higher than for CD quality audio, so handling and storage of uncompressed video is seen as daunting. The problem is solving itself owing to the dramatic reduction in cost of digital storage; the BBC is following this approach for an archive video file standard for professional quality materials (Ingex Archive, 2009).

6.3. Temporary Archiving

Some video (such as VHS) is not professional quality and many institutions do not have the resources of the BBC. For these reasons, PrestoSpace (2006) introduced the concept of Temporary Archiving and its associated roadmap, providing a considered and documented approach for moving to the standard in stages rather than all at once. The key idea is to use a digitization and compression method which is adequate to capture the quality of the original content. When migration is needed (as when the compressed format is obsolete) the roadmap requires moving upward towards fully uncompressed in as few stages as possible. The expectation is that by 2020 the motivation for compression will have faded away because of the reduction in storage costs, so most archives could be digitized today to a compressed format that would last for a decade, and then move in 2020 to the uncompressed standard.

6.4. Digital preservation

The Open Archival Information System (OAIS) is the only approach to digital preservation that has been formally standardized (ISO 14721). The use of OAIS and related technology on audiovisual content has been discussed in Section 5.2.1.

7. Preservation for Access

This section describes major international actions for access to heritage content, highlighting the Europeana project. The technology needed for full access to audiovisual content is reviewed, and finally a brief summary of developments in rights issues associated with access is given.

7.1. Digital libraries and Europeana

Historically people have gone to libraries to find information and content, and now the Europeana project has aggregated the descriptive metadata from the digitization projects of all Europe's national libraries. In the last two years Europeana has added hundreds of other digital collections.

For smaller collections, the significance of Europeana is the potential increase in discovery, the ability for content to be found. Europeana does not collect the actual digital objects (much less preserve them); it collects the cataloguing, and after a search the user clicks through the Europeana portal to view (or listen to) objects provided from the websites of the originating institutions. In this way an institution preserves its identity and web presence, while gaining the benefits of being part of the portal used by a large population.

For content to be discoverable through Europeana, the descriptive information about the content needs to be brought up to a standard that supports Internet discovery, online access and aggregation in major 'ways in'. The basic requirements are:

- converting anything not computer readable to an electronic form;
- mapping at least the 'discovery metadata' to a standard such as Dublin Core; and
- making that metadata available for harvesting through the OAI-PMH protocol.

All the above apply to digital content in general (electronic documents, scanned books, images as well as digital sound and moving images) as described elsewhere. Specific information regarding Europeana and audiovisual content is available from PrestoPrime (Angelaki, 2010).

Europeana operates through a set of specialist aggregator projects. These projects work with collections in a specific area, providing tools and technical support to enable collections to become part of Europeana. The aggregator for video is the EUscreen project. Audio collections are supported by Europeana Connect, and film collections are supported by the European Film Gateway.

In addition to harvesting metadata to form a sort of union catalogue for heritage resources, Europeana supports advanced search and retrieval technology. In 2011 Europeana launched a Linked Open Data pilot (Schreiber, 2011) and also announced co-operation with the Digital Public Library of America. At the end of 2011 most Europeana content was text, not sound or moving images. One reason is the complicated rights situation outlined in Section 7.3 below.

7.2. Access technology

Audiovisual content has a unique feature – the time dimension. The general approach of digital libraries is to operate on content as a single undifferentiated object. The description is at the whole item level, a search returns a list of whole items, and retrieval starts to render or download a whole item. This approach works for images and for documents (though there is no reason not to have lower level metadata, and more precise retrieval, even for books) but can singularly fail for large audiovisual objects. Having to view or listen to a one-hour programme in order to find a particular segment of interest is inefficient in several dimensions: user time, network bandwidth, computer resources. An early JISC study revealed that users of an audiovisual portal wanted access to be 'Quick and efficient, create resources as brief and segmented as possible. It is difficult to "scan" (i.e. review quickly) time-based media' (Asensio, 2003, p.12).

PrestoPRIME elaborated the requirements for making access 'quick and efficient' in a presentation to the Digital Preservation Coalition (Wright, 2011).

The four PrestoPRIME requirements for effective access to time-based media are:

- granularity: division of the content into meaningful units;
- navigation: the ability to select one such unit, and play or download just that piece;
- citation: the ability to cite a point on the time dimension of an audio or video file, using a permanent URI with a standardized, generally accepted and supported method of making the time domain citations (so that the reader of a paper with such a citation can immediately use that URI to reference the cited material, at the point of interest). This point supports a key requirement for enabling audiovisual content to become part of scholarly discourse; and
- annotation: the ability of a user of content to make time-based contributions, which can be collected and added to the descriptive metadata for the object. This point supports social networking aspects of the use of the content.

Citation and annotation technology for audiovisual materials is a problem. Many projects and websites have their own technology, but there is a need for convergence to a common approach, or this information cannot be pooled or shared. There is a World Wide Web Consortium (W3C) Media Annotation Working Group, but as of the end of 2011 their work had not reached 'a web browser near you'.

There are developments aimed at effective use of the time dimension of audiovisual content. An example of systems for analyzing sound and moving images to add metadata or to align such information to the time dimension is the MetaLabs technology (www.metalabs.tv) sponsored by Ireland's National Digital Research Centre (NDRC). This is focused on time domain metadata, the key enabler for all four of the 'requirements for effective access' just listed.

Speech recognition was used over ten years ago to provide access to broadcast news by the THISL research project (Renals *et al*., 2000). Progress in speech research since then has made the approach more generally applicable, and several projects and companies are now using speech recognition as a 'way in' to audio and video material that does not have other discovery metadata.

7.3. Access and rights

Sound and moving picture content arising from cinema, broadcasting and the commercial music industry is constrained by rights issues. Music has copyright protection for the composer and for the physical object containing a performance (so-called magnetic copyright). Cinema productions are protected, and music used in a film retains its separate protections. Broadcasting is even more complicated, as all the parties involved in a production may have rights in future exploitation subsequent to the one or two transmissions that were specified in typical contracts. These rights are seen as protection by rights holders, but are also seen as restrictions on access. The situation for a public broadcaster is particularly difficult. The public invariably feel that any production by a public broadcaster has already been paid for by them, is already publicly owned and should be available for public access. Unfortunately that understandable feeling is not the same as the legal definition governing when a work enters the public domain (usually determined by expiry dates on copyright and other rights).

In the UK various public bodies are combining their efforts in the area of public access. Co-ordinated by the British Film Institute (BFI, 2011) as the UK Sound and Vision Collections group, the BFI, , BBC, the National Archives, the Imperial War Museum, the National Media Museum, the National Library of Scotland, the National Library of Wales and the National Museums Northern Ireland are developing the concept of a Digital Public Space (JISC, 2010; McRoberts, 2011). Issues of rights have plagued the efforts of many institutions to provide public access to heritage and public service material. These partners are developing a non-commercial part of the Internet where rights concerns can be met, while also meeting public desire for access to their content.

The UK Strategic Content Alliance has worked on copyright and public access, and has a range of guidance information including an e-learning module on intellectual property rights (Korn, 2011).

UK copyright and general intellectual property law was recently reviewed (Hargreaves, 2011). Copyright law has always included exceptions, and an important part of the Hargreaves review is detail on digital 'exceptions' to support archiving, teaching and non-commercial research. At the European level there has also been a Green Paper (European Commission, 2011) on the online distribution of audiovisual works, and JISC responded to both these developments (JISC, 2011).

The US report on recorded sound (Bamberger and Brylawski, 2010) has a major section on US rights as they affect preservation and access (pp.108–137). Within Europe, the Arrow project is developing a registry system for orphan works. The PrestoPRIME project has developed a structured vocabulary (ontology) for the description of rights and rights contracts pertaining to the broadcasting industry.

Finally, the general area of access to moving pictures and sound within higher education has been reviewed for JISC (Gerhardt and Kaufman, 2011). Their ten strategic recommendations are a manifesto for progress on serious access to audiovisual content.

8. Implications for small collections and institutions

The previous sections have covered a lot of ground, from conservation to digitization to digital preservation. Large archives generally have the needed expertise. This section addresses small archives, or small audiovisual collections within an institution not focused on such content.

A basic issue is the digitization of analogue content, because so much content is still analogue and audio and video need digitization to survive (film always being the exception: it can survive as film, but access requires digitization). After digitization, the content will be files on digital storage, opening new opportunities for digital access using networks and Internet technology. What can a small institution do about digitization, digital storage and electronic access?

Digitization: the question divides into two – what can a small institution do, and what should it do? If there is equipment and expertise (at least one skilled person and one good machine per format) then a small institution can address its own problems, but see Section 4.1.4. It may not be economically sensible to set up a digitization project in house. There are many service providers for audiovisual digitization, and some specialize in archive preservation. PrestoCentre (2011) will maintain a registry. Prices have fallen by something like 50 per cent in the last decade, owing to increased business and increased efficiency of these companies.

Digital Storage: this area is rapidly changing, with new formats (data tape), new services (The Cloud) and ever lower prices. The fundamental issue is again expertise. An audiovisual collection moving to digital storage either has to have expertise in digital storage, or outsource the whole project. Many small collections are in larger institutions that have data centres, and it is becoming common for an audiovisual collection of a small research unit to move from shelves in the premises of the unit to files on a university data centre. Files can also be placed with an external company such as Arkivum, which is offering new technology arising from project Avatar-m (www.avatar-m.org.uk/) and offering a service that addresses long-term preservation needs with meaningful guarantees.

Electronic Access: again, technology change makes it almost trivial for a small organization to put audiovisual content online. Use YouTube or an equivalent hosting service (of low-quality web access proxies; such services are not a place to store master files) and embed the links and player in your own web pages. This approach removes the need for local hosting of streamed media services, which gets rid of all the cost and complexity that used to be associated with putting content online. However, the vital issue is not how to play content, but how to help users find the content in the first place. The area of discovery is where a small organization is at greatest disadvantage and where there are potential benefits from working with others to form a pool of aggregated content.

Europeana and related developments were described in Section 7.1. In the UK, there is JISC-led co-ordination such as JISC Collections, and a major new initiative linking JISC, the BBC, the British Film Institute and a range of other organizations to create a Digital Public Space (JISC, 2010) that will prepare a protected environment supporting non-commercial public access.

9. Current Activities and Case Studies

9.1. Support activity

General technical advice on audio preservation is available from the British Library Sound Archive; the British Film Institute can advise on film and also on video – they hold a lot of video, and have a Curator for Television.

Academic institutions are fortunate. There is a JISC support unit for digital media based at Bristol University with a wealth of online information, training courses and a free helpdesk.

Table 2: Sources of Technical Support for Sound and Moving Image Collections

Organization	Remit	Website
British Library Sound Archive	Collection and preservation of all forms of audio, and technical advice	www.bl.uk/nsa

British Film Institute	Collection and preservation of film and television, and technical advice	www.bfi.org.uk/ www.movinghistory.ac.uk/archives/
JISC Digital Media	Advice and training on still images, moving images and sound	www.jiscdigitalmedia.ac.uk/
PrestoCentre	General audiovisual information and advice at a European level	www.prestocentre.eu
Film Archives UK	Collection and preservation of general audiovisual content of regional significance	http://filmarchives.org.uk/ www.movinghistory.ac.uk/archives/

In addition, the UK is also fortunate to have services that give general support to digital curation and digital preservation: the Digital Curation Centre (www.dcc.ac.uk/) and the Digital Preservation Coalition (www.dpconline.org/). This *Technology Watch Report* has argued that digital sound and moving images are not 'just like any other data' but of course there is common ground. DCC and DPC information on storage, costs, planning, migration and other issues has relevance for audiovisual collections.

9.2. Case studies

Examples of UK collections that have run preservation and access projects for sound and moving image content include:

The Open University (OU) Access to Video Assets project: this is an access and re-use project. The focus is to digitize (where necessary) audiovisual assets previously created by the OU, and place them in an asset management system so that current OU teaching and other activity can find and use these assets. Preservation is a by-product of the project rather than an end in itself. This project provides an important example of combining preservation of content with use of content, something of value to the institution in order to obtain a budget and deliver a benefit. The project was presented (Allcock and Alexander, 2011) at the DPC Briefing 'Preserving Digital Sound and Vision' (DPC, 2011). The project digitized 1,200 videotapes and films, and placed the results in a Fedora digital repository. Also, 145,000 pages of documentation were digitized, providing the overall educational framework around the 1,200 items, giving them context and enhancing their ability to be re-used. The user interface provides granularity and time-based navigation. Overall this project is an outstanding example of best practice.

British Library Archival Sound Recordings project: this is a JISC-supported preservation and educational access project that ran (in its initial phase) from 2004 to 2006. A second phase added further material. Nearly 50,000 recordings of speech, music and sounds of 'human and natural environments' were digitized and placed online. The online catalogue is open to all (http://sounds.bl.uk/) and licensed UK further or higher education institutions can also listen to the audio. Anyone can listen to 2,000 of the items (or any of them by attending the British Library reading room in London). The differences in access between educational institutions and the general public reflects the overall issue of rights as the one remaining constraint on open access to audiovisual materials in public institutions. More information is on the JISC website: http://www.jisc.ac.uk/whatwedo/programmes/digitisation/blsoundarchive.aspx

Imperial War Museum PSRE project: the Imperial War Museum has one of the UK's major film collections. It has been collecting film since its founding in 1919, beginning with footage from the Great War that led to the institution's founding. The Public Sector Research Exploitation (PSRE) fund made an award of nearly £1 million for cataloguing, digitization and online access (to the catalogue and the footage). The project ran from 2006 to 2009 and is of particular interest in that it is specifically aimed at commercial exploitation of a collection, and at sustainable business models around digitization and web access. The result is a website (http://film.iwmcollections.org.uk/) where anyone can view content in low quality; pull documents, stills and keyframes into a lightbox; and fill a shopping basket to then purchase content. More information is here: http://www.partnershipsuk.org.uk/uploads/documents/Roger%20Smither%20-%20IWM%20-%20web.pdf

British University Film and Video Council Newsfilm Online project: this is another project with JISC sponsorship (http://newsfilm.bufvc.ac.uk/). For four decades to 1960 newsreels shown in cinemas were the main way for the general public to see moving images of current events. The initial project ran from 2004 to 2008. The results are available through a website which, as for the BL Archival Sound Recordings project, has full functionality for registered universities and colleges. The general public can see the full catalogue and can see a single keyframe for each item. Since the original phase of the project, the content has been augmented by ITN/Reuters news covering the events from decades after the decline of newsreels. Newsreel items are short: the initial project provided 3,000 hours of content, but that represented 60,000 items. In addition, as with the Open University project, documentation was also placed online for context and to support search and retrieval: 450,000 pages of bulletin scripts. The actual content is hosted at Edina. More information from JISC: http://www.jisc.ac.uk/whatwedo/programmes/digitisation/bufvc.aspx and Edina: http://www.rsc-northwest.ac.uk/news/142-learning-resources/245-newsfilm-online-project.

BFI and Regional Film Archives Screen Heritage UK (SHUK) project: SHUK is a large (£22.8 million) and complex project (involving 12 regional film archives in addition to the BFI).. The project was complicated by changes in the structure and funding of the BFI, as well as a change of government and a raft of other issues. Nevertheless the project has produced major achievements:

- conservation, not digitization: construction of a £6-million vault for film conservation;
- digitization: film scanning and digital storage equipment for the regional film archives
- access: online catalogues of regional film archive content, available to the general public (for example http://sasesearch.brighton.ac.uk/yourfilmarchives/)

SHUK launched on 5 September 2011 with a BBC BFI joint production, *The Reel History of Britain* (SHUK, 2011).

10.Conclusions and Recommended Actions

The basic technology issue for collections of moving images and sound is the necessity for digitization of all content that is currently sitting on shelves. Audio and video need digitization for their very survival, owing to obsolescence and decay of physical items, whether analogue or digital. Film on shelves can be conserved (unless it is already deteriorating) but needs digitization for access.

Playback for preservation-quality digitization implies the need for optimal recovery of the original quality, which requires professional equipment and experience. The major technical obstacle is that, for many physical formats, the needed equipment is largely obsolete, meaning that parts and repairs and skilled operators are in increasingly short supply. The urgent recommendation is, do not wait! Audiovisual holdings need to be documented and made part of a preservation plan.

The situation for sound heritage is clear. The digitization standards, encoding, wrapper and metadata are all agreed and well documented in IASA TC-04 (IASA, 2009). Uncompressed audio in the Broadcast Wave Format (BWF) wrapper is widely used and well supported. There is no reason for the basic encoding to ever be changed, though the BWF wrapper may eventually become obsolete. The only significant problem is the failure of some standard audio applications to handle embedded BWF metadata correctly (ARSC, 2011). All archives need to be aware of the risk of loss of embedded metadata. Possibly the DPC or the PrestoCentre could maintain a registry of applications that handle embedded BWF metadata properly, though there are difficulties keeping up with the range of applications and their various new releases.

The situation for video is complex, but there is a PrestoSpace roadmap for guiding choices on the digitization of various legacy formats. There is advice from PrestoPRIME, the PrestoCentre and from JISC Digital Media on the digital preservation of the resultant files. A big challenge is a registry of applications that work properly on embedded video metadata, where the diversity is huge. There is no single agreed wrapper, metadata standard or even encoding standard, and the change from standard definition to high definition brings a new set of applications, wrappers and encodings.

There is emerging technology that can improve audio (capture of the bias tone and consequent removal of temporal variation) and video transfers (direct digitization of the RF signal from the read head), which could be useful in those cases where current technology fails. So the recommendation is not to wait until such technology is further advanced and more widely available. If there are playback problems that cannot be resolved, the original audio or video format should be kept so that such advanced technology can be applied in the future.

Quality checking of the results of digitization remains an issue for video. There is a need for effective integration of signal processing technology with human checking in order to produce a really efficient method of quality control within a preservation factory approach. Quality checking is equally relevant to digital preservation – any changes or migrations due to digital obsolescence need to be checked for preservation of signal quality. Again, a purely manual approach does not scale (to the tens of millions of hours of audiovisual content in European collections), while purely algorithmic substitutes for 'looking and listening' have never been completely successful and remain an area where further research is needed.

The UK's moving image and sound content is at risk. The TAPE survey (Klein and de Lusenet, 2008, p125, Table B3) showed that half of all collections are small (5,000 items or less) and don't have the resources for undertaking their own digitization projects. Further, Wright (2010, pp.7–8) estimated (from the TAPE data) that a decade of digitization of analogue holdings (at 1.5 per cent per year, or 0.28 million hours per year) and new digital intake (at 6 per cent per year for broadcast archives) would mean that in 2016 there would be 8 million hours of new digital content in addition to the 16 million analogue and 3 million digital found by the TAPE study in 2006. The analogue holdings (if removed from archives after digitization) would have dropped to 13.3 million hours, and the digital would have risen to 11 million hours. Unless the rate of digitization increases, at 0.28 million hours per year the analogue holdings will take a further 48 years to digitize. If only half the analogue content is selected for digitization, there would be about 25 years of digitization work remaining after 2016, and it is by no means certain that equipment, spares and operators (or budget) will be available for another three decades.

Finally, surveys have shown that in universities there is a major problem of material that is scattered, unidentified, undocumented and not under any form of preservation plan. Casey (2009) found 600,000 hours of content just at Indiana University. We would be complacent to assume that the situation in the UK is any better. There is a need for scattered materials to be identified. The goal is for all institutional holdings of moving image and sound content to be covered by a preservation plan. The first step is to find and document those holdings. A full description of a preservation plan, with real examples, is in the PrestoSpace (2006) wiki.

11.Glossary

4:2:2	The allocation of digital samples to the luminance (black and white dimension) and chrominance (colour) dimensions in the digital representation of video, as used in the ITU Rec. 601 standard
AMIA	Association of Moving Image Archives
viewing proxies	Access copies of digital content, usually in reduced quality but smaller files, faster to transmit over networks or the Internet
A-D Strips	Technology to detect amounts of acetic acid
AMPAS	Academy of Motion Picture Arts and Sciences

analogue recordings	The recording method is an analogue of the original signal: a groove in a vinyl disc is the analogue of the sound pressure into the microphone that eventually produced the groove
asset management system	Software that organizes a collection of files, usually including separate metadata and search and edit tools
AVI	a wrapper format used by Microsoft
bandwidth	The frequency range of a signal, from lowest to highest frequencies
BBC	British Broadcasting Corporation
betacam, betacamSP, betaSP	Varieties of the last Sony analogue videotape format
BFI	British Film Institute
bias signal	A frequency above the range of human hearing, used in recording on analogue audio tape
bit (b), byte (B)	In audiovisual media, data rate for real time playback is measured in bits per second, while file size is measured in bytes; to convert: storage in bytes per hour = ½ of data rate in bits/sec, times 1,000. Example: CD audio at 1.4 Mb/s takes 0.7 GB per hour for storage; this conversion is 90 per cent accurate (overestimates storage)
BL	British Library
born digital	Files that did not come from digitizing an analogue source
Broadcast WAV format, BWF	The EBU standard for a WAV file, with extra metadata; http://www.digitalpreservation.gov/formats/fdd/fdd000003.shtml
BUFVC	British University Film and Video Council
carrier	Something physical that can hold the content
CCAAA	The Coordinating Council of Audiovisual Archives Associations, an umbrella body representing eight archival bodies with a major interest in audiovisual collections: ARSC, AMIA, IASA, ICA, FIAT, IFLA, FIAT-IFTA and SEAPAVAA www.ccaaa.org
CD, CD-ROM	Optical media for audio and general data; stores about 0.7 GB
clone	An exact copy of a digital object
codec	The abbreviation for coder/decoder
coder	The method (software) for assigning numbers to a signal
coding	The process of assigning numbers to a signal using a coder
colour video	A combination of a black and white (luminance, brightness) signal and a separate signal giving colour information
component	Any method of handling video that uses a separate signal, either as a brightness signal separate from two colour signals, or as three colour signals (red, green, blue)
composite	A video signal that mixes the brightness and colour information into a single signal
concealment	Replacing a missing line or group of lines or even an entire frame of information by using a previous line, lines or frame
conservation	Keeping what you have without changing it
Cube-Tec	A company producing professional digitization equipment, including Quadriga Audio and Quadriga Video
datacine	A device for digitization of film. Originally there were telecine machines that made (in real time) a video signal from film. Data cine

	machines make a file instead of a video signal and do not have to run in real time, allowing them to have higher optical resolution.
data tape	Magnetic tape that holds numbers
dB, decibel	A unit of measurement of the relative amplitude of signals. When one signal is twice as large as another (equivalently, has one more bit) it is approximately 6 dB greater; human hearing has a range of about 120 dB; background noise causes a usable range of about 70 dB; the best analogue recording equipment has roughly a 70 dB dynamic range, while an audio CD with 16-bit word length has a 96 dB range (6x16)
decoder	The reverse of the method used by a coder
decoding	Using a decoder to get an unencoded (plain) signal
Digibeta	The Sony professional digital videotape format
digital intermediate	A digital representation of film frames, used in restoration, animation, computer graphics and computer-generated images
digital recordings	Stored representations of signals, using numbers
digitization	The process of assigning numbers to analogue signals
DVD, DVD-ROM	Optical media for video and general data; a basic DVD stores about 4.7 GB, though larger amounts are now possible
dynamic range	The range between maximum size of a signal and either the minimum size or the noise level (whichever is greater); the word length (number of bits) of a sample limits the dynamic range (to approximately 6 dB per bit)
EBU	European Broadcasting Union, an industry association
embedded metadata	Metadata carried within a file
encoder	The same as coder
encoding	The same as coding
FIAF	International Federation of Film Archives
FIAT	International Federation of Television Archives
file	A unit of digital storage. It is surprisingly hard to know what exactly a file is; everything we do with files relies upon multiple levels of technology to create what a file is and does; a file is a performance
fixity check	A method for ensuring the integrity of a file http://id.loc.gov/vocabulary/preservationEvents/fixityCheck.html http://digitalpreservation.ncdcr.gov/newtodp.html and http://archivematica.org/wiki/index.php?title=Overview
flash memory card	Storage with no mechanical or moving parts, as in a memory stick
Front Porch	A company making asset management and digitization equipment
hard drive	Also disc or spinning disc; magnetic storage using spinning discs
high definition, HD	The new standards for television, usually 720 or 1080 vertical lines instead of 576 (onscreen) lines for standard UK TV
Hz	Hertz; cycles per second, the unit of frequency measurement
IASA	International Association of Sound and Audiovisual Archives
interlaced	Television reduces visual flicker by sending images in two halves: the odd numbered lines and then the even numbered ones, allowing the rate of screen refreshment to be doubled, without increasing the overall data rate
ITU Recommendation 601,	The digital video standard from the International

or Rec 601 for short	Telecommunications Union, a standards body
JISC	Joint Information Systems Committee, the infrastructure body supporting UK higher education
JPEG	A (compressed) coding and file type for images, developed by the Joint Images Expert Group
JPEG2000	An updated JPEG codec, which includes lossless coding and supports video as well as still images
k, M, G, T, P	Kilo, mega, giga, tera, peta are the prefixes used to describe large numbers, increasing by a factor of 1,000 for each step in the series: 10 GB is 1,000 times as much as 10 MB, and a million times as much as 10 kB. When dealing with computer memory the factor is 1,024, not 1,000, and the capitalization of k is used inconsistently
lossy encoding	Representing a signal with less data. The representation is only approximate, with a measureable difference between the original and the lossy version, though the difference may not be perceptible
LTFS	Linear Tape File System, and file-management system for LTO data tape. http://www-03.ibm.com/systems/storage/tape/ltfs/
master	The reference version of an object; version with the highest quality
memory stick	A storage device using solid state memory
mezzanine format	A computationally efficient way to produces access proxies may be to use a version that is not the master version, but instead is encoded in a way that supports production of proxies
minidisc	A digital audio recording and storage method from Sony
MOV	A wrapper format used by Apple and associated companies
MXF	A SMPTE standard wrapper used in broadcasting, digital cinema and other professional contexts
NOA	A company producing professional audio workstations
OAIS	Open Archival Information System Reference Model (ISO 14721), a general standard for digital preservation (CCSDS 2002)
PAL	Literally, Phase Alternate Lines. The UK colour TV composite video standard reverses the phase of the colour information on alternate lines, allowing the TV receiver to produce correct colour information despite phase variations in the transmitted signal (a very common problem, caused for instance whenever a plane passes nearby)
Preservation	'Preservation is the totality of the steps necessary to ensure the permanent accessibility – forever – of an audiovisual document with the maximum integrity' (Edmondson, 2004)
preservation action	An intervention in the life of content, taken in order to keep the content usable; digitization is one such action
preservation factory	A concept promoted by the Presto series of projects, involving use of division of labour and other industrial techniques in order to make digitization 'better, faster, cheaper'
Presto, PrestoSpace, PrestoPRIME, PrestoCentre	The Presto series of projects, running from 2000 to 2012 and culminating in the PrestoCentre Competence Centre
quality (of a recording)	An estimate of how closely a recording matches an original signal, as assessed by physical measurements (mainly bandwidth and dynamic range) and perceptual judgements

Rec. 601, properly ITU Recommendation 601	The digital video standard from the International Telecommunications Union, a standards body
recording (of a signal)	A way to make a permanent version of signal
restoration	Changing a recording to correct defects
rip, ripping	The process of moving data from a non-file format (audio CD, video DVD) into a file format
SAMMA	A robotic system for digitizing cassette format videotape
sampling rate	How often number are assigned to a signal, usually given in units of thousands of samples per second; sampling rate controls the upper limit to the bandwidth of a digitized signal
scrubbing	Checking files on a storage system for errors
SDI	Serial Digital Interface, the wiring system for ITU Rec 601 digital video; sometimes used interchangeably with Rec 601
signal	For our purposes, a variation against time. Sound is a variation in air pressure (over time); the variation can be captured by a microphone to produce a time varying voltage, a signal that is the analogue of the original sound; video is also a signal, and film definitely is not a signal
SMPTE	Society of Motion Picture and Television Engineers, a professional and standards body
standard definition, SD	The lines per frame for video that has been used in the UK from the 1960s, with 625 lines total, 576 being visible
sticky shed	A problem with ageing magnetic tape where the oxide starts to come off the tape (shed) and causes the playback device to momentarily stick (again and again), and eventually jam
TBC	Time base corrector; a specialist device that restores the timing of a video signal played back from videotape
Temporary Archiving	A concept promoted by PrestoSpace (2006); a recommended roadmap for format change and migration; the principle is to capture the bandwidth and dynamic range of an analogue original, and then move in steps to an uncompressed format
TIFF	A compressed format for image files; TIFF can be lossless or lossy
time code generator	A device that makes a new time code, possibly in response to codes recovered from an old recording, in order to put time code without defects into a new recording
TDR	trusted digital repository
UNESCO	United Nations Educational Scientific and Cultural Organization; UNESCO is a major stakeholder in heritage and preservation issues
vinegar syndrome	http://www.filmpreservation.org/preservation-basics/vinegar-syndrome (formation of acetic acid from acetate based film)
WAV file	The standard wrapper for audio; see Broadcast WAV Format for the professional variant
word length	The number of bits in the digital representation of the amplitude of a signal
wow	A defect in recorded audio resulting in a slow, cyclic variation in speed or amplitude, or both
wrapper	A method of packaging a coded signal and all related signals and information into a file: commonly video with multiple tracks of audio

	plus time code, subtitles and metadata; see MXF, MOV, AVI

12.Further Reading

One general resource is commonly known as IASA TC-04, full title *Guidelines on the Production and Preservation of Digital Audio Objects* (IASA, 2009). This is the standard guide to digitization of audio, and the sections on metadata and digital storage are of value to all forms of digital media.

Another audio resource (that also includes a range of digitization software tools) comes from the Sound Directions project of Harvard and Indiana Universities: *Best Practices for Audio Preservation* (Casey and Gordon, 2007). As with TC-04, much is also relevant to video digitization.

All the results from the Presto series of projects are on their individual websites. However, updated versions, often with added summaries, have been collected along with many other publications to form the PrestoCentre Library, available at http://prestocentre.eu/library.

Other online information:

- US Library of Congress
  - Digital Preservation http://www.digitalpreservation.gov/
  - Sustainability of Digital Formats http://www.digitalpreservation.gov/formats/index.shtml
- AMIA VideoTape Fact Sheets (these sheets are very concise, but were last updated ten years ago and are very centred on North America and Australia) http://www.amianet.org/resources/guides/fact_sheets.pdf
- TAPE Training for Audiovisual Preservation in Europe http://www.tape-online.net/
- Conservation OnLine:
  - video preservation: http://palimpsest.stanford.edu/bytopic/video/
  - audio preservation: http://palimpsest.stanford.edu/bytopic/audio/
  - film preservation: http://palimpsest.stanford.edu/bytopic/motion-pictures/
- National Film and Sound Archive (Australia): http://nfsa.gov.au/preservation/
- IMAP preservation guide (particularly aimed at Media Art): http://www.eai.org/resourceguide/preservation.html
- Texas Commission on the Arts: Video Identification and Assessment Guide: http://www.arts.state.tx.us/video/
- Video Preservation Website (joint project of Conservation Online, Bay Area Video Coalition and National Center for Preservation Technology and Training) http://videopreservation.stanford.edu/
- Folkstreams Guide to Best Practices in Film Digitization http://www.folkstreams.net/bpg/index.html

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