Sound Preservation: From Analog to Digital

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I. Introduction and Methodology

The simplest part of sound preservation involves technology and its application. The real complexities lie in a mix of social legal, and financial issues. The social issues include how archivists, curators, librarians, historians, or anyone with limited engineering, computing, and other technical training can evaluate competing claims and risks. The legal issues include copyright and the risks that an institution may choose to take about what constitutes fair use and preservation copying. The financial issues include how much of what quality of preservation an institution can afford, and for how many of the items in its collection.

This chapter relies largely on anthropological theory for its methodology and structure. Readers who want to understand more of the theoretical basis for an anthropological analysis of library and archival issues can consult Nardi and O'Day's (1999) *Information Ecologies: Using Technology with Heart*, or my own articles on "project ethnography" (Seadle, 2000a,b). This approach involves recognizing the variety of micro-cultures that need to interact in order to accomplish the technical task of preserving any significant amount of recorded sound. The word *micro-culture* refers to units of shared meaning as small as professions, departments, interest groups. The language and assumptions of members of one micro-culture can seem so opaque and incomprehensible to members of another that key information is missed or misunderstood in ways that undermine the preservation process.

The use of the first person in anthropological articles has always been fairly common, and I will follow the practice here on occasion to remind readers that my own background and micro-cultures necessarily color my judgments, even about technical subjects. I was, for example, a computer

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professional who worked on large corporate systems and mainframe operating systems. This experience gave me a hands-on experience with preserving and recovering digital information that is unusual for members of the other micro-cultures to which I belong: historians and librarians. As a result my approach to digital solutions treats those solutions less as new and unproven technology than as a well-established part of institutional life, though a part of institutional life often unseen by members of the academic community.

If readers take away only one idea from this chapter, it should be that sound preservation is a large and complex social and organizational project, not a set of universally applicable technological fixes, whose effects will endure for all time. Nonetheless the technology and people's reaction to it is important, and will be discussed in Section II of this chapter, not only to give answers but also to provide a shared vocabulary and set the stage for some of the issues about how sound preservation should be carried out. Sections IV and V will discuss the legal and financial aspects.

II. Conversion Technology

A. History

Audio recording technology lacks a stone age. Thomas Edison made the earliest recordings in 1877 on vulnerable wax cylinders—a medium less durable than the worst acidic paper. Shellac discs began to be used in 1897, improved hard wax discs appeared in 1902, and RCA started using vinyl in 1929. (See Schoenherr, 2003a, for a detailed chronology.) Each was an improvement, but all these disc-based media suffered from a destructive playback process that used hard (generally steel) needles, which wore away at the subtle grooves with each performance.

Valdemar Poulsen patented a magnetic wire recorder, first in Denmark in 1898, then in the United States in 1902. It never sold well, however, and after the patents expired, Marvin Camras reinvented wire recording in 1939. Meanwhile German scientists had started working with magnetic tape. Dr. Fritz Pfleumer patented the basics for making magnetic tape in 1928 and demonstrated its use as a recording device in 1935. Americans took an interest in this technology after World War II. While the quality and durability outstripped disc-based systems, tape remained somewhat inconvenient for consumer-use until compact audio cassettes entered the market in the 1960s. (See Schoenherr, 2003b, for further reading about early recording history.)

Magnetic tape became the preservation standard for recorded sound not so much because of its virtues as because of the glaring problems of contemporary pre-digital alternative. (For standards, see Conservation OnLine, 2002.) Tape did suffer some wear with each use, but far less than discs. It was also reasonably inexpensive, lighter and easier to store than discs (which tended to warp when left on their sides), and offered quality so good that it was hard to distinguish from a live performance. Any magnet could erase it, of course, and only machines designed to read that width of tape at its correct recording speed could recover the sound. In other words, magnetic tape remained significantly worse as a preservation medium than the printed book:

> Because access to magnetic tape is dependent upon rapidly changing hardware and software, its long-term viability as a physical medium is a moot question. The need is therefore for information on its short-term life expectancy and particularly on how to determine when the contents should be migrated forward to avoid loss of data. To put it another way, even though it is agreed that magnetic tape is not now a long-term storage medium, we need to understand the mechanisms driving its physical and chemical deterioration in order to develop the best possible strategies for the preservation of its content. Child, 1993.

The vulnerability of tape is also emphasized through the preservation recommendations of the Cutting Corporation, which specializes in the preservation and restoration of sound recordings.

> Analog tape should be kept away from magnetic fields and heat sources at all times. For long term storage, metal reels with an unslotted hub should be used. They should be stored with the end of the program or "tail" of the tape on the out side of the reel. This practice is referred to as "tails out" and is done to reduce audio degradation known as print through. Print through causes a delayed or echo sound in the program....The tapes should also be stored tightly or evenly packed in a sturdy, dust-proof tape care box. A tightly packed tape is a tape that is spooled tightly and evenly around the hub and reduces the damage to the edges of the tape....The room chosen to store reels in should be at a constant temperature of 50°F to 70°F and a relative humidity of 40% to 60%. Cutting Corporation, 2000.

There are other problems with tape. Sticky shed syndrome, where the tape binder deteriorates leaving gummy deposits and the magnetic coating comes off, plagued some tapes manufactured in the United States from 1975 to 1985 (Master Digital, 2002). Tape quality also deteriorates slowly over time, and analog-to-analog copying involves a significant enough quality loss that the deterioration is audible even after several generations of high-quality copying.

The point is simply that magnetic tape is not and never has been a viable long-term preservation medium for recorded sound. (For a summary of the preservation issues, see Dale *et al.*, 1998.) For decades it was, however, the best alternative, and represented a reasonable short-term solution. The problem was that a generation of audio preservation specialists grew up so accustomed to tape that any departure from it felt risky. When the American

Library Association held a pre-conference on digital sound in 1998, it became clear that the speakers felt unready to recommend any new standards that would change how sound recordings were preserved.

Four years later the situation has changed, at least for most large sound archives at major institutions. Digital preservation has become an accepted method, if not always a comfortable one for those with responsibility for the contents.

Some of the key issues will be discussed in the following.

B. Media

One commonly expressed concern about digital preservation is the longevity of the media on which the information is stored. A great deal has been written about how long a compact disk (CD) will survive with its data intact. CDs are so new that no actual historical information about their long-term performance is available. Manufacturer laboratory testing of CDs under conditions that stress them in ways that resemble aging suggest that the best quality CDs, even read–write CDs (CD-Rs), may reliably retain their data for significant periods (Hartke, 2001). Those periods cannot, however, translate reliably into days or years. They are measured in terms of error or failure rates, and any mention of specific safe duration periods would be highly misleading. Such studies have done little to persuade audio preservation specialists or others that CDs can be treated as the digital equivalent of microfilm (Hedstrom, 1998). In fact, it does not matter, and neither do the long-term preservation qualities of digital audio tape (DAT), hard disks, back-up tape, or any other single medium for digital storage.

This is a message that preservation specialists of every sort find perplexing. It goes against all their training, which emphasizes halting or reversing the aging effects of particular media types, and it seems potentially like an attack on their professional micro-culture. It is in fact a principle from a foreign micro-culture. Computer centers have known for decades that all digital storage media fail eventually, some sooner than others, some more predictably than others. For them the key to preserving digital data lies in keeping multiple copies on a variety of media, and having a plan for moving that data to fresh media before all the copies expire. In this paradigm, the predictability of failure matters far more than longevity.

The best medium for digital preservation is arguably the hard disk, not because hard disks last longer, but because testing is easy and can be automated so that problems with one copy become apparent almost immediately after they occur. The use of RAID (redundant arrays of independent disks) and mirrored disks means that at least two copies exist. Daily, weekly, and monthly back-up tapes provide three additional copies of everything over a month old. Nonetheless, vulnerabilities remain without some geographic diversity. The premise of the LOCKSS (lots of copies keeps stuff safe) project from Stanford University Library is as true for a durable medium like microfilm as it is for digital sound (Stanford, 2002). Copies matter, and digital copies have the advantage that they can be made quickly, remotely, and without loss.

For computing professionals this argument seems so overwhelmingly reasonable that it can be difficult to understand how fragile the whole interlocking system of duplicate copies and anticipated failures sounds to those schooled in the common sense principle that valuable materials should be stored on durable media. It is not unusual to see high-quality "gold" CDs (which were once actually made with an actual gold reflective layer) filling the role in today's grant proposals that reel-to-reel analog tape would have had several years ago as the true archival form. The media-based preservation mindset is hard to break.

In the end, however, as Elizabeth Cohen (2001) wrote: "[t]here is no choice but to accept that data migration is the only intelligent policy." Analog tape has essentially already been abandoned. No one except CD manufacturers really believes that they represent a long-term solution. Digital copies on multiple media with anticipated failure rates and regular refreshing is the only way to save sound recordings across the centuries. Once that is accepted, the question becomes how to do it right.

C. Conversion Process

The process of converting analog sound to digital is based on sampling. Analog sound is a continuous wave pattern that captures the movement of air caused by the larynx, lips, strings, wings, or any other object vibrating within a set of frequencies that the ear can perceive. Human ears are definitely not the highest quality receptors in the animal kingdom, but they tend to define our conventional notions of sound. This is important because of the debate between those who want to capture all the sound that a human can hear, and those who want to extend the capture process significantly beyond human range to save information which, at some future point, computers might use to determine the shape of the room, the number of people in it, and other information that trails rapidly into the realm of science fiction (Seadle, 2001). The advocates for the latter tend to be historians and other end-users with vivid imaginations, rather than engineers or computer professionals who have a prosaic awareness of the limits of known tools. Some preservationists also tend to want to save every possible nuance of sound, and prefer over-sampling, even gross over-sampling, as a way of compensating for what they view as the loss of detail in having only samples rather than the whole continuous analog wave.

Theoretically, sampling permits an exact reconstruction of any waveform with frequency less than half that rate. Since this theoretical result cannot be implemented precisely, the usual practice is to over-sample slightly to compensate for the practical realities. Sampling at 44.1 kHz, e.g., theoretically assures perfect reconstruction of all frequencies up to 22.05 kHz. This is well above the normal hearing range of most people. Sound engineers probably have in mind an extreme upper frequency range in the neighborhood of 20 kHz, requiring a theoretical upper sampling rate of 40 kHz. The extra 4.1 kHz is to compensate for the practical realities.

Over-sampling may in fact have no value at all. The wave functions of audible sound do not shift so rapidly or radically that any perceptible difference exists between 96 and 44.1 kHz. The latter sampling rate gives a faithful representation of the shape of the sound wave, and if it did not, interpolation between the samples could reasonably fill in the missing values precisely because the wave is continuous. If over-sampling has any value, it lies in a future beyond current engineering or auditory abilities.

The bit depth is in fact more important, because it determines the resolution of samples, i.e., the "granularity" with which the colors or brightnesses of an image are divided up, or (in rough terms) values representing sound energy. A bit depth of 1 would only indicate whether or not sound exists above the sampler's threshold level: a beep or a silence, e.g., roughly equivalent to black and white color. A depth of 24 gives about 17 million amplitude levels, much like 24 bit color, whose content is visibly more precise than 8 bit color. The current audio CD standard for stereo music is 44.1 kHz, 16 bit. This level of quality sounds perfect even to very sophisticated listeners. Existing analog television broadcasts generally have far lower quality sound, and the typical oral history recordings, made on monaural tape with poor-quality microphones and cheap recording devices that introduce machine noise into the recording, are worse still.

Sampling these recordings at 96 kHz and 24 bit is the equivalent of taking a color photo with an old no-focus, cheap lens camera, letting it fade for 20 or 30 years, and then scanning the result in 600 dpi 24 bit color. The scan will certainly capture every nuance, but they are nuances that reproduce the faded, poorly focused print. The original scene is gone for good. Even if the original image were in perfect condition, it serves no useful purpose to sample the image in space and resolution beyond measures which capture all the visual information that the human eye can perceive.

A number of archives are using, recommending, or at least making provision for 96 kHz 24 bit digital recordings. These include Harvard (2001) and the Library of Congress (2001b). For very high quality original recordings of complex sounds made under studio conditions with musical content whose audio range tests human capacity, some over-sampling could make sense, but the chief consequence of over-sampling as a standard for all recordings is an increase in costs because of extra processing time and extra storage. In a time of tight budgets for even the richest institutions, this almost certainly means a reduction in the numbers of recordings that can be digitally reformatted and preserved.

What does matter enormously to the conversion process is having good analog playback equipment and sound cards that minimize extraneous noise during the conversion process. The hum of a tape deck, a sound card that rattles, the whir of a computer fan, the subtle sound of tape rubbing against a plastic reel all contribute to the degradation of sound before it reaches digital format. Most preservation-aware sound archives already have quality equipment. If not, the equipment is worth spending money on. Getting that single digital reformatting playback right will do more to preserve the original sound than any increase in the sampling rate will ever do. For the same reason, head-cleaning and other equipment maintenance matters, as does the cleaning and handling of the originals. Advice about both is available from the Library of Congress (2002a).

One of the most complex parts of the digitization process involves managing the recording levels as the signal goes from the analog playback device to the computer card. If the recording range is set too high, it can clip off the tops or bottoms of the sound wave and introduce squawks that sound harsh and distorted. If the recording level is set too low, it will reduce the overall dynamic range and the signal-to-noise ratio. A good sound engineer will use a mixer to apply the right amount of compression and limiting to help control levels, optimize the dynamic range, and reduce the chances for clipping (Peiffer, 2002).

The software tools for digital conversion vary with the operating system and the price that an institution is willing to pay. Happily even inexpensive software like Syntrillium's Cool-Edit (http://www.syntrillium.com/cooledit/) can do a good job of handling the reformatting process, which is largely a matter of taking digital output from the sound card and saving it.

Generally experienced preservation specialists have a lively sense of the importance of not adjusting the archival version of a digital sound file, once it has been created. Less experienced people can, however, be seduced by advertisements from restoration companies that promise crisp, clear, digitally improved recordings that are free from any tape whir or vinyl disc pops. This represents the opposite extreme from those who fear that digitization implies quality loss. Restoration can be useful on derivative copies that will be used in settings where the whirs and pops will distract the audience, but those sounds are generally removed at the cost of some variability and richness.

Removing unwanted noises involves excising some part of the recorded sound and perhaps interpolating between remaining samples to fill the gap. Removing whirs and constant background noises is particularly troublesome, since it can affect every part of analog sound wave if it occurred during the initial capture. Whole frequencies of sound can be lost. Some companies are of course more responsible and reliable than others, but none should be trusted to alter the archival original, if for no other reason than the possibility that better tools will come along in the future.

III. Digital Standards

A. Formats

The standards for formats vary with the discipline and purpose. Libraries and archives tend to use uncompressed ".wav" files, which are essentially a pulse-code modulated (PCM) bit-stream with headers for some basic information such as file type, sampling and quantization rates, file size, duration, and whether the recording is monaural or stereo. Engineers tend to prefer "raw" files that are pure PCM without the headers. For most engineering purposes, the sound must also be down-sampled drastically to as little as 8 kHz.

End-users and the digital playback systems popular today tend to use either compressed formats, such as "MP3" or QuickTime, or streaming versions such as RealAudio. MP3 is an audio technology using Motion Picture Experts Group (MPEG) specifications that compress CD quality sound by a factor of 12. Quicktime is a Macintosh product for both audio and video, and Real Audio comes from Real Networks. These formats are definitely non-archival, because the compression is so high that they lose quality, but they are small enough to travel easily over contemporary bandwidth. Napster famously used MP3 files, as do its more decentralized successors KaZaa and Gnutella, and radio stations now often "webcast" using streaming audio.

None of these formats should be regarded as enduring. Some may last for 5 years, others for 50 or more, but eventually they are likely to need migration to some new form of digital encoding. This is another troubling fact for traditional preservationists, whose training warns them away from the ephemeral. Computer professionals, however, take the inevitability of this kind of transformation for granted. A significant part of my own professional computing life was spent transforming digital data from one format to another, and occasionally back again when the new format did not work out as planned. The data survived unscathed, equally useful and complete regardless of format.

Migration is expensive, which is why it matters so very much to use formats that others have accepted as actual or de facto standards, because then standard conversion tools will keep the costs to a minimum. The biggest cost comes from adopting an excellent but idiosyncratic format where a small number of institutions must create their own unique conversion tools. Tool making is expensive. Running the tools is (comparatively) cheap.

B. Metadata

The metadata for digital sound is as important as the sound itself, because without some description of what it is, where it comes from, what formats it is in, and what restrictions it has, the sound file is just a stream of bits that may be obvious and intelligible if it represents a famous speech, such as President Kennedy's inaugural address, but more likely is an unknown voice speaking in an unfathomable context, or an unknown song by an unrecognized performer.

No single standard exists for the ideal digital sound metadata, but four versions have some significant following among sound archives: Machine-Readable Cataloging (MARC) from the Library of Congress, Dublin Core (DC) from OCLC, Encoded Archival Description (EAD) from the Society of American Archivists, and Metadata Encoding and Transmission Standard (METS) from the Digital Library Federation. In general their proponents come from different micro-cultures, and they serve different needs. MARC is the oldest, and METS so new that its first version is only just available from the Library of Congress (2001a, 2002b). Some archives want to know which standard is best for sound preservation. Any answer to that question depends on the contents of the archive, how they will be used, and constraints from existing software.

For some archives, MARC is the only choice because their automation system only handles MARC records, and their catalogers know nothing else. It is certainly a reasonable choice for smaller archives that belong to larger libraries. MARC has fields that can describe every possible medium on which digital sound is stored, and AACR2 (Anglo-American Cataloging Rules, 2nd edn.)-based MARC records can give a rich description of the intellectual contents of any sound file. Library of Congress Subject Headings (LCSH) provide enhanced access, and essentially all contemporary online catalog systems use MARC records. The Vincent Voice Library (VVL) at Michigan State University used to catalog its 40,000 voice recordings in MARC. The problem was the expense.

While cataloging copy exists for commercially produced recordings, many sound archives including the VVL specialize in unique non-commercial materials, such as local speeches, oral histories, or even news broadcasts, which libraries may legally capture and hold (17 USC 108). Unique items require costly original cataloging, especially when each item is treated as if it were a separate work, the intellectual equivalent of a whole monograph. This often makes little sense when the sound bite is only 30 seconds long. The question is, whether a library or archive has too many recordings to afford that approach.

The other metadata options all use XML (Extensible Markup Language). While XML-based metadata are generally simpler than MARC, some of the technical language used to describe them may be less familiar to librarians. XML metadata may have document type definitions (DTDs) that define each tag or attribute within a tag, or "schemas" that define how the components of a document fit together (see Sperberg-McQueen and Thompson, 2003). XML has the preservation advantage that it is composed only of pure ASCII characters, the lowest common denominator of the computing world. MARC now has an XML version too.

Although EAD is encoded in XML, it has been around in archives for a long time in its pre-digital form as "finding aids." More recently it has gained a following in the library community as well. EAD works well as a means of collecting related materials together into a single intellectual unit. It makes sense in particular for the collected records of a single speaker, multiple speakers at a single event such as a conference, or multiple speakers at related events such as a series of readings by local authors. While these recordings could be cataloged separately to match them with the author's books, the cost would be prohibitive, just as it would be to catalog each of an author's articles separately.

EAD has features to encode access restrictions, physical descriptions, and abstracts at the collection and item levels. Because EAD allows large numbers of sound files to be collected and described in one place, it is relatively less expensive than MARC. The biggest problem with EAD at present is that most browsers cannot display native XML. This is expected to change in the future, and in the meantime tools exist to convert to HTML either on-the-fly, such as Cocoon from Apache (Apache, 2002), or in batch mode, such as Saxon (Kay, 2001).

Dublin Core records can also be used to describe recorded sound. While Dublin Core describes item level materials, its format is much simpler and more flexible than MARC, and the rules for what goes in each element are so broad that inconsistency has become one of its major drawbacks. Dublin Core records the same types of information as an EAD or MARC record, but is less specific. One advantage of Dublin Core is its use in Open Archives Initiative Protocol Metadata Harvesting (OAI-PMH), which promises to make large numbers of previously hidden digital collections accessible. The Institute of Museum and Library Services has a project to use OAI-PMH to provide access to collections digitized through its awards.

Some state-wide digitization projects (e.g. Colorado and Michigan) use Dublin Core for oral histories as well as for other digital materials, because the records are easy for non-librarians to understand and create. The inconsistency of the descriptions makes it relatively hard to convert Dublin Core into reliable MARC or EAD, but the reverse process is fairly simple for archives wanting to take advantage of OAI-PMH.

METS is almost too new to be used, except experimentally, for recorded sound materials. The principle behind METS is somewhat different than the metadata types above. It is designed less for description than to collect all the kinds of information that are necessary for the long-term archiving of any digital object. It can serve as a useful checklist for archives already deeply committed to other formats. METS uses XML schemas that allow it to incorporate MARC or EAD or virtually any kind of existing metadata into, e.g., its descriptive section. It also has some unique features, such as the structural map section which "outlines a hierarchical structure for the digital library object, and links the elements of that structure to content files and metadata that pertain to each element" (Library of Congress, 2001a). It also has a behavior section that explains the way an object can be expected to act when activated.

These sections provide a place to record information that people take for granted when dealing with traditional analog materials like a book or a tape. One of the real preservation concerns of many archivists is that people in the future will not know how to use a digital recording, even though the file itself survived unscathed. This is important information, but it can also become very repetitive for data that use consistent formats, open standards, and moderately informative names or headers.

C. Authenticity and Integrity

It is more difficult to guarantee authenticity and integrity in the digital than the analog world, precisely because of the ease with which digital objects can be manipulated. Abby Smith (2000) expressed the concern felt by many:

> Looking ahead, we can reasonably expect that some digital objects will warrant greater skepticism than their analog counterparts. It took centuries for users of print materials to develop the web of trust that now undergirds our current system of publication, dissemination, and preservation. Publishers, libraries, and readers each have their own responsibilities to keep the filaments of that web strong. Making the transition to a trusted digital environment will require much conscious reexamination of what we take for granted in the print and audiovisual media on which we rely.

Integrity and authenticity are separate but related issues. An object can have a measurable form of integrity by being complete and unaltered without being authentically what it claims to be; and it is conceivable that an object could be authentic but with some parts missing. The goal of preservation is, however, clearly to have both, and some technologies contribute to that goal.

Watermarking is often used to prove the origin of copyright-protected materials:

> Digital watermarking refers to the process of embedding an imperceptible signal (the watermark) into a copyrighted host signal (the coversignal). The result is called a stegosignal. The unmarked coversignal is never released [to] the public, and the means for separating the watermark from it are known only to the copyright-holder. When copyright questions arise, the watermark is recovered from the stegosignal as evidence of title. A watermarking scheme generally derives its security from secret codes or patterns, called keys, that are used to embed the watermark. Public knowledge of a watermarking technology should not lessen its security. Deller *et al.*, 2001.

Knowing the origin is a key component of establishing authenticity, and the recovered watermark may also be useful for establishing some aspects of integrity, since attempts to alter the digital sound could affect the watermark image. It might not, however, show whether whole sections had been excised.

Other technologies can help too. Even old-fashioned check-digit routines can be useful for integrity checking, even though they are intended only to catch accidental bit changes, not deliberate alterations. Nonetheless one of the best guarantees of the authenticity and integrity is metadata that records all the characteristics of the digital object. Such metadata needs to have an enduring relationship to the object, and both the object and its metadata should reside in multiple repositories whose security and integrity are unimpeachable.

Multiple repositories are important. They represent a significant difference in the handling of necessarily unique analog objects. Digital objects can have multiple originals, each perfectly identical down to the time-stamp. Algorithms can compare the originals against each other to guard against either intentional or inadvertent damage. This is one of the important features of the LOCKSS project (Stanford, 2002).

Multiple originals and security through consistent exposure are such oxymorons in the analog world that they sound unappealing compared, say, to an underground storage facility with perfect temperature and humidity control and a single identifiable original object that cannot be tampered with because no one can get to it. Yet a LOCKSS-like system should be significantly safer than the current situation for many unique originals. Even when these analog originals sit behind closed doors, a large number of sound archives cannot vouch completely for their integrity and authenticity. The reality of most archives is that janitors, assistants, and sometimes students (or student workers) have complete access to originals, sometimes even to the metadata describing them, and could alter, replace, or outright steal items at any time.

IV. Legal Issues

A. Copyright Protection

The chief legal issue for sound preservation is copyright, and it gives rise to three questions. One is whether a work is protected. Another is when and whether the law permits creating digital preservation copies. The third is when and whether the law permits access to a digital preservation copy of sound recording.

The U.S. copyright law is complex and ever-changing, and the full details of how to determine whether a work is protected are too complex to discuss fully here. As a rule of thumb, it is safe to assume that all works published in the United States from 1923 to the present are likely to be protected. The only major exception is for works created by U.S. Federal employees in the course of their work, such as the President's State of the Union address. The same exemption does not cover speeches by a candidate for the presidency, and may not even cover speeches by a sitting President who is campaigning for reelection. State documents do not fall under this exemption, nor do works created by non-Federal employees, even when found on Federal web sites.

International copyright treaties mean that libraries and archives with non-U.S. materials must also know enough about the law of the country-of-origin to determine the legal status of the work. Berne treaty signators have agreed to treat works from other Berne countries as protected, if they would be protected in their country-of-origin, but protected only under local rules. This means that an audio recording made in Germany in 1920 by someone who did not die until 1950 would still be protected in the United States until after 2020 (the life of the author plus 70 years), even though it would be in the public domain if it had been made in the United States. None of the German moral rights legislation would apply, however, and U.S. "fair use" rules would.

Because the law is complex, interpretations will vary from institution to institution. Some institutions are more willing to take risks than others. Micro-cultures within an institution are also likely to have strongly differing opinions about how strictly to interpret the copyright law. Nothing in this section constitutes legal advice. It is information only.

B. Preservation Copies

The Digital Millennium Copyright Act (1998) updated the U.S. copyright law to permit digital preservation copies of a work under certain conditions. For unpublished works, libraries with collections accessible to the public may make:

> three copies or phonorecords of an unpublished work duplicated solely for purposes of preservation and security or for deposit for research use in another library or archives...if...the copy or phonorecord reproduced is currently in the collections of the library or archives; and any such copy or phonorecord that is reproduced in digital format is not otherwise distributed in that format and is not made available to the public in that format outside the premises of the library or archives. 17 USC 108.

Unpublished works would, e.g., include most oral histories.

"Unpublished works" mean any work that does not meet the strict legal definition of publication:

> "Publication" is the distribution of copies or phonorecords of a work to the public by sale or other transfer of ownership, or by rental, lease, or lending. The offering to distribute copies or phonorecords to a group of persons for purposes of further distribution, public performance, or public display, constitutes publication. A public performance or display of a work does not of itself constitute publication. 17 USC 101.

The last sentence is particularly important because it excludes many works that people think of as published. One example is a recording of speech that was made to a large audience. The act of giving the speech constitutes a performance of the words on the page, not a publication of those words in the legal sense.

Libraries may also make up to three copies of published works when the work was:

> duplicated solely for the purpose of replacement of a copy or phonorecord that is damaged, deteriorating, lost, or stolen, or if the existing format in which the work is stored has become obsolete, if the library or archives has, after a reasonable effort,

> determined that an unused replacement cannot be obtained at a fair price; and [if] any such copy or phonorecord that is reproduced in digital format is not made available to the public in that format outside the premises of the library or archives in lawful possession of such copy. 17 USC 108.

The definition of "obsolete" is so important that it is included in the same section:

> For purposes of this subsection, a format shall be considered obsolete if the machine or device necessary to render perceptible a work stored in that format is no longer manufactured or is no longer reasonably available in the commercial marketplace. 17 USC 108.

Of course the definition of "reasonably available" also matters, but that has been left to the courts, and thus far no case law exists. Many archives now treat disc-based "record players" as obsolete, since the prices on turntables have risen substantially, and since the playback process invariably damages the original, which can no longer be replaced in the same format.

The conditions of the law clearly forbid making digital copies of a current best-selling audio CD. They may well also forbid making a digital copy of a commercially produced cassette that is no longer sold commercially, but is readily available in second-hand stores. For preservation purposes the problem is that any copy in a second-hand store would likely have seen significant use, and would have lost some of the quality of a well-preserved (little used) archival version. The law is deliberately ambiguous, and sound archives need to decide for themselves how literally they wish to interpret the law. As a practical matter, making a digital preservation copy does the rights holder no harm until it is used as a substitute for the original. Because of that, many libraries and archives reconcile themselves to digitizing almost any endangered items that are no longer being sold new, on the theory that no one will know or care.

One of the important restrictions on digital preservation copies is the phrase limiting use to the "premises of the library or archives..." Premises could mean only within the physical space where users would ordinarily be allowed to play the analog copy on a institutionally owned machine. In large institutions that might just be a single department. The word "premises" more often is interpreted to mean the physical building which houses the sound archive. It could also mean the part of the library with public reading/listening rooms, even if the recordings are not ordinarily physically there. A more aggressive interpretation might include all the buildings that belonged to a library on a single campus, or perhaps even all the libraries on all the campuses of a university system, on the grounds that the analog copy might be held at any of those locations. Clearly making the digital copy generally available on the Web is forbidden. Multiple simultaneous uses of copies of the same protected work are also probable violations.

C. Access

While the U.S. law tolerates fairly broad use of digitization for preservation, restrictions on access are much more limited. For materials protected by copyright, there are generally three ways in which they may be made available off the premises.

The safest way is to get a permission from the rights owner for Web or other public use. Institutions should strongly encourage any oral historians and anthropologists who use recording equipment to obtain specific consent forms from their subjects. The same is true for speakers who are being recorded at public events. Permissions from commercial produces can cost money, but those from other sources tend to be free.

Changes to the copyright law from the "Technology Education and Technology Harmonization Act" (TEACH Act), which President Bush signed into law on 2 November 2002, enable the use of recorded sound materials in distance education teaching settings. The act permits the "display of a work in an amount comparable to that which is typically displayed in the course of a live classroom session" under certain circumstances without seeking permission (TEACH Act, 2002). There are important restrictions and definitions, such as the meaning of "session" in a distance education context, which must still be worked out (Crews, 2002). For example, does class session in distance education: (a) take place at a particular time; (b) take place for a particular length of time; or (c) encompass any time during whole semester to adjust to each student's own pace and schedule? There is no agreement on this. The requirements for institutions are also significant. They include not only providing information about copyright, but applying "technological measures that reasonably prevent...retention of the work in accessible form...for longer than the class session..." (TEACH Act, 2002)

Not everyone will want to use the TEACH Act. As Georgia Harper writes:

> This statute's complexity provides a new context within which to think about fair use: compared to the many conditions and limits contained in Section 110(2), the four factor fair use test seems, well, simple and elegant. Harper, 2002.

Fair use (17 USC 107) offers the main legal exception for using copyright-protected materials. While the prologue to the fair use section suggests broad access for educational purposes, courts have invariably focused on the tests:

1. the purpose and character of the use, including whether such use is of a commercial nature or is for non-profit educational purposes;
2. the nature of the copyrighted work;
3. the amount and substantiality of the portion used in relation to the copyrighted work as a whole; and
4. the effect of the use upon the potential market for or value of the copyrighted work.

A great deal has been written about how to apply fair use safely, and institutional policies vary widely. The House Subcommittee on Courts and Intellectual Property, Committee on the Judiciary adopted a non-legislative report that provided fair use guidelines (U.S. House of Representatives, 1996). The guidelines are not law, and can be seen as overly restrictive, but they provide a relatively safe harbor for multimedia users. For "motion media" they suggest 10% or up to 3 minutes. For music it is 10% or up to 30 seconds. While these limits are short, they may suffice to give something of the flavor of a work.

At the Folk Heritage Collections in Crisis conference (Library of Congress, 2001c) in December 2000 a significant number of people argued in favor of levels of access to digital sound recordings that would imply massive copyright infringement. Many belonged to a micro-culture that had strong feelings about the importance of their own educational mission, and little active sympathy for commercial recording studios. Ignoring the law is a potentially expensive position that no institution can afford to adopt.

Some old-time preservationists are fond of saying that digitization is good for access, but it is not preservation. The truth is almost the opposite. While digitization is the only viable long-term preservation method for recorded sound, it does little to enhance access without permission from the rights owner.

V. Financial Issues

Understanding the costs of digital preservation is important, but the costs are hard to measure for several reasons. One is that prices for computers and digital storage continue to fall, while prices for computing professionals continue to rise. Another is that the media refreshing and format migration rates depend on estimates that vary wildly.

It is easy for critics of digital preservation to impute impossible costs by calculating the staff time for checking each archival medium and allocating the whole of the programming time for format conversion to every institution. In fact the automated checking of a LOCKSS-type system costs little more than a $1000 machine that needs replacement at most every couple of years, and the programming costs for reformatting tools can be shared across thousands of institutions when standard formats are broadly used, so that format conversion might cost only a couple of hundred dollars every 5 or 10 years. The cost of running an automated tool in batch mode against sound files already in digital form is trivial. Conservative sites may want to build in some random checking to make sure the process worked, but that too can be automated and shared.

Electricity, disk storage replacement, and some maintenance time to keep systems running need to be included on an ongoing basis. These costs will also vary widely. For a substantial data center, maintaining one more server represents a marginal cost, say 3 days effort or roughly $1000 per year for a mid-level computer professional making $60,000 plus benefits. Electricity costs vary widely across the country, but $300 per year should more than suffice. The cost of storage has fallen dramatically. A half terabyte of storage including rack and computer can be bought today for less than $15,000. Replacing 20% of that storage per year would total $3000.

By these estimates the cost of long-term preservation for digital sound adds up to about $5100 per year for about 3000 hours of sound at 44.1 kHz, 16 bit (Table I).

Naturally an argument can be made about each of these costs. They could well be off in either direction by 50%, perhaps even 75%, but the order of magnitude is probably correct. For most large institutions, this is a fairly manageable amount. The largest cost of digital preservation comes in the conversion from analog formats.

Michigan State University Libraries has 3 years of experience with large-scale conversion of spoken word sound materials from analog to digital formats. During that time the number of hours of staff time needed to convert

Table I
Annual costs for digital preservation of 3000 hours of sound

LOCKSS machine replacement every 2 years	$500
Storage replacement (20% per year)	$3000
Programming maintenance time (3 days per year)	$1000
Future format conversion software (over 5 years)	$100
Conversion time (amortized over 5 years)	$100
Spot checking (amortized over 5 years)	$100
Electricity per year	$300
Total	$5100

1 hour of sound has fallen from over three to slightly over one. The largest factor in the improved speed was establishing networked storage and automating the process of loading sound files to it. One staff member can in fact manage the conversion of more than one tape at a time, depending on the length (longer tapes are easier because they just keep running). At $10 per hour for student labor (no benefits), and at an average of 2 work hours per hour of sound, the labor cost of converting 3000 hours of sound is about $60,000.

Equipment costs are lower, but can be substantial if additional analog playback units are needed. Most places wanting to preserve sound recordings should have them already. A computer will cost about $1000, a good sound card about $400, a mixing station perhaps $2000, and software less than $300. In other words, the hardware cost is under $3000, not including the analog playback units.

VI. Conclusion

If the 100 year cost of preserving 3000 hours of sound in digital form is around $5,200,000 in constant dollars (100 years at $5100 per year for preservation, plus $63,000 for a one-time analog-to-digital conversion), the cost of the alternative is losing the content altogether. Analog tape, the old pre-digital archival standard, is increasingly expensive and hard to find, and the machines to play it are becoming museum pieces. But even if they could be obtained, the deterioration from copying, wear, and time itself would leave only a shadowy record of today's sound.

This is a troubling message for many collectors, archivists, librarians, and sound engineers. Often they belong to micro-cultures whose acceptance of computers has been slow, often limited to e-mail and word processing, and whose personal experience with computers includes disk crashes, software problems, costly upgrades, and a maddening dependence on arrogant outsiders who sometimes fix and sometimes ignore their problems.

The message is troubling also because so many important factors, such as the dramatic drop in disk storage prices and the LOCKSS-type experimentation, have come so recently as to be unfamiliar, even a bit unbelievable. It may be as unbelievable as the first Edison recording seemed to the public in 1877.

Sound recording is a modern machine-dependent technology. Unlike text, sound cannot be marked on a clay tablet, etched in stone, or written on any flat absorbent surface (vellum, papyrus, rag paper, pulp paper) and subsequently played back with the aid of human senses alone. As technologies change, sound recording must change, and those who wish to preserve recorded sound must change with it.

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