Capturing Analog Sound for Digital Preservation:

Report of a Roundtable Discussion of Best Practices for Transferring Analog Discs and Tapes

March 2006

The National Recording Preservation Board

The National Recording Preservation Board was established at the Library of Congress by the National Recording Preservation Act of 2000. Among the provisions of the law are a directive to the Board to study and report on the state of sound recording preservation in the United States. More information about the National Recording Preservation Board can be found at http://www.loc.gov/rr/record/nrpb/.

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Foreword

For more than 115 years audio recordings have documented our culture and enabled us to share artistic expressions and entertainment. Among all the media employed to record human creativity, sound recordings have undergone particularly radical changes in the last 25 years. The "digital revolution" has introduced new audio formats to consumers and library collections. Institutional archives are now making a transition from preserving audio collections on tape reels to creating digital files. Libraries and archives face both opportunities and challenges. New distribution systems have provided archives with a broader universe from which to acquire collections, but, at the same time, new formats have created new demands on our preservation resources.

In the National Recording Preservation Act of 2000, the U.S. Congress recognized the significance of sound recordings in our lives and the need to sustain them for future generations. That law created in the Library of Congress the National Recording Registry of historically, culturally, and aesthetically significant recordings; the National Recording Preservation Foundation; and the National Recording Preservation Board, a body of recording industry and library professionals who advise the Library of Congress on preservation issues.

Congress's commitment to assuring the future of professional audio preservation was further demonstrated in the law's directive to the Recording Board to conduct a study of "the current state of sound recording archiving, preservation and restoration activities." The study was to include, according to the legislation, an examination of "the establishment of clear standards for copying old sound recordings." This publication, the third in the series for the preservation study and the first to address technical issues relating to audio preservation, provides some useful indicators of progress in audio preservation standards by reviewing current practices in copying analog discs and tapes.

While libraries develop ways to maintain and serve their digital collections, they still face challenges in maintaining audio collections in older formats. Analog discs and tapes continue to require attention and pose particular challenges. For historical audio recordings to be accessible to researchers in the future, specialized equipment must be maintained for playback. Many of these analog recordings are deteriorating and must be reformatted while they are still playable.

Authoritative manuals on how to create preservation copies of analog audio recordings do not yet exist. There are, however, many highly skilled preservation engineers working throughout the United States. To begin to fulfill the Congressional mandate to establish standards for audio preservation, the Library hosted a roundtable discussion in 2004 and invited some of these talented engineers to share their methods for copying recordings. The roundtable revealed agreement on most practices and on a number of areas in which further research is needed. I am extremely grateful to these professionals for donating their time and sharing their expertise. As this report indicates, much more work remains if we are to preserve the knowledge and expertise of these individuals in order to inform preservation professionals in the future. The National Recording Preservation Board is committed to documenting best practices for sustenance of our audio heritage and sharing that work with the preservation community.

James H. Billington
Librarian of Congress

Preface

The ability to record and play back the sounds that surround us—human voices, musical performances, the sounds of nature—has existed for little more than 125 years. Yet the body of recorded sound that has been produced since its inception in 1877 already constitutes one of the greatest creative, historical, and scientific legacies of the United States. Given the importance of recorded sound to our economic well-being, cultural enrichment, and ability to stay informed by means of radio, television, and the World Wide Web, it is alarming to realize that nearly all recorded sound is in peril of disappearing or becoming inaccessible within a few generations.

Our audio heritage is fragile because it depends on technologies and media that are constantly improving and are thus constantly replaced and unsupported by newer generations of hardware and software. Our continued ability to hear recorded sound will depend, first and foremost, on technologies that capture audio signal on obsolete formats—such as wire recordings, cylinders, instantaneous lacquer discs—and migrate or reformat them onto current technologies. To ensure that the recorded sounds of the past century are available for study and pleasure by future generations, we must not only preserve the media on which they were recorded but also guarantee that we have the hardware to play back the recordings, an understanding of the media, and the expertise to extract the best-possible sounds from antique recordings of all types. That said, the formidable technical challenges are merely the proximate cause of the fragility of these recordings. The ultimate challenge to providing access now and in the future is political and organizational: As a society, we must find the will and the resources to define this problem as a priority and to address the problems that technology poses.

Recognizing the importance of our audio heritage to the nation, the U.S. Congress created the National Recording Preservation Board (NRPB) in the National Recording Preservation Act of 2000. Operating under the aegis of the Library of Congress (LC), the NRPB is leading a national effort to address the preservation of and access to the recorded sound held by libraries, archives, historical societies, studio vaults, and private collectors as well as by others who create, care for, and care about audio. In the legislation that created the NRPB, Congress directed the Board and the Library to report on the current state of recorded sound preservation and to develop a national plan to preserve and broaden access to recorded sound. The Library asked the Council on Library and Information Resources (CLIR) to commission background investigations and to convene experts to inform their study. This publication is the third of a series that has been produced in response to the LC's request. The first two publications reported on the accessibility of out-of-print recordings and copyright of recorded sound.*

This report is the first of two documents that will investigate procedures to reformat sound on analog carriers to digital media or files. It summarizes discussions and recommendations emerging from a meeting of leading audio preservation engineers held January 29–30, 2004, to assess the present state of standards and best practices for capturing sound from analog discs and tapes.

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* *Survey of Reissues of U. S. Recordings*, by Tim Brooks (August 2005) and *Copyright Issues Relevant to Digital Preservation and Dissemination of Pre-1972 Commercial Sound Recordings by Libraries and Archives*, by June M. Besek (December 2005).

A companion report, dealing with key aspects of digital technologies, including file formats and standards, metadata, storage media, repositories, software tools, and collaboration between the archival and scientific community, will be published later this year.

The meeting summary, presented in part one of this report, was written by music writer and historian Paul Kingsbury. Prior to the meeting, Larry Appelbaum and Peter Alyea of the Library of Congress prepared a step-by-step description of practices for transferring two source materials—analog audio tape and analog audio disc—to digital for the purpose of preservation reformatting. These workflow documents were edited and distributed to participants before the meeting and served as the focus of in-depth discussions of preferred reformatting practices at the meeting. Annotations were made to the documents as a result of these discussions, and the revised drafts were then sent back to participants for further comment and annotation through a listserv. That online discussion was closed April 1, 2004. The resulting document is presented in part two of this report.

Much may be learned from the collective expertise of the roundtable members, many of whom are the country's most respected audio preservation engineers. Documented here are some of the techniques that have been developed to transfer deteriorating sound recordings, and the tools used. The discussions reveal the many times these engineers agree on approaches to obtain the best possible audio transfer from historical recordings, and the occasional instances in which they disagree. The report is not intended to be a handbook on audio preservation engineering. Rather, it is an important component of the study of the current state of audio preservation that Congress requested of the National Recording Preservation Board: a survey of achievements, concurrence, divergence, and needs for further research.

The meeting was devoted nearly exclusively to a discussion of signal-capture techniques. The NRPB sponsored a subsequent round of discussions on March 10–11, 2006; the topic at these sessions was digital file standards and metadata schema. In preparation for those discussions, recording engineer and producer George Massenburg prepared a set of proposed standards for digital file creation; it is provided in Appendix 1.

Responsibility for ensuring long-term access to the recorded-sound heritage of this nation rests with many communities and organizations, public and private, technical and legal, scholarly and popular—indeed, with all who care about recorded sound. LC and the NRPB hope that this report and others that follow will enable those involved to work from a common pool of knowledge and expertise toward solutions that will benefit all.

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PART ONE

Paul Kingsbury

INTRODUCTION

The Preservation Challenge: Changing Technologies for Recorded Sound

The recording and playback of sound began with Thomas Edison's invention of the phonograph in 1877. In the wake of that landmark innovation, history has seen the emergence of one innovative recording technology after another. Each new technology has rapidly supplanted its predecessor. Thus, 10 years after the arrival of Edison's phonograph, Emile Berliner patented his disc gramophone. And within a few decades, Edison's cylinder recordings were largely replaced by Berliner's more-convenient flat audio discs, recorded at approximately 78 revolutions per minute (rpm) and usually composed of hard but brittle shellac. Following World War II, the shellac 78 gave way to the almost-simultaneous introduction of the flexible vinyl 45–rpm single and 33-1/3–rpm long-playing (LP) record in 1948–1949 and to magnetic recording tape. Magnetic tape, developed in Germany and brought to the United States after World War II, came into widespread use in commercial recording sessions by the late 1940s.

By the mid-1960s, when record companies began to offer for sale prerecorded, continuous-loop, eight-track tapes, consumers began participating in the audio tape revolution in earnest. Smaller, more-convenient cassette tapes—both blank and prerecorded—reached the market by the end of the 1960s. The next major breakthrough in consumer playback came with the arrival of the first widely available digital carrier, the compact disc (CD), which was introduced in 1982. Since then, the parade of new playback and recording formats has continued. As digital audio has gained precedence, new digital carriers—digital versatile discs (DVDs) and MP3 players, among others—are already jostling the CD for preeminence.

As one considers the swift evolution and succession of recording and playback technology, it is clear that innovation and obsolescence are constants in audio recording. Cylinders, 78-rpm shellac records, and eight-track tapes are no longer commercially viable media. The LP disc and the cassette tape have seen declining sales for some time.

For many years after digital recording and playback came into wide use in the 1980s, there was an ongoing debate in the recording community about the merits of preserving audio programs in a digital, rather than analog, format. In 1997, in an in-depth, two-part series on problems of audio preservation and storage within the major record companies in the United States published in *Billboard* magazine, reporter Bill Holland stated that the consensus among leading audio engineers and such organizations as the Audio Engineering Society (AES), the National Academy of Recording Arts and Sciences (NARAS), and the Association for Recorded Sound Collections (ARSC) was that "because analog tape has been proved to last, generally, and because the shelf life of digital tape is unknown, recordings should be stored or backed up, at least in the analog tape format."[1]

Since that time, however, it has become increasingly clear that analog magnetic tape no longer provides the safe haven for preservation that it once may have. As of 2005, only one major manufacturer, Quantegy (formerly Ampex), still manufactures analog magnetic recording tape stock for the U.S. market. Only a handful of companies still manufacture the machines that play open-reel tapes. Some tapes manufactured for preservation reformatting, such as polyester tape, have been found to deteriorate over time. For example, they can be damaged by hydrolysis, the process by which the chemical that bonds the recording oxide to the polyester base absorbs moisture from the air. Upon playback, these tapes can break down and become unplayable.

Increasingly, leading audio engineers and audio preservationists believe that the future of audio preservation is in the digital arena. Unlike subsequent generations of analog dubs, each of which is farther removed from the original sound (much as a copy of a film photograph is removed in quality from that of the original image), each digital capture is capable of producing an identical copy of the original recording. Digital recordings are also easily transported and transmitted in a variety of ways, including the World Wide Web, making public access easy and cost-effective. Acknowledging that digital tape is as subject to deterioration as analog tape, some preservationists are developing systems to manage sound recordings as digital files, to be archived in repositories and periodically refreshed and migrated.

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[1] Holland, Bill. 1997. Upgrading Labels' Vaults No Easy Archival Task. *Billboard* (July 19): 99.

Addressing the Challenge of
Preserving Our Audio Heritage

The importance of preserving and ensuring access to the nation's audio heritage is now widely recognized, and many in the public and private sectors have called for a coordinated national effort to address the preservation challenge.

In response, in 2000 the U.S. Congress enacted Public Law 106-474, creating the National Recording Preservation Board (NRPB) under the aegis of the Library of Congress (LC) and charging these bodies to identify and address the major challenges to audio preservation. The legislation specifically charges the LC and NRPB to conduct a study of "the current state of sound recording archiving, preservation, and restoration activities." Areas to be explored include "the methodology and standards needed to make the transition from analog 'open reel' preservation of sound recordings to digital preservation of sound recordings," "standards for access to preserved sound recordings by researchers, educators, and other interested parties," and "the establishment of clear standards for copying old sound recordings (including equipment specifications and equalization guidelines)." The study is intended to inform key players in the preservation of recorded sound and to be a prelude to a national plan.

As a first step in this process, in January 2004 LC and CLIR convened a group of leading audio engineers and audio preservation specialists, including several audio engineer members of the NRPB, to participate in a roundtable discussion of preferred methods of transferring analog audio for reformatting as digital files. (A list of participants is provided in Appendix 2.) The goals of the meeting were to determine what areas of agreement and disagreement exist among reformatting experts, to identify gaps in knowledge about crucial techniques in audio transfer, and to make recommendations to LC and the NRPB about actions to be taken to address those problems. This roundtable group was charged with focusing on migrating an audio signal from endangered analog carriers—disc and tape primarily—and the challenges of capturing that signal digitally. A second group of engineers and librarians met in March 2006 to discuss issues related to conversion to digital media and metadata.

Participants were asked to confine their discussions to the two most common forms of analog media—audio discs and audio tapes. (Less-prevalent forms, such as cylinders and magnetized steel wire recordings, were left for future, more-detailed study.) Participants worked from two workflow documents prepared by preservation reformatting experts at LC. By working through each step in the process of reformatting analog tapes and discs, participants were able to identify areas of accord on best practice; areas of disagreement; and areas where further study, or further development of effective solutions, is needed.

Although group members represented a fairly broad range of audio engineering specialties, they found themselves in agreement on nearly all the discussed aspects of transferring analog audio to

digital. The following text summarizes these major points. For more details, readers are invited to turn to part two, which contains the original workflow documents along with extensive annotations made by meeting participants.

SUMMARY OF MEETING DISCUSSIONS

This section summarizes the main technical points covered in the discussions. It shows where participants agreed and disagreed on preservation procedures and what topics they felt needed further study. Roundtable members' recommendations on procedure are displayed in italics.

One point emerged clearly from the discussions: Although many aspects of transferring analog audio to digital media require hardware and software tools and some are amenable to automation and batch processing, there are many areas in which a trained ear and years of experience are by far the most important tools. "The ideal," one participant noted, "is to use ears in conjunction with measurement." Another engineer stated, "Technology will never replace the listener." Subjective as listening can be, there is still no substitute for the trained ear when reformatting sound recordings.

Mitigating Deterioration of the Original Analog Carrier

Audio Discs

Commercial audio discs date from 1894; two-sided discs first appeared in 1907–1908. In physical composition, audio discs can range from fragile forms such as rubber (the earliest disc recordings), acetate or lacquer (sometimes with glass, aluminum, or cardboard backings), to more-durable shellac and vinyl discs and the metal masters ("metal parts") used to stamp out commercial discs. The distinct physical characteristics of each disc type require different, often highly specialized, techniques to coax the sound from the carrier.

Although participants did discuss the possibility of using advanced materials-science technology (such as laser refraction and spectroscopy) to help identify disc composition, it appears that no archives in the preservation field currently uses such high-tech assessment tools. Roundtable members agreed that in nearly all cases, experienced audio engineers could readily identify the composition of a recorded disc. Thus, although use of such technologies may be desirable, these experts did not see it as urgent or essential.

The roundtable panel identified several best practices that hold true for virtually all disc formats. These practices are as follows:

- **Cleaning the disc**. When transferring an audio program from an analog disc, one should *always clean the disc first, except in the cases of cracks or delamination*. Cleaning methods vary somewhat depending upon the composition of the disc. Generally, one should

start with nondestructive, dry methods, such as gentle dusting, vacuuming, and antistatic brushing. Nondestructive cleaning solutions, such as deionized water or a "pure" (i.e., fragrance- and additive-free), mild, low-sudsing liquid soap, are also recommended.

- **Choosing the stylus**. The second step is to *carefully determine the correct stylus size*. This is essential for several reasons. First, record grooves can vary from one disc format to the next. Moreover, previous playings of a recording often wear one part of the groove. In such cases, a larger or smaller stylus may be selected to track a higher or lower section, respectively, of the groove wall; this tactic often produces a cleaner signal. Selection of the best stylus, in the opinion of the roundtable participants, is the most important factor in the signal-extraction stage of transferring audio from disc and achieving accurate sound reproduction. (This assumes that all the equipment has been carefully selected and set up.)

    Participants agreed that the ability to choose the correct stylus is a skill that comes only with experience and with expert listening comparisons. They disagreed to some extent, however, about whether it is possible to save time spent in trial-and-error needle drops by making scientific determinations about the record grooves—namely, by examining the grooves with a microscope and taking measurements. Some audio engineers suggested that this might be a fruitful approach, while some who specialize in historic discs were convinced that the choice of a stylus is a matter that can be determined best by an experienced engineer on the basis of expert listening, and that use of a microscope and measurements was unimportant.

    Once the best stylus is chosen, it is important to *set the tracking force at the lowest weight that still gives optimum signal capture and fidelity* so that wear on the grooves can be minimized.

    There was some disagreement on whether the stylus itself should be used as a cleaning tool, allowing it to scrape out dirt upon playback as it passes through the groove. Participants ultimately agreed that this method, if used at all, should be restricted to shellac discs and metal parts, which are harder than vinyl or lacquer. Using the stylus to clean record grooves tends to do more damage to vinyl records, especially if they have not been properly cleaned.

- **Choosing the playback speed**. The next step is to *determine the correct playback speed*. In discs manufactured since World War II, speed is usually a clear case of 78, 45, or 33-1/3 rpm, but there are exceptions to these generally reliable categories. Before World War II, even though discs were generally recorded at approximately 78 rpm, there was no consistent and precise calibration of record speed in the commercial recording industry. Likewise, the speed of discs cut in field recordings can vary, depending on the regularity of the power source for the disc-cutting machine.

Audio Tape

Audio tape is a German invention, perfected during World War II when electrical giant AEG joined forces with the chemical firm I. G. Farben to create recording tape covered with magnetized iron oxides. Tape recording machines manufactured by the Brush and Ampex companies made their way into some recording studios as early as 1947. The earliest audio tapes were paper based, followed not long after by tapes with a cellulose acetate base, which were in wide use from the 1940s into the early 1960s. Since that time, magnetic recording tapes have been produced primarily on polyester tape (sometimes known by the trade name Mylar) in the United States; polyvinyl chloride is also sometimes used in Europe.

- **Identifying the tape**. When preparing to transfer sound from an analog audio tape, the engineer's first step is to *examine the original tape box, if available, and any accompanying documentation*. Knowledge of the age and make of the tape will help the engineer decide what to do to mitigate any problems that may arise.

    However, documentation may be misleading. Notations may be inaccurate, or the tape could be in the wrong box and therefore have improper documentation. One roundtable member lamented that while one cannot rely on the tape box to provide definitive information, it is often the best or the only source available. In some cases, an engineer may ask the person who provided the tape about the source and date of this tape.

    To handle a tape properly and anticipate problems that may arise in playing it, the audio engineer must *identify the tape's composition*. Visual inspection of an original source tape may reveal a number of physical problems that will need to be dealt with to preserve the tape and to capture the best-possible signal from it. Materials-science technologies can be used, especially by an archive that is based within a research university and that can engage a university's science and engineering departments in cooperative programs. Such expertise might prove helpful in identifying mystery tape stock; investigating cases of outgassing of unusual chemicals, emulsion components, or constituents; or examining subconventional microscopic tears and stress fractures. Few archives in the preservation field have access to such high-tech assessment tools. Fortunately, visual inspection alone will generally tell an experienced engineer what sort of tape he or she is dealing with. Above all, the roundtable discussants agreed, the best technique for evaluating the tape is one that is nondestructive.

- **Handling splices**. The most serious problem frequently encountered in working with analog tapes is damaged splices. Roundtable participants strongly *recommended that all damaged splices be repaired before transfer*. They identified this as a best practice.

    However, some participants noted that there is a physical risk to tapes when removing splices. Audio preservationists should have wide latitude in removing and repairing damaged or de-

teriorating splices. One recommended cleaning method is to *use naphtha-based lighter fluid or isopropyl alcohol to remove adhesive residue from plastic or polyester tapes*. This method, however, has not been thoroughly tested for its potential long-term effect on tape. *Alcohol should not be used on acetate tapes because it will dissolve them*. Roundtable members agreed that proper cleaning and repair of damaged tape splices is a key core competency for audio preservation engineers. As one participant noted, "Splice cleaning takes a lot of experience and expertise. Otherwise, you will destroy something you cannot get back."

As an additional best practice, participants stated that when repairing problem splices, one should *always replace old paper or plastic tape leaders with new, acid-free paper leaders*. Old paper leaders may be acidic and cause tape deformations, and plastic leaders may accumulate electrostatic charges that could discharge during playback. A paper leader, by contrast, is electrically inert. Finally, whenever possible, the engineer should *slowly rewind the respliced original tape* onto a clean, slotless NAB hub and metal reel.

- **Handling damage and deformation**. Audio tapes may have suffered from poor storage conditions. Dampness can lead to a warping of the tape, a condition known as *cupping*. This condition primarily affects acetate tape and prevents the full surface of the tape from coming into flat contact with tape heads during playback. The ideal way to mitigate cupping is to *slowly wind the tape onto a clean, slotless NAB hub and metal take-up reel in a "B wind" (i.e., oxide side out), tails out, and store it in a climate-controlled environment for three to six months*. Roundtable participants identified this as a best practice. If an archive's transfer schedule does not permit three to six months of B-wind storage, any amount of storage in B-wind might be helpful. If necessary, advanced techniques can be used. These include adjusting tape-to-head tension or, as a final resort, using pressure pads for playback.

  Some tapes, because of inherent manufacturing defects, may suffer loss of oxide. When the oxide comes off the tape in strips, this condition is known as *blocking*. If the oxide particles are powdery, the condition is known as *shedding*. Whereas a tape suffering from blocking cannot be played without permanently damaging the tape and should be set aside for future transfer with later technologies, tapes that shed can be transferred, provided the engineer periodically removes loose oxide from the tape path.

  Some polyester tapes suffer from hydrolysis, in which the chemical that bonds the recording oxide to the tape absorbs moisture from the air. This condition is commonly referred to as *sticky shed* or *binder breakdown*. When played, these tapes make a telltale squealing sound. They may break down and become unplayable. The currently recommended best practice is to *bake such tapes at low heat in a convection oven or an incubator before playback*. Participants noted, however, that this remedy is temporary; the tape will revert over time. Roundtable members agreed that more research

needs to be done on alternative ways of alleviating hydrolysis for polyester tapes. (Acetate tapes may also emit a squealing noise during playback. This is a different problem, known as *lubricant loss*, that should be treated through relubrication. Acetate tapes should never be baked because the heat will ruin the tape.)

- **Cleaning**. Tapes often require cleaning because of poor long-term storage that can leave deposits ranging from dust and dirt to mold and infestation. As with discs, the preferred cleaning methods to begin with are nondestructive and dry. *Vacuuming using a HEPA filter whenever possible* to guard against health hazards (such as mold and hazardous particulates) or contamination of other media *is a recommended first step when dealing with dry deposits*. Tapes, unlike discs, should not be cleaned as a matter of course: Cleaning should be done only when needed to achieve accurate playback.

    For cleaning tapes, some roundtable members highly recommended Pellon, a commercially available, nonabrasive, nonlubricant synthetic material developed in the 1930s for the garment industry. For complete cleaning, each side of the audio tape—backing and oxide—should be wound slowly against the Pellon. *Slow-wind cleaning of tapes using Pellon (by hand or by machine) is a recommended best practice*.

    If a tape is wet, a distilled-water rinse can be helpful, followed by air-drying, vacuuming, and a slow Pellon wind. Although naphtha-based lighter fluid is recommended for spot cleaning of damaged splices and adhesive residue, it is not recommended for cleaning of entire tapes.

Obtaining an Accurate Transfer

Audio Discs

Often, fragile shellac or glass discs suffer breakage, or some lacquer may peel off of instantaneous discs. Damage may make playback on a conventional turntable impossible. Lacquer shards, even if all of them have been saved, can sometimes no longer be pieced together because of shrinkage. In such instances, the roundtable group unanimously recommended to *save all pieces of the broken record*. Signal-reconstruction methods, such as optical imaging technologies that are now being developed, could recapture audio programs from such discs within the foreseeable future. *With respect to both audio tape and audio discs, roundtable members recommended that damaged, unplayable recordings be stored until appropriate treatment becomes available*.

Damaged discs. If an audio disc is damaged but not broken into pieces, various methods can be used to play it. Cracks and scratches should simply be played through, with the attendant noise noted in the metadata to accompany the digital preservation copy. Warps can sometimes be played either by using a slower speed or adjusting tracking weight. As always, thorough documentation of transfer techniques is highly recommended. One participant noted that Sony BMG Music Studios has had success using a special turntable fitted

with a vacuum pump to correct for warps. However, this vacuum arrangement can be used only with flexible vinyl recordings and not with shellac or lacquer-coated instantaneous discs. Furthermore, it is expensive.

Groove abnormalities. A number of groove abnormalities can be compensated for. In the absence of a lead-in groove, the roundtable members recommended trial-and-error stylus drops until as much of the audio program as possible, including the needle drop, has been captured. The problem should be documented in accompanying metadata. Shallow or worn grooves can be dealt with by trial-and-error stylus selection, making careful comparisons of various dubs recorded from each stylus. Nonconcentric grooves (a manufacturing error) create an audio problem called *wow*—a low-pitch deviation of frequency resulting from irregular motion in the disc. Roundtable consensus was that *adjustments for wow can be made only at the time of transfer by adjusting the disc on the turntable*. No post-transfer tools are currently available to compensate for wow. Thus, the group agreed that *wow should always be corrected for prior to transfer* and that it is pointless to make transfers that simply preserve a disc's wow. Similarly, a disc whose spindle hole is punched off-center can be compensated for mechanically by using a smaller-than-standard spindle and adjusting the positioning of the disc to get an accurate playback.

Audio Tape

Choosing the playback speed. Once an original analog tape is in condition to play, the correct playback speed must be determined. The audio preservation engineer should have playback machines capable of playing at all known speeds with all known tape head configurations, plus a variable pitch control. When in doubt about a tape's speed, the engineer should start at 7-1/2 inches per second and listen.

Expert listening is the first step in determining playback speed. Roundtable members shared a few basic guidelines for determining correct speed. For example, piano recordings are usually tuned to a standard middle A (440 Hz). Music or language specialists may be able to determine correct pitch on the basis of their knowledge of the program content. In addition, the discussants recommended listening for low-level ambient, electrical-power-line hum (50 Hz for European recordings; 60 Hz for North American). Checking background electrical hum with test equipment may help determine the correct playback speed. Audio preservation engineers should be aware that recording speed can vary throughout the recording; this is particularly true of field recordings.

Preparing the tape for transfer. Roundtable members recommended that engineers undertake the following steps when transferring sound from analog tape:

- Always *adjust the azimuth of the tape head to the original source tape being transferred* to accommodate the possibility that the source tape was originally recorded off azimuth. In addition to using an oscilloscope to adjust for optimal high frequency and phase coher-

ence, the transfer engineer should listen to the recording. (Some roundtable participants noted that repeated adjustment of tape head azimuth could increase the chances of uneven head wear, requiring more maintenance.)

- *In setting recording levels, use a recording industry-accepted frequency-alignment tape*. Have a collection of various frequency-alignment tapes to accommodate different flux densities.
- *Use peak-level meters*, rather than volume-unit meters, to check record levels.
- *Be certain that the monitoring equipment does not introduce distortion into the signal chain*.
- Be aware that *knowing the target medium (e.g., CD-R, DAT) is essential in setting proper recording levels*. When creating a digital preservation copy, level setting is dependent on the bit depth of the linear PCM (pulse code modulation) recording. Higher bit depths provide greater dynamic range. Recordings of speeches and panel discussions may include random, momentary noises such as coughs and table bumping. Levels need not be adjusted to compensate for such sporadic, unintended spikes. Under certain well-defined circumstances, automated level adjusting processors (such as compressors or limiters) may be acceptable during transfer.
- *Make sure that the playback chain has a playback curve that matches the source*. Most analog tapes are set to standard playback equalization (EQ) curves, either that of the NAB (National Association of Broadcasters) or the CCIR (Consultative Committee for International Radio).

Roundtable participants could not agree as to whether it is ever possible to transfer audio from an original source without introducing some level of signal alteration, however negligible. Some argued that systems do exist that will pass a signal unprocessed in its purest original form (although such systems were not identified). Members did agree on the necessity of monitoring whether noise has been unintentionally introduced during the transfer.

Best Practices for Digital Conversion/Considering a Sampling Standard

Once an analog disc or tape has been readied for transfer and the signal path has been properly tested and calibrated, the signal is ready for digital capture.

Roundtable members did not deal in depth with the details of digital conversion. However, one of the engineers attending submitted a suggested road map that outlined their recommended best practices for digital capture (Appendix 1). Following a brief, inconclusive discussion of the document, the group agreed that it was a useful work in progress and that it should be shared with the audio engineering community for future comment and possible group ratification.

It should be noted, however, that the first two recommendations on the road map document, namely, recommended digital bit depth and sample rate for archival preservation, were discussed at some length and that there was disagreement over them.

Choosing the sampling rate. Since the commercial introduction of the compact disc in 1982, the standard sampling rate for CDs (known within the audio engineering trade as the "red book standard") has been 44.1 kHz, with a bit depth of 16 bits. The sampling rate of 44.1 kHz was a deliberate compromise by the developers of the CD in which they balanced audio fidelity versus time capacity of the discs. In the 20 years since those compromises were made, the storage capacity for digital recording and digital carriers has increased considerably. The DVD is emerging as a carrier preferred by some, and it has been configured to handle 96 kHz, 24 bits. The International Association for Sound and Video Archives (IASA), based in Europe, has embraced 96/24 as its standard. Roundtable members noted that it would be beneficial for the United States to set a standard that is interoperable with that of Europe.

Near the conclusion of the meeting, discussions focused on recommended sampling rate and bit depth for audio preservation. There was considerable disagreement within the group about setting 96/24 as the new digital audio preservation standard. Those who disagreed noted that down sampling from 96 kHz to 44.1 kHz for audio CD-Rs has in the past not faithfully reproduced the original sound. They recommended 88.2 kHz instead of 96 kHz. Those in favor of the 96/24 standard noted that new digital converters are much better at down sampling, with negligible loss of audio information. In addition, they noted that no less than the 96/24 configuration would be recommended for preservation copies; if user access copies down sampled to 44.1/16 suffered a minuscule loss in audio quality, that seemed (to those in favor) an acceptable compromise to keep the preservation standard high. This issue will be investigated in greater detail at the next roundtable.

The Human Touch versus Automated Transfer

Although the process of digital capture itself was left mostly for future discussion, participants at the first roundtable did discuss, but not agree on, a proposal from one group member that a listener monitor the entire program every time an archival transfer is made to a preservation copy. This proposal, which seemed eminently sensible to several participants, inspired much debate. Ultimately, participants agreed that however desirable, such a standard is not practical at a time of real-world budget constraints and staffing exigencies. Batch processing, or high-throughput transferring, is often a necessary compromise for archives that possess large collections of fragile, often deteriorating, recordings and small staffs and budgets. The financial concerns are real for archives, and automation is one of the keys to affordable solutions.

However, roundtable members were wary of any reformatting operation that does not entail monitoring by trained, critical listeners. Several participants recommended strongly that when automation, or other techniques that reduce the amount of real-time monitoring, are introduced into a preservation program, there must be minimum standards for quality control employed to assure that a flat or straight-across transfer has been made. Tests for such standards can be scientifically established. Some of the participants suggested that statisticians or operations research scientists or both be enlisted to help establish guidelines when non-optimal monitoring conditions are necessary.

Deciding whether or not to use automated or high-throughput transfer practices can be a complex risk-assessment task. As a best practice, roundtable members recommended that before a large-scale digital transfer, an audio archive's staff *carefully review recordings earmarked for transfer and create risk-assessment reports to determine which ones can be safely transferred through automated processes and which will need staff attention during the transfer*.

Preservation archives doing automated transfers need guidelines and sources of expertise. Roundtable members recommended that guidelines be developed on how to select which types of recordings are appropriate for high-throughput preservation. Such guidelines would factor in the format, content, and condition of media to be transferred as well as the intended use of the copies. Members noted that tools also need to be developed to mitigate the damage of poorly done automated transfers.

Creating Metadata

Metadata is data about data. A digital recording can be accompanied by several kinds of metadata, including descriptive (e.g., track listings), administrative, and technical (e.g., a description of audio hardware used in digital transfer, hardware settings, and data compression used). Roundtable discussions of metadata were confined almost exclusively to administrative and technical metadata, with the understanding that metadata for preservation warrants a separate and more detailed discussion.

The roundtable group strongly recommended that, whenever possible, transfer engineers should *note all documentation (e.g., box notations) that accompanies the analog source tape*. During the preservation transfer process, transfer engineers should note anomalies in tape (splice problems/repairs, speed variations, blocking/shedding, etc.) as metadata to accompany the digital preservation copy. Such metadata could be embedded, eye legible, or both.

Slate announcements, i.e., brief, spoken, prefatory announcements commonly used in identifying analog preservation copies, *need not be used in digital preservation copies if the engineer is already embedding identifying metadata as part of the transfer process*. Including such announcements would be a needless redundancy.

Correct and sufficient documentation is of paramount importance in archiving digital recordings to produce an authentic digital copy that can be retrieved and migrated as necessary to new platforms and media. The need for proper identification and labeling cannot be overstated, and the methods for retaining metadata will depend on the destination media. Overall, the roundtable group agreed that transfer engineers should *generate as much metadata as is reasonably possible about the nature of the tape, the original recording, and the transfer*. Roundtable members noted that it is much easier to include metadata while one is working with a recording than to try to find it later.

Recommendations

In the final segment of the two-day roundtable meetings, participants made a series of broad recommendations for improving the practice of analog audio transfer for preservation. The recommendations were grouped into categories. The salient and most widely supported recommendations appear below. Each paragraph includes the recommendation's priority, as voted by the roundtable participants.

The group was also asked to assign priority for action on these recommendations. The sidebar on page 14 lists the 15 recommendations that members believed were most important, presented in order of priority

Resources/Tools Needed

- Develop a one-page flowchart that offers a series of yes/no questions to help audio preservation archivists identify the composition of various types of audio discs and audio tapes. Such a chart could be invaluable to staff of archives that outsource their audio preservation transfers. Knowing the composition of the recording at hand could significantly influence risk-assessment decisions for the recordings to be transferred (Priority #7).
- Develop a reference chart of problematic media issues, including tape brands, years of manufacture, etc. (Priority #8).
- Investigate the relevance of technology-transfer methods from such fields as chemistry and materials science to audio preservation, particularly in identifying the composition of audio discs and tapes and the nondestructive playback of discs (Priority #15).

Reference Materials

- Develop a Web site that identifies the core competencies for audio preservation engineers. This information could be distributed in video format (Priority #1; see related item below, Core Competencies).
- Develop a Web-based clearinghouse for information on how archives can develop a program of digital preservation transfer, including, for example, information on potential sources of grants for audio preservation; a resource list of experts on audio preservation and transfer; lists of equipment for audio preservation and

transfer needs; and technical manuals and key specifications for obsolete and hard-to-find equipment. The resource would include guidelines for developing an audio preservation workstation, including selection of hardware, configuration of equipment, optimum wiring for signal flow, and testing (Priority #5).

- Develop a list of music experts who could be consulted for advice on problems that arise in analog audio transfer of specific types of musical content (e.g., determining the proper key so that the correct playback speed can be established). In addition, develop a source of references for issues that might arise in any audio transfer particular to specific types of musical and spoken-word content (Priority #11).

Research and Development
- Conduct research on magnetic tape problems: (1) research a better (i.e., more permanent, less destructive) solution than baking to solve the problem of binder hydrolysis of polyester tapes; (2) devise methods for relubricating acetate tapes; (3) research how to abate print-through; and 4) research cures for cupping (Priority #3).
- Do further research into noncontact reading (i.e., nondestructive playback) of broken audio discs. Great strides have been made in developing turntables that read audio discs with lasers. Other methods have shown potential for playing some kinds of broken discs. In addition, prototyping technologies might be used in "virtually" reconstructing disc grooves (Priority #6).
- Research safe and effective cleaning methods for analog tapes and discs (Priority #10).
- Research the life expectancy of various audio formats (Priority #12).
- Develop tools that measure the shape, size, and wear of record grooves.
- Develop systems for automated metadata collection.
- Research error detection in large digital files through the use of embedded, noninvasive signals.
- Develop noise-reduction detection equipment. Many tapes since the 1980s have been processed for noise reduction, to the detriment of the sound. As one roundtable participant put it, "How does one detect this and mitigate it?"

Infrastructure Needs
- Develop arrangements among smaller institutions that allow for cooperative buying of esoteric materials and supplies. Given that there are fewer and fewer suppliers of phonograph styli, tape heads, and other obsolete and soon-to-be obsolete equipment, cooperative buying might yield dual benefits. First, it would make it easier for small archival organizations to afford equipment and supplies without each having to buy in bulk. Second, it might establish a stable market and provide enough economic incentive to keep some of these suppliers in business (Priority #2).
- Establish regional digital audio repositories. Although some major institutions, such as university libraries and LC, may be able

to afford the care, upkeep, and digital migration associated with maintaining a digital repository, many smaller archival organizations—such as state and local historical societies and independent nonprofit music archives devoted to jazz, blues, and other forms of music—may be unable to afford to store and care for their digital preservation copies over time without cooperative arrangements with other institutions (Priority #13).

• Cooperate to develop a common vocabulary within the field of audio preservation. Roundtable participants recommended the development of an online glossary and suggested that this might be something that LC could undertake (Priority #14).

Standards

• Develop guidelines for archives on how to judge when to use automated transfer of analog audio to digital preservation copies. This is a complex risk-assessment task. Those doing automated transfers need guidelines and sources of expertise (Priority #4).

• Develop a collation of the existing relevant audio engineering standards from organizations such as AES, ARSC, IASA, and NARAS. Roundtable members recommended reviewing all international standards (Priority #9).

Developing Core Competencies in Audio Preservation Engineering

(Priority #1; see related additional #1 item on page 13, Web site, under "Reference Materials")

Roundtable members expressed concern that in some archives, fragile audio recordings are being handled, played, and transferred for digital preservation by staff who have limited experience working with audio recordings or little knowledge about the sonic characteristics and weaknesses of various audio formats. The group strongly recommended that audio preservation transfers be done by trained and experienced audio engineers.

Participants identified a number of core competencies that an audio preservation engineer should have. Among other things, these would include the ability to

• identify the composition of audio tape and audio discs
• clean and resplice damaged splices on analog audio tape
• determine the correct stylus type for faithful playback of audio discs

Until recently, there have been few university programs to train audio preservation engineers. Roundtable participants agreed that audio preservation engineers should be trained in postgraduate audio engineering courses that include a practicum or laboratory component. They recommended that coursework be coupled with an apprenticeship with a skilled audio engineer experienced in audio preservation. "We should err toward professionalizing music archiving and music conservation," said one participant. "If we can just get these programs into universities, this would be genuine

progress." Ideally, such coursework would include instruction in the following:

- the history of various recording media that have been used through the years.
- hands-on exposure to recording media of past and current generations
- recording media science and preservation
- the nature of computer data files, metadata, data integrity, data management systems, information retrieval systems, and data migration
- how to recognize failure modes of various media and the proper techniques to mitigate those failures
- proper storage environments for various recording media
- the proper functioning of equipment and techniques for equipment repair, maintenance, and testing
- environmental hazards of handling various materials
- cataloging issues that pertain to audiovisual material
- curatorial issues that pertain to audiovisual material
- curatorial issues that relate to audio and collections (e.g., how audiovisual materials might be integrated into a large paper archive)
- intellectual property issues that pertain to audiovisual materials
- basic business ("Business 101")
- the ethics of preservation

Conclusion

As new audio technologies evolve and supplant older ones, we risk losing decades of spoken-word and musical recordings that are valuable not only as commercial products but also as cultural touchstones that document who we are, what we feel, and how we experience our world. At present, there are both audio engineers and equipment capable of transferring even the oldest analog recordings safely to digital. But this will not be true for long. As one roundtable participant noted, "The pool of expertise is shrinking every day." If key technical knowledge is not passed along soon, thousands of recordings may not be accessible to America's listeners 20 or 30 years from now.

Roundtable members agreed that sharing their expertise with colleagues in audio archiving and audio engineering, both now and in the future, is of vital importance. Participants noted that some of the leading associations in the audio field—such as AES, ARSC, IASA, and NARAS—have unilateral efforts afoot that may lead to some progress in developing standards for digital preservation. They agreed that more communication across these groups—through the Web and group meetings—should be encouraged to facilitate the sharing of information and recommendations.

PART TWO

Recommended Procedures for Transferring Analog Audio Tape and Analog Audio Disc for Digital Output, with Participant Commentary

The following is an edited, expanded version of the proposed workflow documents created by Larry Appelbaum and Peter Alyea before the roundtable meeting. It sets forth the transfer practices agreed on by roundtable participants and incorporates comments and annotations made by individual participants during the online discussion period after the meeting. The roundtable meeting was held in January 2004 and the ensuing online discussion continued until April 1, 2004.

Many of the comments made during the online discussion were highly technical, delving into areas of dissent and controversy as well as agreement. While this document does not incorporate every comment made online, it does include most of them. The goal of this document is to stimulate further debate and to share roundtable participants' expertise with the broader community.

1. Pretransfer issues

1.1. Inspecting, preparing, and cleaning the source materials

1.1.1. Determining the composition (polyester [e.g., Mylar], acetate, paper) and the thickness

Optimal practice: Inspect the tape visually; this is usually adequate. Consider nondestructive testing methods. Tape boxes and labels can aid identification but are not always reliable. The optimal inspection technique is nonintrusive; however, the use of destructive techniques can sometimes be justified.

Occasionally, a single tape reel held in an archive or a collection may hold tapes of differing compositions. These tapes may be spliced or simply wound together. Such reels ought to be set aside and examined individually.

Thickness is important because it can help determine how a tape responds to stress and how it should be handled. In addition, tape thickness is an indication of tape length, which may be helpful in predicting program length.

Recommendation: Produce a flowchart or logic tool to identify the composition of the tape.

1.1.2. Methods or techniques used to address specific physical problems or conditions

1.1.2.1. Brittleness
Brittleness affects acetate and paper tape.

Optimal practice: Visually inspect the tape, then slowly wind and play it. If a scrap piece is available, test it by bending. Identify brittleness to implement appropriate handling techniques.

1.1.2.2. Splices (loose, broken [i.e., separated splices], or bleeding)
Splicing is one of the biggest problems associated with audio tape preservation.

Optimal practice: Repair all damaged splices before beginning transfer. Remove and repair bad splices if the splices pose a physical risk to the media or compromise sonic quality. Clean with naphtha-based lighter fluid or isopropyl alcohol (alcohol should not be used on acetate tape) and resplice.

Once the splice has been repaired, remove the tape from any consumer or non–preservation-quality plastic reel and rewind it onto a clean, standard, slotless NAB hub and metal reels.

Core competency: The ability to remove adhesive from old splices and to resplice tape. It is assumed that transfer engineers who clean tapes also possess basic tape-handling skills.

Recommendation: Articulate the exact steps for repairing and cleaning tape in a workflow document.

1.1.2.3. Miscellaneous tape issues
Overarching recommendation: Store tapes that cannot be transferred because of limitations in current technology until appropriate treatment procedures become available.

1.1.2.3.1. Cupping
Cupping is a deformation in which the tape, when viewed end-on, appears curled instead of flat. Cupping is most common in acetate tape that has been stored in damp conditions.

   Optimal practice: Let the tape sit as a B-wind for three to six months if possible. If that amount of time is not available, the tape may still benefit from a shorter period in the B-wind configuration. If a dub must be made immediately, either (1) adjust the tension of the playback machine or (2) use pressure pads. A tape that is severely cupped could expand and come off the reel. For this reason, it is important to wind slowly and to monitor the take-up wind.

   A B-wind involves packing the tape with the oxide on the outside and the backing on the inside. (Other wind descriptions that preservationists should be aware of are A-wind, flat wind, library wind, fast wind, tail-in wind, and tail-out wind.)

1.1.2.3.2. Edge wear/edge damage
Optimal practice: Use a narrower track head for playback. Be aware, however, that this practice may sacrifice some signal-to-noise ratio and fidelity.[2]

1.1.2.3.3. Leader
There are two types of leader: plastic and paper. Plastic leaders can accumulate electrostatic charges that, if discharged during playback, could disrupt the signal.

   Lack of consensus: Sprays are available to help remove electrostatic charges. Participants disagreed on whether such spraying could contaminate the tape. One engineer noted that to his knowledge, use of such sprays was not an accepted practice. He further stated that he was unaware of any research confirming their effects. Thus, the value of sprays cannot be supported or refuted at this point.

   Optimal practice: When repairing splices as part of routine conservation activity, replace plastic leaders with paper leaders. Proper control of room humidity can also reduce electrostatic buildup.

1.1.2.3.4. Loss of oxide
Blocking. Blocking occurs when the oxide comes off the tape in strips. Such tapes should not be played or wound. At present, there is no remedy for blocking. Future research may result in techniques for preventing or remedying this problem.

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[2] For more information on problems faced when playing back open reel tapes, see D. Michael Shields, Dennis D. Rooney, and Seth B. Winner. 2003. Considerations in the Playback of Archival Analog Magnetic Recordings with Wide Recorded Tracks. *ARSC Journal*, 34(1): 48–53.

Shedding. Some tapes shed as they degrade because of aging. Strict environmental controls can help minimize the rate of degradation; little else can be done to prevent it. Shedding differs from a condition sometimes referred to as *sticky shed*, which is discussed in section 1.1.3.3.

Optimal practice: Remove loose oxide from the tape and tape path whenever shedding interferes with optimal playback. Remove heavily shedding tape with Pellon cleaning tape (see section 1.1.3.1) before audio transfer. In addition, clean the machine transport as often as necessary.

Preventive measures for blocking and shedding include proper storage and cleaning.

Store tapes that cannot currently be transferred because of technical limitations until appropriate treatment measures are available.

1.1.2.3.5. Wind types: scatter/smooth, tension

Optimal practice: Do not put loosely wound tape under tension, and do not play it back in a loose wind on any servo-motor transport; hand winding is preferred for loose winds. Wind the tape onto a slotless NAB hub and metal reel. Experiment with different winding speeds and transports. To promote longevity of heads, it may be preferable to bypass them when winding.

1.1.3. Methods for removing or mitigating surface problems

1.1.3.1. Topical debris

Optimal practice: Depending on the amount of debris, address the pack first by vacuuming it before winding. Consider winding against Pellon cleaning tape. When using Pellon cleaning tape, clean both sides of original magnetic tape, i.e., the backing as well as the oxide. Feed the Pellon strip slowly and incrementally in order to present a constantly clean surface and to prevent accumulation of debris on a fixed pad of Pellon.

1.1.3.2. Mold

Optimal practice: Vacuum with a HEPA filter. Follow with Pellon cleaning on both sides of tape—backing and oxide.

Note: This procedure is a potential health hazard, and appropriate protection is advised. Cleaning should be done in an environment where it will not place other media at risk for contamination.

1.1.3.3. Stickiness

Two distinct conditions may cause tapes to become sticky and emit a telltale squealing noise during playback. One condition is *sticky shed*, also known as *binder breakdown*. It affects polyester tape and is an indication of binder hydrolysis. The second is *lubricant loss*, which primarily affects acetate tapes.

The most common practice for making sticky polyester tapes playable is extended baking at low heat in a scientific or convection oven. Other treatment methods include using environmental chambers and desiccants. Alternative methods should be explored.

Lubricant loss in acetate tapes should be treated through a relubrication process. Acetate tapes should never be baked.

In both instances, treatment results may vary, depending on the physical and chemical makeup of a specific brand and manufacturing run of tape.

Further research: Research is needed on (1) alternatives to oven baking for reversing hydrolysis in polyester tapes; (2) methods of vacuum sealing polyester tapes that have been baked in order to keep them from reabsorbing moisture; and (3) new methods for relubricating acetate tapes suffering from lubricant loss.

1.1.3.4. Water damage
Optimal practice: If the tape is dry, vacuum with a HEPA filter to remove debris, use Pellon in a slow wind, and replace the splices. If the tape is still wet, consider a distilled-water rinse. Allow the tape to dry, vacuum debris, use Pellon in a slow wind, and replace the splices.

1.1.4. Choosing cleaning methods
For spot cleaning of old splices, a naphtha-based lighter fluid (such as Ronsonol) or isopropyl alcohol is recommended. However, users are advised to consult relevant Material Safety Data Sheets (MSDS) before employing these chemicals.

For overall cleaning to remove oxide shedding or other dry, loose debris, dry cleaning using Pellon is recommended.

Optimal practice: Use judgment to determine whether tape degradation is present and whether intervention is needed. Every tape does not need to be cleaned before transfer.

1.2. Configuring and calibrating playback equipment

1.2.1. Determining playback speed
Optimal practice: Start by playing the tape at 7.5 inches per second. Listen carefully. If possible, have machines that can play back at all known speeds and head configurations that may be encountered, plus variable pitch control. Note all speed variations as documentation to accompany the digital preservation copy.

On the basis of their knowledge of program content, music or subject specialists may be able to help identify speed. Listening (or inspecting with test equipment) for low-level power-line hum at 50 to 60 cycles per second may help determine speed. This is because 50 and 60 cycles per second are the standard frequencies at which electrical current alternates (depending on which part of the world you are in). However, there may be slight fluctuations to this, i.e., rates may fall below 50 or exceed 60. Additionally, pitch may vary throughout the recording. (This is particularly true of field recordings.)

1.2.2. Modifying playback technique to maximize quality transfer of problematic sources

Adjust for azimuth. To maximize the transfer quality of the original tape, align azimuth to that of the original tape. Use an oscilloscope to adjust azimuth for optimal high frequency and phase coherence, where applicable. Over time, aligning azimuth to various source tapes may cause tape head surfaces to wear unevenly and become deformed, with a resultant loss in fidelity. This wear will require regular relapping of tape heads.

If the tape being copied is second or third generation, it can be difficult to optimize for azimuth correction. The azimuth alignment of each recording deck used to make each generational copy could differ, thus preventing optimal reproduction because cancellations will take place.

1.2.3. Monitoring aurally and with test equipment for anomalies

Both the experienced, trained human ear and carefully calibrated testing equipment should be used to monitor recorded-sound transfers.

Tools are available to assist in distinguishing transient, event-based anomalies (e.g., clicks and pops) from global anomalies that may affect the entire tape (e.g., bandwidth and dynamic-range limitations). Sources of anomalies in recordings include the original recording itself, degradation of the tape, playback-transport error, and signal-path error. Correctly identifying the source of recording anomalies is imperative for preservation of the recorded content.

1.2.4. Setting level gain throughout signal chain with or without tones

There is no industry-wide agreement on level setting. When a digital preservation copy is being created, level setting is dependent on the bit depth of the linear PCM recording. Higher bit depths provide greater dynamic range. Use peak-level metering, not volume-unit metering, when available.

1.2.5. Setting record level

Optimal practice: Use reference-set alignment tones provided at the beginning of the source tape if they are available. If the source tape has no reference tones, use an industry-accepted frequency-alignment tape as a baseline reference in setting playback levels.[3] Have on hand a repertoire of alignment tapes to accommodate various flux densities.

Using a standard alignment tape to set playback level may occasionally result in very high noise in the case of a low-level source tape (e.g., some amateur recordings). It could also result in clipping

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[3] Frequency-alignment tapes may be purchased from Magnetic Reference Laboratory on the Web at http://home.flash.net/~mrltapes/ or by phone at 650-965-8187. Tapes may also be purchased from JRF Magnetics on the Web at www.JRFmagnetics.com or by phone at 973-579-5773.

the playback amp or in the subsequent analog chain in the case of an inordinately high-level source tape (e.g., early Atlantic Recording Studios rhythm and blues recordings).

For these reasons, setting the recording level for material without reference tones requires the optimization of levels throughout the analog signal chain for maximum signal-to-noise ratio without risk of overload or clipping (overloading) the signal. The engineer must determine the average level of the source tape and adjust gain stages appropriately, while observing the principles of unity gain. The optimal recording level for digitization is as close to digital zero as possible, without clipping.

2. Transfer

2.1. Guidelines or methods for setting playback curves

Most tapes conform to standard playback curves, either NAB or CCIR. The CCIR curve is typical in Europe, and the NAB curve is used in the Americas. The playback-machine curve should match the source.

To determine the proper playback curve, the engineer should take note of documentation included on the tape or with the tape box and use EQ-alignment reference tones provided at the beginning of the tape.

If there are no EQ reference tones on the tape, the engineer should mount a standard alignment tape conforming to the presumed general EQ curve and align the playback deck's EQ to that tape. The source tape should then be mounted, and the azimuth should be adjusted to match that tape. Determining the proper playback curve of a tape with no documentation or tones can be difficult.

If the EQ tones are included on the source tape, the playback equalization should be set to play back the tones as nearly as possible to the same level. If there is a large discrepancy in this result, the operator should suspect that the overall EQ curve is different from that in the player. Switching to another type of EQ curve may allow the tones to be adjusted to the same level.

2.2. Guidelines or methods for making slate announcements

Slate announcements are considered metadata. It is generally believed that slate announcements are not needed if it is possible to embed metadata within digital preservation copies. The need for proper identification and labeling cannot be overstated, and the methods for retaining metadata will depend on destination media.

Disagreement: One engineer cautioned that he did not think enough discussion had occurred during the roundtable to regard the substitution of embedded metadata for slate announcements as an optimal practice. When slate announcements are used, he suggested, they should be well separated from the audio content being preserved.

2.3. Playing the source tape

See 1.2.1 through 1.2.5.

2.4. Monitoring aurally and with test equipment for anomalies

Experienced listening and proper test equipment can confirm anomalies.

2.5. Monitoring physical playback mechanism

Participants concurred that playback and recording mechanisms should be monitored throughout the transfer process.

2.6. Take-up reel wind type (A/B wind, heads out, tails out)

Optimal practice: When the recording goes in only one direction, store the tape tails out. When the recording goes in two directions, store it with side-A heads out. (This also results in a tighter wind.) Experiment with A/B wind only when there is poor packing of tape for long-term storage. Some European tapes are stored using a reverse wind.

3. Post-Transfer Quality Control

3.1. Methods or techniques for real-time spot-checking

Participants suggested creation and use of a "transfer confidence index" to assist the engineer in designating the quality of the transfer in the metadata file. A "transfer confidence index," refers to an assessment of the quality of the transfer to guide future use of the transfer and disposition of the original media (though it is very rarely recommended that original materials be disposed of).

3.1.1. Aural monitoring

Monitoring systems should achieve accurate reproduction to allow for proper evaluation of quality. They should be capable of accurately monitoring the highest-resolution source employed in the preservation signal chain. In some cases this will be the playback medium; in others, it is equipment farther downstream in the signal chain.

   Recommendation: One engineer suggested that one characteristic of the monitoring system (including the room itself) should be a flat frequency response up to 20 kHz in the listening position.

3.1.2. Peak/average level meter

Optimal practice: Use peak metering for all level measurements.

   Disagreement: Participants failed to reach a consensus on how best to set levels in a disc with high-amplitude transients—namely,

they wondered whether "overs" are ever acceptable. One view holds that they are not. Some believe that decisions concerning whether it is easier to remove these with software filtering or to raise low-level signals must be made in conjunction with the rest of the music and available processing capabilities.

3.1.3. Waveform display (amplitude over time)

Use a waveform display to confirm what you hear. Predigitization test equipment should not be in the recording chain but parallel to it. Postdigitization tools are acceptable.

The following instruments may be useful in the post-transfer listening suite; in this case, their purpose should be to confirm an anomaly that has already been noted in the documentation accompanying the archived program. These instruments are also recommended for inclusion in the pretransfer suite to identify problems such as azimuth drift, dropouts, and unusual frequency-response characteristics. The transfer technician should note such problems in the metadata.

3.1.4. X-Y scope

The X-Y scope is essential for setting azimuth in stereo, 2T mono, or multitrack pairs. It is also useful for analyzing phase.

3.1.5. Correlation (phase) meter

This tool can be used in analyzing two different signal sources as in stereo, two-track, or multitrack pairs.

3.1.6. Frequency analyzer

A frequency analyzer can be useful in identifying and confirming the frequency information of a recording. It can help locate and identify components of hums or other repetitive anomalies.

3.1.7. Spectrum analyzer

A spectrum analyzer can be useful in identifying and confirming the spectral-frequency information of a recording. It can locate and identify components of hums or other repetitive anomalies (e.g., turntable rumble) that may be present in the source recording or the playback chain.

3.2. Methods or techniques for automated checking

Advanced error detection: Participants suggested that a software-based system could be employed as an aid for error detection in files and that a combination hardware/software solution may be used to flag errors in physical digital media. For quality-control purposes, data integrity should be checked at some point after the transfer is completed.

4. Pretransfer issues

4.1. Inspecting, preparing, and cleaning the source materials

4.1.1. Determining the composition (shellac, lacquer/ acetate, aluminum, vinyl, metal parts)

Identify disc composition before cleaning or outsourcing for transfer in order to specify cleaning methods and to anticipate problems. Experienced engineers can readily identify disc composition.

Recommendation: Research on the various formulations of shellac discs is needed. Advanced materials science could be helpful in this area.

4.1.2. Methods or techniques used to address specific physical problems

4.1.2.1. Physical damage (broken or missing pieces)
Optimal practice: If a glass or shellac disc is broken, reconstruction can be attempted. If a broken disc cannot be satisfactorily restored because of deformations or missing shards, keep all the pieces for potential future signal-reconstruction techniques. Consider special housing for badly broken discs.

4.1.2.2. Broken substrate
Some discs can be played in spite of broken substrate.

4.1.2.3. Loss of lacquer (separated lacquer)
Save all pieces for possible future signal-reconstruction methods.

4.1.2.4. Cracks and scratches
Depending on severity, play through them and make notes for metadata.

4.1.2.5. Warps
Some warped discs can be played at a much lower speed than originally intended; in other cases, additional tracking force can be applied. The deciding factor is the severity of the warping. Take note of speed for metadata and note if any EQ is applied. Do not apply playback EQ curves during low-speed transfers.

A vacuum turntable works with vinyl but not shellac. It is also an expensive, highly specialized piece of equipment.

4.1.2.6. Groove abnormalities (no lead-in groove)
If the disc has no lead-in groove, record the sound of the stylus dropping. Keep trying until you get as much information or signal as possible. Document all abnormalities.

4.1.2.7. Shallow grooves

Experiment with styli of different sizes and shapes. Some standard groove geometries can be inferred from the record label, brand, or type. For example, Edison Diamond Discs are typically very uniform and are ordinarily played with the same shape and size stylus, but Pathé Sapphire Discs from the same era require a different-size stylus. Yet another size is used for pre-stereo microgroove records, and so on. Try a commonly recommended stylus first. If there are problems with noise or distortion, apply an array of alternate choices.

4.1.2.8. Nonconcentric grooves

Nonconcentric grooves are a manufacturing-related problem that causes wow. No post-transfer wow-removal tool is currently available.

4.1.2.9. Hole punched off-center

This problem is similar to nonconcentric grooves. To correct both problems, mount the record on a turntable with a smaller-than-normal spindle to allow some adjustment of the centering. Alternatively, use a turntable with an adjustable spindle. Centering of the record can be done visually to a high degree of accuracy.

4.1.2.10. Worn grooves

Optimal practice: Careful stylus selection and careful cleaning are essential. If dictated by the condition of the disc, make multiple dubs and listen to them to determine the best recording.

4.1.3. Methods for removing or mitigating surface problems such as topical debris, exudation, and presence of oils or fingerprints

Optimal practice: When transferring an audio program from an analog disc, clean the disc first, unless cleaning will damage the media. Alcohol should *not* be used to clean any disc records except Edison Diamond Discs and metal parts.

When cleaning, start dry: Use dusting and vacuuming. Then, in descending order, try antistatic brushing, deionized water, "pure" (i.e., fragrance- and additive-free) liquid soap, and scrubbing. Mechanical disc washers are also commercially available.

Disagreement: Some engineers advocate using a stylus as a cleaning tool. This method can work with shellac records but can subject the disc to degradation. Special caution is needed when using a stylus for vinyl records if they have not been properly cleaned first. Some engineers believe that it is advisable to use a stylus only to clean metal parts. All agreed that it is best to remove as much debris as possible before passing a stylus through the grooves.

4.1.4. Choosing cleaning solutions

Cleaning solutions must not leave residue or cause damage. Research and development must verify a solution as safe before use. Disc recordings that cannot currently be transferred because of

technical limitations should be stored until appropriate treatment is available.

4.2. Configuring and calibrating playback equipment

4.2.1. Choosing a stylus

Stylus choice is one of the most important factors in transferring audio from disc. Most audio preservation engineers choose the proper stylus through a combination of experience, educated guesswork, and expert listening. Participants noted that a stereo lab-microscope and a good groove microscope with a reticle calibrated in 1-mil increments can reveal a great deal about groove condition and stylus requirement. The microscope does not, however, replace the role of expert listening in finalizing the choice of stylus.

Disagreement: Can a stylus be selected on a purely scientific basis or is it a subjective decision that is based on expert listening? Or are both required? What methodology can be developed for blending the two approaches? Time pressures or lack of equipment for examination and analysis of the groove may make it necessary for an expert to rely on a subjective method. But, as one engineer offered, one "can envision a procedure where there is some preparatory visual groove/stylus matching, using a microscope. By building up the needle profiles and storing them as data files, certain images could be taken of the disc and then correlated with the stylus types. This gives an approximate result and a range of styli to be considered."

4.2.2. Determining playback speed

While approximately 78 rpm was the predominant speed of early discs, there was no standard disc speed until late in the 78-rpm era. Many of the same guidelines discussed under tape transfer apply to disc transfers. Careful listening is essential. Use a variable speed turntable. Note disc speed and variations as documentation to accompany the digital preservation copy. On the basis of their knowledge of program content, music or subject specialists may be able to help identify speed.

Recommendation: Compile and document available research to provide guidelines for determining playback speed.

4.2.3. Setting tone arm tracking force and height

Tracking force, also called *stylus force*, is the static force between a stationary record and the stylus tip, in the playing position. With traditional, stylus-based playback technology, the optimal adjustment of tracking force is a trade-off between record wear and dependable tracking and tracing of the groove. To minimize record wear, use the lowest tracking force that reliably maintains *continuous* contact between the stylus tip and the groove, as indicated by a minimum of audible distortion in the extracted audio signal.

Phonograph-cartridge manufacturers usually recommend a range of tracking-force values over which a given cartridge may be expected to perform within its rated specifications. However, car-

tridges are typically characterized for playback of stereo LPs and 45-rpm records that are in good physical condition, and the tracking-force values depend on equipment properties such as tonearm mass and damping.

For any turntable setup, the minimum practical value of tracking force is influenced by the prevailing conditions of groove-modulation level, record warp, and the motional dynamics of the overall pickup-and-tonearm system.

When using a stereo phonograph cartridge to play vertical-cut discs, 78s, or other pre-microgroove record formats, the transfer engineer should be alert for tracing or tracking problems, displayed as audible distortion. As the tracking force is reduced, the stylus eventually begins to lose contact with the groove. The signal becomes "fuzzy," then gradually more "buzzy," until the stylus ultimately fails to track the groove (it "skips"). Heavily modulated, warped, or locally "bumpy" records may require increased values of tracking force to improve tracking and extract a cleaner signal.

Modern, high-compliance phonograph cartridges are typically rated for a maximum tracking force of only a few grams. If loaded at significantly higher forces, the stylus-suspension system in many cartridges will "bottom out," making the cartridge inoperative when the stylus cantilever recedes into or strikes the cartridge housing. One workaround for this limitation, when the goal is to track warped or "bumpy" records, is to increase the stiffness of the stylus-suspension elastomer in the stylus assembly. Another approach is to mount the cartridge in a "floating" (i.e., pivoted and spring-loaded) headshell, to reduce the effective mass of the pickup assembly.

It is important to set the tracking force high enough to avoid *mistracking*—a condition in which the stylus leaves the groove and may then return, slamming into the record surface. Mistracking can seriously damage records made of softer materials, such as vinyl, lacquer, or wax.

4.2.4. Setting antiskate compensation

Pivoted tonearms (as compared with linear-tracking or radial-tracking arms) experience a phenomenon called *skating* when playing a disc record. This is caused by the bend, or dogleg, that is designed into the tonearm. The bend is there to reduce the incidence of lateral tracking angle error, which is a natural consequence of using a single lateral pivot point in the tonearm. The skating force causes the stylus to bear with greater force on the inner groove wall (stereo left channel) than it does on the outer groove wall (stereo right channel). This can result in more distortion in the right channel when playing stereo records. The antiskating compensation has been added to modern turntables to apply an outward torque to the tonearm, which counteracts the skating force, resulting in nearly even tracking forces on both the inner and outer groove walls. Test records are available for use in adjusting the antiskate compensation. Alternatively, as a temporary corrective procedure, the technician can adjust the compensator to reduce groove sticking or skipping.

Some believe that this issue primarily involves stereo recordings. However, the online discussion revealed that physical problems caused by not riding in the center of the groove are the same for all records. To many, standard preservation dictates that both groove walls of a mono recording be preserved if transferred using a stereo cartridge; the right channel from a mono recording cannot be ignored. A bias toward vinyl stereo recordings might be perceived even in the mention of an S-shaped tone arm. LC engineers stated that they use straight tonearms for most of their nonvinyl transfers.

4.2.5. Monitoring aurally and with test equipment for anomalies
See section 1.2.3.

4.2.6. Setting level gain throughout signal chain
See section 1.2.4.

4.2.7. Setting record level
See sections 1.2.5 and 3.1.2.

5. Transfer

5.1. Methods or techniques for setting playback EQ curves

If the type of recording EQ curve for a disc recording is not known or cannot be assumed with a high degree of assurance, or if no recording EQ was used (as with the early acoustic recordings), it is generally recommended that the disc be transferred "flat" with no playback EQ curve compensation. If necessary, these recordings can be adjusted post-transfer. The EQ used should be noted in the documentation. Not all phono preamplifiers allow for the EQ to be switched off, and switching off the EQ is not easy to do with most phono preamps. The Recording Industry Association of America (RIAA) playback curve is often designed into the constant-velocity to constant-amplitude compensation that is intended to be used with magnetic (dynamic) phono cartridges. If one uses a flat amplifier instead of the RIAA magnetic preamp circuit, the result is a very tinny sound from a magnetic cartridge. Although this can be useful for preservation, it is not recommended for standard playback. A separate preamp velocity-compensation equalizer is required to convert the magnetic cartridge response to constant amplitude that does not have RIAA compensation added as well. This circuit is rarely found in any commercial preamps.

5.2. Methods or techniques for recording test tones

There is no need to record a series of test tones onto the digital preservation copy unless those tones are part of the original program on the source tape. Digital recording is inherently flat in frequency

response at all signal levels, and no digital EQ is used, so there is no purpose served by the inclusion of test tones.

5.3. Methods or techniques for making slate announcements

See section 2.2.

5.4. Starting the recording device

Start the recording device first, and then start the playback.

5.5. Playing the disc

The group did not want to discuss playing discs wet versus dry.

Disagreement/Further research: One engineer who opposed playing discs wet stated by e-mail, "All commercially made records are designed to perform perfectly well when played back in their dry condition. The wetting of the surface is more likely to introduce undesired artifacts such as a change in the damping of the playback stylus cantilever, which will result in an improper frequency response. Furthermore, the wetting can trap dirt on both the record and inside the playback cartridge. I do not recommend wet playback under any circumstances, with the possible exception of playing non-commercially made aluminum disc records."

In contrast, an engineer who has had success with wet-disc transfers stated, "I am not convinced nor have I seen any evidence that wet playing of commercially made shellac 78-rpm discs or lacquer-coated discs introduces more unwanted artifacts than it removes. Personally, I have had success in wet transfer of acetate-coated discs and shellac 78s, resulting in a lessening of surface noise. *I feel this is a subject in need of more research.*"

5.6. Monitoring aurally and with test equipment for anomalies

See section 2.4.

5.7. Monitoring physical playback mechanism

Roundtable members agreed that ideally, all transfer equipment and processes should be monitored from beginning to end.

6. Post-Transfer Quality Control

Participants suggested use of a "confidence index" to assist engineers in designating the quality of the transfer in the metadata file.

6.1. Methods or techniques for real-time spot-checking

In addition to aurally monitoring, one should use a peak/average level meter and waveform display (amplitude over time). Software tools that incorporate an X-Y scope, correlation (phase) meter, frequency analyzer, and spectrum analyzer should also be used.

6.2. Automated checking

Advanced error detection: See section 3.2.

7. Other Issues

7.1. Choosing sampling rate and bit depth

Recommendation from George Massenburg: 96 kHz, 24 bit, linear PCM files are the minimum standard for digital audio preservation files.

Reasoning: The emerging standard is the DVD, on which audio is 96 kHz. Storage space is becoming cheaper all the time. IASA has embraced 96 kHz as its specification, and we want to be interoperable with Europe. At least one roundtable member recommended sampling at 88.2kHz in order to best produce a 44.1kHz file. It was pointed out that good digital converters can now down sample 96 kHz to 44.1 kHz much better than they used to, with negligible loss of audio fidelity. And the point was made that 44.1 kHz would be used only for access copies, not for preservation copies. A minuscule loss of audio quality in such copies would be acceptable to most attending the roundtable.

Although there was some discussion that preservation of lower-fidelity media (e.g., oral histories on cassette) might not currently benefit from 96kHz/24 bit, 96kHz/24 bit is nevertheless recommended for all media and all content whenever possible. One cannot foresee how the transferred audio may eventually be repurposed and how future restoration technologies might be used.

One engineer noted that as of early 2004, the AES had a proposal on the table recommending setting a new digital preservation standard at 192 kHz/24 bits.

7.2. Compromises

To accommodate limited budgets or other resources, preservation reformatting often involves compromises between best practices and acceptable results. Roundtable participants suggested that guidelines be created to assist in making decisions that result in compromises to the quality of the product.
- Define and spell out compromises and trade-offs.
- Provide guidance to all institutions, regardless of size and budget, on how to deal with any needed compromises between best practices and acceptable results.

- Store recorded media that cannot currently be transferred because of technical limitations until appropriate treatment is available.
- Develop and define new standards for the archival community.
- Develop guidelines on how to make judgment calls.

8. General comments from the listserv discussion

Recommendations: Create the following three resource documents:
1. a list of suggested equipment that should be available to perform routine digital audio archiving tasks at a 96 kHz/24 bits standard;
2. "Sources of Equipment and Supplies for Audio Archives" (this document should be updated regularly); and
3. advice for small archiving institutions on how to obtain grants and other funds for digital preservation.

Suggested Road Map for Best Practices Document for Analog-to-Digital Conversion

January 30, 2004

George Massenburg

George Massenburg, a recording engineer and producer, and AES representative to the NRPB, presented this document to the participants on the second day of their meeting. Its purpose was to facilitate conversation about analog-to-digital conversion. The document sparked lively debate about such issues as the preferred sampling rate (e.g., for reformatting of audiocassettes) and evaluation criteria. Participants subsequently recommended that a separate meeting be focused solely on the topic of conversion. Mr. Massenburg's document is produced here as a record of the meeting.

Objective: To capture complex analog signals with as much transparency to the original as practical.

1. Converter hardware criteria

1.1 Technical evaluation issues

1.1.1 Bit depth
Recommend: 24 bit

1.1.2 Sample rate
Recommend: 96 kHz or better

1.1.3 Linearity

1.1.4 Stability of clock reference (perhaps external)
Recommend: 100ps or better RMS jitter

1.1.5 Type and quality of anti-aliasing filter (mandate optimizing brick wall filter to track sample rate)

1.1.6 Noise
- level (weighting)
  Recommend: 110dBFS A-weighted or better
- quality and nature of artifacts
  Refer to FFT evaluation of performance, observe relatively few spikes

1.1.7 Dither (word-length reduction) methodology (if applicable for 16-bit archives)

1.2 Perceptive evaluation issues and protocols

1.2.1 Establish testing protocols
- choose protocol, preferably utilizing two or more methods; from simple (alternate D/A/D process with original analog source) through multidimensional scaling, A-B-X, et al.
- establish conditions, including suggested standardized monitoring and listening rooms
- establish trusted reference D/A converter to check complete conversion process
- verify level calibration to ±0.05 dB max, in particular the A-B path and the SOURCE (analog original) vs. D/A converter path

1.2.2 Establish source reference materials
- consider breadth of "quality" (especially low-quality end) of different ingested materials
- establish categories

1.2.3 Isolate evaluation criteria
- perceived resolution: How well are very low-level sounds articulated, especially low-level, high-frequency percussives and transients?
- spectral balance: perceived "flatness" and "neutrality," lack of harshness
- image stability: In stereo and multichannel, is the spatial image laterally stable?
- organization of report database

2. Processing

2.1 Baseline procedures

2.1.1 Standardize subjective evaluation criteria

2.1.2 Develop conversion objectives
- budget contingencies
- estimate archive lifetime
- ongoing costs versus quality
- storage type efficiency/reliability/commonality

Observe that the costs of storage technologies are constantly shifting; determine possible interchangeability issues with other archives.

2.1.3 Establish evaluator group constituency

2.1.4 Establish consistency criteria across evaluators/technicians

2.1.5 Establish technical specifications (e.g., dynamic range, noise, flatness) for equipment and specifications for monitoring, including monitor speakers and room acoustics

2.1.6 Establish criteria (suggested is a "transfer confidence index") to determine whether and when original materials must be retained for future reconversion

2.2 Archival processing—transfer

2.2.1 Specify conversion parameters within latitude of conversion options, if scaling of methodologies is determined to be acceptable
Examples: Recommend limiting single-channel conversion and single-channel files for purely monophonic sources (requiring more expert evaluation); recommend a deprecated bandwidth and resolution for limited-quality originals (for instance, old 78s and cylinders)

2.2.2 Determine the "transfer confidence" index
To what degree do I think that this conversion represents the best (i.e., maximally transparent, to a described, agreed-upon standard)?

2.2.3 Determine whether the specific original physical archive element is so deteriorated that improvements in conversion would provide little or no further advantage to existing archive materials

2.2.4 Establish whether and when original materials can be disposed of with confidence
• establish a redundancy protocol for a given digital archive and for the *migration* of the digital archive media as well as the underlying digital archive technology
• verify effectiveness of the integrity of the migration protocols including background archive soft error checking

2.3 Ongoing review

2.3.1 Calibrate and do technical reevaluation of equipment

2.3.2 Review and oversee methodologies; track technology

2.3.3 Correlate the database's "transfer confidence" index with possible improvements in technology

APPENDIX 2

Meeting Participants

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Library of Congress

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Chris Lacinak
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George Massenburg
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Graham Newton
Graham Newton Audio Restoration

Pete Reiniger
Smithsonian Folkways Recordings

Dennis Rooney
Freelance audio producer and engineer

Alan Stoker
Country Music Hall of Fame and Museum

Seth Winner
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