Some Assembly Required: Low-Cost Digitization of Materials from Magnetic Tape Formats for Preservation and Access

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Some Assembly Required: Low-Cost Digitization of Materials from Magnetic Tape Formats for Preservation and Access

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Abstract: Recent work discussing the digitization and preservation of magnetic tape materials has maintained that it should be left to expert practitioners and that the resulting digital materials should be stored in digital repositories. This article suggests that librarians and archivists lacking extensive technical skills or access to expertise can digitize these materials themselves. It provides a detailed account, including challenges faced, of how a team of practitioners without prior training or experience digitized historical audio recordings on cassette and open reel tape at Northern Illinois University Libraries. The discussion reviews the assembly of equipment and software that the team used for digitization work, discussing each element's significance and how they came together as a functioning workflow. The authors also emphasize the fact that while the digitization of fragile and/or degraded magnetic tape materials may contribute to the preservation of their contents, this action also creates a new set of materials with their own preservation needs. Realizing that many practitioners serving medium-sized and smaller institutions lacking large financial resources may not have access to a full-fledged digital repository, they suggest the use of the National Digital Stewardship Alliance’s Levels of Digital Preservation rubric as a means by which practitioners may incrementally increase the probability that digital materials made from magnetic tapes will remain accessible.

Keywords: archives, audio recording, digitization, magnetic tape, preservation

1 Introduction

Magnetic tape found wide use as a medium for audio recording between the 1950s and the mid-1990s, and today many libraries, archives, and museums hold tapes containing unique performances or other audio and visual recordings in their collections (Behl 2015, 22–23; Hill 2012, 90; IASA Technical Committee 2009, 5.4.1.1, 5.4.1.21). This situation presents librarians, archivists, and curators with a challenge because magnetic tapes have proven to be subject to significant deterioration over time.1 In fact, the National Film and Sound Archive of Australia released a report in 2017 stating that magnetic media not digitized by 2025 “will in most cases be lost forever” (2). In this context researchers and practitioners increasingly realize that they must convert magnetic tape materials into a digital format before degradation occurs so that the data they contain can remain available for use (Casey and Gordon 2007, 33; Chase 2015, 110; CLIR 2006, 2; Eisloeffel 2006a, 28; Hill 2012, 90, 94). The digitization of magnetic tape materials differs in several respects from the digitization of other, more common forms of library materials, such as texts and images, and requires a different set of skills and equipment. Authors discussing the digitization of magnetic tape materials often conclude that practitioners lacking access

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1 Several problems can arise with aging magnetic media. The materials containing the magnetic particles that represent the recording itself can separate from the backing layer to which they are joined (“soft binder syndrome” or in specific cases “sticky shed syndrome”) or tape on a reel can begin to stick together (Behl 2015, 23–24; Hess 2008, 251; Hill 2012, 90–91; IASA Technical Committee 2009, 5.4.1.3). The substrate or the tape itself can become deformed due to improper care and storage conditions; the lubricant that reduces friction and wear when the tape is played can be lost; or magnetic particles that store the recorded information can become unstable (Hess 2008, 244, 251; Van Bogart 1995, 5–9). Any one of these cases could result in possible data loss. Manufacturers have also ceased production of the equipment that meets IASA specifications for digitizing magnetic tapes, making them increasingly difficult to find (Wallaskovits 2010, 96).
to expertise and supporting infrastructure should turn the work over to vendors or seek assistance from institutions possessing them (see Section 2). This article takes issue with that contention. It argues that practitioners at institutions lacking knowledge of and equipment for magnetic tape digitization may have little or no recourse to this type of outside assistance and suggests that, within specific parameters, they often can learn to do the work themselves by following the detailed instructions provided in the text below.

Audio digitization from magnetic tape can proceed along two paths, one aimed at preservation of the material and the other concerned with the restoration of materials that may contain imperfections or have lost data (as in the case of recordings stored on damaged or compromised magnetic tapes) (Chase 2015, 111). As the activities described in this article include work with audio materials suffering from pronounced degradation, it contains a discussion of restoration activities as well as digitization for preservation. Experience has shown that digitization is no magic bullet for the preservation of analog materials, as digital materials require a concerted set of preservation activities as well. Nevertheless, experts concerned with the preservation of library materials often suggest that practitioners digitize recordings stored on legacy material to protect against total loss, even if this transfer cannot be done to professional standards (Phillips et al. 2013, 1–4; Schumacher et al. 2014, 4–6, 14–15). Collections of digital files can be administered in keeping with best practices and protocols extending their useful life, while magnetic tapes very often cannot. Section 6 of this article will discuss the long-term preservation of digitized materials.

2 Literature Review

Experts discussing how practitioners might digitize magnetic tapes have described a set of best practices. They begin with the assessment of the collection or collections under consideration; making note of playing time and technical parameters needed for replay equipment (CLIR 2006, 9–10; Wallaskovits 2010, 91); making a preservation plan including a sequence of actions to be taken to address the state and priority of individual collections (Wallaskovits 2010, 93); and implementing “a stringent copy and safety strategy using unique identifiers” for digital files produced (93). Best-practice standards require the production of a preservation master file in an uncompressed state, at a 24-bit depth, and a sampling rate of 96 kHz, as well as a production master copy and access copies as needed (CARLI 2020, 1; Chase 2015, 111; CLIR 2006, 34; see Chase 2015, 112; Eisloeffel 2006b, 23 for further discussion about bit depth and sampling rate). Like other digital materials, reformatted sound recordings should be accompanied by descriptive, administrative, and structural metadata (Chase 2015, 112). In addition, and before beginning work, practitioners must assemble a set of necessary equipment including an analog replay device or devices, an analog-to-digital converter, a digitization workstation or workstations, and the cables used to connect the devices. These devices fit together in a digitization workflow in which an analog replay device produces a signal containing the recording on the magnetic tape being played and conveys it to the analog-to-digital converter, which in turn sends the file (now in digital form) to the workstation, where practitioners may use digital audio capturing and editing software to save it to a storage device. Before beginning use of this set of devices, practitioners should also consider where they will turn for the maintenance, repair, or spare parts for older equipment (Wallaskovits 2010, 93).

The digitization of sound materials from magnetic tape is a significantly more complicated process than flatbed scanning of text and image materials and several authors have maintained that the work’s technical nature demands that experts take leading roles in it. Chase (2015, 119–120) has argued that “Preservation reformatting of audio material requires specialized skill sets in multiple fields that are not commonly found in many institutions,” including audio technology and electrical engineering. Casey and Gordon (2007, 154) include a reliance on “audio engineers and technicians with solid technical skills and well-developed critical listening abilities” in their description of best practices, and Hill (2012, 94) has concluded that “Perhaps the most important component to successful preservation is a properly trained technician.” Chase (2015, 123) and Eisloeffel (2006c, 33) have discouraged practitioners working at smaller institutions, and/or institutions lacking significant financial resources, from proceeding on their own, suggesting that they should outsource the work. Hill has also stated that only a full-fledged digital
repository is suitable for the storage and presentation of digitized sound materials. While these repositories are complex and expensive, other options (e.g., local media storage) are unreliable for preservation purposes. The best way for digital repositories to be available for all institutions is for larger institutions such as major universities to collaborate with smaller organizations to care for these sound recordings (Hill 2012, 95). These authors have emphasized how the digitization of magnetic tape materials may be accomplished in toto, achieving format conversion, storage, and preservation at once, and at a very high level. While quite pragmatic in many cases, this advice leaves many practitioners attending to unique and meaningful collections without a viable way forward toward digitizing their materials.

Outsourcing and collaboration with larger institutions is not always possible for a variety of reasons including limited financial resources, collections unsuitable for outsourcing, an institution’s geographic isolation, and lack of available collaborators. In some cases, practitioners will find that they can only attempt to devise a process by which they might digitize and curate magnetic tape materials themselves or do nothing.

The following text provides step-by-step accounts of two cases of magnetic tape digitization at Northern Illinois University (NIU) Libraries in hopes of informing others’ successful practice. It provides detailed discussions of the operation of individual pieces of hardware and software and how they may be assembled in a productive workflow, as well as discussions of how to work around several difficulties that emerged. It also applies the approach of the NIU-based Digital POWRR Project to the longer-term curation of the resulting digital materials. Since 2014, POWRR has developed a low-resource approach to the preservation of digital objects (Schumacher et al. 2014, 6–13). Its white paper and professional development events have addressed an audience principally made up of practitioners at medium-sized and smaller institutions lacking large financial resources, emphasizing that the successful preservation of digital objects is not an all-or-nothing proposition (Digital POWRR 2012, para. 1; Schumacher et al. 2014, 4–5, 14–15).

POWRR emphasizes the provisional nature of digital preservation work and the incremental accumulation of new capacity for it, resulting in a local and sustainable model that supports the long-term preservation and access to materials (Schumacher et al. 2014, 4–6, 14–15). Using POWRR’s approach, practitioners producing digital files from magnetic tapes at institutions unable to afford or develop a digital repository can establish a curation regime that can in turn increase these materials’ chance of survival for future use.

### 3 Digitization Case Studies

The Department of Distinctive Collections at Northern Illinois University Libraries contains a number of small units, including Rare Books and Special Collections, the Music Library, and the Regional History Center and University Archives. When Distinctive Collections staff members first received patron requests for the digitization of magnetic tape materials, they sent them to the NIU Creative Services Unit for digitization. This arrangement came to an end when the unit stopped providing these services in 2018, and Department of Distinctive Collections staff members began attempting to collect the hardware and software that would allow them to perform requested digitization work themselves. Despite their lack of specialized training, they acquired the skills needed to operate the equipment and successfully produced digital objects. This article argues that other practitioners can do the same. That being said, several caveats are in order.

First, Northern Illinois University Libraries’ magnetic tape digitization work benefited from existing institutional capacity. It made use of a PC workstation and Adobe

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2 Digital repositories are typically made up of relatively complex sets of complementary open source software or are provided by vendors for a subscription fee. For example, Northern Illinois University Libraries employs a digital repository made up of Fedora Commons (https://duraspace.org/fedora/), an open source digital asset management system that stores and facilitates the management and dissemination of digital materials; Solr (https://lucene.apache.org/solr/), an open source indexing and search server; Drupal (https://www.drupal.org/), an open source content management framework that utilizes a stack of software to administer websites and web applications; and Islandora (https://islandora.ca/), an open source software framework designed as a collection of Drupal modules that act as middleware to facilitate the communication between Fedora Commons, Solr, and Drupal in creating, managing, and displaying digital collections. Amazon Web Services provides storage, dark storage, and backups using S3, Glacier, and Elastic Block Store (EBS). An example of a proprietary, vendor-provided digital repository is Preservica (https://preservica.com/), which provides the same base services as NIU’s digital libraries, but offers additional features for assessing and migrating files to new formats, providing more robust audit reports, synchronizing with other catalogs like ArchivesSpace, and providing ready usability for non-technical staff.

3 [http://digitalpowrr.niu.edu](http://digitalpowrr.niu.edu).
Provided this institutional capacity suggests that other staff, they lack a digitization unit familiar with work in non-digital preservation expertise from Digital POWRR Project authors of this article. Although NIU Libraries has access to permission of their supervisors. They are the middle two the technical and creative work described below, with the tasks beyond their usual responsibilities and performed Department and the Public Services Department took on union of negotiations with Human Resources departments and/or staff or faculty members. This may of course involve new skills and perspectives within the ranks of their own remains a potential source of new capacity.

Second, staff (i.e., non-faculty) employees of Northern Illinois University Libraries’ Distinctive Collections Department and the Public Services Department took on tasks beyond their usual responsibilities and performed the technical and creative work described below, with the permission of their supervisors. They are the middle two authors of this article. Although NIU Libraries has access to digital preservation expertise from Digital POWRR Project staff, they lack a digitization unit familiar with work in non-print formats. The fact that NIU Libraries staff members provided this institutional capacity suggests that other libraries, archives, and museums can often find access to new skills and perspectives within the ranks of their own staff or faculty members. This may of course involve negotiations with Human Resources departments and/or union officials representing staff or faculty members, but it remains a potential source of new capacity.

Finally, the fact that this article encourages practitioners to digitize magnetic tape materials themselves does not mean that readers of this article should immediately move forward with this work in all cases. Practitioners considering the digitization of a limited number of recordings should weigh the amount of money, time, and effort required to assemble the software and hardware, including out-of-production audio equipment, needed to build a workflow against an estimate provided by a qualified vendor (Dale 2012, 3–8, 11). The in-house digitization of each magnetic tape recording in a collection may not be possible as condition issues will often require special consideration. For example, if an institution’s collection includes tapes containing especially rare or important recordings that show signs of advanced deterioration, practitioners should proceed with caution and seek to determine if attempting to digitize the materials themselves may only serve to destroy the tape with no guarantee of producing a viable digital copy. In this case, a vendor’s equipment may provide the best chance to save the recording contents and practitioners may cite the recording’s significance when attempting to raise funds for its digitization. New York University’s visual inspection guide provides a list of common open reel tape curation issues that will help practitioners decide which course of action to pursue (https://guides.nyu.edu/id.php?content_id=24823233). Another provided by the University of Illinois covers all types of magnetic tapes (https://psap.library.illinois.edu/collection-id-guide/audiotape).

An expert working in a library, museum, or institution of higher education may supply an assessment of media containing cultural heritage material to another non-profit organization at no charge and a vendor should be willing to provide a free estimate of the cost of work to be done. A list of qualified vendors can be found in the Association for Recorded Sounds Collections’ (ARSC) Audio Preservation and Restoration Directory (http://www.arsc-audio.org/pdf/directory.pdf).

Practitioners can immediately use the procedures described in this article most constructively when working with recordings that are important or unique enough in their contents to merit extended curation (or attract a patron request for digitization). Practitioners may choose to make this determination in consultation with researchers working in the field of study to which the recording or recordings pertain. Similarly, they can make best use of these procedures when working with individual media objects that have become compromised enough in their physical properties to call their continued usability into question, but not so compromised as to indicate that a digitization attempt will destroy the original recording.

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4 The PC workstation used the Windows 7 operating system with Service Pack 1. The machine contained 1 GB of RAM, an Intel Core i5-1130G7 processor, an Nvidia 680 graphics card, a 1280 x 800 display, a sound card compatible with ASIO protocol or Microsoft WDM/MME, a DVD-ROM drive. Adobe Audition is a comprehensive audio recording and editing software. This project used Audition version 5 (CS6) for Windows, which was included in the Adobe Creative Suite 6 license purchased by the library. At the time this research took place, the newest release of the software was version 12 (CC 2019). This software is no longer available for outright purchase, but colleges and universities can purchase licenses for a cloud-based version of it at a monthly rate of $14.99 per user. Adobe Audition is compatible with both Windows and macOS. Version 12 installation requirements can be found at https://helpx.adobe.com/audition/system-requirements.html. Practitioners seeking an alternative to Audition may consider Cockos REAPER, Audacity, Garage Band, Pro Tools, and Ableton Live.

5 The Behringer UCA202 is a 16-bit converter. It can sample at 32.0, 44.1, or 48.0 kHz and relies on a USB connection power supply. At the time of this article’s preparation, Behringer UCA202 devices were available from a large number of online vendors for approximately $30.
Again, practitioners may want to consult outside experts in making this determination.

Practitioners should address their organization’s commitment to the preservation of items digitized as a response to a patron driven request, particularly those deemed not culturally or historically significant, during the policy creation stage. They might also consider whether patron driven requests will always result in digitization at a preservation level (i.e., creation of an uncompressed, archival master) Unless curators have identified the original recording as significant during the collection inventory, digitization may meet patron needs by the creation of an access level (i.e., compressed format) copy.

4 Project 1

The team’s first project digitized a cassette tape containing a recording of an oral history interview from 1981. Figure 1 documents how the lead authors of this article assembled individual pieces of equipment and software into a workflow. In addition to the PC workstation mentioned above, staff used an Eiki 5090A portable cassette tape player connected to the Behringer UCA202 device by a 3.5 mm to two-male RCA audio stereo cable. Figure 2 shows both connector ends of the stereo cable. An RCA connector is a type of cable used to carry audio and video signals between devices widely used in home stereo and home theater systems in the 1970s, 80s, and 90s. The 3.5 mm stereo plug required a 1/4” TS jack plug adapter for the cable to be plugged into the headphone jack of the cassette player (see Figure 3).

Participating staff members also attached the two-male RCA connectors, which consist of left (white) and right (red) audio jack plugs, to the Behringer device. The Behringer analog-to-digital converter connected to the PC workstation by the USB 2.0 cable built into the converter. Staff members used Adobe Audition software installed on the workstation to capture and edit the sound materials contained on the cassette tape.

The project team encountered several difficulties in the course of their work on the initial project. They first discovered that the Behringer analog-to-digital converter device lacked a volume control. This required the team to adjust the microphone level found under the computer’s built-in sound recording settings to a level that would not cause distortion. The team also found that the Behringer device enhanced the electronic noise produced by the cassette player in the sound signal captured by the digitization software. Only use of Audition’s Noise Print tool could remove this unwanted noise, at a cost of reducing the voice recording’s human qualities. After this experience, the team purchased another interface device (see Section 5 for

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6 Practitioners will likely find analog tape players to be the most difficult equipment to acquire. Reel-to-reel players are no longer produced new for sale. Some manufactures have begun producing cassette players that meet digitization standards. Older models of reel-to-reel and cassette players can be purchased second-hand through online vendors. As in any case of buying a second-hand item online, practitioners should thoroughly investigate vendors’ reputations and policies before making a purchase.
description) with a volume control feature, which added less unwanted noise to the audio signal. The team also found that the use of old cables, already on hand with the cassette player and employed to connect it to the analog-to-digital converter and that device to the computer workstation, negatively affected the quality of the recorded signal. The purchase of new cables remedied this problem (see Section 5). In addition, they discovered that the Eiki cassette player’s heads (the portion of the device coming into contact with the magnetic tape) had accumulated a significant amount of foreign matter over the course of their life. This problem will likely occur in any analog device used for the playback of magnetic tape over extended periods of time (Hess 2008, 251; Van Bogart 1995, 5). The team found that a cleaning and calibration of the Eiki device’s heads, performed by a member of NIU Creative Services Unit staff, corrected this problem.

In addition to producing a preservation master copy of the interview, project staff members attempted to create another version by restoring the degraded interview sound files to better quality using Adobe Audition’s Capture Noise Print feature. With this tool, Audition scours the wave form of the recording to locate and isolate any possible extraneous background frequencies and track noises captured during the original recording. Once the software isolates these frequencies, the user may remove them by degrees with a series of sliders and presets found in its controls. A practitioner may initially use these tools to remove all unwanted frequencies, but the team found that they worked best when used with a light touch. Overuse of these tools will cause the recording to sound very unnatural. Team members also used Audition’s Dehum and Volume/Compression features. The project team discovered that the 40-year-old tape recording often contained a pronounced humming sound, and the use of the former feature helped to correct this noise distortion. The team also found that the individual recording the oral history sound file had not employed best practices for collecting this type of data. Some participants sounded loud and muffled, as if they were too close to the microphone. Others sounded too far away, causing them to be inaudible at times. To make matters worse, the interview moderator failed to prevent participants from talking over one another, making the recorded conversation very difficult to understand. Ultimately, the team used Audition’s Volume/Compression tool, which brings the volume of a recording’s quietest and loudest moments closer together, to produce an intelligible digital copy. Practitioners should use compression sparingly and thoughtfully, as its overuse can also negatively affect a recording. A process of trial and error taught the team to step back and listen to a track after each change to determine if alteration improved the digital copy. Finally, team members used Audition’s Slice tool to remove excess tape run off (or “dead air”) existing at the beginning and end of the digitized file.

5 Project 2

The team’s second project produced a digital copy of a spoken-word interview recorded on a 1/4” reel-to-reel audio tape to fulfill a patron driven request. In the time between the completion of the first project and the beginning of this work, NIU University Libraries budgeted $200 for the acquisition of additional equipment. With this support, they replaced the Behringer analog-to-digital converter (or interface) device with an Audient iD14 USB Audio Interface and purchased new cables, including a 1/4” TRS male to 1/4” TS dual-male insert cable. A TRS cable is often used to carry a stereo signal, and unlike a TS cable, it produces a balanced signal (see Figure 4).

For this project, the team connected a SONY TC-270 reel-to-reel tape player, already owned by the department, to the Audient iD14 analog-to-digital converter by way of the newly purchased insert cable (1/4” TRS male to 1/4” TS dual-male). The 1/4” TS dual-male end of the cable plugged into the headphone port on the reel-to-reel player and the 1/4” TRS dual-male end plugged into the line-in ports on the back of the interface device. The team connected the Audient analog-to-digital converter to a Mac Mini workstation by the built-in USB 2.0 cable on the device. The Mac Mini featured a 2.6 GHz Dual-Core Intel Core i5 processor, 8 GB DDR3 memory, and a 1 TB hard drive and ran the

7 Project team members also purchased a 1/4” TS dual-male to RCA dual-male audio cable to connect the cassette player to the Audient interface device (https://audient.com/), but it was not needed for either of the projects described in this article.
In this project the team used Cockos REAPER audio production software, which filled the same function in the workflow that Adobe Audition had occupied in the first project. REAPER replaced Audition for this work because the newly purchased and more effective Audient analog-to-digital converter would not communicate with Audition on the PC Windows workstation. Team members employed the Mac Mini for this project in order to evaluate an Apple product’s effectiveness in magnetic tape digitization. REAPER is compatible with Windows and macOS. It also is compatible with Linux on an experimental basis. Although the Cockos REAPER technical specifications did not mention any operating requirements, it emphasized that it is best used on modestly equipped devices. Novice practitioners may find it challenging to use as the screen that users initially encounter offers very few prompts or clues about how to proceed; however, Cockos provides a user guide (available at https://www.cockos.com/reaper/userguide.php). Before beginning the second project, the team again benefited from access to NIU Creative Services, which refurbished the SONY TC-270 reel-to-reel tape player at no charge.

The team encountered a number of challenges in the course of digitizing its second item. The original recording from the 1920s existed in a magnetic wire format. At a later date, unknown parties transferred it to cassette and reel-to-reel formats by recording the playback of the wire recording. Both versions of the interview on magnetic tape showed the limitations of the wire format, but the team chose to work with the reel-to-reel version of the material as it provided a much more intelligible version of the original recording. The team had no experience with the operation of reel-to-reel tape players and failed to locate an equipment manual for the SONY tape deck, so they proceeded by a process of trial and error and eventually learned how to use the player effectively. They encountered several issues that may also confront practitioners seeking to digitize reel-to-reel magnetic tape.

Reel-to-reel tape players use two tape reels attached to spindles, with the “supply reel” on the left and the “take-up reel” on the right, to unspool and collect open reel tapes (see Figure 6). The supply reel consists of an open reel tape containing the recording to be played. As the tape unspools from the supply reel the player mechanism guides it across the erase, record, and playback heads (“head unit”) of the player. The take-up reel collects the tape after it passes the head unit. Magnetic tape is extremely delicate and, unlike tape protected by a cassette housing, quite exposed to damage, especially during the process of threading it through the head unit and attaching it to a take-up reel. In order to bring the tape into appropriately steady contact with the deck’s heads, it must pass over a guide roller and a series of tape lifters.

After bringing the tape into contact with the head unit, the team attached the tape to the take-up reel by wrapping...
the tape partly around its hub and then slipping the leading end of the tape into a small, shallow notch set into the hub. The leading end of the tape must stay in that notch for the take-up reel to pull tape from the supply reel and over the heads. Team members found the notch very difficult to reach, and the tape quite slippery and likely to work free from the notch. A user must maintain tension on the tape running between the reels while attaching the tape to the take-up reel. This simply required a great deal of patience and delicate work. Practitioners attempting to digitize magnetic tape materials should be aware that this aspect of the operation of reel-to-reel tape decks, whether it be due to the age of the device or its inherent delicacy, may present an ongoing obstacle to progress. New users of reel-to-reel tape decks should note that the University of California at Santa Cruz has provided a helpful reference at http://artsites.ucsc.edu/EMS/music/equipment/analog_recorders/reel_to_reel/R_T_R.html.

Team members next discovered that the reel-to-reel tape player added a considerable amount of unwanted noise to the original audio signal, a problem that they learned to correct by adjusting the volume outputs for the player’s right and left signals. They removed additional noise in the recording by the use of REAPER’s equalization feature. Equalization involves boosting or reducing the output or level of different frequencies in an audio signal. In this case, its use enabled team members to reduce the prominence of those frequencies containing extraneous noise within the overall audio signal, making the recording’s voice content more intelligible to listeners.

### 6 Long-Term Preservation of Digital Files

Digital sound materials present practitioners with a significant curation and preservation challenge. Hill’s insistence that only a digital repository can manage and preserve them sets a worthy goal for best practices but may leave practitioners without access to one with the impression that even if they were able to digitize magnetic tape materials, they would have nowhere to put them (95). Practitioners might conclude that until they are able to digitize and preserve audio recordings in accordance with best practices they must leave unique sound recordings stored on legacy media at a continued, escalating risk of loss. This article has discussed provisional digitization practices for use when strict adherence to best practices used at elite institutions, and/or recourse to vendor solutions, remain out of reach. It also proposes a similar approach to the preservation of the digital objects that digitization produces. Archivists and librarians digitizing sound recordings from magnetic tapes may make incremental progress toward better preservation practices by taking a series of actions that allow them, over time, to reach benchmarks established by the National Digital Stewardship Alliance’s Levels of Digital Preservation guide (https://ndsa.org/publications/levels-of-digital-preservation/). As they continue to reach new levels of digital preservation capacity, their work will ensure that digitized materials become increasingly likely to remain accessible.

The NDSA Levels of Digital Preservation provide what four members of their development team describe as “a tiered set of guidelines and practices intended to offer clear, baseline instructions on preserving digital content at four progressive levels of sophistication across five different functional areas:” storage, integrity, control, metadata, and content (Phillips et al. 1). The Levels address a variety of situations, including those in which practitioners are unable to make use of a digital repository. Their developers go on to explain that the recommended activities “are agnostic towards both content type and technology,” (2019, 1) and emphasize specific, discrete steps that institutions of all sizes and financial capacities can take to improve their digital preservation practices. This section will provide a brief discussion of how practitioners might implement NDSA Levels 1 (Know your content) and 2
Practitioners digitizing sound materials from magnetic tape will immediately encounter the issue of digital storage, and the NDSA Levels advise that they first place two copies of all materials in stable storage devices at different locations and document the devices on which all materials reside (Levels of Preservation Revision Working Group 2019, 8). An example of stable storage would be a computer attached to a network, as opposed to DVDs or standalone devices like portable hard drives. A practitioner might store files in different locations by saving one copy to their local machine’s hard drive and another to the network drive, provided the drive itself is located in a different building. In order to advance to Level 2, a practitioner would store each file in three separate places, including one situated in a different geographical location than their institution (2019, 8). A practitioner might also attain Level 2 status by depositing materials with a cloud storage provider demonstrably retaining several copies of a file in data centers located in different parts of the world. Level 2 guidelines also call for practitioners to document the storage media as well as the software that must be in operation for the storage device to function.

The NDSA Levels also address practitioners’ ability to ensure that their files remain exactly as they were at the time of their deposit for storage. Level 1 asks practitioners to check all materials for viruses before storage and verify or generate integrity information for them (2019, 8). Checksum utilities produce digital object integrity information by generating a lengthy string of characters (a checksum) for a digital object. To assess that object’s integrity, a curator need not open it and inspect it themselves.

Rather, they would only refer to the original checksum generated for the object upon deposit. If the checksum generator produces the same string of characters when next used to examine the file, the file has retained its integrity. In this case, a practitioner would begin use of a checksum application at regular intervals in order to verify their materials’ continued integrity. Open-source checksum devices can be found on the Community Owned digital Preservation Tool Registry (COPTR) at https://coptr. digipres.org/Category:Fixity. In order to reach Level 2 in this aspect of digital preservation work, practitioners would use checksum verification each time they move stored files to another device or location and store this checksum data in a location other than that used for the storage of the digital objects themselves. They would also begin use of a write-blocker device to prevent the

| Functional Area | Level 1 (Know your content) | Level 2 (Protect your content) | Level 3 (Monitor your content) | Level 4 (Sustain your content) |
|-----------------|----------------------------|-------------------------------|-------------------------------|-------------------------------|
| Storage         | Have two complete copies in separate locations. Document all storage media where content is stored. Put content into stable storage. | Have three complete copies with at least one copy in a separate geographic location. Document storage and storage media indicating the resources and dependencies they require to function. | Have at least one copy in a geographic location with a different disaster threat than the other copies. Have at least one copy on a different storage media type. Track the obsolescence of storage and media. | Have at least three copies in geographic locations, each with a different disaster threat. Maximize storage diversification to avoid single points of failure. Have a plan and execute actions to address obsolescence of storage hardware, software, and media. |
| Integrity       | Verify integrity information if it has been provided with the content. Generate integrity information if not provided with the content. Virus check all content; isolate content for quarantine as needed. | Verify integrity information when moving or copying content. Use write-blockers when working with original media. Back up integrity information and store copy in a separate location from the content. | Verify integrity information of content at fixed intervals. Document integrity information verification processes and outcomes. Perform audit of integrity information on demand. | Verify integrity information in response to specific events or activities. Replace or repair corrupted content as necessary. |
| Control         | Determine the human and software agents that should be authorized to read, write, move, and delete content. Document the human and software agents authorized to read, write, move, and delete content and apply these. | Maintain logs and identify the human and software agents that performed actions on content. | Perform periodic review of actions/access logs. | |
| Metadata        | Create inventory of content, also documenting current storage locations. Backup inventory and store at least one copy separately from content. | Store enough metadata to know what the content is (this might include some combination of administrative, technical, descriptive, preservation, and structural). | Determine what metadata standards to apply. Find and fill gaps in your metadata to meet those standards. | Record preservation actions associated with content and when those actions occur. Implement metadata standards chosen. |
| Content         | Document the formats and other essential content characteristics including how and when these were identified. Build relationships with content creators to encourage sustainable file choices. | Verify file formats and other essential content characteristics. | Monitor for obsolescence, and changes in technologies on which content is dependent. | Perform migrations, normalizations, emulation, and similar activities that ensure content can be accessed. |

Figure 7: NDSA Levels of Digital Preservation version 2.0. Carol Kussman, Paige Walker, and Alya Reich, NDSA Levels of Preservation, Washington, DC: National Digital Stewardship Alliance, 2019. https://doi.org/10.17605/OSF.IO/QGZ98.
accidental overwriting of digital objects. Write-blocking software and hardware is available for purchase. The software must be installed on a single workstation, whereas hardware takes the form of a portable device that works independently and can be used with any compatible computer.

In regard to control of digital objects to be preserved, the NDSA Levels first ask that practitioners with the authority to set policy decide which individuals and software applications are allowed to interact with the materials, then specify that practitioners document this policy for future reference (2019, 8). Limiting the number of individuals and applications with permission to read, write, delete, or move files can reduce their risk of unwanted modification or loss. Storing materials on a network can help to accomplish this since the network administrator can grant different permissions for each user.

The NDSA Levels’ guidelines for metadata state that practitioners should create and back up an inventory of materials being curated and generate enough metadata to document the individual objects’ identifying characteristics, such as their creator, date of creation, and/or subject-matter (2019, 8). The Digital POWRR Project used the open-source Data Accessioner and its Metadata Transformer tool for transferring digital objects from freestanding devices to a central storage location (see https://digitalpowrr.niu.edu/digital-preservation-101/digital-powrr-webinar/, module 2; and http://dataaccessioner.org/).

The NDSA Levels’ advice regarding content focuses on file formats. In order to reach Level 1, a practitioner would document the file formats in which the various materials exist along with the date that this was performed (2019, 8). In order to advance to Level 2, a practitioner would continue to verify these content types and other essential characteristics and begin to urge content creators to use open formats that safeguard accessibility through sustainability (2019, 8). For example, the use of proprietary file formats can decrease the longevity of digital objects because newer versions of an application often cannot open files created with earlier versions of it. In addition, software vendors can go out of business, making the application needed to open a file very difficult to find. The Library of Congress (2020, 22) has identified the Broadcast Wave File (BWF) Format as the standard best suited to the preservation of digital sound files.

7 Conclusion

The literature discussing the digitization of sound recordings from magnetic tape emphasizes its complexity and often suggests that practitioners consider outsourcing work and/or relying on collaborations with other institutions possessing superior resources and technical capacity. This advice will likely be productive in many cases, but it seemingly leaves institutions and practitioners unable to take the prescribed actions with no alternatives to continuing to risk the loss of unique sound recordings due to magnetic tape deterioration over time, with complete loss predicted by 2025. This article describes a process that staff members at a medium-sized university with very limited financial resources used to fulfill patron requests for digitized versions of analog materials that existed in the library’s special collections. It may certainly be used in a broader initiative to begin to preserve at-risk materials stored on deteriorated or damaged tape for future use. In either case, archivists and librarians considering the digitization of magnetic tape materials should weigh the costs and benefits of digitizing unique recordings very carefully. In making these decisions, they should consult literature in the field and/or experts familiar with the assessment of magnetic tapes’ condition and suitability for digitization. They should also make every effort to consult subject-matter experts familiar with individual recordings’ cultural or historical significance.

Before beginning digitization activities, practitioners should follow the best practices described in the existing literature to create 1) an assessment of collections to be digitized; 2) a preservation plan; and 3) a unique identifier system for storing digital files. This article principally focuses on the next portion of the work. The existing literature discusses it in relatively scant detail, perhaps assuming that highly trained technical personnel will do the work. Practitioners seeking to digitize magnetic tape materials should assemble a set of hardware and software for the task. The main portion of this article has discussed how they may build a functional workflow from a collection of equipment. Any project will need access to a reasonably capable workstation, an analog-to-digital converter (or “interface”) device, digital recording and editing software, proper cabling, and analog tape decks necessary to play the magnetic tapes. This article emphasizes that unforeseen difficulties will likely arise and has highlighted those faced by the team at Northern Illinois University Libraries. The article also highlights that practitioners should identify sources of maintenance and repair work for analog devices.

Upon beginning digitization, practitioners can return to the existing literature, which states that they should produce a preservation master copy (i.e., a digital copy unaffected by any restoration attempts) of each magnetic tape recording and restored master and access copies, as
needed. They should also create metadata for each master copy, keeping with institutional policies for metadata development and standards, and package it with the master copy. Practitioners should make every effort to store this package in a networked environment with additional copies moved to different physical locations.

Practitioners unable to make use of a digital repository may follow the practices described in the NDSA’s Levels of Digital Preservation Version 2.0 to preserve digital materials beyond their storage on a single device. In order to comply with these standards, practitioners will need to assemble a set of open-source software, including a file integrity checker (or checksum tool), a metadata generation tool, and other necessary utilities that their local workflow requires.

Like the Digital POWRR Project’s earlier works, this article has proposed a good-enough approach to important aspects of archives and library work. It has emphasized how practitioners struggling with restricted resources and limited access to technical expertise can move toward improving their own, and their institution’s, digitization and preservation practices in order to meet institutional and patron needs more fully. In both cases it suggests that librarians and archivists can do so by developing a workflow closely adapted to local conditions by assembling a set of individual devices and utilities into a functioning whole. In a context increasingly marked by severe funding reductions for archives, libraries, museums, and other similar institutions, as well as the likelihood that magnetic tape materials will soon deteriorate to a point preventing future use and access, this approach may prove fruitful in an increasing number of settings.

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