A WORKFLOW STUDY OF MIGRATING ANALOGUE MULTI-TRACK AUDIO RECORDINGS TO DIGITAL PRESERVATION FILE SETS

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Abstract

Migrating obsolete carriers to digital file sets is a common and accepted practice for preservation and access within the audiovisual archival community. In the creation of these digital preservation and access files, archivists are presented a wealth of opportunities, obstacles and considerations with regards to workflow and file management. Specifically, this paper examines migration workflow for analogue multi-track audiotapes and discusses media assessment, playback preparation, digitization, file management, ephemeral document capture, and metadata entry in the context of both technical and time resources. While this paper does not speak specifically to born-digital multi-track audio, many of the file management issues are the same.

Workflow methods and observations for this paper were made in the course of ongoing digitization projects within the Drexel University Audio Archives. By studying cases from this collection of diverse formats and content, this paper describes workflow processes from playback to descriptions while identifying management priorities and inefficiencies when migrating multi-track audio objects. Statistical time-cost analysis of the collection will display many of the issues involved in managing such file sets, such as file count, file association and file searching.

1. Introduction

The principles for using digitization as a preservation method are clearly established within the audiovisual preservation discipline. With regard to audio objects, digitization is usually used as a preservation method because of the condition of deteriorating media or the diminishing supply of functioning obsolete playback equipment. In either case, there is a potential threat that an audio object might become unplayable. Therefore, an active approach to migration is necessary to assure that recorded sound survives in perpetuity. The IASA technical council document *The Safeguarding of the Audio Heritage: Ethics, Principles and Preservation Strategy* (IASA TC03 2005) states that no matter how robust the carrier is, "preservation of the document in the long term can only be achieved by copying the contents to new carriers/systems". However, copying recorded sound from one carrier to another will result in generational loss such as signal degradation and added noise if the migration is performed to a new analogue carrier. Therefore, a one-time high-resolution migration to the digital domain is preferred. Not because a digital transfer is exempt from its own anomalies, but because additional noise from the migration process is minimized and, as stated in IASA TC03, "only the digital domain offers the possibility of lossless copying". As long as great care is taken to maximize the quality of the playback system and that the digitization parameters provide for a high-quality conversion, any future migrations will be performed in the digital domain, allowing for exact copies with no signal degradation or data loss. It is with these principles in mind that IASA TC03 proposed that "for the long-term preservation of the primary information contained on an analogue carrier it is necessary, therefore, to first transfer it to the digital domain"

By using digital migration as part of a preservation plan, archives must develop workflows to process audio materials in both its analogue and digital form. These include cataloging materials, preparing the analogue object for playback, digitization, and capturing all necessary descriptive metadata. These workflows are fairly well established in most audiovisual archives and file formats and metadata standards align well with mono and stereo audio objects. For instance, an audiotape becomes a .wav file while the tape boxes and paper documentation become associated .tif files.

For the digital file, all metadata needed to describe it can be neatly embedded in the file header as well as a central database for easy searching. However, when processing a multi-track object, the complexity is greatly magnified. While a .wav file can contain both streams of a stereo recording, it is unable to contain sixteen or twenty-four streams of audio that make up a multi-track tape. Therefore, each stream is contained within its own mono .wav file and additional metadata must be created to keep these files associated with each other. While embedding metadata is still possible, the description of each file within a multi-track set will be different from one another. For instance, the first file in the set may contain a recording of the bass guitar while the second file may contain a recording of the bass drum. Each file contains a recording that, by itself, does not represent the complete recorded performance. Therefore, great care must be taken for individual elements of a recording to be described in a meaningful way while maintaining its place within a complete set of elements.

This paper examines these process workflows as they relate to multi-track audio objects and the complexities that arise from a complete digital object existing as numerous discrete elements. Specifically, this paper describes each workflow process while measuring the processing time for a small set of multi-track objects that were studied during the summer of 2011 at the Drexel University Audio Archives and included selected recordings from the Sigma Sound Studios Collection. From this collection, twelve multi-track tapes were chosen. Though this is not a large sample, tapes were only processed when staffing was available to complete each step of the workflow. For data consistency, all of these objects were twenty-four-track two-inch tapes. In order to demonstrate added complexities, six of these tapes were forty-eight-track tape sets. In other words, the first tape in the set contains tracks one through twenty-four and is called the "master", while the second tape contains tracks twenty-five through forty-eight and is called the "slave". This master/slave scenario creates added complexities to processing, as two analogue objects become two sets of twenty-four .wav files that must remain associated in order to maintain record completeness.

In demonstrating workflow, one set of master/slave tapes was examined for this paper. Specifically, this tape set is a forty-eight track Gloria Gaynor recording from December 1980. Produced by Gene McFadden and John Whitehead, these recordings were released in 1981 by Polydor on the album "I Kinda Like Me". In measuring the processing time, average times from all twelve tapes were used. The workflow is broken into these processes: Object Description, Object Digitization Preparation, Digitization and Processing, Preservation and Track Metadata, and File Management.

2. Object Description

Basic object description is necessary regardless of the preservation plan. In order to have a meaningful search, each object needs to be described by a minimum set of fields. This basic set of descriptors can constitute the entire catalog entry for an analogue object. As shown in Figure 1, these fields include necessary information such as Object ID, Object Title, and Artist as well as fields to describe the objects physical characteristics and location within the repository. Furthermore, the basic description provides information regarding the contents of the recording. In the case of a music studio multi-track recording, such as this Gloria Gaynor recording, song titles and notes regarding those songs help complete the description. The information in this basic description can mostly be gleaned from written documentation on the container and included paper records.

Field Title	Field Value	Field Title	Field Value	Field Title	Field Value
Object ID	558781345	**Record Creation Date**	5/6/10	**Song 01 Name**	Chasin' Me Into Someone Else's Arms
Object Creation	12/23/80	**Legacy ID**	C316-24-1	**Song 02 Name**	The Story of the Joneses
Object Title	Gloria Gaynor Multitrack Master	**Location**	Drexel University Audio Archives	**Song 03 Name**	Yesterday We Were Like Buddies
Artist	Gloria Gaynor	**Shelf Location**	F	**Song 04 Name**	Yesterday We Were Like Buddies
Studio of Origin	Sigma Sound Studios	**Shelf Number**	23	**Song 05 Name**	I Kinda Like Me
City of Origin	Philadelphia, PA	**Project Title**	Sigma Sound Studio Collection	**Song 01 Notes**	HL + TL
Object Number of Set	1	**Object Status**	OK	**Song 02 Notes**	HL + TL
Objects in Set	2	**Status Date**	5/6/10	**Song 03 Notes**	HL + TL (Outtake)
Object Format	Analog Audio	**Object Condition**	Excellent	**Song 04 Notes**	HL + TL
Object Type	2" Tape	**Condition Date**	5/6/10	**Song 05 Notes**	HL
Manufacturer	Scotch	**Accession Source**	Sigma Sound Studios		
Make and Model	250	**General Notes**	Multitrack Master used for June 15, 1981 Polydor Album Release of Gloria Gaynor - I Kinda Like Me.		

Figure 1. Basic Object Description

This basic description provides the necessary information to clearly understand the recorded contents of an analogue object. Since this description is derived from already existing documents, the time it takes to enter the data is not great. However, this description is inadequate to describe the object once it has been digitally migrated. Therefore, once digitization has been identified as a preservation method for an analogue object, a richer set of metadata must be captured. This richer set, however, cannot be entered until the digitization process has been completed, as the necessary information will not be entirely known.

3. Object Digitization Preparation

Before an audio object can be digitized for preservation, preparations must be made to assure a successful migration. The first step in this process is to assess the objects condition and playability. This step is usually accomplished by a simple visual inspection. With most modern multi-track tapes, the main concern is sticky-shed syndrome, whereby hydrolysis can greatly hinder playback quality (IASA 2009, p.51). Examining the tape pack and observing if the tape falls easily away from the pack can usually determine this condition. Once the overall condition is determined, it is possible to create a playback strategy that may or may not include restoration processes to maximize playability. For instance, if mold growth has been detected, cleaning the tape may be necessary before playback. If sticky-shed syndrome has been detected, baking the tape may be necessary. However, while baking a two-inch tape can take many hours to perform, it does not require active monitoring. Therefore, without the need for person-hours, calculations in this paper do not include baking time.

Once the object is ready for playback, all necessary equipment must be calibrated to maximize playback quality. This process starts with demagnetizing the playback machine and cleaning all tape path surfaces. The playback machine must then be calibrated so that the playback will match any included project tones. Or, if there are no available project tones, it must be calibrated to an appropriate playback level using a test tape. Calibration will also include aligning any noise reduction system that was used in the original recording. In the case of studio created musical recordings, Dolby™ type A or SR noise reduction is commonly used. While calibration is a fairly straightforward technical process, the shear number of presented audio paths can complicate multi-track calibration. For instance, processing time to calibrate twenty-four channels of playback simply takes considerably more time to complete than a two-track playback calibration.

Lastly, the Digital Audio Workstation (DAW) must be prepared for digitization. This may include calibrating the converters to a specific operating reference level and setting all appropriate input paths. However, the primary preparation is to assure that the appropriate file types are chosen and that all the conversion parameters are set to preservation quality standards.

Object digitization preparation time can vary depending on the object condition and the complexity of the calibration. However, proper preparation is vital for successful digitization and cannot be minimized to save time. While this description of preparation is not a step-by-step procedure, it serves to show the scope of the process and its importance.

4. Digitization and Processing

Digitization of the analogue object is simply a real-time playback while re-recording the audio streams into a DAW. Therefore, after object preparation, the time spent digitizing is roughly equal to the playing time of the object. However, it is vital to monitor the process to assure that the quality of all audio streams are not compromised and that there are no unforeseen circumstances that interrupt the process.

After digitization, it is also wise to examine the files for quality assurance. Digitization, however, is not only an audio event. All documentation that is written on the analogue container as well as all paper documents that accompany the object requires scanning to preservation quality .tif files. The number of scans will vary. However, most studio created tapes will require scanning of the tape box, a take sheet, and a track sheet for each song. Other documents may include musical charts, lyric sheets, and equipment recall sheets.

After digitization, it is important to export each song, or recorded event, to an individual file set. For instance, each song on a twenty-four-track object should constitute an individual file set of twenty-four discrete mono high-resolution .wav files. The reasoning is simple. When it comes to file naming, each song's set will require different names per track that match that song. For instance, track nine of song one may be a guitar recording while track nine of song two may be a piano recording. While this may add to any potential disassociations, having discrete files sets for each song will allow for more meaningful metadata regarding each track to be collected. Figure 2 shows the completed file sets for object one of the Gloria Gaynor tapes. Displayed are the song file sets along with the associated scanned documents.

558781345_Gloria_Gaynor	Jul 12, 2011 2:50 PM	--	Folder
01_Chasin'_Me_Into_Someone_Elses_Arms	Jul 8, 2011 4:15 PM	--	Folder
_MD5	Jul 8, 2011 4:15 PM	--	Folder
(01)Bass.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(02)Lead_Vocal.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(03)Kick.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(04)Snare.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(05)Hat.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(06)Drums.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(07)Drums.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(08)Guitar.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(09)Guitar.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(10)Quadra_Reeds.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(11)Prophet.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(12)Rhodes.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(13)Rhodes.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(14)SMPTE.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(15)Organ_Lo.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(16)Organ_Hi.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(17)Data_A.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(18)Prophet.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(19)Data_B.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(20)BGV_1.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(21)BGV_2.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(22)Prophet.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(23)Arp.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
(24)Arp.wav	Jul 8, 2011 4:11 PM	80.7 MB	Waveform audio
02_Jones_vs_Jones	Jul 8, 2011 4:15 PM	--	Folder
03_Yesterday_We_Were_Like_Buddies	Jul 8, 2011 4:15 PM	--	Folder
04_Yesterday_We_Were_Like_Buddies	Jul 8, 2011 4:15 PM	--	Folder
05_I_Kind_Of_Like_Me	Jul 8, 2011 4:15 PM	--	Folder
Documents	Today, 1:30 PM	--	Folder
558781345_Spine.tif	Jul 8, 2011 12:22 PM	9.5 MB	TIFF image
558781345_Take_Sheet.tif	Jul 8, 2011 12:12 PM	28.4 MB	TIFF image
558781345_Track_Sheet_01.tif	Jul 8, 2011 12:14 PM	28.5 MB	TIFF image
558781345_Track_Sheet_02.tif	Jul 8, 2011 12:16 PM	28.6 MB	TIFF image
558781345_Track_Sheet_03.tif	Jul 8, 2011 12:18 PM	28.6 MB	TIFF image
558781345_Track_Sheet_04.tif	Jul 8, 2011 12:20 PM	28.6 MB	TIFF image
558781345_Track_Sheet_05.tif	Nov 29, 2010 3:00 PM	28.5 MB	TIFF image
558781345.pdf	Jul 8, 2011 2:58 PM	1.3 MB	Portable...at (PDF)

Figure 2. Individual File Sets

5. Preservation and Track Metadata

Preservation metadata describes the process and technical parameters of the migration process. This data set contains information about tape preservation, playback equipment, calibration specifications and digital conversion parameters. Figure 3 shows the preservation metadata that was captured for the Gloria Gaynor tape set and the metadata that is traditionally captured for each audio object. Many of these fields are auto-filled, as most of the technical specifications rarely change. For instance, the same digital converters are used for all digitization within the Drexel University Audio Archives. Therefore, once calibration specifications are determined, the calibration and conversion parameters will generally remain the same.

Field Title	Field Value	Field Title	Field Value
Tape Baked	No	Track Count	24
Date Baked	n/a	Noise Reduction	Dolby A
Baking Temperature	n/a	A/D Converter	Apogee AD-16X
Hours Baked	n/a	File Format	BWF
Hours Cooled	n/a	Sample Rate	96 KHz
Transfer Date	11/29/10	Bit Depth	24 Bits
Object Sides	1	Alignment Tones	558781345
Source Machine	Studer 827	Conversion Reference	-16 dBFS = 0 VU
Object Speed	15 ips	Transfer Software	Pro Tools 9
Track Configuration	Multitrack	Transfer Drive	DUAA_INT_01

Figure 3. Preservation Metadata

While preservation metadata is comprised of a small and consistent set of information, track metadata is much more complicated. For instance, track metadata must include information for each song as well as metadata to describe each file in the set for each song. In Figure 4, the information for one song from the Gloria Gaynor objects is shown. Each individual song will not only have its own title, but often a different set of songwriters, producers and engineers. It is in this data scheme where the complexity of describing multi-track audio objects becomes apparent.

Field Title	Field Value
Song 05	I Kinda Like Me
Songwriter	Gloria Gaynor
Songwriter	Edward Alfred Sierra
Producer	Gene McFadden
Producer	John Whitehead
Engineer	Dirk Devlin

Figure 4. Song Information (Song 05 from object one of the Gloria Gaynor set)

However, these complexities become more apparent once metadata for each file is created. For instance, with a twenty-four-track object, descriptions are required for all twenty-four files created for each song. The track number (to maintain original order), track name and comments can generally be gleaned directly from the original track sheets of the analogue object. However, there are a few issues with using this information verbatim. For instance, the Drexel University Audio Archives collects the track name verbatim under the heading of "original name". This allows for any original misspellings, abbreviations or colloquialisms to be included in the record. However, a standard vocabulary within the database is maintained under the heading "track name". This requires the cataloger to translate the original name to the track name using an established vocabulary. Furthermore, it is also important to make sure that what is listed on the original track sheet is indeed what that file contains. The differentiation between original name and track name allows for the correction of potential inconsistencies. Figure 5 shows the entered data for a single twenty-four-track song and the relationship between fields.

Track Number	Track Name	Performer(s)	Comments	Original Name
1	Bass	Jimmy Williams	Dir	Bass
2	Lead Vocal	Gloria Gaynor	3/23/81 O/D Bounced 87 Hi Pass -2@1.2pre, +2@10kpost	New Lead
3	Kick	Keith Benson		BD
4	Snare	Keith Benson		Snare
5	Hat	Keith Benson		Sock
6	Drums	Keith Benson	Sc	Drums
7	Drums	Keith Benson	Flt	Drums
8	Guitar	Roland Chambers		GTR
9	Guitar	Dennis Harris	Denis	GTR
10	Prophet	Jerry Cohen	#2	Prophet
11	Sax	Sam Peake	O/D #3 Key from 18	Sax
12	Clavinet	Jerry Cohen	3-19-81	Clav
13	Clavinet	Jerry Cohen	3-19-81	Clav
14	Congas	Daryl Burgee	3-18-81 O/D #2 Prime Choice	Congas
15	Data B			Data B
16	Crumar	Jerry Cohen	3-19-81 O/D #1 Hi	Crumar
17	Prophet	Jerry Cohen	3-19-81 O/D #1	Prophet
18	Sax	Sam Peake	1-18-81 O/D 1	Sax
19	Sax	Sam Peake	3-18-81 O/D #2 Kepex from Trk 18	Sax
20	BGV 1	Carla Benson, Evette Benton, Barbara Ingram	3-18-18 Girls O/D	BKGD
21	BGV 2	Carla Benson, Evette Benton, Barbara Ingram	3-18-18 Girls O/D	BKGD
22	Crumar	Jerry Cohen	1-12-81 O/D #2 Lo	Crumar
23	SMPTE		off sync head	SMPTE
24	Claps		1-12-81 O/D #2	Claps

Figure 5. Track Metadata for a single song (Song 05 from object one of the Gloria Gaynor set)

When entering track metadata, the cataloger has the opportunity to enrich this data with information not readily available. For instance, the original track sheets may include performer information. However, it may not, and, as seen with track naming, spellings may be inconsistent. Therefore, in an effort to maximize the database search potential, researching performer information and entering performer names using an authority file can greatly enhance the track metadata. However, this research time and data entry increases processing time that may or may not be deemed cost effective. For this paper, this additional processing time was measured to quantify its impact on data entry.

6. File Management

To complete processing, file management procedures are needed. These procedures include file naming, Global Unique Identifier (GUID) creation and MD5 Checksum creation. In the case of the Drexel University Audio Archives, these final processes are automated. For instance, information from the database is collected and, with custom software, all files are renamed to match the database names, GUIDs are created and inserted into the file header and MD5 Checksums are created for future data integrity checks. Once this process is completed, all GUID and MD5 data is imported into the database to complete the record. At this point, all files, objects and descriptions are formally tied together. The processing time for these file management procedures is quite consistent due to the automated process. Therefore, while this step is vital in maintaining proper file association, its impact on processing time is minimal.

7. Conclusions

7.1. Processing Results – Gloria Gaynor tape set

The Gloria Gaynor tape set that has been used to illustrate each workflow process consisted of two tapes, a master and a slave. The master tape contained five songs, while the slave tape contained only four. This song imbalance is due to an outtake of one song remaining on the master tape for which a slave object was never created. Therefore, from these two tapes are nine audio file sets. Within these file sets are 216 .wav files with their corresponding 216 .md5 checksum files. Scans of the container and paper documents yielded 13 .tif files. Managing these file sets was complex, because four of the songs on the master require association to the four songs on the slave to maintain completeness. However, these file sets represent separate

analogue objects. Their digital migration results in files that need to remain together while also maintaining a representation of separate original objects. Figure 6 illustrates this file association.

558781345_Gloria_Gaynor	Jul 12, 2011 2:50 PM	--	Folder
01_Chasin'_Me_Into_Someone_Elses_Arms	Jul 8, 2011 4:15 PM	--	Folder
02_Jones_vs_Jones	Jul 8, 2011 4:15 PM	--	Folder
03_Yesterday_We_Were_Like_Buddies	Jul 8, 2011 4:15 PM	--	Folder
04_Yesterday_We_Were_Like_Buddies	Jul 8, 2011 4:15 PM	--	Folder
05_I_Kind_Of_Like_Me	Jul 8, 2011 4:15 PM	--	Folder
_MD5	Jul 8, 2011 4:15 PM	--	Folder
(01)Bass.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(02)Lead_Vocal.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(03)Kick.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(04)Snare.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(05)Hat.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(06)Drums.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(07)Drums.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(08)Guitar.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(09)Guitar.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(10)Prophet.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(11)Sax.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(12)Clavinet.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(13)Clavinet.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(14)Congas.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(15)Data_B.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(16)Crumar.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(17)Prophet.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(18)Sax.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(19)Sax.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(20)BGV_1.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(21)BGV_2.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(22)Crumar.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(23)SMPTE.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
(24)Claps.wav	Jul 8, 2011 4:11 PM	12...MB	Waveform audio
Documents	Today, 1:30 PM	--	Folder

558781346_Gloria_Gaynor	Jul 12, 2011 2:50 PM	--	Folder
01_Chasin'_Me_Into_Someone_Elses_Arms	Jul 12, 2011 2:43 PM	--	Folder
02_Jones_vs_Jones	Jul 12, 2011 2:43 PM	--	Folder
03_Yesterday_We_Were_Like_Buddies	Jul 12, 2011 2:43 PM	--	Folder
04_I Kind_Of_Like_Me	Jul 12, 2011 2:43 PM	--	Folder
_MD5	Jul 12, 2011 2:43 PM	--	Folder
(01)Bass.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(02)Kick.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(03)Drums.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(04)Drums.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(05)Rhythm_Track.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(06)Rhythm_Track.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(07)Synth_Track.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(08)Synth_Track.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(09)BGV.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(10)Room.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(11)Lead_Vocal.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(12)Horns.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(13)Room.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(14)Violins.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(15)Violas.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(16)Celli.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(17)Violins.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(18)Violas.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(19)Celli.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(20)Room.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(21)Room.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(22)(blank).wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(23)SMPTE.wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
(24)(blank).wav	Jul 12, 2011 2:41 PM	12...MB	Waveform audio
Documents	Today, 1:31 PM	--	Folder

Figure 6. File association for Master and Slave multi-track tapes.

Processing this tape set took a total of 5.1 hours to complete. In that time a total of 1832 description fields were added to the database. Of those 1832 fields, 1100 were automated, which saved significant processing time. Of the manually entered fields, only 66 were entered for the basic description, 40 were entered as preservation metadata, and 732 were entered as track metadata. From these numbers, it is clear that multi-track processing can be a labor-intensive endeavor. Specifically, the greatest number of entered fields is in track metadata. However, this data is vital to keeping files properly named and described. While these fields also include enhanced metadata that requires research time, there is no shortcut to track names and comments. Furthermore, the 5.1 hours of processing time assumes 100% productivity. Therefore, processing these two tapes would roughly constitute an entire workday's worth of processing time.

7.2. Processing Results – Complete Study

With regard to the entire bulk of studied tapes, processes were measured and averaged to get a sense of what full multi-track processing entails. Each process in the workflow was timed, recorded and averaged to not only determine how long each process takes, but to also help identify processes for which the time-cost involved might be deemed too high and where efficiencies might be made. For instance, the average time to complete a twenty-four-track object with a full description is 2.2 hours. However, if the enriched information and its research time are excluded, processing is reduced to an average of 1.9 hours. While this reduction in processing time is not insignificant, it is also not a huge burden. Therefore, it must be determined if the additional descriptive information is worth the time-cost involved. A case could be made either way. For instance, the added information aids in searching and provides more meaning to search results. However, with limited resources, an institution may determine that any savings in processing time is necessary.

With regards to object description, the basic description for each analogue object takes an average of 7.6 minutes. For data entry consistency, authority files were consulted. This process took an average of 5.7 minutes per object. However, it was observed that commercial recordings garnered more results from authority files than non-commercial recordings. Therefore, the recorded content may have some effect on authority file searches. Furthermore, authority file searches for the basic description only need to be performed on one object of a set, because the information will be the same for all objects. In the case of a master/slave set, only one search for two objects needs to be performed.

In the case of digitization preparation, an average of 18.5 minutes per object was measured. This average time is greatly effected by the availability of project test tones and the quality of those tones. For instance, in some cases, the printed project tones change level unexpectedly or certain channels were printed improperly. In these cases, the operator may need to check with a standardized test tape for level assurance. To gain consistent results, the study performed for this paper used only twenty-four-track objects. However, the number of audio channels that require calibration will have an impact on calibration time. For instance, a sixteen-track object will require less time to calibrate than a twenty-four-track object. As stated earlier about restorative practices, because tape baking does not require staff activity, any necessary restorative baking time was not included in this calculation.

Digitization is roughly a real-time endeavor. Therefore, a recording's content length has great affect on digitization time. However, as mentioned before, each song or recorded element needs to be exported as a separate set of files. Therefore, after digitization, some post processing time is needed. With that in mind, the average time needed for digitization and post processing was 29.1 minutes per object. Unlike authority file searching, there is no reduction in processing time with digitization. Each object requires real-time playback regardless of its associations. With each object studied, containers and paper documents were scanned, averaging 5.2 scans per object. The time it took to scan these documents was an average of 7.5 minutes. Obviously, scanner speed and document quantity have a significant effect on this measurement.

Preservation metadata entry incurred the smallest amount of processing time. As many of these parameters do not change, the database can easily be designed with pull-down fields, which allows for quick data entry. Therefore, the average time to enter preservation metadata was only 2.8 minutes. Regardless of the content, this entry time is extremely consistent.

Unlike preservation metadata, track metadata requires significantly more entry time. For instance, the average time to enter track metadata is 31.3 minutes per object. This measurement translates into an average of 9.7 minutes per song. Therefore, given an identical track count, there is a direct correlation between entry time and the number of songs per object. For instance, if a tape was recorded at a tape speed of 15 inches per second, it is possible for that tape to contain more songs than one recorded at a speed of 30 inches per second. Additionally, there exists the opportunity to enrich the track metadata by researching and entering performers, songwriters and any other pertinent information that is deemed valuable for searching or research. In this study, the time it took to research and enter enriched metadata averaged 15.2 minutes per object. This process represents a significant amount of time-cost. However, it can be argued that this enriched metadata provides valuable information to potential researchers. Similar in nature to the authority file search, more information can be found regarding commercially released recordings, which can increase the time to complete this process.

File management is another process that, because of automation, does not incur a great time-cost in processing. For instance, the average time to names files, create GUIDs and MD5 Checksums and import that data back into the database only takes 11.1 minutes. Considering that this process requires multiple data exports and imports, file management is a rather efficient endeavor.

With these measurements, it is possible to paint a complete picture of processing workflow and time-cost for multi-track audio object processing. For instance, it takes a total average of 13.3 minutes to describe a twenty-four-track audio object. That time includes authority file searching. To digitize the same object and describe it to its fullest extent, it takes an average of 2.2 hours.

If one excludes the enriched metadata when entering track metadata, total processing time can be reduced to an average of 1.9 hours. To put these numbers into perspective, they will be applied to the holdings of the Drexel University Audio Archives, which houses 1201

twenty-four-track objects. Table 1 shows how many 40-hour workweeks are required to complete each scenario. It is important to keep in mind that these numbers assume 100% productivity.

Processing	**Time per object**	**Total 40-hour workweeks required**
Analogue Objects with Basic Description	13.3 minutes	6.7
Digital Objects with Full Description	2.2 hours	66
Digital Objects with basic Description (no enriched metadata)	1.9 hours	57

Table 1. Required processing time for 1201 objects

With the complexity and time costs associated with multi-track audio processing, any repository interested in maintaining a multi-track collection must determine feasibility. For instance, can the processing time-costs for the digital preservation of multi-track audio objects be absorbed? While archival value is not always defined in monetary terms, the additional time-cost may seem reasonable if it provides a high level of research value. For instance, the additional time can garner a rich database, which can help open access to researchers. But then we must ask: does better access justify the processing costs? Or, would it be more appropriate to take a targeted digitization approach, where objects are only processed when requested or in need of preservation? In any case, the processing of multi-track audio objects is a significant undertaking. Defining appropriate workflows and efficiencies is vital to the success of maintaining a multi-track audio collection with digitization as the primary preservation plan.

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