Understanding Reformatting Options and Providing Access

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Stephanie Renne
Audiovisual Archivist
George Blood Audio & Video

Audio Digitization Work Flow
Digital Archival Set

- Preservation Master
- Use and Access Copy
- Web-Accessible Copy

Preservation Master

- Key Traits
  - Rarely accessed (Dark Archive)
  - Most important to manage
  - Typically 96kHz/24bit or 44.1kHz/16bit
    - kHz of PCM = dpi of TIFF
    - bit resolution (in volume or amplitude) = bit of TIFF (range of colors)
  - .WAV or .BWF
    - “wave” or “broadcast wave”
Preservation Master

• Key Advantages of broadcast wave
  – Widely used
  – Higher resolution than 99+% of sources
  – Better than most playback chains
  – Derivatives easily created
  – EBU standard
  – Think of PCM like a sound TIFF

Preservation Master

• Key Difficulties of files
  – No standard storage medium
  – Data tapes expensive to maintain
  – Too big for CD-ROM
  – On-line storage requires ongoing maintenance
  – Internet delivery impractical
    – 5x play time for T1 .ftp
Preservation Master

- Typical Solution
  - 96/24 on hard drive to digital library
    - Enterprise-level storage
  - 96/24 on DVD-ROM
    - Can be migrated to HDD when available
  - Do something else
    - Gold CD-R
    - CD-ROM
    - LTO-3 data tape

Use & Access Copy

- Key Traits (and Advantages!)
  - Readily accessible
  - User-friendly format
  - Good enough to substitute if
  - Preservation Master is lost
  - Nearly always CD-Audio
Use & Access Copy

• Key Difficulties (CD-Audio vs. CD-ROM)
  – CD-DA (digital audio)
    • Pure serial-read (can’t re-read to correct errors, even transient errors)
  – CD-ROM (digital audio as data)
    • Sector-based, so can re-read (more reliable)
    • Requires computers (software, OS, etc.) to retrieve

• Summary
  – CD-DA more widely playable
  – CD-ROM more reliably played

Use & Access Copy

• Typical Solutions (depend somewhat on Preservation Master)
  – CD-DA for near-universal playability
  – Multiple copies
    • CD-DA, one copy on “gold,” one on “green”
    • CD-ROM (gold?) and CD-DA (green)
  – Gold CD-R for Preservation Master, Green for U&A
Web-Accessible Copy

- Depends on Rights
  - RA & AAC more secure than MP3 or WMA
- Depends on Needs
  - Too restricted to put on-line
  - Beyond institutional abilities or needs
- Perhaps as-needed only

Preservation Master

- Analog
  - 1/4” Tape
  - Quantegy GP-9
  - Quantegy 499
  - Quantegy 456
- 96/24
  - DVD-ROM
  - HDD
  - "Enterprise" Hard Drive
  - Data Tape
- CD-R
  - CD-DA
  - CD-ROM
  - Gold
  - Green
Digital is not forever.

Preservation for Access

- ALA PARS definition of Digital Preservation:
  "Digital preservation combines policies, strategies and actions to ensure access to reformatted and born digital content regardless of the challenges of media failure and technological change. The goal of digital preservation is the accurate rendering of authenticated content over time."
- Preservation of information / content over medium
- Audiovisual media deteriorates rapidly
- Digital is not forever but analog is dead
The “Catch”

“regardless of the challenges of media failure and technological change”

Digital makes migration a way of life!

Migration

- How frequent? (How long will it last?)
- What determines when?
  - Format obsolescence [WAV or BWAV]
    - Not such a big problem
  - Carrier obsolescence [LTO, HDD, CD]
    - Really big problem
What is Obsolescence?

- CD-R vs. LTO
- “Bunch of Drives on a Shelf” vs. IT support for “enterprise-level” storage

What can your institution support?

- LTO: cheap, reliable, high density, high resolution
- LTO: IT intensive, short life cycles, complex machine-dependency
- CDs: cheap(ish), widely available, mid-resolution
- CDs: lots of handling to migrate, no metadata (except label)
- “BODOAS”: cheap, fast, familiar
- “BODOAS”: cheap, fragile (die easily & easily erased)
- Enterprise-class HDD: fast, preferred solution
- Enterprise-class HDD: expensive; needs technical staff
Conclusion:

- IT gets ever cheaper, ever more quickly.
- IT gets obsolete ever more quickly.
- What is the life-cycle cost, over multiple migrations?
- What ability will your institution have at any given future time to support the migration of digital content? The decisions you make today are governed by that future ability.

Standards

- BWAV
- bext and INFO chunks
- ID3 tags
- AES-57
- PB Core
- Checksums
WAV / BWAV

- Part of the RIFF Standard (Resource Interchange File Format)
- Released in 1992 as a part of Windows 3.1

Standard : BWAV

- File automation at George Blood Audio & Video
  - All files created from single original capture file
  - Specific file info gathered from FileMaker Pro Database
  - LINUX command line audio utilities
Standard: BWAV

- SoX - Sound eXchange
  - "Swiss Army Knife of sound processing"
  - Sample rate and format conversion
  - http://sox.sourceforge.net/
- libsndfile
  - "C" library
  - Contains an example program that gives a lot of useful info about files "sndfile-info"
    - BEXT embedding
    - http://www.mega-nerd.com

Standard: BWAV

- Mandatory WAV Chunks
  - "FMT" - Describes the contents of the WAV file
    - Format
    - Number of Channels
    - Sample Rate
    - Bit Depth
    - Streaming Info
  - "DATA" - Audio data
    - WAV PCM - no compressions
    - WAV PCM EX - Extensible. Handles higher resolution audio files, multi-channel formats and 64 bit audio
    - Many others
Standard: BWAV

• Optional WAV Chunks
  o LIST (INFO) Chunk
    1. Stores Metadata in a WAV file
    2. Any new INFO field may be defined, but an application should ignore any chunk it doesn't understand
    3. Common registered INFO fields
       4. artist
       5. comments
       6. copyright
       7. genre
       8. name

Standard: BWAV

• Optional WAV Chunks (continued)
  o SMPL Chunk
    ▪ Info useful when data is used in samplers
    ▪ Rarely holds value in the preservation world
  o PEAK (all versions) inserts a SMPL chunk in every WAV file it saves!
Standard: BWAV

- Optional WAV Chunks (continued)
  - PAD or JUNK Chunks
    - Place holder chunks
    - Allows quick expansion of any header chunks
    - WavLab inserts pad chunks in all saved WAV files

```
<table>
<thead>
<tr>
<th>FMT</th>
<th>LIST</th>
<th>PAD</th>
<th>DATA</th>
</tr>
</thead>
</table>
```

Standard: BWAV

- BWAV
  - Includes mandatory BEXT chunk
    - Defined Metadata Fields
    - Controlled and Suggested vocabulary for most fields

- Description
- Originator
- Originator Reference
- Origination Date
- Origination Time
- Time Reference
- Coding History

- Limits DATA chunk to PCM or MPEG formats
```
<table>
<thead>
<tr>
<th>FMT</th>
<th>BEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DATA (PCM or MPEG)</td>
</tr>
</tbody>
</table>
```
Standard : BWAV

• BEXT chunk:
  Description : Ross Lee Finney; String Quartet No. 6 in E: 2.
  Allegro Scherzando
  Originator : George Blood Audio & Video
  Origination ref : New World Records CRI DRAM
  Origination date : 2009-04-16
  Origination time : 08-16-04
  Time ref : 0
  BWF version : 1
  UMID : 
  Coding history :
  A=ANALOG,M=stereo,T=Studer_A-80RC; 21569; Scotch_111A-24R
  A=PCM,F=96000,W=24,M=stereo,T=PrismSound; ADA-8XR; A/D
  A=PCM,F=96000,W=24,M=dual-mono,T=MetricHalo; ULN-2; DIO
  A=PCM,F=96000,W=24,M=stereo,T=SoX14.1; DAE
  A=PCM,F=96000,W=24,M=stereo,T=libsndfile-1.0.18pre24j

Problems with WAVs

  o Proprietary Chunks
    ▪ PEAK
      ▪ No other app will read this
      ▪ All info is redundant
    ▪ Older apps don't always ignore superfluous chunks.
    ▪ Efforts should be taken to write the most basic WAV file you can. The simpler it is, the more interoperable it will be.
Standard : WAV

Programs to strip extraneous chunks from your WAV files:

- WAVtrim – a windows app to remove superfluous chunks from wav files (www.mptrim.com)

SOX – command line application that does many audio utilities. Can clean superfluous chunks from WAV files. Download from sourceforge.net

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Standard : WAV

- Problems (continued)
  - Lack of WAVEFORMATEXTENSIBLE support
    - Windows 2000 update to the spec to support
      - higher sampling rates
      - greater bit depths
      - multiple channel (greater than stereo) audio
    - Best to avoid if you can
Standard : BWAV

- BWAV Problems
  - Implementation
    - Few/no commercial software titles read BEXT chunk info
    - Few pro audio apps embed metadata
    - Yes
      - Peak 6
      - Adobe Audition
      - WavLab
    - No
      - Peak 5
      - Audacity
      - iTunes
      - SoundForge

Standard : BWAV

- BWAV Problems (continued)
  - Application
    - Fields geared towards broadcast applications
    - Short field limits for info preservationists would want to convey
Standard: BWAV

- BWAV Review
  - Keep it simple
  - Avoid WAVPCMEX (Extensible)
  - Know your software

ID3 Tags

- Several different versions of tag implementation
- Metadata embedded into either the beginning or end of MP3 files, depending on version
- Not for WMA, AAC, Ogg Vorbis, etc. (they each have their own tagging format)
- id3.org - Website full of information on ID3 tag history and implementation
**ID3 Tags**

Version 1 - Most widely compatible, Least capable

- Title - 30 characters
- Artist - 30 characters
- Album - 30 characters
- Year - 4 characters
- Comment - 30 characters
- Genre - 1 byte

**ID3 Tags**

Version 2 - Most capable, but tricky to support

- Use of chunks give great power and flexibility
- Applications are not very responsible with this power, abuse for proprietary reasons
ID3 Tags

Extra flavors....

- 2.3 most popular (stores tag at beginning of file)
- 2.4 hasn't caught on as successor (stores tag at the end of file)

ID3 Tags

Princeton Story...

≠ ≠ ≠
ID3 Tags

iTunes

Real Player

ID3 Tags

- Pick a version, use that version *only (either 1.1 or 2.3)*
- One tool to embed, another to check
- Beware of using multiple tools to embed!
ID3 Tags

- Winamp: Windows program which can be used to write and view version 1 and 2 tags.
- id3v2: Command-line tool for writing, extracting, and erasing version 1 and 2 tags.

AES57-2011

http://www.aes.org/publications/standards/search.cfm?docID=84

- Published in 2011
- Sets out to develop a vocabulary to describe both digital and analog audiovisual elements
- Uses extensible markup language (XML)
- Provides structured human readable document that is easily parsed and manipulated using different tools
- Concerns the technical documentation (metadata) for long-term storage and preservation
- Links document to physical object
PB Core (Public Broadcasting Metadata Dictionary Project)

http://pbcore.org/index.php
http://pbcore.org/news/introducing-pbcore-2-0/

• Organized as a set of specified fields that can be used in database applications, PBCore is utilized as a data model for media cataloging and asset management systems. As a schema, it enables data exchange between media collections, systems and organizations.
• Developed by Corporation for Public Broadcasting and based on Dublin Core
• Version 2.0 released in 2011
• A format for “semantic web applications involving media”
• Free with Creative Commons licensing
Checksum Formula

/* Process each 16-word block. */
For i = 0 to N/16-1 do
/* Copy block i into X. */
For j = 0 to 15 do
Set X[j] to M[i*16+j].
end /* of loop on j */
/* Save A as AA, B as BB, C as CC, and D as DD. */
AA = A
BB = B
RFC 1321
MD5 Message-Digest Algorithm April 1992
CC = C
DD = D
/* Round 1. */
/* Let [abcd k s t] denote the operation */
a = b + ((a + F(b,c,d) + X[k] + T[i]) <<< s). /*
/* Do the following 16 operations. */
[ABCD 0 7 1] [DABC 1 12 2] [CDAB 2 17 3] [BCDA 3 22 4]
[ABCD 4 7 5] [DABC 5 12 6] [CDAB 6 17 7] [BCDA 7 22 8]
/* Round 2. */
/* Let [abcd k s t] denote the operation */
a = b + ((a + G(b,c,d) + X[k] + T[i]) <<< s). /*
/* Do the following 16 operations. */
[ABCD 1 5 17] [DABC 6 9 18] [CDAB 11 14 19] [BCDA 0 20 20]
[ABCD 5 5 21] [DABC 10 9 22] [CDAB 15 14 23] [BCDA 4 20 24]
/* Round 3. */
/* Let [abcd k s t] denote the operation */
a = b + ((a + H(b,c,d) + X[k] + T[i]) <<< s). /*
/* Do the following 16 operations. */
[ABCD 5 4 33] [DABC 8 11 34] [CDAB 11 16 35] [BCDA 14 23 36]
/* Round 4. */
/* Let [abcd k s t] denote the operation */
a = b + ((a + I(b,c,d) + X[k] + T[i]) <<< s). /*
/* Do the following 16 operations. */
[ABCD 9 5 37] [DABC 14 21 38] [CDAB 17 18 39] [BCDA 20 26 40]
/* Round 5. */
/* Let [abcd k s t] denote the operation */
a = b + ((a + J(b,c,d) + X[k] + T[i]) <<< s). /*
/* Do the following 16 operations. */
[ABCD 13 5 29] [DABC 2 9 30] [CDAB 7 14 31] [BCDA 12 20 32]
/* Round 6. */
/* Let [abcd k s t] denote the operation */
a = b + ((a + K(b,c,d) + X[k] + T[i]) <<< s). /*
/* Do the following 16 operations. */
[ABCD 26 9 11] [DABC 1 27 6] [CDAB 5 12 7] [BCDA 18 22 8]

x^6+y^3+z+1

X = 09, Y = 06, Z = 11
9^6 + 6^3 + 11 + 1 =
531,441 + 216 + 11 + 1 = 531,669

X = 08, Y = 06, Z = 11
8^6 + 6^3 + 11 + 1 =
262,144 + 216 + 11 + 1 = 262,372
Change +1 in one value

\[ x^6 + y^3 + z + 1 \]

\[ X = 09, \ Y = 06, \ Z = 11 \]
\[ 9^6 + 6^3 + 11 + 1 = \]
\[ 531,441 + 216 + 11 + 1 = 531,669 \]

\[ X = 08, \ Y = 06, \ Z = 11 \]
\[ 8^6 + 6^3 + 11 + 1 = \]
\[ 262,144 + 216 + 11 + 1 = 262,372 \]

Checksum: Does unique matter?

No!

Does the stored value match the calculated value?

Change of a single bit gives very different value
change isn’t subtle

3.4 x 10^{38} possible values
Probability

- Chance of drawing 1 pair in poker
  1:1.36
- Chance of drawing 2 pair in poker
  1:20
- Chance a book will circulate
  1:50
- Chance of dying in a plane crash
  1:1,000,000
- Chance of winning the Mega Millions Lottery
  1:175,000,000
- Chance of 2 files having the same checksum
  1:34,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000

Probability

- Chance of 2 files having the same checksum value
  1: $3.4 \times 10^{38}$
- Chance of having any given combination on a chess board
  1: $10^{52}$
- Number of atoms in the known universe
  $10^{78}$
- Chance of 2 bits changing and yielding the same checksum
  depends on number of bits in the file
Checksum family

- MD5 (message digest #5)
- SHA-1
- SHA-256

- 128bit value
  - That’s a lot of ones and zeros
  - Converted to hex to make it easier for humans to read
  - 32 place values, base16 (16 values in each column)

Example:
be6af004116d5378064b411177c12940

Checksum

Binary:
1011110111010110111100000000010000010001000101101
101010100000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000

Hex:
be6af004116d5378064b411177c12940
Checksum

Binary:
10111110011101011011111000000000100000100101101
101010100000000000000000000000000000000000000
000000000000000000000000000000000000

Hex:
be6af004116d5000000000000000000

Checksum

Binary:
101111100110101010101111000000001000001000101101
101010100000000000000000000000000000000000000
000000000000000000000000000000000000

Hex:
be6af004116d5000000000000000000

be6af004116d5000000000000000000

be6af004116d5000000000000000000
Conclusions...

- No magic solutions - expect a catch
- Test Again!
- Use established tools
- Upgrade cautiously
- *Every* solution is temporary

Questions?

Stephanie Renne
Audiovisual Archivist
stephanie.renne@georgeblood.com

George Blood Audio & Video
21 West Highland Avenue
Philadelphia, PA 19118
PH # 215-248-2100

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Resources

**Principles of Digital Audio** by Ken C. Pohlmann

Preservation and Reformatting Section – American Library Association:
www.ala.org/alcts/mgrps/pars
www.ala.org/alcts/resources/preserv/defdigpres0408

ID3 Tags: [http://id3lib.sourceforge.net/id3/id3v2.4.0-structure.txt](http://id3lib.sourceforge.net/id3/id3v2.4.0-structure.txt)


AES57:

Software programs available for download:
www.mptrim.com
http://sox.sourceforge.net
http://www.mega-nerd.com