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DIGITAL PRESERVATION METADATA STANDARDS

TRUSTWORTHY DIGITAL REPOSITORIES

UNIFIED DIGITAL FORMATS REGISTRY

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DIGITAL PRESERVATION EDUCATION

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Format Considerations in Audio-Visual Preservation Reformatting:

Snapshots from the Federal Agencies Digitization Guidelines Initiative

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Introduction

Digitization practices have developed and matured in phases. Documents, books, and photographs were among the first items to be digitized by memory institutions—roughly speaking, beginning in the 1980s—and the practices for making still images from these source materials are reasonably mature. The digitization of sound recordings made headway in the late 1990s, with the last decade bringing good levels of consensus on the best approaches to use. Although mature, however, the practices for creating still images and digital audio continue to be refined. Meanwhile, practices for the preservation digitization of moving image content—at least in our memory institutions—are still in their infancy.

Using examples from the Federal Agencies Digitization Guidelines Initiative, this article will provide a few snapshots of digital reformatting practices with an emphasis on formats as they continue to evolve and, for moving images, as they begin to emerge. The federal agencies initiative has two Working Groups. The Still Image Working Group is concerned with the reformatting of books, manuscripts, photographs, maps, and the like, while the Audio-Visual Working Group is concerned with sound recordings, video recordings, and motion picture film. This writer coordinates the Audio-Visual Working Group and the description that follows concerns recorded sound reformatting (with a glimpse of the still image environment) and the group's exploration of moving image content.

"What formats do you recommend?" That is a question we often hear and, more often than not, people expect a three-letter answer, e.g., *wav, mpg*, or *mxf.* Alas, just naming a file format only begins to answer the question. In addition to the file format as container—what the three letters point to—we must attend to the encoding of the data within the container, its organization, and its internal description. My use of the terms *format* and *formatting* is in sync with the usage of the Library of Congress Format Sustainability website. (See the *What is a Format* page.)

The work of the Federal Agencies Working Groups is currently focused on *files*. All reformatting activities produce files and this common ground makes a good fit for interagency deliberations. Members of both Working Groups, to be sure, understand the importance of digital resources comprised of multiple files: *packages* in the parlance of the Open Archival Information System. Searchable access to digital resources is often provided at the package level. In a library setting, *packages* often correlate to what are called *manifestations* in the terminology of the Functional Requirements for Bibliographic Records (FRBR). Library cataloging typically describes content manifestations. In an archive, digital *packages* generally correlate to an item in, say, an EAD (Encoded Archival Description) finding aid, where items are typically part of series and collections or record groups. However, the practices for packaging digital resources vary so much from agency to agency (and even within agencies) that we decided "files first, packages later."

In our considerations, three aspects of formatting are at stake:

1. The **file format**, what is sometimes called the *container* for the encoded bitstreams and other elements
2. The **encoded bitstream**, i.e., the content *data*, what is often called the *essence* in broadcast and professional media production circles
3. The **metadata** that is embedded in the file, inevitably including some technical metadata ("you can't open a file in an application without it"), sometimes supplemented by judiciously chosen elements of descriptive and administrative metadata

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Embedded metadata

Most archives and libraries that manage digital content depend upon the metadata in databases, integrated library systems, and/or digital content management systems. These systems or their extensions also support patron discovery and retrieval of digital content. Thus we all tend to think of these database and database-like systems as the real home for our metadata, although they generally do not include the finest-grained elements of technical information about the content, e.g., the color space of an image file.

What is the value, then, of file-embedded metadata? The charter for the Federal Agencies subgroup devoted to the topic states that embedded metadata plays an important role "in the management, use, and sustainability of digital assets," noting that the adoption of practices that take advantage of such metadata have been inhibited by "the lack of clear, comprehensive, and uniform guidelines." The preservation-related importance of embedded metadata is also expressed in one of the Working Group's use cases for archival master images: "Disaster recovery in the event of the impairment of digital asset management systems depends upon the availability of metadata in standardized formats, including embedded image-level metadata and work-level descriptive, administrative, and structural metadata." Meanwhile, at the Format Sustainability website, *self documentation*, which refers to embedded metadata, is defined as one of the sustainability factors for digital formats.

Beyond reformatting, embedded metadata takes on special importance for libraries or archives that receive born-digital content. The acquisition of digital content with a useful mix of descriptive, administrative, and technical metadata in standardized structures will reduce the effort required to ingest and manage that content over the long term. Leaving long term management aside, it is fair to say that the seemingly simple action of transferring digital content from one organization to another is well supported by the presence of embedded metadata.

The Library's interest in promoting the embedding of metadata by content creators accounts for our support of efforts like PhotoMetadata.org, organized by the Stock Artists Alliance. We endorse the idea of embedding at least some metadata at or near the beginning of the content lifecycle. The PhotoMetadata outreach activity received matching funds from the Library's National Digital Information Infrastructure and Preservation Program (NDIIPP), and it encourages photographers to make good use of the metadata specifications from the International Press Telecommunications Council (IPTC), as a supplement to the EXIF metadata (a standard of the Japan Electronics and Information Technology Industries Association, JEITA) that is embedded in files by the camera.

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One sign of the maturity of recorded sound reformatting practices was the absence of debate within the Working Group about file formats and bitstream encoding. Every participating audio specialist accepted the idea that the file format should be WAVE and that the encoding should take the form of linear pulse code modulation (LPCM).

WAVE files for recorded sound

One sign of the maturity of recorded sound reformatting practices was the absence of debate within the Working Group about file formats and bitstream encoding. Every participating audio specialist accepted the idea that the file format should be WAVE (more on this in a moment) and that the encoding should take the form of linear pulse code modulation (LPCM). This consensus owes a great debt to the work carried out over the last decade by the International Association of Sound and Audiovisual Archives (IASA) and to pathfinding projects like *Sound Directions*, carried out at Indiana and Harvard Universities.

Sound quality correlates to the sampling frequency and bit depth selected for LPCM encoding. Both IASA and Sound Directions push for sampling rates of 96 kilohertz (with a bit of grudging room for 48) and a bit depth of 24 per sample. For comparison, audio compact disks are pegged at 44.1 kilohertz and 16 bits per sample, considered to be inferior for archival masters. Members of the Working Group concur in these judgments.

The name WAVE is generally glossed as short for *waveform audio format*. The file format is one of the subtypes of the more generic RIFF (Resource Interchange File Format) format, whose specification was published in 1991 by Microsoft and IBM to serve the then-new Windows 3.1 operating system. In turn, WAVE has its own subtypes, one of which is especially important to the Working Group: the Broadcast WAVE Audio File Format (nicknamed BWF or BWAV), developed in the late 1990s by the European Broadcast Union (EBU).

Although WAVE was created in the private sector, the relevant specifications are publicly available and, as noted, the format has formed the basis for additional work by the EBU standards body. (In this aspect, WAVE can be compared to TIFF, usually glossed as *Tagged Image File Format*, an open proprietary specification, now from Adobe, that has provided the foundation for ISO standardization efforts like TIFF/EP and TIFF/IT.) WAVE and its RIFF siblings have several virtues, including that their architecture is transparent and they can be written and read in a number of software applications.

The underlying structure for the RIFF format family consists of what are called *chunks*. The specification permits anyone to add new chunks, which is exactly what the EBU did when it specified the BWF format. Applications that play or read RIFF-family files are designed to harmlessly skip over chunks they do not understand. The structural transparency of formats like WAVE and the BWF subtype together with their widespread adoption—they are readable in many applications—make them very sustainable choices for the preservation of recorded sound.

WAVE files employ 32-bit addressing and this limits their size to 4 gigabytes (2 GB in some software applications or operating systems). Many recordists today produce high resolution files that exceed these limits and that has led to extended specifications for WAVE and BWF files. These new formats are closely patterned on their predecessors but they employ 64-bit addressing. This permits files of virtually any size, up to the limits of available disk space on a given workstation. The extended documentation includes a Microsoft specification referred to as WAVEFORMATEXTENSIBLE and the EBU standard *An Extended File Format for Audio* (EBU-TECH-3306-2007). For the time being, the Working Group is deferring an examination of 64-bit extended formats.

Metadata in WAVE files

Although happy to minimize the discussion of audio file formats and encodings, the Working Group spent some time refining a guideline for embedding descriptive and administrative metadata in WAVE files. The Working Group saw no need for action regarding the technical file-characteristics metadata required by playback applications in order to open a given file. This type of metadata is provided by the *format chunk* defined by the 1991 Microsoft-IBM RIFF specification. (The actual essence bitstream is contained in the RIFF data chunk; in the case of a WAVE file, this is the recorded sound data.) Additional information on these chunks will be found in an explanatory paper from the Working Group: *Embedding Metadata in Digital Audio Files*.

Existing WAVE specifications define some chunks for descriptive and administrative metadata. The 1991 Microsoft-IBM RIFF specification defines the *LIST info chunk*, more often referred to as the *INFO chunk*, which includes twenty-odd tagged elements ranging from *title* to *copyright* to *dots per inch* (for an image file). As far as we were able to determine,

the INFO chunk (or family of subchunks) is typically used by practitioners (not archivists) in fairly loose fashion.

Meanwhile, the BWF specification family adds three metadata chunks to WAVE: the widely adopted *bext chunk* (formally the *broadcast extension*) and the less widely used *aXML chunk* and *iXML chunk*. aXML is named after an XML expression of the Dublin Core-based core audio descriptive metadata standard. The specification allows for the storage of any valid XML document (version 1 or higher) that may be of any length (limited by RIFF specifications) and may appear in any order with the other chunks. The aXML chunk does not constrain how the user defines the data. The iXML chunk was created by audio hardware and software manufacturers to facilitate transfer of production metadata across systems. The chunk contains a defined XML document for production information such as *project*, *tape*, *note*, and *user*. On paper, the aXML and iXML chunks have much to recommend them, including an XML approach and a relatively large capacity for data. The lack of adoption and the consequent shortage of tools for writing and reading data to those chunks, however, led the Working Group to set aXML and iXML aside for now and to concentrate on making the most of the bext chunk.

The BWF bext chunk offers nine elements, generally constrained by low character counts, and customarily inscribed as ASCII strings. One of the nice touches is an element named *CodingHistory*, in which you can write a very short story about where the sound came from and how it was transferred. Here's an example (and a translation) of CodingHistory:

```
A=ANALOG,M=mono,T=Studer816; SN1007; 15 ips; open reel tape,    1
A=PCM,F=96000,W=24,M=mono,T=Pyramix1; SN16986,                  2
A=PCM,F=96000,W=24,M=mono,T=Lynx; AES16; DIO,                   3
```

Explanation: Line 1 reads: an analog, mono, open-reel tape played back on a Studer 816 tape machine with serial number 1007 at tape speed 15 ips. **Line 2 reads:** tape was digitized to PCM coding in mono mode at 96 kHz sampling frequency and 24 bits per sample on a Pyramix 1 DAW with serial number 16986. **Line 3 reads:** the audio was stored as a BWF file with PCM coding in mono mode at 96 kHz sampling frequency and 24 bits per sample using a Lynx AES16 digital input/output interface.

As the example indicates, CodingHistory does not permit the elaborate descriptions that are possible with the extension schemas typically used in METS (Metadata Encoding and Transmission Standard) implementations, under the headings *sourceMD* (about the item you started with) and *digiprovMD* ("digital provenance," about the conversion process you used when reformatting).

As the example indicates, CodingHistory does not permit the elaborate descriptions that are possible with the extension schemas typically used in METS (Metadata Encoding and Transmission Standard) implementations, under the headings *sourceMD* (about the item you started with) and *digiprovMD* ("digital provenance," about the conversion process you used when reformatting). Two very rich schemas that make great candidates for METS extensions have been defined by the Audio Engineering Society, usually referred to as *Administrative and Structural Metadata for Audio Objects* and *Process and Handling History of Audio*. Draft versions of these standards were employed in the Sound Directions project. The Working Group is not aware of any practice that embeds this metadata in files, although presumably the EBU aXML chunk could be used in this way.

As we drafted our WAVE guideline, we were repeatedly struck by the relatively skeletal nature of the bext chunk and the imperfectly-defined INFO list chunk. To

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When promoting a guideline or standard, one of the issues to address concerns the ease with which the user community can comply: are there tools for the job? After publishing our guideline for metadata in the EBU bext chunk and the RIFF/WAVE INFO chunk, we asked our expert consultants from AudioVisual Preservation Solutions to produce an edit-and-embedding tool.

be fair, this state of affairs is understandable: the bext chunk had been designed to support the exchange of program content between broadcasters, using only a few data elements written in short ASCII strings. The INFO list was designed in the early days of digital formatting, before practitioners had sophisticated views of content transfer and identification.

Identifiers were a point of particular concern for the Working Group. The bext specification defines one main element for an identifier (*OriginatorReference*) and it is limited to 32 characters. (In the second version of the specification, there was also a place defined for the Unique Material Identifier (UMID) defined by the Society of Motion Picture and Television Engineers as standard 330M.) In the reformatting work carried out by our member agencies, there is often an interest in recording an identifier for "the original" and another for the digital reproduction that results from the reformatting process (and sometimes more). And our identifiers can easily exceed 32 characters. Therefore, in our final published guideline, we departed from the EBU specification and recommended placing one or more tagged identifiers in the 256-character bext *Description* element. This conflicts with the EBU specification, which defines *Description* as an "ASCII string…containing a free description of the sequence. To help applications which only display a short description, it is recommended that a résumé of the description is contained in the first 64 characters, and the last 192 characters are use for details."

When promoting a guideline or standard, one of the issues to address concerns the ease with which the user community can comply: are there tools for the job? After publishing our guideline for metadata in the EBU bext chunk and the RIFF/WAVE INFO chunk, we asked our expert consultants from AudioVisual Preservation Solutions to produce an edit-and-embedding tool. The resulting software package is named *BWF MetaEdit* and it has been pilot-tested by three federal agencies. We plan to place it on the SourceForge website during the summer of 2010 as an open-source offering to all interested archives.

As we drafted our guideline, we found that we were not alone in facing header anemia. When the Still Image Working Group developed their initial guideline for embedding metadata in image files, they started with the TIFF header and found that the options for identifier embedding were limited and there was no good way to identify certain details, e.g., an image's color space (except in rather general terms) or a scanning device's color profile. The shortfalls encountered while developing WAVE and TIFF guidelines have motivated both Working Groups to explore additional approaches to embedding metadata. For example, the Audio-Visual Working Group plans to revisit the two underused WAVE-related specifications from EBU: aXML and iXML.

One option for the Still Image Working Group is the useful ANSI/NISO Z39.87 standard, *Data Dictionary – Technical Metadata for Digital Still Images.* The development of Z39.87 by NISO was itself motivated in part by a perception of TIFF header anemia. The Z39.87 standard offers several dozen data elements that document technical features at the file level. The XML manifestation for this data set is called *NISO Metadata for Images in XML* (MIX). Since most archives implement this data set using MIX as an extension schema of METS, however, most expressions of Z39.87 metadata are managed in package-level metadata sets and are not embedded in image files directly, our quest at the moment.

The Still Image Working Group is exploring XMP (eXtensible Metadata Platform), an open specification for embedded, file-level metadata from Adobe. XMP is supported by the widespread availability of tools from Adobe and others, most of which permit both the creation of the data and its automated migration within the family of common images formats, e.g., TIFF, PDF, GIF, PNG, SVG, JPEG, and JPEG 2000. Easy metadata migration would be very helpful in a reformatting program that creates

masters in one format and derivative images in another. The group noted that many professional photographers make use of the combined metadata specifications of XMP and IPTC, the data set standardized by the International Press Telecommunication Council. Incidentally, IPTC picture data includes elements for multiple identifiers.

Moving image formatting

Recommendations and guidelines should follow and reflect experience, and the Working Group has been tracking the progress being made by the three federal agencies that have begun to digitally reformat analog, standard definition videotapes. Our interest, however, is by no means limited to standard definition video. All of our participating agencies look forward to digitally reformatting high definition video and motion picture film in a few years' time and we seek an extensible approach to formatting.

To date, the Library of Congress has done the most digital video reformatting while the National Archives and Records Administration and the Smithsonian Institution are starting to carry out projects of their own. All three agencies have purchased SAMMA devices, a product of the Front Porch Digital company. The Library is using SAMMA's best-known implementation in a workflow that produces a stream of video-frame images, each encoded in lossless JPEG 2000. This picture data, together with soundtrack, timecode, closed captioning, and so on, is wrapped in the Material eXchange Format (MXF) file format. Files in this format serve as archival masters for preservation in the moving image collections at the Packard Campus for Audio-Visual Conservation, Culpeper, Virginia.

JPEG 2000 is a standard from the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). MXF is a standard of the Society of Motion Picture and Television Engineers, and some refer to it as a *container* or a *wrapper*. The growing body of experience with MXF-wrapped JPEG 2000 files means that this is an important target format for the Working Group to consider. At the same time, we are tracking other video reformatting efforts, including a trio of activities that entail the capture and storage of uncompressed video streams. One of these is at Stanford University, another at Rutgers, and a third at the BBC. The BBC approach is of special interest because it also employs the MXF container format.

What are the Working Group's impressions thus far? First, we see merit in exploring an approach based in the MXF standard, which is seeing increasing adoption in the professional broadcast industry, and in JPEG 2000 picture encoding, which is also seeing increasing adoption in various moving image sectors, e.g., as part of the digital cinema specification. Nevertheless, we want to keep an eye on uncompressed picture encoding as well, especially in examples like the one from the BBC, with wrapping in MXF.

Second, we are aware that MXF and JPEG 2000 are broad-spectrum standards that feature many options for packaging, metadata, and encoding. The successful implementation of an approach that uses these standards—and/or uncompressed video encoding, for that matter—will be enhanced if we users define a set of constraints. Well-defined constraints will support the development of tools to validate files and encourage multiple vendors to provide conforming equipment. A documented set of constraints increases the level of standardization applied to digital content, which in turn increases interoperability, content exchange, and long-term, preservation-oriented data management.

For users of the MXF standard, formal constraint statements are called *Application Specifications*. These can be compared to JPEG 2000 *profiles* or to the *profiles* and *levels* that characterize MPEG video content. The incubation of MXF Application Specifications is the special province of the Advanced Media Workflow Association, an organization that provides a meeting ground for professional moving-image users and vendors. Our Working Group plans to work with the AMWA to define one or more preservation-oriented Application Specifications.

The development of an application specification for moving image preservation will benefit from the involvement of archives beyond our federal agencies. For this reason, the Working Group is planning a technical meeting on digital-video-reformatting target formats to coincide with the joint conference of the International Association of Sound and Audiovisual Archives (IASA) and the Association of Moving Image Archivists (AMIA) in Philadelphia in November 2010. Technically oriented persons from interested organizations who wish to attend should contact the writer of this article for more information.

Conclusion

The examination—one might even say unpacking—of formatting elements for sound recordings and moving image content highlights the many, complex facets that must be considered. The Working Group's investigation points to the high value of documents like profiles and application specifications that supplement published standards for important formats. Such documents provide a detailed record of what is being produced, thus supporting the interoperability of content between organizations and over time. Finally, as the snapshots in this article show, preservation *practices* will be built upon many *standards* from many sources. Both federal agencies Working Groups hope to offer guidelines for good practices that reference well-chosen standards.

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