Audio-Visual Format Documentation Project: Background Paper

Federal Agencies Audio-Visual Digitization Guidelines Working Group[1]

October 7, 2010

Table of Contents

[1] The principal contributors to this paper are Carl Fleischhauer, Chris Lacinak, Oliver Morgan, and James Snyder.

What is this document?

This is a background paper for a user-community technical meeting on digital-moving-image-reformatting target formats, scheduled 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 on November 1, 2010, beginning at 3 pm, in the "Washington B" room at the conference hotel, the Loews Philadelphia. Technically oriented persons from interested organizations who wish to attend should contact Working Group coordinator Carl Fleischhauer for more information.[2] This meeting is intended to provide a forum for the end-users of preservation target formats to exchange views on the topic. Although vendors will also be welcome to attend, this meeting is not intended to provide vendors with promotional opportunities.

Overview at a high level (executive summary)

The project is about formats for audio-visual content preservation and not about the immediate provision of online access. Of course, the formats selected for long-term archiving ought not create any technical barriers to the subsequent availability of end-user copies. For the Federal Agencies Audio-Visual Digitization Guidelines Working Group, the starting point has been in the moving image area, especially concerning finding the best solutions for the file-based reformatting of conventional videotapes. However, our interests are broader. At least one of our member archives already faces the need to address "incoming" digital-serial-interface streams (standard and high definition SDI). We would also like to lay a foundation for an approach that can eventually embrace other source-content types, including scanned motion picture film. There is also interest in using a common packaging format for recorded sound, to permit an archive to consider using the same structure for both audio and moving image content.

The Working Group sees merit in pursuing an approach based in (1) the MXF standard, which is seeing increasing adoption in professional content production (e.g., broadcasting), and (2) in JPEG 2000 picture encoding, which is also seeing increasing adoption in various moving image sectors. At the same time, several Working Group members have signaled their continued interest in exploring (3) uncompressed picture encoding as well. MXF is a "wrapper" that can contain a variety of content "essences," such as JPEG 2000 or uncompressed picture data.

MXF and JPEG 2000 are broad-spectrum standards that offer many options for formatting encodings, packaging, and metadata. The successful implementation of an approach that uses these standards will be enhanced if users define a set of constraints. As has been demonstrated by the published specifications for *profiles* and *levels* for MPEG and JPEG 2000, well-chosen constraints increase digital-content interoperability, exchange, and long-term, preservation-oriented data management. Standardized constraints also encourage multiple vendors to provide conforming equipment and permit the development of tools to validate files.

How are constraints expressed? In the MXF environment, formal constraint statements are called Application Specifications (AS). The incubation of MXF ASes is the special province of

[2] Email: cfle@loc.gov; telephone: +1 202 7073979

the Advanced Media Workflow Association.[3] The AMWA provides a meeting ground for users and vendors, and the Working Group proposes working with them as one or more preservation-oriented ASes take shape.[4] As we proceed, we are being assisted by the expert consultant Oliver Morgan. Meanwhile, we are aware that there are other industry activities that are aimed at similar goals and we hope to cooperate with and benefit from these other efforts.

The AMWA published AS-03 (*Program Delivery*) in July 2010. This AS is based on an earlier PBS profile and it defines MXF files that are optimized for direct playout via a video server. AMWA is also beginning the development of one (or more) ASes for what are sometimes called *contribution* or *mezzanine* file formats, the higher-resolution versions of finished, edited programs that are sent to a distributor, broadcast, or cable network where the program-delivery versions will be produced.

The Federal Agencies Working Group effort concerns the development of an AS that will complement the preceding pair, i.e., an AS to serve the needs of moving image preservation. As the work proceeds, we hope that the AS (or ASes) will support the assembly of "libraries" of content that are destined for further distribution as well as the "archives" associated with the work of memory institutions.[5] Thus our planned effort will benefit from the involvement of archives beyond our federal agencies. The November 1 meeting in Philadelphia will provide the opportunity for interested persons to offer their ideas and suggestions about the general approach and desired outcomes, as well as indicating their willingness to participate in the process.

Background: audio-visual content: embracing a wide range of originals

The Working Group's exploration begins with video content and a special, initial concern for our legacy collections of tens of thousands of standard-definition videotapes. Even as we develop one or more target-format specification appropriate to this content category, however, we also want to keep an eye on broader or extended specifications that may emerge over time and embrace a wider range of materials, including sound recordings.

The moving image collections held by U.S. federal government agencies run the gamut from historical videotapes and motion picture film to recent acquisitions of "born digital" files. Significant collections are held by such agencies as the Library of Congress,[6] the National

---

[3] Home page: http://www.amwa.tv/. Application specification page: http://www.amwa.tv/projects/application_specifications.shtml.

[4] AMWA is a professional association and--in the terminology of the International Standard Organization (ISO)--it is a Standards Setting Organization (SSO) and not a Standards Developing Organization (SDO), a category made up of organizations accredited by the ISO or the International Electrotechnical Commission (IEC). AMWA has a strong working relationship with the Society of Motion Pictures and Television Engineers (SMPTE), which is a SDO. AMWA incubates and delivers well formed specifications to SMPTE in order to expedite the standardization process.

[5] This usage is taken from *The Digital Dilemma*, a 2007 report from the Science and Technology Council of the Academy of Motion Pictures Arts and Sciences (http://www.oscars.org/science-technology/council/projects/digitaldilemma/download.php). The report states that a motion picture industry "*archive* holds master-level content in preservation conditions with long-term access capability. A *library* is a temporary storage site, circulating its duplicated holdings on demand. An archive that stores digital materials has long-term objectives. By current practice and definition, digital data storage is short-term" (p.1).

[6] http://www.loc.gov/rr/mopic/findaid/mpfind.html

Archives and Records Administration,[7] the National Aeronautical and Space Administration,[8] and the Smithsonian Institution; represented in this example by the National Anthropological Archives and Human Studies Film Archives.[9] Many other agencies also have valuable holdings.

Within each of the moving image format categories--videotapes, motion picture films, born digital files--there is considerable variation of type. The agencies possess tapes in many video formats, films in several gauges, and files in a number of digital formats. A desire to provide access and to preserve the underlying content for the long term has motivated the agencies to begin digitizing the tapes and files and (in a few cases) to digitally transcode the files. As this digitization proceeds, the agencies report a desire to identify common digital *target formats* (the digital formats that you digitize or transcode "to"). The agencies wish to create digital master files--from all of these varied source items--with as much in common as possible.

As examples, one member of the Working Group has highlighted essence types that represent two points on the wide spectrum in which we are interested in the long term:

- Uncompressed video content up to the highest resolution available today (1920x1080p24 RGB color space or 3G HD-SDI)
- D-cinema content with the accepted JPEG 2000 profile resolution and color space

The adoption of common master-file formats will facilitate the production of copies for online access and the provision of services copies to third-party organizations who seek footage for, say, the creation of new television documentaries. The adoption of common formats will also support long term content management and preservation. If the master formats are more or less the same, then one set of hardware and software will be able to process most or all of an agency's holdings.

The desire for common formatting includes metadata. Standardized, common-format metadata will support interoperability within an agency and, when needed, interoperability across agencies or with third parties. For the Working Group, metadata recommendations fall into an evolving area, with work under way to refine our ideas and approach. Appendix A describes some aspects of the metadata of interest the Working Group.

Two sets of factors are relevant to the selection of a format or format family to meet the needs of preservation. One set of factors is somewhat abstract, having to do with levels of standardization, the possibility of high quality reproduction, and a variety of functional features. The second set of factors is practical and pragmatic. Is there ample equipment and software in the marketplace to support the creation and use of a given format? Has a given format been adopted by others with similar needs, e.g., the broadcast and motion picture industries? The Working Group understands that theoretically ideal solutions, if unsupported in the marketplace, will not provide good service.

[7] http://www.archives.gov/research/formats/film-sound-video.html
[8] http://www.nasa.gov/multimedia/index.html
[9] http://www.nmnh.si.edu/naa/guide/film_intro.htm

The MXF standard

Although we are not yet at the point of making a specific recommendation, the Working Group believes that the MXF wrapper provides a sensible solution for preservation reformatting, especially when coupled with standardized picture-essence encodings like JPEG 2000, uncompressed video and audio essences, and MPEG video streams. Over the long term, the MXF specification should be able to wrap a very wide range of content in a standardized way, extendable to any future format developed, as long as the platform doing the wrapping can handle the data requirements.

History of the standard

The Material eXchange Format (MXF) is a container format for professional digital video and audio media defined by a set of SMPTE standards. It is a subtype of the Advanced Authoring Format (AAF) developed under a policy known as the Zero Divergence Directive (ZDD) which enables MXF/AAF workflows between non-linear editing (NLE) systems using AAF and cameras, servers, and other devices using MXF. MXF and AAF were developed during the same period, i.e., approximately 1998-2004, with many of the same players participating. The Advanced Media Workflow Association (AMWA) is a broadly based trade association that promotes the development and adoption of AAF, MXF, and Service Oriented Architecture (SOA) technology in media workflows.

Two of the primary goals in the inception and development of MXF were interchange and flexibility. Interchange was intended to be delivered via independent development of a format standard recognized by many of the leading manufacturers of audiovisual hardware and software. Flexibility was designed into the standard allowing for scenarios encompassing wrapping of one or many files, with their associated edit decision lists, closed captioning, metadata, and more.

Flexibility in structure

The overarching MXF standard, SMPTE 377M-2004, "does not define either the essence container or the descriptive metadata. Instead, it defines the requirements for these components to be added as a plug-in to an MXF file."[10] Additional MXF SMPTE standards including 379M, 381M, 383M, and 384M (just to name a few) specify the placement of the essence container in the MXF wrapper. SMPTE 380M defines the framework available within the MXF file header to document descriptive metadata.

The flexibility enabling 'plug-in' type behavior for essence and metadata poses an exceedingly large number of potential variables to software and hardware MXF readers. In addition, the structural pliancy of MXF to accommodate multi-file packages yields an even greater number of variables. The implicit result of increased flexibility is the corresponding increased risk of interchange.

Standardization of the essence mappings, such as those listed above, promotes interchange between two systems that share a common codec. However, the variations in structure may still

[10] SMPTE 377M-2004: Material Exchange Format (MXF) — File Format Specification (Standard)

create interchange obstacles if there is not a common mechanism for communicating and interpreting structural metadata. To mitigate prospective interoperability issues the SMPTE standard committee developed sets of standardized rules representing varying degrees of structural complexity based on anticipated workflows called *Operational Patterns*. This enabled different hardware and software manufacturers to comply with specific operational patterns, encouraging interoperability. "In order to create an application to solve a particular interchange problem, some constraints and structural metadata definitions are required before SMPTE 377M can be used. An operational pattern defines those restrictions of the format that allow interoperability between applications of defined levels of complexity. Applications that use the MXF format must adhere to one of the operational patterns in order to achieve interchange."[11]

However, upon implementation it was found that "files created by products from different manufacturers may vary significantly in their structure and contents, even if they comply with the same Operational Pattern specification."[12]

Constraints for interoperability documented in Application Specifications

The need for tighter, more explicit constraints and specifications has been addressed by the Advanced Media Workflow Association (AMWA, described above). In recent years the AMWA has published (or is soon to publish) a number of *Application Specifications* or *ASes*, described as "attempts (a) to document the operational practice of an organization and (b) to constrain the total number of options (and hence cost) associated with the use of MXF in a facility – yet at the same time preserving flexible work practices that MXF makes possible."[13] Recently, AMWA has developed an additional level of specification (the provision of further detail) called a *shim*. Multiple shims may be created and documented as part of a given Application Specification. Once mature, ASes move to SMPTE where they are standardized as a Registered Disclosure Documents (RDD).

As noted above, AMWA has produced an AS for program delivery (AS-03) and is planning to develop ASes for contribution and/or mezzanine files. To date, however, no MXF AS exists to specifically serve the needs of archiving and preservation. Even in the absence of a firm recommendation, the Working Group believes the process of developing such an AS for preservation target format(s) will advance the community's analysis and thinking about this general topic.

JPEG 2000 picture encoding

Members of the Working Group are interested in JPEG 2000, an image compression format that is capable of encoding lossless and lossy profiles. JPEG2000 allows the encoding of visual content of any resolution and frame rate (the compression standard is agnostic), which means the limitation of the JPEG2000 encoding system is only the processing speed and storage capacity of the encoders and allows the standard to be usable into the distant future.

---

[11] SMPTE EG-41-2004: Material Exchange Format (MXF) — Engineering Guideline

[12] http://www.avid.com/resources/whitepapers/mxf.pdf?featureID=997&marketID=1

[13] Nick Wells, Bruce Devlin, Jim Wilkinson, Matt Beard and Phil Tudor, *The MXF Book: An Introduction to the Material Exchange Format* (Focal Press, 2006).

JPEG 2000 and the role of profiles

Particular implementations of JPEG 2000 Core Coding (ISO/IEC 15444-1:2004:2004) may be established as profiles. In *JPEG2000: Image Compression Fundamentals, Standards and Practices* (2002), David S. Taubman and Michael W. Marcellin compare JPEG 2000 profiles to those in MPEG standards: "In JPEG 2000, however, profiles play a much less significant role, since compliant processors are not required to recover all of the information in the codestream." Nevertheless, JPEG 2000 profiles aid in managing, accessing and preserving content being encoded by making the codestream specifications explicit and enabling development of tools and other resources.

The Working Group's understanding is that most profiles are agnostic regarding the use of lossless compression (reversible transform) and lossy compression (irreversible transform), although most of the profiles are designed for service in applications where lossy compression will be employed.

Examples of JPEG 2000 profiles may be found in a variety of locations.

- ISO/IEC 15444-1:2004:2004/Amd.1:2006 (includes profiles 0 through 4, in its amended form)
- Profile for the National Digital Newspaper Program at the Library of Congress[14]
- Profile associated with NATO and military imagery[15]

The Working Group understands that an ISO committee has drafted a set of JPEG 2000 profiles for broadcast purposes. The specification has not been published as of this writing but the Working Group believes that these profiles will provide an important reference for a preservation-oriented MXF AS.

Other picture encoding

Uncompressed picture essences

Members of the Working Group are also interested in the use of uncompressed video picture data for preservation storage. This approach would be comparable to the approach used for still images and audio in many memory institutions today; uncompressed image bitmaps and linear PCM streams are stored for the long term. A reasonable reference for Working Group's planned AS is SMPTE 384M (*Mapping of Uncompressed Pictures into the MXF Generic Container*), which embraces a number of "raster and sampling formats." The Working Group may, in addition, identify a subset of these raster and sampling formats as preferred for preservation purposes.

Born digital encodings "native, as acquired"

Several agencies receive born digital content in file form, generally with one or another lossy encoding applied. In some cases, these native encodings are widely adopted and well supported by various software applications and a good case can be made to retain the encoding in its

[14] http://www.loc.gov/ndnp/pdf/NDNP_JP2HistNewsProfile.pdf
[15] http://164.214.2.51/ntb/baseline/docs/bpj2k01/ISOJ2K_profile.pdf

acquired form for several years, at which point it may be wise to transcode for longer term storage. There may also be cases in which legal considerations require an agency to retain the video content "as is." For these reasons, the desired MXF application specification should provide for the "re-packaging" of such content. At this writing, this seems like a plausible solution for encodings that SMPTE has already mapped to the MXF Generic Container, or is in the process of so doing.

MPEG encodings

The work of the agencies can and does include the creation of MPEG-encoded essences. At this writing, the Working Group believes that if an MXF AS is desired for this purpose, it will be able to make use of AS-03 or another AS (e.g., for contribution formats) developed under the auspices of the AMWA.

Other elements to include in an MXF file

The Working Group understands that specifications will be needed for sound tracks, closed captioning and other ancillary data, the handling of interlaced picture data, and more. These elements will be fleshed out at the desired AS is drafted.

Elements may sometimes include still images, script texts, etc.

It is often the case that a videotape will be accompanied by or packaged with non-video elements: a printed box, a paper list of selections, notes from an ethnographer's log sheet, related photographs, transcripts (bitmapped or machine-readable texts), etc. The Working Group is interested in a formatting approach--if practical--that permits the inclusion of scanned still images, machine-readable text, or other representations of non-audiovisual content within the same wrapper as the video recording.

Interest in exploring the inclusion of audio-only content

Some members of the Working Group are also interested in exploring the possibility of using MXF to wrap audio-only content, i.e., to consider MXF-wrapping Broadcast WAVE files as an approach for the preservation of sound recordings in agency collections. This exploration, however, carries a lower priority than the development of initial specification for moving image content. An audio "package" in a single MXF wrapper might contain multiple sound essence elements ("Side A, Side B") and same types of images, transcripts, and container elements as outlined in the preceding section. The Working Group understands that the SMPTE infrastructure committee named Files Structures 31FS is developing a specification for multi-track sound in MXF and this may prove to be a useful reference in a preservation-oriented AS.

Metadata

Federal agencies, like other archiving organizations, maintain metadata in collection-management databases, cataloging or access-support databases, and embedded in content files. The databases support flexibility, updating, and efficient access; the embedded metadata supports preservation-safety through redundancy and provides an additional source for data when the database of out of reach. In the context of this Application Specification project, however, the Working Group's main concern is the metadata that may be embedded in files.

The types of metadata encountered in the work of the federal agencies in our Working Group are described in appendix A, *Metadata Categories and Identifiers in the Federal Agency Setting*.

The Working Group would like to explore some use of the MXF DMS[16] approach to KLV-encoded metadata (perhaps for a minimum set of data), together with the option to store more extensive XML-encoded metadata as MXF *generic streams*.[17] These latter blocks of metadata would then be available "for extraction" from the file by users.

Conformance and testing

Once an archival organization has fully implemented a target format like MXF/JPEG 2000 or MXF/uncompressed, it will wish to have sample "test" files and analytic tools for operations like the following:

- Determine that the reformatting-encoding system produces a valid, properly encoded, and well-formed output. At its heart, this is about the MXF container.
- Possess methods and tools suitable for testing the various essences. To a significant degree, this concerns the examination of essence bitstreams and the determination of the performance success of the devices used to "extract" signal (especially when the source is an analog videotape and the action requires a composite to component transform) as well as encoders and decoders.
- Although there will be great value in the establishment of recommendations for device selection and for the performance-measurement of devices, this is not part within scope for this format-specification-drafting project.

The AMWA process for developing an AS requires the provision of a *reference implementation* and *reference files*, elements that support the first bullet above. Testing and compliance at this level is about the MXF package qua package (like JHOVE testing for valid and well-formed files) but without any quality checking of the included essence-as-essence.

Regarding the evaluation and validation of essence as essence, the Working Group expects that some specifications will emerge in the course of drafting the desired AS. Other specifications, test files, and evaluation tools will be developed later. Readers should note the special aspects of JPEG 2000 that pertain to conformance and compliance, as described in part four of the JPEG 2000 specification (ISO/IEC 15444-4:2004). This topic is discussed in appendix B of this document: *JPEG 2000 Compliance, Cclasses, and Conformance*.

---

[16] Descriptive Metadata Schemes (DMSes) are defined by SMPTE MXF standards, especially SMPTE 377-1 and EG42. There are several schemes in use, including "DMS-AS-03" (related to AMWA Application Specification AS-03) and DMS-1 (SMPTE 380M).

[17] SMPTE 0410-2008, *Material Exchange Format - Generic Stream Partition*. From the SMPTE Web site: "This document defines an extension of the MXF File Format that allows specific classes of data streams to be contained in MXF Body Partitions. The classes of data streams are either essence that is unevenly distributed along the timeline or large amounts of metadata that cannot suitably be stored in the Header Metadata."

Appendix A. Metadata Categories and Identifiers in the Federal Agency Setting

The Working Group identifies following ad hoc categories of metadata as relevant to this project. Each category receives discussion in the "more info" sections below.

Term in this document	**Definition**
Essence-level metadata	Metadata embedded within the essence, whether the essence is within an MXF file or not. This is an "inevitable" part of many essence bitstreams. Examples include *KLV data* in a video stream, the *format chunk* in a Broadcast WAVE file
Technical metadata about the physical source item	Data in an external database, generally includes one or more identifiers, generally referenced to the original physical item, e.g., the source videotape
Process-logging metadata	Data created by the reformatting transfer system, a record of what happened during the process, including reports on anomalies. For a comparative reference pertaining to audio, see AES draft specification X098C.
Embedded technical metadata *required* to render an MXF file	Metadata that any "player" application needs to play back an MXF file. The Working Group assumes that any MXF-compliant wrapping application will provide this metadata.
Embedded technical metadata *not required* to render an MXF file	Metadata about the technical features of the digital file at hand (i.e., about the essences and other related information), but not necessary for an MXF player to render the file. For a comparative reference pertaining to audio, see AES draft specification X098B.
Embedded non-technical metadata	Additional metadata to be embedded in the file, including descriptive and administrative.

Essence-level metadata

Encoding systems in general produce certain metadata that is embedded in the essence bitstream or in the "immediate-wrapper-file" (e.g., Broadcast WAVE for audio). Essence-level metadata includes technical information that is produced in any and every production process. Examples include data that documents the picture size, data rate, sampling rate, bit depth, and color space. Data of this type is needed by any reader or decoder applications that render the content. The Working Group believes that the documentation of (or at least reference to) this metadata is will be a normal part of any JPEG 2000 profile and/or an MXF Application Specification.

Technical metadata about the physical source item

This can be described by a hypothetical example: A worker at the head end of the reformatting production line prepares videotapes for reformatting, performing a visual inspection of the item perhaps and using a tape inspection and cleaning device. A database is used to record the findings of the preparation process, e.g., the report generated by the inspection device and data keyboarded by the operator.

Process-logging metadata

This type of metadata would result from an application associated with the transfer system (the system that plays back the tape and creates the digital file-based "recording"). Such a system may have a feature that monitors playback performance and the resulting signal flow. Such a system may create a log of any errors and the corrections made, possibly referenced to timecode. The Working Group believes that this type of information is valuable as a record of the condition of the tape prior to transfer.

Embedded technical metadata required to render an MXF file

The Working Group has a rudimentary understanding of the structure of an MXF file and the metadata that is relevant to this structure. For example, we understand the importance of documenting such things as the *operational pattern* in play and the role played by the metadata that makes up the MXF file's *timeline*. The Working Group is working to develop additional information on this topic and its relevance to Application Specifications.

Embedded technical metadata not required to render an MXF file

There are schools of thought on this topic within the Working Group.

- Some recommend placing a *minimal amount of data "at the top of the file,"* believing that most rendering or data-management (for preservation) applications will be able to find most of the technical data they need at or within the essence.
- Others recommend including a *broad range of technical metadata "at the top"* (echoing what is also in the essences) in order to make it more readily available for applications, documentation, and file-integrity monitoring.
- Still others call attention to the value of *complete technical metadata to support long-term preservation*: "Would it not be good to have redundant metadata in both the MXF file and the collections management database? If you lost the database, you could restore your knowledge with what is embedded in the preservation files themselves."

As this matter continues to be discussed, the Working Group plans to include "placeholder space" for not-required-to-render technical metadata in the Application Specifications that are drafted.

Embedded non-technical metadata

A number of types of metadata may be desirable in a file:

- Descriptive or other cataloging metadata
- Additional curatorial metadata
- Administrative metadata, e.g., boilerplate language about restrictions on use
- Other types to be determined

In addition to the preceding, one member of the Working Group has mused about *meta-metadata*: "Shall we include a guide document within the wrapper that states what items are in the wrapper and how they relate to the essence. This could include a file-tree hierarchy type of structure that can show multiple parent-child and essence-metadata relationships." This concept can be compared to the purpose and effect of the Metadata Encoding and Transmission Standard (METS).[18] As this matter continues to be discussed, the Working Group plans to include "placeholder space" for not-required-to-render technical metadata in the Application Specifications that are drafted.

[18] http://www.loc.gov/standards/mets/METS%20Documentation%20final%20070930%20msw.pdf.

Identifiers: a complex topic on their own

In the work of federal agencies, especially at the Library of Congress, the National Archives, and the Smithsonian Institution, a variety of identifiers coexist and operate at varying levels of granularity and actionability (i.e., "click and go"). Federal agencies and other archives employ identifiers with little consistency, thus inhibiting the interoperability of their digital content. Some agencies use identifiers that link digital files to a metadata record in the system an agency uses to provide public access, while others use identifiers that connect solely to a local database, not accessible to the public. (Some content within an agency will be associated with both types of identifiers.) Some identifiers are attributes of the metadata while others are attributes of the digital content itself. For a lengthy discussion of this topic, see appendix C of *Embedding Metadata in Digital Audio Files: Introductory Discussion for the Federal Agencies Guideline*.[19]

Members of the Working Group have repeatedly encountered the need to provide multiple identifiers for a given item. This topic is addressed in our guideline for the bext chunk in a Broadcast WAVE file.[20] In the most elaborate recommended expression of an identifier, three data elements have been established:

- Identifier [value]
- Type
- Comment
- Example: ID="306-MUSA-9658B" ; Type="local" ; Comment="RG-Series-Item Number"

[19] http://www.digitizationguidelines.gov/audio-visual/documents/Embed_Intro_090915.pdf, pp. 15ff.
[20] http://www.digitizationguidelines.gov/audio-visual/documents/Embed_Guideline_090915r.pdf.

Appendix B. JPEG 2000 Compliance, Cclasses, and Conformance

JPEG 2000 compliance is simple at the fundamental level yet evasive in other ways. Regarding *encoder* compliance, the ISO/IEC standard document states, "The only requirement for encoder compliance is to produce compliant codestreams."[21] The standard defines a *codestream* as "A collection of one or more bit streams and the main header, tile-part headers, and the EOC required for their decoding and expansion into image data. This is the image data in a compressed form with all of the signaling needed to decode."[22]

Addressing *Codestream* compliance, at a basic level the codestream need only conform to the fundamental structure and organization in the standard. However, the JPEG 2000 standard offers a rich feature set and capabilities, represented by the codestream syntax specified in: "15444-1:2004, Core coding system". The codestream syntax contains information for interpreting the compressed image data. This range of capabilities and features creates a great number of possibilities, complicating compliance and interchange.

"In order to promote the wide inter-operability of JPEG 2000 codestream, codestream restrictions are introduced… Maximum interchange will be achieved for codestreams corresponding to Profile-0, and medium interchange for codestreams corresponding to Profile-1."[23] Codestream restrictions take the form of profiles and they document the limitations imposed on a codestream for a given purpose. The profile offers a way to specify the decisions, or range of decisions allowable within a given codestream. It is notable in the excerpt above that Profile-0 contains more restrictions than Profile-1, yielding greater interchange. Profile-0 is also considered a subset of profile-1. 15444-1:2004, and its amendments currently provide 5 profiles (although one contains absolutely no restrictions).

Addressing *decoder* compliance "In order to conform to this Recommendation | International Standard, a decoder shall convert all, or specific parts of, any compressed image data that conform to the codestream syntax specified in Annex A to a reconstructed image."[24]
Given the limitless possibilities for compliant codestreams the above statement necessarily binds decoder compliance to a given profile. Furthermore, the standard states "Perhaps the most distinctive feature of JPEG 2000 is its emphasis on and support for scalability. An existing codestream may be accessed at a reduced resolution, at a reduced quality (higher compression), at a reduced number of components, and even over a reduced spatial region. Moreover, this Recommendation | International Standard supports a rich family of information progression sequences whereby the information may be reordered without introducing additional distortion. This enables a single compressed codestream to serve the needs of a diverse range of applications."[25]

The implication of this is that decoders are created to fail gracefully without notifying the user by scaling the quality based on the resources available vs. those required. Given the fact that scalability is a cornerstone of JPEG 2000 decoding process, decoders are rated using compliance

[21] ISO Standard 15444-4:2004, JPEG 2000 image coding system: Conformance testing , Annex F.
[22] ISO Standard 15444-1:2004, JPEG 2000 image coding system: Core coding system, Definitions.
[23] ISO Standard 15444-1:2004, JPEG 2000 image coding system: Core coding system, Annex A.
[24] ISO Standard 15444-1:2004, JPEG 2000 image coding system: Core coding system, Decoder requirements.
[25] ISO Standard 15444-4:2004, JPEG 2000 image coding system: Conformance testing, General Description.

classes, or Cclasses[26] for a given profile. Compliance Classes guarantee a defined level of performance. There are multiple Compliance Classes for a given profile and "These guarantees are directly connected with the resources required by a decoder. They may be interpreted as a contract by the implementation to recover, decode and transform a well-defined minimal subset of the information contained in any codestream. This contract is described in a manner that scales with the Cclass." [ISO Standard 15444-4:2004, JPEG 2000 image coding system: Conformance testing, Decoders] The higher the Cclass the better the performance. Compliance Classes are stated in reference to a particular profile or set of profiles.

Linking all of these components, "Profiles define a subset of technology, from ITU-T Rec. T.800 | ISO/IEC 15444-1:2004: JPEG 2000, that meets the needs of a given application with limits on parameters within a selected technology. Profiles limit bitstreams. Decoders define capabilities for all bitstreams within a profile. Encoders achieve quality guarantees for particular decoders by encoding bitstreams which meet a particular profile definition. Compliance classes (Cclass) define guarantees of a given level of image quality for a decoder and guidance for encoders to produce codestreams that are easily decodable by compliant decoders."

In summary, the flexibility and feature set require interchange considerations to carry over beyond the codestream itself and into encoding and decoding environments. It is not enough to simply define a profile for archiving without considering specification of compliance classes for prospective decoders, which in turn informs development of encoders.

Furthermore, Lossless Compression does not equate to definite lossless reproduction. Failure to specify the associated compliance class may yield decoders that produce results that do not create a faithful reproduction of the original recording and lose the integrity of the original. This is imperative when considering migration from JPEG 2000 to a prospective future format. In support of this concern, the standard states, "The minimum compliance point, Cclass 0, guarantees sufficient resources to ensure truly lossless decoding to a bit-depth of at least 8 bits per sample. However, this does not mean that lossless performance will be achieved, even if the codestream contains a lossless representation of the image. A compliant Cclass 0 decoder may fail to reproduce a perfectly reconstructed 8-bit version of a losslessly compressed image…. The compressor is at liberty to make such choices and their potential impact on decoders at any Cclass should be considered."[27]

[26] Our understanding is that the equivalent term used for discussions revolving around Motion JPEG 2000 is Compliance Points, or Cpoints.
[27] ISO Standard 15444-4:2004, JPEG 2000 image coding system: Conformance testing, Annex A.