

MXF Application Specification for Archiving and Preservation

The U.S. Federal Agencies Digitization Initiative

AMIA/IASA 2010

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Library of Congress
Washington, DC

The Library of Congress

National Digital Information Infrastructure and Preservation Program (NDIIPP)

www.digitalpreservation.gov



The Federal Agencies Digitization Guidelines Initiative was launched in 2007 under the auspices of the National Digital Information Infrastructure and Preservation Program (NDIIPP) at the Library.



It is a collaborative effort with participation from a number of federal agencies, including the U.S. National Archives, the National Gallery of Art, the Voice of America, the National Library of Medicine, the Smithsonian Institution, and several others.

. . . common body of digitization standards and practices will provide the public with products of uniform quality, set common benchmarks for digitization service providers, support content preservation for the long term

Charter for the Audio-Visual Digitization Working Group

Version of July 14, 2008

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Purpose. The goal of this project is to identify, establish, and disseminate information about standards and practices for the digital reformatting of audio-visual materials by federal agencies. The acceptance of a common body of digitization standards and practices will provide the public with products of uniform quality, set common benchmarks for digitization service providers, support content preservation for the long term, and facilitate the exchange of findings from related research.

<http://www.digitizationguidelines.gov/audio-visual/charter.html>

We want to develop guidelines that are comparable from agency to agency, for the sake of uniformity and to make it easier for the vendors who provide equipment and services.

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- Glossary of Terms
- Sustainable Formats

RSS E-Mail



STILL IMAGE WORKING GROUP

This group is involved in a cooperative effort to develop common digitization guidelines for still image materials (such as textual content, maps, photographic prints and negatives). The expectation is that this work will enhance the exchange of research results and developments, encourage collaborative digitization practices and projects among [federal agencies](#) and institutions and provide the public with a product of uniform quality. It will also serve to set uniform quality and establish a common set of benchmarks for digitization service providers and manufacturers.

The work will focus on guidelines intended for works categorized as historical, cultural and/or archival. In addition to digital imaging and encoding, guidelines will be developed for the metadata that is embedded in digital image files, with a view to increasing the extent to which the files can be "self-describing."

Primary considerations in the development of specific guidelines will be:

- > Defined objectives for the digital object being produced
- > Defined categories and characteristics of content to digitally represented
- > Common image performance measures and methods of validating those measures to defined requirements

Our main emphasis is digitization--the conversion of analog originals into digital form. There are two working groups: one for still images -- they look at things like scanning books, photos, and maps.



And one for audio-visual materials, focused on sound and video recordings and motion picture film. This group (and to a lesser degree the still image group) also has an interest in the preservation of born digital content.

DRAFT

Strawman Specification
FADGI Application Specification
AS-AP MXF Archive and Preservation
October 20, 2010 (rev 1d_cf)

Document Status

This document-in-progress has been drafted for the Audio-Visual Working Group of the Federal Agencies Digitization Guidelines Initiative (FADGI). The intention is for a subsequent and refined iteration of this document to provide a starting point for finalization as an MXF Application Specification within the Advanced Media Workflow Association (AMWA).

Note that sections 5 and 6 have not yet been drafted. In order to give readers a sense of the types of information that will be presented in sections 5 and 6 as the document is completed, however, a set of section headings and subheadings is provided. Readers should also note that the single example of a shim presented in annex A is very provisional.

This document is being posted on the Federal Agencies Web site on October 20, 2010, in order to provide progress information to archivist-attendees at a special technical meeting scheduled for November 1, 2010. The Audio-Visual Working Group anticipates that a further revision (filling in some of the uncompleted sections) will be posted prior to the meeting. Readers and meeting attendees are encouraged to check project Web page to determine if a new version is available: http://www.digitizationguidelines.gov/audio-visual/documents/MXF_app_spec.html

Executive Summary

This document-in-progress describes a vendor-neutral subset of the MXF file format to use for long-term archiving and preservation of moving image content and associated materials including audio, captions and metadata. Archive and Preservation and files (AS-AP files) may contain a single item, or an entire series of items. Various configurations of sets of AS-AP files are discussed in the Overview.

The AV Working Group is pushing along a proposal for an archiving and preservation format based in the Material eXchange Format (MXF)--a standard from Society of Motion Picture and Television Engineers (SMPTE).



What started us down this path? It was the pressing need to reformat videotapes. Our agencies have extensive holdings of the obsolescent magnetic recordings and want to transfer them to a file-based format, while working playback devices can still be found.

Library of Congress
Packard Campus,
Culpeper, Virginia



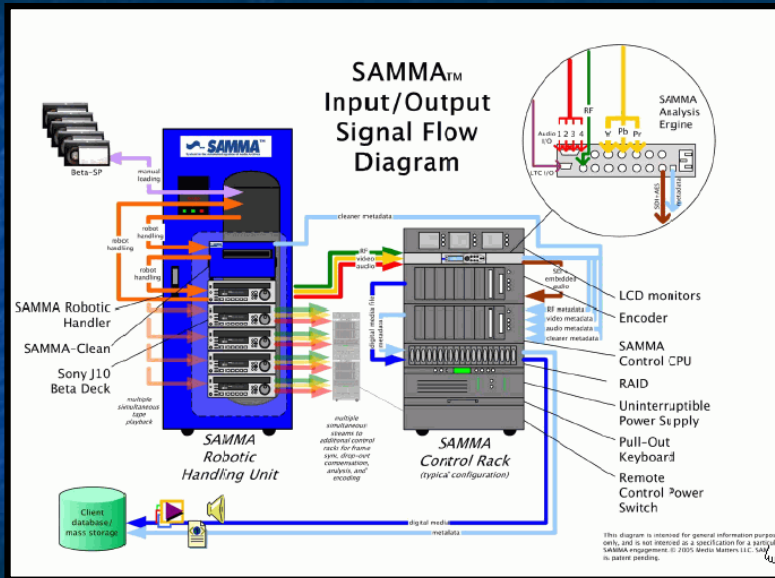
National Archives,
College Park,
Maryland

Smithsonian
Institution Archives,
Washington DC



In fact, three members of our Federal Agencies Working Group are doing some digital reformatting of video.

SAMMA System



They have purchased SAMMA devices, a product of the Front Porch Digital company. The Library of Congress has done the most work thus far, while the National Archives and the Smithsonian Institution are starting to carry out projects of their own.

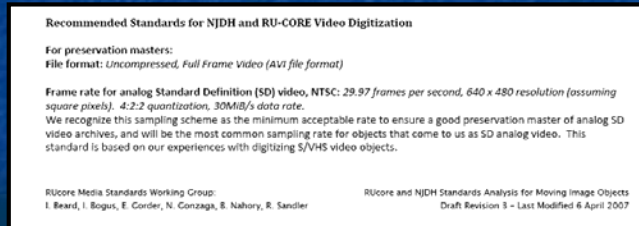
Lossless compressed

- Each frame is a JPEG 2000 image
- Wrapped in MXF (SMPTE standard)
- . . . along with soundtrack, timecode, closed captioning, etc.
- Lossless (reversible) transform
- If 8-bit, 25-35 GB per content-hour
- If 10-bit, 35-50 GB per content-hour

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 MXF. 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. File sizes for standard definition video run from 25 to 50 gigabytes per hour, depending on variables like bit depth.

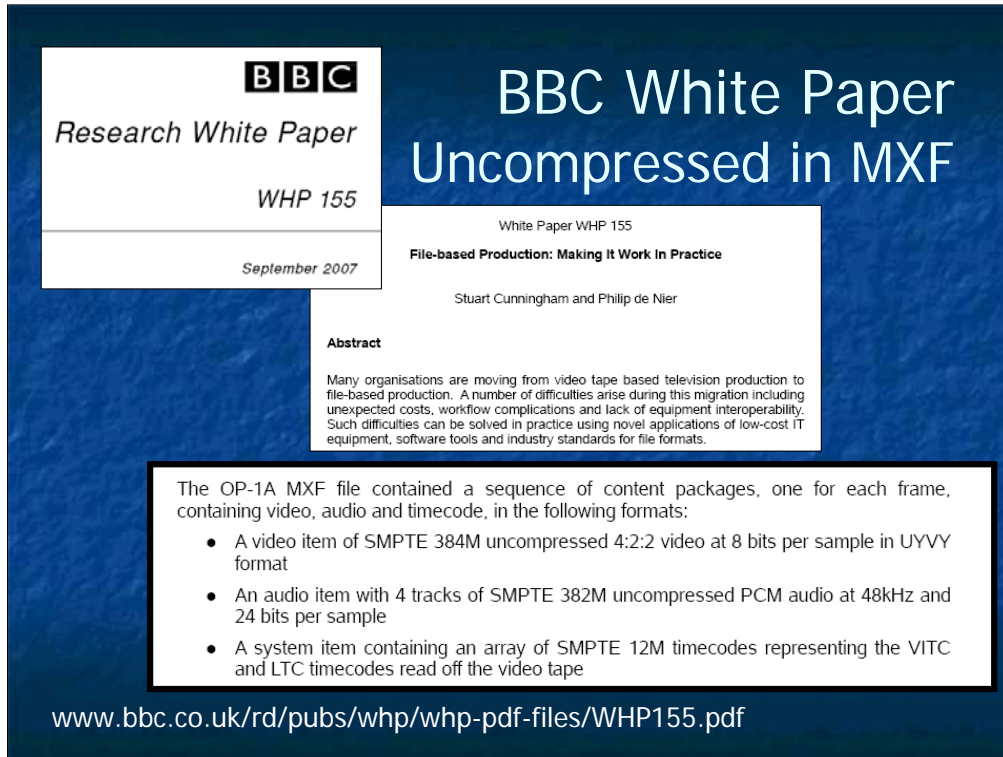
Also of interest: uncompressed video

- U.S. activities: Stanford Univ., Rutgers Univ.
- 4:2:2 or 4:4:4, 10-bit SDI stream
- About 100 GB per content-hour
 - Another source reported 70 GB for 8-bit video



Rutgers spec: http://rucore.libraries.rutgers.edu/collab/ref/dos_avwg_video_obj_standard.pdf

At the same time, others in the Working Group--notably the National Archives--are interested in essences that consist of uncompressed video streams. In this, they echo the specifications in use at Stanford and Rutgers universities, as well as the BBC. File sizes for standard definition video run from 75 to 100 gigabytes per hour.



The image shows the cover page of a BBC White Paper. The background is a dark blue gradient. In the top left, there is a white box containing the BBC logo, the text 'Research White Paper', 'WHP 155', and 'September 2007'. To the right of this box, the title 'BBC White Paper Uncompressed in MXF' is written in large white font. Below the title, another white box contains the subtitle 'File-based Production: Making it Work In Practice' and the authors 'Stuart Cunningham and Philip de Nier'. A third white box contains an abstract and a list of details about the OP-1A MXF file format. At the bottom, a white box contains the URL 'www.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP155.pdf'.

BBC
Research White Paper
WHP 155
September 2007

BBC White Paper Uncompressed in MXF

White Paper WHP 155
File-based Production: Making it Work In Practice
Stuart Cunningham and Philip de Nier

Abstract
Many organisations are moving from video tape based television production to file-based production. A number of difficulties arise during this migration including unexpected costs, workflow complications and lack of equipment interoperability. Such difficulties can be solved in practice using novel applications of low-cost IT equipment, software tools and industry standards for file formats.

The OP-1A MXF file contained a sequence of content packages, one for each frame, containing video, audio and timecode, in the following formats:

- A video item of SMPTE 384M uncompressed 4:2:2 video at 8 bits per sample in UYVY format
- An audio item with 4 tracks of SMPTE 382M uncompressed PCM audio at 48kHz and 24 bits per sample
- A system item containing an array of SMPTE 12M timecodes representing the VITC and LTC timecodes read off the video tape

www.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP155.pdf

The BBC approach is of special interest because it also employs the MXF container format.

Born Digital

- **This topic comes up with great frequency, especially from “non-memory” operating agencies, e.g., NOAA with scientific footage, VOA with current broadcast production**

In addition to our current central concern with reformatting old tapes, we also hear a lot about born digital video content, especially from “non-memory” operating agencies, e.g., NOAA with scientific footage and VOA with current broadcast production. Some of these files are in native encodings--for example MPEG-2, or file-form DV--that are probably sustainable for a few years without transcoding. So as we began to shape the MXF application specification, we wanted to allow for the wrapping of at least some "safe" born digital encodings.

Recommendation Comes Later

- Working Group members are cautious about embracing MXF at this time
 - Complex standard
 - Fewer well established tools than we would wish (although that seems to be improving)
- Look forward to increased implementation and *experience* with MXF for archiving and preservation – a prerequisite to making real recommendations

As an aside, let me emphasize that the Working Group knows that we are at an early stage in this process; we have comparatively little experience. We believe that there is value in drafting a thorough specification--a gesture in the direction of standardization. But we will wait until we have more experience under our belts before making a real recommendation.

About MXF and Application Specifications

MXF Package

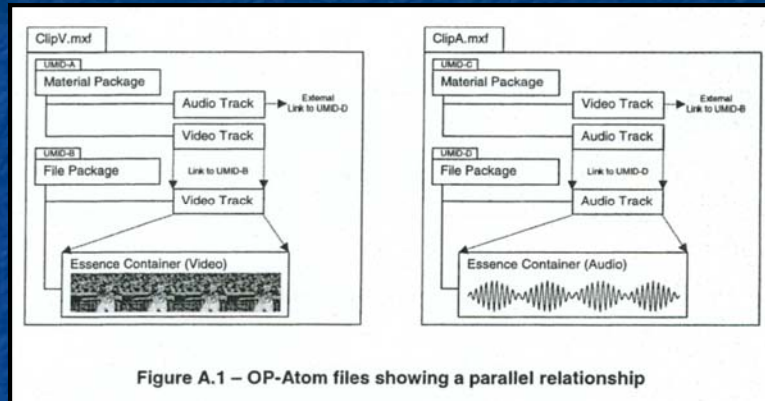
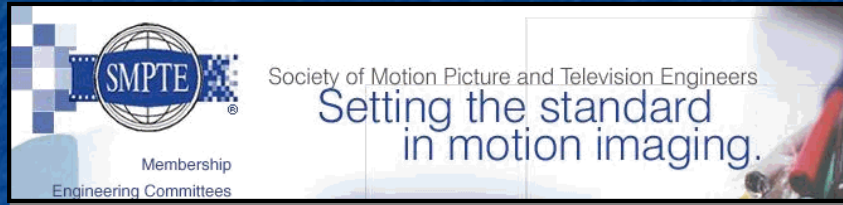


Diagram for the simple “OP-Atom” structure, from SMPTE spec 390M

MXF can usefully be thought of as a wrapper or a container, one that can hold a variety of "essences," as AV specialists call the bitstreams for moving image content ("video") and audio. MXF is seeing increasing adoption in broadcast and motion picture industries. It is central to the digital cinema specification developed in Hollywood for theatrical distribution. SMPTE is the most important standards organization for professional broadcasters and movie-makers and they are the big customers for whom tools are built.

A few examples of MXF specifications . . .



SMPTE 377M-2004	Television Material Exchange Format (MXF) File Format Specification (Standard) \$90.00 - Purchase this Document
SMPTE 378M-2004	Proposed Material Exchange Format (MXF) — Operational pattern 1A (Single Item, Single Package) \$26.00 - Purchase this Document
SMPTE 379M-2004	Material Exchange Format (MXF) — MXF Generic Container \$30.00 - Purchase this Document

MXF is a broad-spectrum standard that features many options for packaging, embedded metadata, and essence encoding. The successful implementation of an MXF approach 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, and this increase in the level of standardization applied will in turn increase interoperability, content exchange, and long-term, preservation-oriented data management.

The screenshot shows the website for the Advanced Media Workflow Association. The header includes the logo and the text "Advanced Media Workflow Association" and "Your Source For Professional Networked Media Workflow Innovation". A navigation menu contains links for HOME, ABOUT, PROJECTS, JOIN AMWA, MEMBERS, PUBLICATIONS, and DEVELOPERS. The main content area is titled "APPLICATION SPECIFICATIONS" with a link to "Back to Projects Overview". Below this, a definition of AS (Application Specification) is provided. A table lists six specifications:

AMWA ID	Name	Description
AS-01	AAF Edit Protocol	Edit metadata interchange using AAF. Includes base set of effects.
AS-02	MXF Versioning (was MXF Mastering Format)	Storage of MXF program components to enable versions & inventories, for use in a multi-version, multi-lingual, multi-delivery media environment.
AS-03	MXF Program Delivery	MXF optimized for program delivery intended for direct playout via a video server for example. This is based on a PBS profile for MXF program delivery.
AS-04	Language Tagging	Language tagging of audio tracks for international operations. Used with AS-02 for example.
AS-05	AAF Effects Protocol	Extends AS-01 with color, text & opacity effects
AS-06	MXF File Integrity	Provide users with a method for ensuring file integrity after a process or transfer has occurred in the workflow

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. We will work with AMWA as this proceeds.

Factors: Extensibility

- extensible specification
- video emphasis today
- film scanning to come
- some interest in wrapping audio-only materials
- some interest in things like film strips
- include associated items
 - e.g., scans of the tape box and documents found in the tape box, oral history transcripts, and so on

With archiving and preservation in mind, we are seeking a specification or family of specifications that are

Extensible in scope

> video emphasis today

> film scanning to come

> some interest in wrapping audio-only materials

> some interest in things like film strips

> general interest in including associated items: scans of the tape box and documents found in the tape box, oral history transcripts, and so on

Other Factors

- Specification that vendor-manufacturers can build to
- Develop tools that use the spec to validate files

[and]

Something vendor-manufacturers can build to (we want more than one company in the game)

Validation tools can use the spec to validate

Key parameters: 1 of 4

- **Picture**
 - What are permitted or preferred essence schemes (encodings), bitrate, format (raster, aspect ratio)? Refer to other specifications, e.g., ISO/IEC broadcast profiles for JPEG 2000
- **Sound**
 - What are permitted or preferred essence schemes (encodings), tracks and track listings (including SAP and DVS)?

What might you find in an Application Specification? I'm not going to read or explain the individual items on the slides, but they are a few of the typical parameters for an MXF AS.

Picture -- the permitted essence schemes (encodings) and other elements

Sound -- again, permitted or preferred essence schemes and other elements

Key parameters: 2 of 4

- **Closed Captions and other VBI**
 - How to handle CEA-608 and/or CEA-708? Timed Text?
 - What other elements are in the vertical blanking interval that we want to keep in the digital copy, and where?
- **Associated content elements**
 - Wrapper to contain associated items like still images, documents, texts, etc.

Closed Captions and other VBI -- about the elements are in the vertical blanking interval of the source signal that we want to keep in the digital copy, and where?

Associated content elements -- we want the wrapper to embrace associated items like still images, documents, texts, etc.

Key parameters: 3 of 4

- **Embedded metadata**
 - Specify a minimal embedded slate/header segment, not unlike the BWF bext chunk
 - Leave space for more embedded, text-based metadata, e.g., descriptive, administrative, and technical metadata, understood to include "process history" metadata

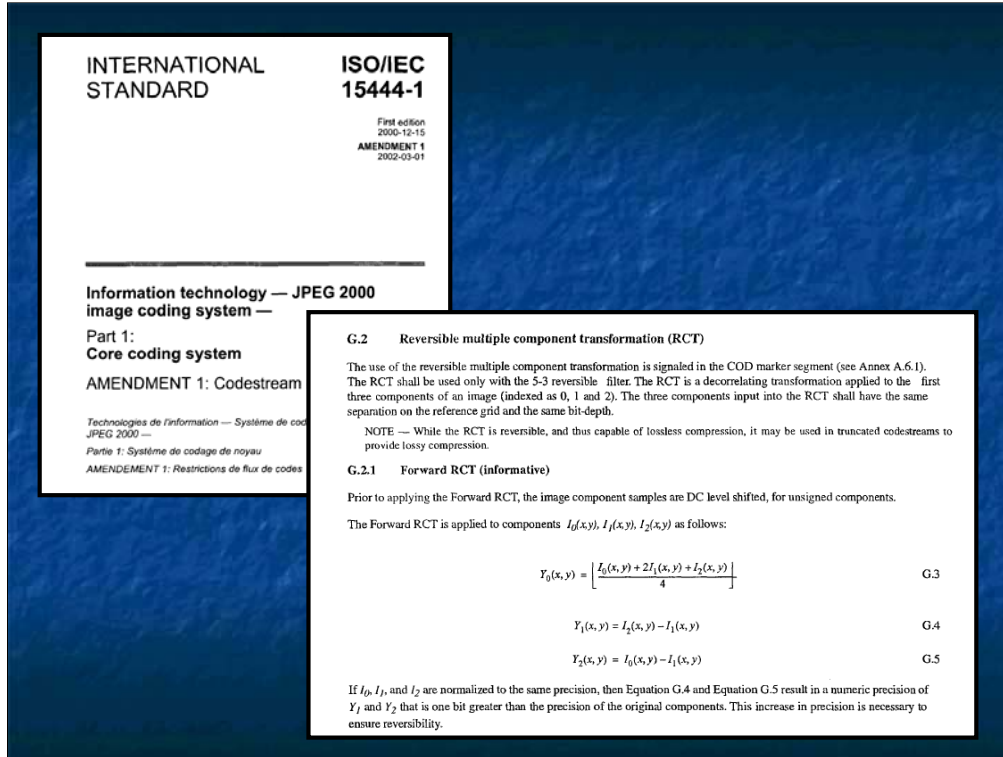
Embedded metadata -- we are thinking of a minimal embedded slate/header segment, not unlike the BWF bext chunk, and leaving space for more embedded, text-based metadata, e.g., descriptive, administrative, and technical metadata

Key parameters: 4 of 4

- **"Architecture" of the wrapped package**
 - Operational patterns
 - Timecode
 - Frame-wrapped vs. clip-wrapped essences
 - Interleaving
 - Bundling multiple segments, episodes
 - Include file-integrity "checksum" data to support essence monitoring over time.

"Architecture" of the wrapped package -- MXF operational patterns, Timecode, Frame-wrapped vs. clip-wrapped essences, Bundling multiple segments, and file-integrity "checksum" data to support essence monitoring over time.

About JPEG 2000



Like MXF, JPEG 2000 is broad-spectrum standard with many options. Developed by the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC), the JPEG 2000 compression approach is based on what is called the *wavelet* transform. When using JPEG 2000, one notable option is whether this transform is applied in an irreversible manner--resulting in lossy compression--or in a reversible manner--producing lossless compression. For our preservation-oriented application, the most desirable JPEG 2000 profiles are those that feature the reversible transform.

INFORMATION TECHNOLOGY – JPEG 2000 IMAGE CODING SYSTEM:
CORE CODING SYSTEM

AMENDMENT 1
Profiles for digital cinema applications

A.10.1 Codestream restrictions for digital cinema

In addition to Profile-0 and Profile-1, two profiles are defined for digital cinema applications. These profiles are Profile-3 and Profile-4, and are detailed in Table A-46.

Table A-46 — Codestream restrictions for digital cinema applications

	2K digital cinema profile	4K digital cinema profile
SIZ marker segment		
Profile Indication	Rsiz=3	Rsiz=4
Image size	Xsiz ≤ 2048, Ysiz ≤ 1080	Xsiz ≤ 4096, Ysiz ≤ 2160
Tiles	one tile for the whole image: Ttsiz = YTOsiz = Ysiz XTsiz = XTOsiz = Xsiz	Same
Image and tile origin	XOtsiz = YOtsiz = XTOtsiz = YTOtsiz = 0	Same
Sub-sampling	XRsiz = YRsiz = 1	Same
Number of components	Csiz = 3	Same
Bitdepth	Ssiz = 11 (i.e., 12 bit unsigned)	Same
RGN marker segment	Disallowed, i.e., no region of interest	Same
Marker locations		
Packed headers (PPM, PPT)	Disallowed	Same
COD, COC, QCD, QCC	Main header only	Same
COD/COC marker segments		
Number of decomposition levels	$N_L \leq 5$ Every component of every image of a distribution shall have the same number of wavelet transform levels.	$1 \leq N_L \leq 6$ Every component of every image of a distribution shall have the same number of wavelet transform levels.
Number of layers	Shall be exactly 1	Same
Code-block size	xcbl=ycbl=5	Same
Code-block style	SPcod, SPcoc = 0000 0000	Same
Precinct size	PPx = PPy = 7 for N_L LL band, else 8	Same
Progression order	CPRL, POC marker disallowed	There shall be exactly one POC marker segment in the main header. Other POC marker segments are disallowed. The POC marker segment shall specify exactly two progressions having the following

As luck would have it, some in the broadcast community--especially in Europe--have been working up what they call *broadcast profiles* for JPEG 2000. The most recent set has not yet been published -- that is why I am showing a page from the digital cinema profiles -- but we understand that it will include two profiles that feature the reversible wavelet transform, i.e., lossless compression. When available, we will reference these profiles in our MXF specification.

About Metadata

Technical metadata PBCore instantiation elements

25.00	pbcoreInstantiation	25.12	Element formatDuration
25.01	Element dateCreated	25.13	Element formatDataRate
25.02	Element dateIssued	25.14	Element formatBitDepth
25.03	Element formatPhysical	25.15	Element formatSamplingRate
25.04	Element formatDigital	25.16	Element formatFrameSize
25.05	Element formatLocation	25.17	Element formatAspectRatio
25.06	Element formatMediaType	25.18	Element formatFrameRate
25.07	Element formatGenerations	25.19	Element formatColors
25.08	Element formatStandard	25.20	Element formatTracks
25.09	Element formatEncoding	25.21	Element formatChannelConfig
25.10	Element formatFileSize	25.22	Element language
25.11	Element formatTimeStart	25.23	Element alternativeModes

My colleagues Kate Murray and James Snyder chair a sub-working-group devoted to technical metadata. Their work is still under development, but this list of elements from the PBCore specification from public broadcasting gives you the flavor of what is at stake.

Descriptive metadata

- Libraries prefer bibliographic records
 - Tilt toward single item, “monograph”
 - Notional digital package, intellectual entity
 - Metadata: author, title, subjects, publication
- Archives prefer finding aids
 - Collections and series, made up of items
 - Notional digital package may be a multipart item
 - Little or no item-level description

Descriptive metadata is another matter. I don't have to tell this audience that approaches to the provision of descriptive metadata vary in striking ways between libraries (“bibliographic data”) and archives (“finding aids”). In simplified terms, the librarian’s bibliographic record uses tagged elements to provide such information as author, title, publication place and date, and subject terms, generally selected from a thesaurus. Meanwhile (simplifying again), the archivist’s finding aid helps researchers see the coherence of a given collection, the archival *fond*, and presenting blocks of related documents in what are often call *series*. Only a handful of finding aids describe content at the level of an individual document and it is rare for them to provide author’s names, titles, and formal subject terms.

Descriptive metadata

- Federal agency members: *libraries* and *archives*
- Agreement that “packages” contain multiple files (alho package concepts vary)
- The MXF Application Specification will include a potential structure for “collections” (groups of items)

The Federal Agencies Working Group includes representatives from both archive and library organizations, and their practices for resource description vary in significant ways. In addition, their approaches to content packaging—the “binding” of multiple related files—also vary. Nevertheless, as the archiving and preservation MXF application specification takes shape, we will include a way to wrap *collections*, i.e., sets of items.

Descriptive metadata

- For the moment, no clear pattern for recommending approaches for *descriptive* and *packaging* metadata
- . . . we look at files-as-files
- What metadata ought be embedded?
 - Most important: identifier, name of the archive, date that digital resource was created, title or quasi-title

But it is the case that we will not make strong recommendations regarding descriptive metadata. We will probably recommend--as we did for audio embedding--that everyone include an identifier, the name of the archive that takes responsibility for the content, and a working title or something like it. But our emphasis on metadata tilts toward the technical and our emphasis on digital objects tilts toward files (rather than packages), since files are produced by all reformatting activities.

Send us your thoughts

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*** Required**

Name

Group/Organization

*** E-Mail**

<http://www.digitizationguidelines.gov/contact/index.php>

Thanks for your attention -- let us know your thoughts.