MXF — the Material eXchange Format

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"We are on the verge of a metadata revolution. Get your data models clean and prepare for an interesting ride"

Tim Berners-Lee, 1999

The Material eXchange Format is an open file format, aimed at the interchange of AV material along with associated data and metadata. It establishes interoperability of content between various applications used in the television production chain. This leads to operational efficiency and creative freedom through a unified networked environment.

What is MXF?

The Material eXchange Format (MXF) is an open file format, targeted at the interchange of audio-visual material with associated data and metadata. It has been designed and implemented with the aim of improving file-based interoperability between servers, workstations and other content-creation devices. These improvements should result in improved workflows and in more efficient working practices than is possible with today's mixed and proprietary file formats.

MXF has been designed by the leading players in the broadcast industry – with an enormous amount of input from the user community – to ensure that the format really meets their demands. It is being put forward as an Open Standard which means it is a file transfer format that is openly available to all interested parties. It is not compression-scheme-specific and it simplifies the integration of systems using MPEG and DV as well as future, as yet unspecified, compression strategies. This means that the transportation of these different files will be independent of content, and will not dictate the use of specific manufacturers' equipment. Any required processing can simply be achieved by automatically invoking the appropriate hardware or software codec. However, MXF is designed for operational use and so all the handling processes are seamless to the user. It just works quietly in the background.

Besides offering better interoperability – working with video and audio between different equipment and different applications – its other major contribution is the transport of metadata. By developing MXF from the beginning as a new file format, considerable thought has gone into the implementation and use of metadata. Not only is this important for the proper functioning of MXF files, it will also enable powerful new tools for media management as well as improving the content-creation workflows by eliminating repetitive metadata re-entry.

The changing technologies in television production, and in transmission to the viewers, means that the traditional methods for moving the content – programme video and audio – within studios is changing too. Not

only is there far greater use of computers and IT-related products such as servers, but also the reliance on automation and the re-use of material have expanded. Besides the need to carry metadata, file transfers are needed to fit in with computer operations and they must be capable of being streamed for real-time operations.

The development of the Material eXchange Format (MXF) is a remarkable achievement of collaboration between manufacturers and major organizations such as Pro-MPEG, the EBU and the AAF Association. It establishes interoperability of content between various applications used in the television production chain. This leads to operational efficiency and creative freedom through a unified networked environment.

How does MXF improve my workflow?

The existence of an open industry-wide, metadata-aware, file format will have a big impact on the way in which material is handled. The typical stages in creating a TV programme are shown in *Fig. 1*. At present, the handover from one stage to the next comprises a mix of videotape, proprietary multi-media files, Word documents, Excel spreadsheets, faxes, sticky labels, Post-It™ notes and word-of-mouth metadata transfer. In fact, the only metadata which is handled in a reasonably universal way is timecode. Experienced professionals will know, however, that even the handling of timecode is not "clean" throughout many workflows: often, much time is wasted on Timecode metadata problems rather than reaping the benefits of a clean metadata chain.

Figure 1
Stages in creating a TV programme

As MXF gets adopted by more manufacturers, more and more of the transfer stages in *Fig. 2* will allow a rich variety of metadata to be transferred to the next production stage, allowing media professionals to concentrate on using the multimedia content and metadata – rather than hunting for the information they need. This can be demonstrated with a simple example. Imagine that some wildlife footage is shot on location at Masai Mara in Kenya. GPS metadata (i.e. the geographical coordinates of the camera) is added to each camera shot as an annotation. This metadata will stay with the essence inside the MXF file while the programme is being created. An automatic production process could then convert GPS coordinate information into additional human-readable metadata such as "Masai Mara". This workflow automation reduces the mundane human chores and improves the accuracy of the stored data.

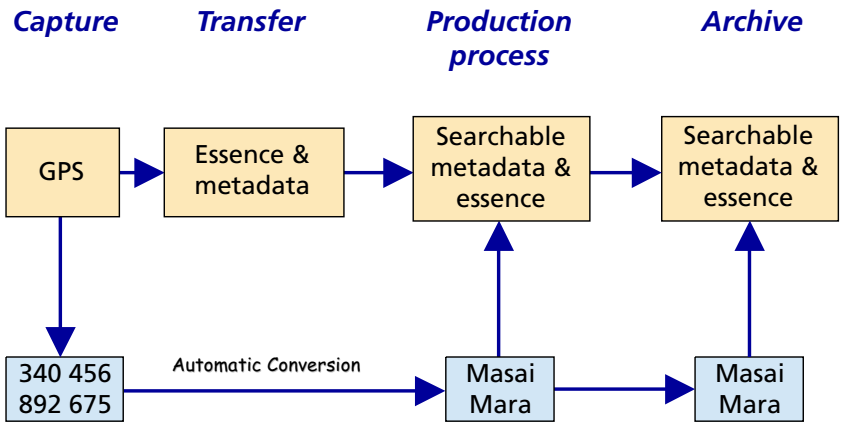

Figure 2
Use of MXF to transfer metadata

MXF has the added benefit that it shares a common object model with the Advanced Authoring For-

mat (AAF). AAF is a sophisticated data model and software toolset which allows complex post-production devices to share essence data and metadata. This means that taking material into the post-production environment and extracting the finished content from that environment is done in a seamless fashion.

What can MXF do?

MXF is a versatile file format which can perform a number of tasks. It can:

- store simple completed works with metadata (tape replacement);
- store files in a streamable format which allows viewing while transferring;
- wrap up a playlist of files and store the synchronization information;
- wrap any compression format;
- store cuts-only EDLs and the material they act on.

To understand more, it is important to appreciate the difference between *streaming* and *file transfers*. Traditionally, broadcast television has been built around streaming video and audio. This is logical as the original scene action and the viewer expectation is of continuous real-time video and audio – supported by continuous streaming. PAL and NTSC analogue composite video, SDI and SDTI all stream. But computer systems exchange data by means of file transfers.

Streaming media:

- is viewable during transfer – before all the data is delivered;
- offers minimum delay for live action;
- is point-to-point with no bottlenecks – it offers reliable, continuous operation.

Networked media:

- uses low-priced, standard IT components;
- may be stored on a wide variety of devices including disks and tape;
- offers flexible data exchange, sharing and distribution.

Both real-time streaming and file transfer have their advantages and both will continue in use. Therefore, it is essential that both have some degree of compatibility so they can co-exist and allow material exchange between them. With this in mind, the design of MXF makes it a file format that can stream – creating a seamless bridge between the two transfer types. Operationally, there is no effort involved beyond requesting the transfer. So, for example, advantage can be taken of the flexibility of AAF in postproduction. Then, by using an “invisible” simple file conversion, MXF can be used for the finished playout to the tape streamer or server storage. Note that the file conversion is lossless for video and audio, if the compression scheme is not changed.

In a similar way, operational and creative staff want to concentrate on their tasks and not bother with compression issues. But is it also true that no single compression format will suit all applications, and various schemes will continue to be used. Therefore MXF is compression-independent, offering the same service regardless of the compression in use. This allows manufacturers to provide equipment with multiple compression codecs, which could lead to seamless working between – for example, MPEG and DV-based systems

Open formats and standardization

MXF is an open solution and so has been submitted to the SMPTE for standardization. Together, the Pro-MPEG Forum and the AAF Association have support from a substantial cross-section of the industry. In addition, close collaboration with user groups, such as the EBU, ensure that users’ needs are incorporated. At the same time, many manufacturers and suppliers of software and hardware are keen to implement MXF as soon as possible.

In a move towards early standardization, as mentioned above, MXF already adheres to the SMPTE KLV guidelines (Key, Length, Value – a method for wrapping data for transport over networks) and has extensively used and tested the SMPTE dictionary and other registries.

Achieving interoperability is the prime objective of Pro-MPEG and MXF. This has been implemented in three areas:

- ***Cross-platform***. It will work across different network protocols and across operating systems including Windows, Mac, OS, Unix and Linux.
- ***Compression-independent***. It does not convert between compression formats; it does make it easier to manage more than one format in a single environment. It can handle uncompressed video.
- ***Streaming / transfer bridging***. MXF interoperates seamlessly with streaming media – especially SDTI where fully-transparent interchange is achieved. This performance is bi-directional: it is achieved going from MXF to streaming and vice versa, and means that SDTI fits easily into a file-based environment. This is true convergence.

How does MXF work?

A simple MXF file looks quite unexciting on first inspection *(see Fig. 3)*.

It has a header at the head of the file, a footer at the foot of the file and some essence in the body of the file. Every item in an MXF file is KLV-coded. This means that every item within the file is identified by a unique 16-byte key and by its length. Defining the length of every field in the file (including the essence) allows simple MXF decoders and processing engines to ignore bits of the file they don't understand i.e. keys they don't recognize. This in turn allows the file format to grow, and for extra features to be added as new compression techniques and metadata schemes are defined.

The header metadata area of the MXF file is where much of the benefit of MXF comes. It is the area where metadata is added, and the timing and synchronization parameters of the file are defined. The synchronization and description of the essence is controlled by three packages:

- Material Package (MP)
- File Package (FP)
- Source Package (SP)

The MP represents the output timeline of the file. The actual

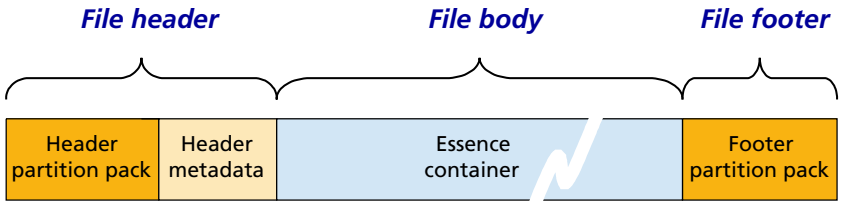

Figure 3
Simple MXF file structure

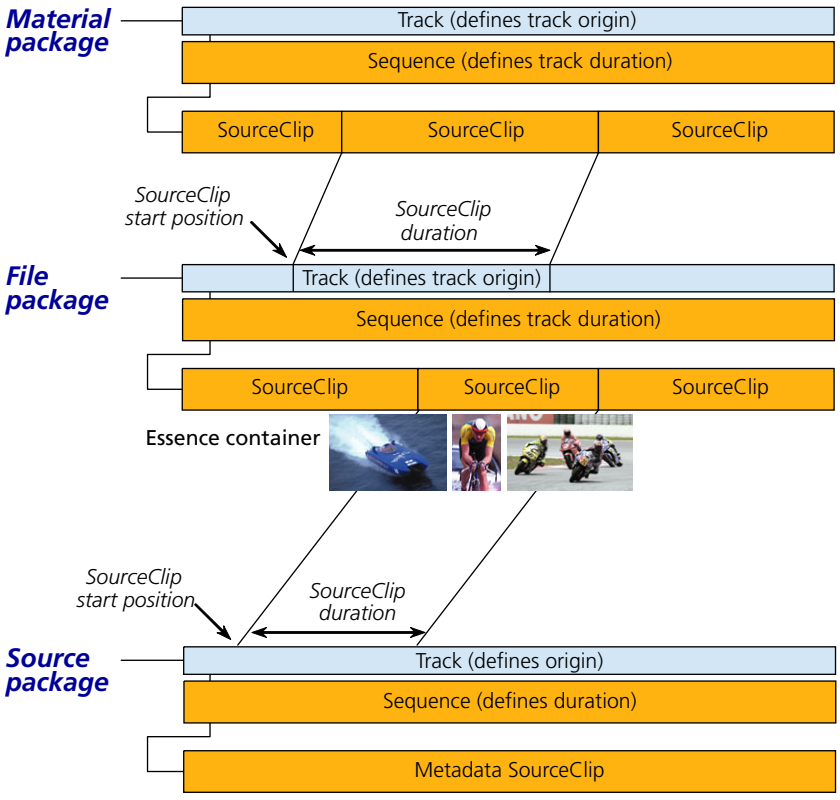

Figure 4
The essence container comprises packages and tracks

essence is described by the FP. The derivation of that essence (previous EDLs, descriptions of original film stock, etc.) are contained within the SP. It can be seen in *Fig. 4* that each of the file packages can have a number of tracks. The tracks represent each of the different elements of the essence (e.g. a picture track for the video, a sound track for each of the audio channels, and a metadata track). These tracks in turn hold a sequence of SourceClips which define how to create the desired output of the file.

If there is a single SourceClip in the MP which corresponds to an entire FP, then we have an MXF file which represents a simple tape. If the MP has many SourceClips coming from many file packages (which are wrapped up within the MXF file) then we have an MXF file which represents an EDL. To manage the complexity of MXF, operational patterns have been defined which limit the features which can be used in different applications. These form a grid *(see Fig. 5)* which is divided vertically depending on the timeline complexity within the file, and horizontally depending on the number of different packages within the file.

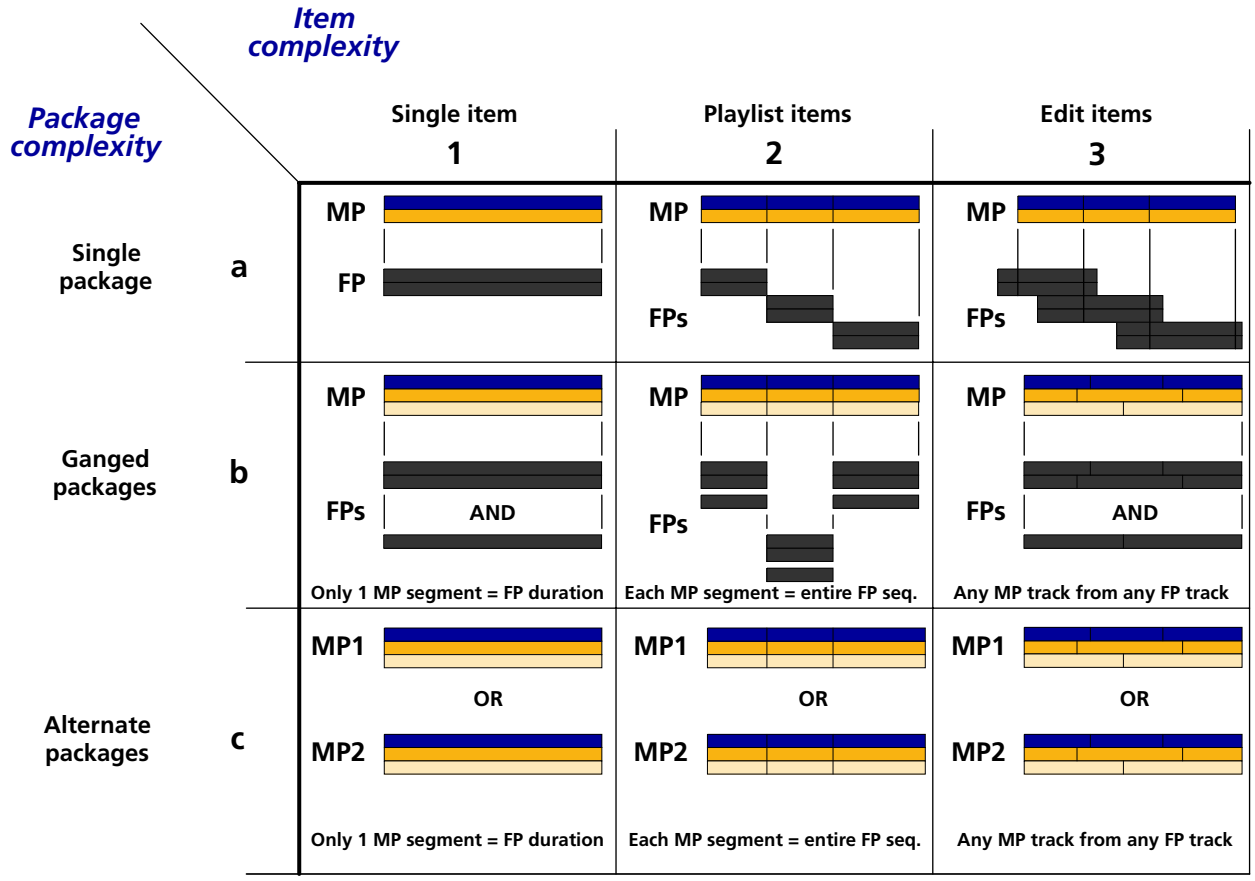

Figure 5
The features that can be used in different applications

MXF provides additional tools such as index tables, partitioning for streaming, partitioning for file transfer recovery, UMID support and many other features to make it the format of choice for media-rich applications.

Metadata

A major aim of MXF is the seamless passage of programme content and its associated metadata.

Also referred to as “data about data”, metadata exists in any system today. For example, timecode is a form of metadata. The problem is that, due to incompatibilities, this information is currently lost as the content moves between systems. MXF-enabled systems will communicate using metadata, video and audio. MXF metadata may carry information about:

- the file structure;

- the body contents – e.g., MPEG or DV ... 525 or 625 ... etc.;
- key words or titles;
- subtitles;
- reference numbers;
- editing notes;
- location, time, date and version number:
- ……

The list may be endless. In extreme cases, files may contain more metadata than video or audio content! However, the efficient implementation of metadata is seen as the key to material management. The metadata may be filtered to hold only what is relevant to the particular operational environment, thereby cutting possible meta-mountains.

Industry support

The speed of progress of MXF is a tribute to the many dedicated engineers across the industry, working together towards a common objective. Manufacturers and users both recognize that there is a window of opportunity to establish an industry file-format standard. The use of video will increase into an expanding array of broadcast and allied applications, as will the use of IT and servers. Any delay in establishing standards will make the task more difficult – as proprietary solutions will spread into the format vacuum.

To speed implementations, a number of SDK (software development kit) efforts are underway. The software source code is available for free and, using the available tools, can give products a basic MXF awareness very quickly. Details of the code is available via the Pro-MPEG forum, the AAF association and the EBU.

MXF and AAF

Advanced Authoring Format (AAF) is an industry-driven open standard for multimedia authoring and post-production. It enables content creators to easily exchange digital media and metadata across platforms and between applications. It simplifies project management, saves time and preserves valuable metadata that was often lost in the past during media transfers.

MXF is derived from the AAF data model and is a simple interchange format, primarily to facilitate the transfer of finished content, whole programmes or completed sections, between servers and to tape streamers. MXF also helps with the migration of playout operations and simpler production systems into standard networked environments.

Abbreviations

AAF	Advanced Authoring Format
DV	(Sony) Digital Video compression format
DVB	Digital Video Broadcasting
EDL	Edit Decision List
FP	(MXF) File Package
GPS	Global Positioning System
KLV	(SMPTE) Key Length Value
MP	(MXF) Material Package
MPEG	Moving Picture Experts Group
MXF	(Pro-MPEG) Material eXchange Format
NTSC	National Television System Committee (USA)
PAL	Phase Alternation Line
SDI	Serial Digital Interface
SDTI	Serial Data Transport Interface
SDK	Software Development Kit
SMPTE	Society of Motion Picture and Television Engineers (USA)
SP	(MXF) Source Package
UMID	(SMPTE) Unique Material Identifier

Bruce Devlin graduated in 1986 from Queens' College, Cambridge (UK), and has been working in the broadcast industry ever since. He joined BBC Research Department to work on radio-camera systems before moving to France where his work on sub-band and MPEG coding led to the design of a Satellite News Gathering chipset.

In 1993, Mr Devlin joined Snell & Wilcox where he started the company's work on compression coding. He holds several patents in the field of compression, has written international standards on MPEG interoperability and is leading various collaborative projects towards the creation of an international standard for broadcast file interoperability. He is editor and document controller of the MXF file format specification.

The two formats are especially complementary.

Whereas AAF integrates closely with, and complements, the existing media file formats, MXF offers the same for existing streaming formats as well as AAF files. Both formats can stand on their own and each has a functionality and design that is optimized for their particular spheres of application. At the same time, one does not depend on the other. For example, a whole broadcast system may use only MXF and a post-production house, just AAF. However, a broadcaster with a post-production facility may well use both formats.

While MXF and AAF are complementary, there are many differences between them. One is that AAF may carry references to outside material held in other places, to be used in an edit, whereas MXF is always complete and self-contained: it does not require any access to outside material. In addition, AAF includes basic video transition processing whereas MXF, carrying completed programme material, has no need of that.

Conclusions

MXF is driven by user needs and, so, has a strong commercial base. Even normally competitive manufacturers are working together at high speed to provide an open industry solution to file interchange. Working together, targets have been met; MXF has been submitted to the SMPTE and is well on its way to helping media flow in the television / IT convergent world. End users will be able to better manage their media and to concentrate on their prime tasks of productivity and creativity.

Further information

Further information on MXF, software development kits, AAF and the SMPTE can be obtained via the web and e-mail links given below:

MXF information and downloads from Pro-MPEG	**http://www.pro-mpeg.org**
MXF downloads and use information	**http://www.g-fors.com**
MXF Software Development Kit	**mailto:hoffmann@ebu.ch**
AAF Association information & Software Development Kit	**http://www.aafassociation.org**
SMPTE	**http://www.smpte.org**