European Digital Cinema Forum

EDCF

The EDCF Guide to DIGITAL CINEMA MASTERING

August 2007

The European Digital Cinema Forum

The European Digital Cinema Forum – EDCF was formed in June 2001 as the result of an initiative between the CNC/CST (France), the DTI/BKSTS (UK) and the SFI (Sweden).

This association of professionals interested in the progression of digital technology in cinema was formalised as a non-profit making foundation - a "Stichting" - under Dutch law in June 2004

EDCF has subsequently played a major role in collecting requirements, issues and concerns for collective consideration by public and commercial entities.

EDCF is the leading networking, information sharing & lobbying organisation for Digital Cinema in Europe and for 5 years has been the most important link between Europe and the US Studios.
Its business is managed by a Board, which is elected bi-annually by the Forum's members.

There are three working groups within the Forum
- Technical Support Group
- Exhibition Support Group and
- Distribution Support Group

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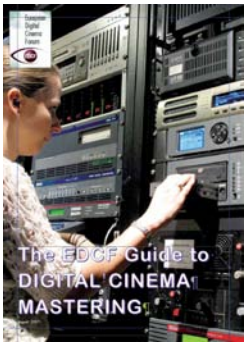
THE EDCF GUIDE TO DIGITAL CINEMA MASTERING



has been created by the EDCF Technical Support Group, which is chaired by Peter Wilson. The aim of this guide is to provide a tutorial, preliminary information and guidelines to those who need to understand the processes involved in assembling the components required to produce a Digital Cinema Master – the Digital Cinema Package or DCP. This booklet cannot pursue all the systems architectures but the intention is to do so in a subsequent publication.

The EDCF is extremely grateful to the following Member companies who have aided and sponsored the publication of this *EDCF Guide to Digital Cinema Mastering*.

The EDCF Guide to DIGITAL CINEMA MASTERING

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1. Introduction to DC Mastering

Peter Wilson
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The context of this guide is set in a time where Digital Cinema compression, security and packaging are in their infancy.

Digital Cinema Initiatives, a company formed originally from members of the seven Hollywood majors, wished to set the scene as to how Digital Cinema technology and services might be operated. They spent much time on a document called DCI Digital Cinema Specification V1.0, which was released to the public on July 20th 2005. This has recently been updated to incorporate some Errata and was updated to v1.1 on the 3rd May 2007. Copies of the DCI specification can be downloaded at *www.dcimovies.com*.

This sets out the general requirements which the Major Studios expect to be adhered to contractually before providing current mainstream content to the distribution and exhibition chains. The DCI specification is not a standard and has no legal jurisdiction, though it may be specified in Studio contracts.

To make a standard for Digital Cinema the requirements document was passed to the Society of Motion Picture and Television Engineers to generate first a US standard for Digital Cinema Distribution and Exhibition, followed by ratification by organisations such as the ITU (International Telecommunications Union) or ISO (International Standardisation Organisation). The SMPTE Committee for Digital Cinema is called DC28, and work has been ongoing for several years already with several DCI members sitting in the committee groups. Much of the work is nearly completed but has to go through an American National Standards Institute (ANSI) regulated Ballot process to become a formal Standard.

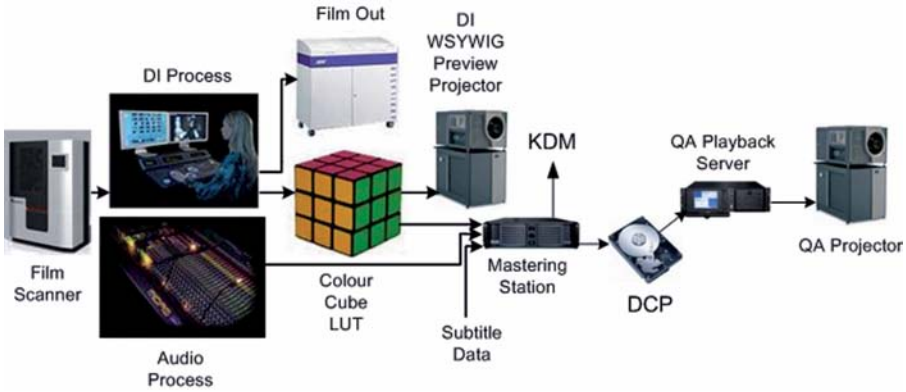
During all of this time there have been numerous digital movies released to the relatively small number of screens. A big issue found in this pioneering time was lack of interoperability - put frankly, system X is not compatible with system Y so you have significant problems. Initially, when MPEG was the most common compression method, a system called MXF Interop was used. This was a system put together by a collection of manufacturers where they guaranteed interoperability. Things moved on to JPEG Interop, this uses JPEG 2000 compression with an MXF Wrapper. Towards the end of 2007 there will be a final move to the SMPTE DC28 standard. This uses JPEG2000 wrapped in MXF in its final version, and upgrading will be made en-masse during a quiet period to ensure continued interoperability. At the time of writing there were just over 3000 systems to update.

The DC28 standard is very complicated, so to assist the users and manufacturers in obtaining Interoperability the DCI placed a contract with the Fraunhofer Institute in Germany to generate a set of test materials and procedures. This work was finished around Christmas 2006. The studios were reluctant to publish the security sections of this report and in fact have contracted a US Company called Cinecert to complete the work. *http://www.cinecert.com/*. Once this is done manufacturers will have a set of tools to use to guarantee interoperability at all levels. To police compliance with the DCI Specification it is intended to set up a network of compliance laboratories. There are also European Interoperability Initiatives in France and Norway, and in the US, such as the ISDCF (see *www.isdcf.com*)

What is Digital Cinema Mastering?

Firstly, the term, though in common use, actually describes a system of data reduction (JPEG2000 Compression), then reel building with Audio and Subtitles, Security and Packaging. The process flow is highlighted in the above mentioned DCI Document but is shown in basic form in the diagram below.

During the Post Production of a movie it is common to scan the camera original negative into an IT system. Each picture becomes a digital data file. This can be carried out at a variety of resolutions commonly 4K which is 4096 picture elements horizontally (Pixels) x 3112 picture elements vertically. This can also happen at 2K which is 2048 elements horizontally x 1556 ele-



ments vertically. Typical file formats are Kodak Cineon or Digital Picture Exchange (DPX).

These numbers over scan an Academy Aperture on the film which is the old 1:1.371 Aspect Ratio with sound. It is strange that these numbers are not referred back to the still picture resolution, for example 4K is 12.7 Mega pixels and 2K is 3.18 Mega pixels per image.

After the scanning the data enters into the **Digital Intermediate (DI)** process which can add computer graphics and animations, special effects and colour correction. The DI will be tuned to output to Film Recorders and a second output will go through a process commonly called **Colour Cube** for Digital Cinema and other digital releases. A colour cube is also put in the path to the grading projector to simulate the film. This data file is called a **Digital Source Master (DSM)**. A colour cube is a multidimensional look up table and it modifies the Red, Green Blue values; the numbers in the cube are normally proprietary.

A colour cube is a 3 dimensional representation of colour. Its function in the DI suite is to modify the film information sent to the film recorder to match the film characteristics to the colourist's view. It is basically a 3D lookup table in hardware or software. The numbers are a prized secret between post-houses.

To make a digital cinema release, this Digital Source Master is further preprocessed to conform to the requirements of the DCI. For example the projector resolutions are only 8.8 Megapixels for 4K and 2.2 Megapixels for 2K. This reformatted file is called a **Digital Cinema Distribution Master** or **DCDM** and is normally in the form of a Tagged Image File Format (TIFF) file.

Practical Mastering

You start with a Digital Source Master; however this is not quite as simple as it sounds. The DSM can be a collection of disparate elements such as picture, up to sixteen audio tracks, subtitle and subpicture files. These elements may well not arrive together or from one source so there is a significant logistics task to do.

Problem number 1: The master elements are unsecured, which means you need to operate in a trusted environment with a trusted delivery path. Currently that means most of the work is carried out in Hollywood. If your business already works with Hollywood studios pre-release you should be ok.

Problem number 2: Assuming you can get the master files, they are huge - in the region of 2 terabytes for a regular 2K movie.

Problem number 3: The equipment necessary to carry out the job may well cost you in excess of €500,000 and with a current market price of €5,000 to €15,000 per movie it is unlikely it that it will be a profitable business unless connected with some other service.

Problem number 4: once you have the Digital Cinema Package (DCP) you have to dispatch it to the duplicator and dispatch the master **Key Delivery Message (KDM)** to the key management organisation, often part of the duplication company.

The Mastering Process

This first example assumes that you are in a trusted environment and can work on original files.

• The DCDM picture files will arrive as an enormous set of sequentially numbered uncompressed TIFF files. There are other file varieties such as Cineon or DPX files but the industry usually expects to work with TIFF.

• The colour space in these TIFF may be RGB or (CAPital) XYZ.

• The DCI calls for XYZ colour space so a mathematical conversion may be necessary before compression encoding into JPEG 2000 (J2C) files.

XYZ colour space just describes a pipe with a wider colour space than any current display technology. The reason this computationally intensive pipe is used is to allow for future display technologies with a wider colour space than is possible today. An example would be a Laser projector. There is of course the implication that any new technology will mean reworking the mastering QA facility.

• The Audio files will arrive as a set of up to 16 uncompressed, broadcast quality Wave files. (.WAV)

• With luck there may be a post-production Edit Decision List (EDL) available which will simplify the splitting of the output into virtual reels.

• The sub-pictures (like DVD overlays) are Portable Network Graphics (PNG) files and the subtitle files are eXtensible Markup Language (XML). These are both rendered in the projector head.

• These components are organised by a Composition Play List which gives timing information for all the elements to ensure synchronisation and allows the DCP to be split into into virtual reels.

• Most of the processed elements will be encrypted by a very powerful encryption system called the **Advanced Encryption Standard (AES)** which is very commonly used by the world's military. The cipher was invented by two Belgians and is known as Rijndael. DCI calls for 128 bit keys which gives 340282366920938000000000000000000000000.00 tries before exhausting the possible key permutations.

• Once the key elements are encrypted they are then packaged together using a standardised file wrapping system called **Media Exchange Format (MXF)**. MXF is basically a wrapping system which has nested levels.

In Post Production there is also a wrapping system called **Advanced Authoring Format (AAF)**. AAF may also describe the process by which the movie was made and then be transcoded into MXF with the lowest levels missing, as these may be unnecessary for distribution. A key requirement of this system is human readable file headers.

Included also in the MXF wrapper is the track file information, this tells the equipment in the cinema how to play back the various elements of the complete presentation.

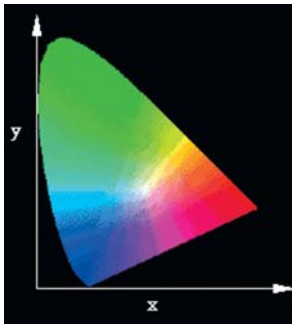
There is provision for more than one way to playback the files. For example, the track files may contain an original version presentation and a French language presentation. All the elements would be present at all the shows but the actual show playback may be with the original language or for another a translated or censored version. Although it is theoretically possible to substitute different languages at run time it is not so useful as the dialogue is normally mixed in with the surround sound.

As an alternative to transporting all the elements in their raw form it is possible to take an existing DCP and explode it, modify the track files, add new elements and repackage it when for example adding languages. This does require a trusted environment and the correct keys.

Once the DCP is generated it can be transported for duplication by network link or hard drive. Currently most digital movies are distributed by either hard drives or satellite. Currently there is no standard for which type of hard drive interface may be used.The ISDCF (see above) in the USA has started a digital cinema group to study this issue and others which may escape the net of standardisation.

XYZ revisited

XYZ is not a new concept but until now it has not been used. Colour is very much related to the human visual system. Humans have a fairly narrow colour capability which luckily matches fairly well what we actually want to see. The International Commission for Illumination (CIE) set out a 3 dimensional chart called The *CIE 1931 colour space chromaticity diagram*. This diagram has an X, Y and Z axis. X and Y values can represent any colour but the Z axis represents



luminosity. Digital Cinema projectors today do not quite match the limits of 35mm colour Film. The current projectors have a Xenon light source which sets the limits of the displayed colour. As other projector technologies may come along with much wider colour gamuts than currently available, for example laser based, some manufacturers representatives felt that digital cinema should be upgradeable in the future to the wider colour space which could then represent films full capabilities. As current film projectors are also Xenon lamp based this would offer an improvement on today's film exhibition.

The way the committee chose to preserve future options was to make a pipeline able to work at the limits of the CIE colour space which was called CAPital XYZ. In post production, colour mastering is done using a What You See Is What You Get (WYSIWYG) projection system using Texas Instruments Primaries commonly known as P3. The resulting values in TI space are mathematically processed into XYZ space by a 3 dimensional transform. At the cinema end the XYZ is processed back into the projection device's colour space.

If in the future Laser projectors with wider primaries come into use they can be mapped into the XYZ "pipe and legacy projectors can use a special set of numbers to display the colours correctly. To make use of this wider colour space all mastering projectors would need replacing with the laser versions, te laser projectors should be able to perfectly replicate the Xenon colour space. Though this approach is well meaning it does result in a serious processing overhead in the mastering process and projection booth.

Frame Rates

Though the initial DCI requirements only called for 24 and 48 frames per second it was recognised that there was a need to support 25 and 50 frames per second for 50Hz countries as Film is commonly shot and projected at 25 FPS in these regions. There was also a strong request for 60 Hz by Imago the European Cinematographers association.

SMPTE created a study group to assess the impact and requirement for additional frame rates. The study group report which identified the need for additional frame rates was recently released for review and work will shortly start on developing the required standards documents.

Purpose of this Guide

The EDCF previously published the EDCF Early Adopters Guide, which was aimed at those new to the digital cinema debate, with limited technical knowledge.

This Guide attempts to do the improbable, that is to be informative and usable for the digital cinema layman but also to contain enough technical information to be genuinely useful to those wishing to start out in the digital cinema mastering business.

The guide is divided into relevant segments, each of which has been written by people from the industry who are experts in their field.

The Guide covers:

- Logistics • Picture Element Compression • Audio
- Subtitle & Subpicture • Making track files • Security
- MXF Wrapping • Distribution • What can go wrong

Peter Wilson
Director of the EDCF Technical Support Group and Board Member

2. Mastering - The Main Process

Jim Whittlesey
DeLuxe Laboratories

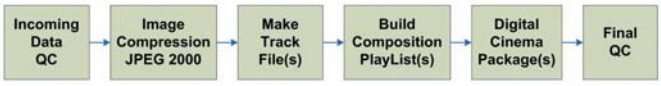
Introduction

Digital Cinema Mastering is the process of converting the Digital Intermediate film out (image) files into compressed, encrypted track files, this being the digital cinema equivalent of film reels, and then combining (in sync) these image track files with the uncompressed audio track files and subtitle track files to form a DCI/SMPTE compliant Digital Cinema Package.

The Digital Cinema Mastering workflow starts with a verification and quality control of the massive amounts of incoming data. The incoming data consists of a .tiff file for each frame of image; this can be upwards of 200,000 frames consuming as much as 2 TBytes of disk space – this is for a 2K movie! There is four times more data or ~ 8 TBytes for a 4K movie. The incoming audio data is a single broadcast .wav file for each channel and each reel (i.e. for the 5.1 audio in a 6 reel movie there are 36 broadcast .wav files; 6 .wav per reel, 6 movie reels).

The next process is to encode or compress the thousands of .tiff files into .j2c (jpeg 2000) files. This process compresses the image down to a size that is manageable and can be economically distributed to theatres.

The final step to is to carry out a through QC of all versions of the content to make sure the content is ready for show time.

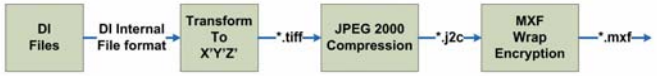


Defining Data File Formats

The Digital Cinema Distribution Master (DCDM) defines the interchange file format for Image, Audio and subtitle data. There is a separate standard for image, audio and subtitles elements.

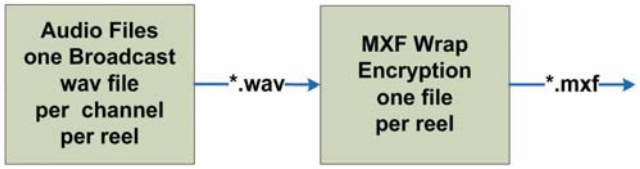
Image file formats

Typically the image files are stored in a proprietary RGB format within a DI facility. Once the color grading has been approved, these RGB images files are converted (color space converted) to standard .tiff in X'Y'Z'. This is the DCDM file format for image data. The .tiff file is the input to JPEG 2000 compression with the output being the JPEG 2000 compressed file format or .j2c. All the .j2c files for a given reel are wrapped (and may be encrypted) into a single image .MXF track file. See work flow diagram below.



Audio file formats

The DCDM file format is a single broadcast wav file per channel per reel. It is important that all audio files have an academy leader (8 seconds or 192 frames at 24 FPS) with a proper "two pop ident" – an audio pop precisely two seconds before the first frame of action.



Subtitle file formats

These are easy ones – there is an XML file per reel that basically defines when and where the subtitle is put on the screen. It also defines when the subtitle is taken off the screen. For Timed Text subtitle there may be a True Type font file. For PNG subtitles there will be a separate PNG file for each subtitle rendered on screen. In current practice, the subtitle files are used as delivered in the Digital Cinema Packages.

QC and Verification of Incoming Assets/Elements

It is important for each mastering facility to define exactly how image and audio files are to be delivered. Attached to this white paper are examples of the Image and Audio file requirements as used at Deluxe Digital Cinema. These requirements are freely given to any post facility that provides image and/or audio files to Deluxe Digital Cinema.

It is important to verify that the incoming files are made according to your requirements. Just because you provide a specification defining how you would like data delivered doesn't mean the workflow upstream will follow your requirements – trust me. Also, because of the long time it takes to process (compress images, wrap and encrypt into an MXF file) it is necessary to verify the incoming elements are correct otherwise you will be doing the same work twice.

Image Verification

Verify that there are no missing files within a folder/directory (reel). Also verify that each frame file name meets your requirements. This can be done with a simple Perl program that verifies that the files have proper sequential numbering per your requirements document. Missing or improper number sequences will cause problems when creating the MXF track file(s).

Verify that the .tiff files are in the correct image structure. See table below. This can be done by simply opening a *.tiff with a TIFF file viewer and doing an "image info" command. One should verify at least one frame from each reel. This step can be combined with the following step, which is to verify the first and last frame of action within each reel.

Aspect Ratio	*4K Image*	*2K Image*
Flat (1.85)	3996 x 2160	1998 x 1080
Scope (2.39)	4096x1716	2048 x 858

Verify the first frame of action and the last frame of action for each reel. This information should have been supplied from the post house providing the images. This can simply be done by opening the first frame of action for each reel. You should see an image. Then open the preceding frame and

you should see a black frame. This does not work for the first reel since there is most likely a black fade into the studio logo. Repeat this procedure for the last frame of action; open the last frame of action and you should see an image. Then open the following fame and you should see a black frame. Warning this does not work on the last reel; since there is probably a black fade into the "tail" leader.

With the above information one can generate a spread sheet that has first frame of action, last frame of action, the duration of each reel and time codes for each reel. See example below. The **first frame of action** and **duration of action** for each reel will be needed to make the Composition PlayList(s). The time codes will be most useful in final QC to verify proper reel splices.

Feature: *feature name* Flat Audio 5.1 (Studio)								
Reel name	**total # of Frames**	**1st frame of Action**	**Last Frame of Action**	**Last frame**	**Duration of Action**	**Running total # of frames**	**1st frame of Action**	**Last frame of Action**
reel 1	26781	192	26692	22848	26501	26501	00:00:00:00	00:18:24:05
reel 2	29194	192	29105	29114	28914	55415	00:18:24:06	00:38:28:23
reel 3	26396	192	26307	29491	26116	81531	00:38:29:00	00:56:37:03
reel 4	28749	192	28660	25841	28469	110000	00:56:37:04	01:16:23:08
reel 5	18739	192	18650	18550	18459	128459	01:16:23:09	01:29:12:11
reel 6	26353	192	26300	17857	26109	154568	01:29:12:12	01:47:20:08
	156,212				**154,568**			
First Frame of Action and Last Frame of Action are inclusive								

Verify correct color – if you are not familiar with the look of the movie this is very difficult. Typically the *.tiff files are in X'Y'Z' color space. You will need a display device capable to X'Y'Z' display. This will mostly likely be your Digital Cinema projector.

Audio Files Verification

Verify that the audio sampling frequency is exactly 48.000 kHz and the "two pop" is properly aligned within a 24.000 frame per second. This can be done with Pro Tools. If the audio files are sampled at 47.952 kHz (a typical problem caused when the audio suite is used for TV work), you will find the audio will drift out of sync. By the end of a standard 20 minute reel the audio will be out by about ~1.5 seconds. You do not want to find this out in final QC of a movie and have to go back to the audio post to request new audio files – it will kill your schedule.

Subtitle File(s) Verification

Here in lies a problem – there are no software tools to verify the XML subtitle files. This is an issue, especially with the current growth in distribution of digital cinema outside the US domestic market . Hopefully the lack of subtitle verification tools will be rectified soon.

Image Encoding/Compression

The next step in the Master Workflow is to compress the image files. DCI selected JPEG 2000 for Digital Cinema. It is intra frame compression – no temporal encoding. This reduces the complexity of the compression system since each frame is compressed with no information needed from the preceding image frame or the image frame after the current frame under compression. This also allows editing of a track file on any frame boundary – useful for versioning and censorship edits that may be needed for a given territory.
The files sizes or average bit rate will be higher for flat aspect ratio content vs. scope content since there are ~20% more pixels in a flat image then a scope image.

Typical compression ratios are:
- Animated content expect a compression ratio of ~20:1
- 2K content (film or digital camera) expect a compression ratio of ~10:1
- 4K content (film or digital camera) expect compression ratios 30 to 40:1

Below is a table of uncompressed reels sizes and compressed reels sizes. This is from a recent 'scope movie.

	uncompressed	**compressed**	**compression ratio**
reel 1	246	26	9.46 : 1
reel 2	288	35	8.23 : 1
reel 3	293	35	8.37 : 1
reel 4	277	34	8.15 : 1
reel 5	300	36	8.33 : 1
reel 6	292	34	8.59 : 1
reel 7	293	35	8.37 : 1
Totals	**1989 GBytes**	**235 GBytes**	8.46 : 1

Compression timeline:

For 2K image frames it is about 8 frames per second and 2 frames per second for 4K content. This is using the Doremi DMS 2000 mastering system. The DMS 2000 uses a hardware JPEG2000 compression. There are other master systems that use the infrastructure within a Digital Intermediate facility (high speed networks, lots of fast storage and "render farms" of processors) that deliver real time compression for both 2K and 4K images. They are claiming "real time" compression of 4K images with enough processor nodes and fast enough networks and disk.

Make the Track Files

In digital cinema the track file is the equivalent of a reel of film. Unlike film, where a reel of film will contain the image, the audio and subtitles, in the digital domain there are separate track files for each element; image, audio and subtitle.

Picture Track Files

The individual JPEG 2000 compressed files are wrapped into

a single MXF picture track file. At 24 frames per second and ~20 minute reels there are 28,800 frames per reel. So we are wrapping 28,800 compressed (.j2c) files into a single MXF picture track file. Each .j2c is ~1Mbyte or so, therefore the resulting MXF picture track files is ~30GBytes. Picture track files can optionally be encrypted per the SMPTE MXF Track File Essence Encryption standard.

Often the incoming .tiff files will include the head leader (SMPTE is creating a standard for the digital cinema leader) and a tail leader. It is important that one include both when making the track files. This is true for both sound and picture track files. It is not a significant impact on the track files size and the CPL will allow one to start playing track files after the header leader. The header leader will include the "2 pop" and this is sometime helpful in verifying audio sync in the final QC process.

Sound Track Files

The broadcast wav files are combined into a single audio track file. Each broadcast wave file is hard mapped to a channel number within the MXF track file. See table below. For a 5.1 audio mix only the first six channels are used and channels 7 and 8 are not populated with data. Encryption of audio track file(s) is optional according to the DCI specification but if it is decided to encrypt the image track file(s), then there is no compelling reason not to also encrypt the audio track file(s). It would be very easy for someone to copy the audio MXF track files, unwrap the MXF and play the broadcast wav files on any multi-media home PC.

Audio Channel mapping shall be:

Channel Number	Label / Name	Description
1	L/Left	Far left screen loudspeaker
2	R/Right	Far right screen loudspeaker
3	C/Center	Center screen loudspeaker
4	LFE/Screen	Screen Low Frequency Effects subwoofer loudspeakers
5	Ls/Left Surround	Left wall surround loudspeakers
6	Rs/Right Surround	Right wall surround loudspeakers
7	LC/Left Center	Left Center
8	RC/Right Center	Right Center

The mastering system must generate a symmetrical AES key for the encryption of the track file. This requires a sophisticated random number generator. The master system must store these AES keys in a secure data base for later use to generate a Key Delivery Message. Also it is absolutely imperative that there is a method to backup this secure data base of keys and association to encrypted track files. The loss of this data would mean that all encrypted track files are useless bit of data since you no longer have the symmetrical AES key needed to decrypt the track file.

Build Composition PlayList(s) CPLs

The Composition Playlist (CPL) defines how a movie is played. It defines the order in which each track file is played. The CPL also defines the starting frame and the duration of frames to be played within a track file.

The Composition Playlist (CPL) is an XML document for a complete digital cinema work, such as a motion picture or a trailer. The Composition Playlist consists of an ordered sequence of "reels", each referencing an external set of track file(s). These track files could be one or more of the following; a sound, a picture or subtitle track file. Each CPL reel is similar to a film reel.

The CPL can be used to implement a simple edit decision list. For example a CPL could define a reel as starting at frame number 100 and playing the next 2000 frames for a given picture track file. On the next reel, the CPL could define the reel as starting at frame number 2500 and playing until the end of the track file for the same above picture track file. The effect for this picture track file would be that frame numbers 2099 thru 2499 would not play as defined by the CPL. This represents how a censorship cut could be accomplished.

Make the Digital Cinema Package (DCP)

A complete Digital Cinema Package (DCP) is the collection of all files necessary for a digital cinema work such as a motion picture or a trailer. This will include an ASSETMAP, a VOLINDEX, a Packing List (PKL), one or more Composition Playlist(s) and all sound, picture and subtitle track file referenced by the CPL(s). The Packing List defines all elements/files within a DCP. The Packing List also includes useful data to determine if one has received the DCP intact and without errors.

A single DCP may contain several CPLs. For example a FIGS (French, Italian, German and Spanish) release: the DCP may contain a common set of picture track files and separate dubbed sound track files for each of the above languages. There would be four CPLs to define how to play the four versions of the movie, each CPL referencing a different set of sound track files. This DCP could be delivered to any theatre in France, Italy, Germany or Spain and the projectionist would select the appropriate CPL for the audience.

A complete DCP typically contains a motion picture and several trailers.

QC of the Final DPCs

It is important to have a proper QC environment. This consists of the following:

• **Screening Room**

The most important is the screening room itself. The screening room should be large enough to support a screen size of at least 8 metres x 3.3 metres for scope and 6 metres x 2.5 metres for flat aspect ratio. The screening room should be deep enough to provide viewing at least 2.5 screen heights or 8 metres from the screen.

• **Projector**

You will need an "approved" digital cinema projector – either 2K or 4K. See SMPTE reference projector standard. You will also need a photo meter to measure light level and spectro-radiometer meter to measure colors. These are needed to

maintain proper calibration on the project. The projector calibration must be checked prior to each QC event and if necessary re-calibrated.

• Server

An approved Digital Cinema server. And here lies another issue – there are no post production digital cinema playback servers, i.e. a server that provides jog/shuttle (remote) playback control. The majority of playback servers are designed for theatrical playback with no ability to fast forward or rewind – they just play the movie from start to finish. Doremi provide a "post production" version of their DCP-2000 which allows one to run a playback control program called "list-maker". This interface provides the ability to jump to anytime timecode and play. This interface also allows for single step playback both forward and reverse. Unfortunately no fast forward or rewind at this time.

• A proper audio "b-chain" with at least 5.1 channels.

When QC-ing a movie, remove the screen masking from the image so that one can clearly view the edges of the Digital Cinema presentation. Please take great care! There may be re-sizing issues such that the sides (left/right or top/bottom) of the image may move in for a scene. An example would be the left edge of the image may move in towards the center of the screen by as much as 100 pixels. Another common issue is that the DI facility did not do a proper camera/projector safe area cutout from the scanned film frame and you will see fringing or matting along the edges. If screen masking is applied to the presentation you may miss these issues during QC.

First check all reel "splices" to make sure there are no "added frames of black" or there are no missing frames of image. Go to the reel time code and step one frame at a time through the reel splice and check the images against the .tiff files. Also play through each reel splice listening for any audio pops, click or discontinuity. Start play ~10 seconds prior to the reel splice and play ~10 beyond the reel splice.

For the internal QC, play the movie from start to finish with at least two experienced QC personnel. Each QC person should take note on a QC form. The QC personnel should be within 2 screen heights from the screen when performing QC tasks. At the end, any issues between the two QC reports should be reviewed and resolved to produce a final QC report for the client.

When QC-ing content with subtitles or foreign language dubbed audio at least one QC person must be fluent in the subtitle or dubbed language.

Conclusions

This paper has given a high level overview of the Digital Cinema mastering workflow starting with the incoming data verification and QC. The old adage "garbage in garbage out" applies to digital cinema mastering. The next step is JPEG 2000 compression of the image files. This is followed by creating picture track files from the compressed image files and also creating the sound track files from the uncompressed broadcast wave files.

Once you have the sound and picture track files, you need to make the Composition Playlist (CPL) that defines how the sound, picture and subtitles track files are played back. A complete Digital Cinema Package consists of all the CPLs and associated elements/files. This paper finishes with tips for the final QC of the completed Digital Cinema Package.

Now you are ready to distribute the DCP to theatres!

There are many details left for the "student" to discover, most of which can only be learned by jumping in and doing the mastering work. The mastering tools are simple yet powerful enough to provide work-arounds for problems that may occur.

References

SMPTE 426-3 Sound and Picture Track File
SMPTE 426-4 MXF JPEG 2000 Application for D-Cinema
SMPTE 426-5 Subtitle Track File
SMPTE 426-6 MXF Track File Essence Encryption
SMPTE 429-7 Composition Playlist.
SMPTE 429-8 Packing List
SMPTE 429-9 Asset Map

The following is Deluxe Digital Cinema's specification for how sound and picture content should be prepared and delivered for mastering digital cinema. It is provide as a reference.

Image DCDM File Requirements for Deluxe Digital Cinema, 10-12-06

File Format

The file format shall be a single .tiff file per frame and shall conform to the current version of the SMPTE for Image DCDM file format. For example: 12 bits per sample, X'Y'Z' color space and the following image sizes:

• 2K scope: 2048 x 858 • 2K flat: 1998 x 1080
• 4K scope: 4096 x1716 • 4K flat: 3996 x 2160

File Naming Convention

The file name shall include the name of the feature or an abbreviated name, the reel number and frame number. The frame number within the file name shall be specified such that when listing the files within a directory or folder the frame files are listed in frame sequential order; for example frame 1 shall have enough leading zeros. The frame numbers shall be in sequential order with no discontinuities or gaps. The file name shall NOT contain any spaces ("white space"). Some acceptable examples are:

Title_r1_00001.tiff
Title.r1.00001.tiff
Title_r1_12345.tiff
Title.r1.21452.tiff

Directory or Folder Naming Convention

The Directory or Folder name shall include only alpha-numeric character, dashes "-" and under scores "_ ". The Directory or Folder name shall not contain any spaces ("white space").

Reel Structure

There shall be a directory or folder that contains all frames for that reel. Each reel shall have a leader (preferably 192 frames) with a frame identifying the "2 pop" that is 48 frames before the "first frame of action".

Media

For a feature film, SCSI Ultra 160 or 320 using an XFS or ext3 (UNIX/Linux) file system. For PC/Mac environments, a FAT32 file system is also acceptable. For a trailer, an external USB with EXT-3 (extended file system 3 UNIX/Linux). For a small number of frames (less than 300 frames), a DVD-ROM with UDF file system is acceptable.

Reel List

There shall be a document or spreadsheet with the reel list information. At the very least, I need to know the first frame of action and the last frame of action and the duration of each reel. An example is shown.

Reel name	total # of frames	1st frame of Action	Last Frame of Action	Duration of Action	Duration of Action	running total # frames
reel 1	20653	192	20564	20373	20373	20373
reel 2	21209	192	21120	20929	20929	41302
reel 3	28329	192	28240	28049	28049	69351
reel 4	29228	192	29139	28948	28948	98299
reel 5	29037	192	28948	28757	28757	127056
	128,456			**127,056**	**127,056**	

Audio File Requirements for Deluxe Digital Cinema, 10-20-06

The file format shall be a single Broadcast wave file per channel per reel

File Naming Convention

The file name shall include the name of the feature, the reel number and channel assignment. The file name will NOT contain any spaces ("white space"). Some acceptable abbreviations are:

R1 or r1 - reel 1
R or r – right channel
L or l – left channel
C or c – center channel
LFE or lfe or boom or sub – low frequency effects or sub
LS or ls – left surround
RS or ls – right surround

The following are some file name examples:
what_ever_r1_r.wav - this is the right channel of reel 1 for the feature title "what_ever"
what_ever_reel_2_left.wav - this is the left channel of reel 2 for the feature title "what_ever"

Sampling Bit Depth

The audio bit depth shall be 24bit

Sampling frequency

The sampling clock rate shall be exactly 48,000.000 Hz or 48 kHz.

Frame Rate

The frame rate shall be exactly 24.000 frames per second.

"2 pop" alignment

At a frame rate of 24 frames per second and a sampling frequency of 48 kHz, there are exactly 2,000 audio samples per frame:

48,000 samples/sec / 24 frames/sec
= 2,000 samples per frame

The "2 pop" sound is exactly one frame in length (1/24 sec) and the "2 pop" starts exactly 2 seconds before the start of the first fame of action. The 2,000 audio samples for the "2 pop" shall be aligned exactly within a single "film" frame that is 48 frames before the first "film" frame of action.

Delivery Media

First choice is DVD-ROM(s) with UDF file system. Firewire or USB external hard drive with either UNIX/Linux ext3 files system or a Windows NFTS file system.

Jim Whittlesey

Jim Whittlesey is currently VP of Technology for Deluxe Digital Cinema. He previously held the position of Director of Technology for Digital Cinema Initiatives (DCI). Prior to DCI, Jim was a product design engineer with Grass Valley Group for about 10 years. He was a member of the engineering team that developed the prototype video disk recorder that became the Profile series video disk recorders. Jim has also designed colour graphics display terminals and colour printers for Tektronix.

3. Audio Processing

Richard Welsh
Dolby Laboratories

Introduction

Ostensibly, audio is considered to be one of the easier elements of Digital Cinema because it is uncompressed, discreet digital audio, carried alongside the picture in the final DCP. However in order for the movie director's artistic intention be reproduced accurately in the cinema, most of the rules followed for audio for 35mm film need to be adhered to along with a host of new considerations for Digital Cinema. Digital Cinema also offers a number of advantages which can be exploited by the content producers and distributors.

Primarily, this section is intended to outline good working practice for D-Cinema audio in order to get the best results from the final DCP and minimise technical difficulties in the mastering process and subsequent exhibition.

The cinema sound experience has in its lifetime progressed from the early days of silent movies accompanied by live musical performances, through the first mono soundtracks, "talkies" to stereo and multi-channel sound. In 1990 the first 35mm movie with a digital soundtrack was released using the CDS format invented by Kodak and Optical Radiation Corp. This soundtrack took up the space on film normally used for the analogue soundtrack, and was superseded by the DTS, Dolby Digital and SDDS formats which retained the analogue soundtrack and thereby backwards compatibility for cinemas that were not equipped with a digital system. Backwards compatibility will in the future be an important factor for D-Cinema, which has been addressed for image by the use of the device independent X'Y'Z' colour space and resolution layered coding in JPEG2000. In audio, the same consideration needs to be made, and as will be discussed later, technologies currently available can make this a realistic possibility. Importantly, with both film sound dubbing, and film soundtracks being digital for almost 20 years, there is both stability and a wealth of practical knowledge in the post production process and exhibition that can be passed on to Digital Cinema.

Audio Source

All cinema sound studios now use some form of digital record/replay, digital consoles and digital processing devices, so the handling of digital audio is well understood. Since Digital Cinema requires uncompressed audio, it should be fairly simple for the sound studio to provide the required deliverables to the Digital Cinema mastering facility. The audio will ultimately need to be handled as Broadcast Wave (.wav) files so it is simplest and best to supply them in this format. Generally, any format other than that defined as the DCDM is undesirable, and increases both the time required for mastering and the margin for error. However, it is accepted that the source material for Digital Cinema movies outside the high budget mainstream, frequently does not meet the DCDM specification, and it is often left up to the Digital Cinema mastering facility to take the undefined Digital Source Master (DSM) and perform the necessary steps to create the DCDM, and ultimately the DCP. This section deals with the principles of audio for Digital Cinema and practical aspects of transforming the DSM into the DCDM.

Mixing Environment

As for 35mm film, audio for Digital Cinema should have been mixed in an audio environment that represents that of the cinema. There are existing standards for electro acoustic alignment of cinemas and feature film dubbing studios which are usually maintained globally through initiatives such as the Dolby Feature and Commercials studio licensing programme. These standards do not require adjustment for mixing sound tracks for Digital Cinema. However, there is no requirement for the producers of movies for Digital Cinema to use licensed studios. Whilst 35mm film remains the dominant exhibition format, movie soundtracks will continue to be mixed in such studios and in the longer term this is unlikely to affect mainstream high budget movies, whose producers will wish to use dubbing studios maintained to high standards. However the temptation to avoid the cost of using such facilities for lower budget movies could ultimately lead to a raft of movie soundtracks which are not referenced to any standard, causing totally unpredictable results and chaos in cinemas as projectionists struggle to deal with wildly varying sound on each movie. This clearly goes against the principle of Digital Cinema to have a minimum exhibition quality standard equal to 35mm film. It is essential as a first principle that the soundtrack supplied for Digital Cinema has been mixed in a sound studio aligned to the same standards as cinemas.

Deliverables

The first choice for audio deliverables for any Digital Cinema mastering facility is to receive a properly formatted audio DCDM (see DCDM Definition section). However, depending upon the mastering facility, it may be acceptable to deliver other digital formats, for instance digital tape such as the Hi8 format, but this usually represents a quality compromise, and will require extra work on the part of the mastering facility which is unlikely to be free. Tape delivery also increases the inherent risk of incorrect sample rates, synchronisation problems and reel length accuracy. The most common issues arise from the re-purposing of broadcast standard material for Digital Cinema. Both picture and sound for a movie will frequently exist as a high definition broadcast format such as HD-Cam or HD-D5 as these often appear on movie distributor's deliverables requirements. At face value these offer an easy route to Digital Cinema since they can carry a high resolution digital picture and the full uncompressed 5.1 soundtrack. However in truth, an HD digital tape will require a number of steps in order to create the picture and sound DCDM.

Splitting Continuous Audio to Reels

The first problem with a broadcast HD tape is that it is conformed into a single continuous movie, rather than reels. In theory the reel splits for Digital Cinema are seamless, since the audio and image are frame based and therefore can be cut anywhere to absolute sample accuracy. However, in the case of a broadcast standard tape, the frame-rate may be 23.98, 25 or 29.97. (Only progressive formats are considered here.) This means the audio will have to be time-stretched to meet 24 frames per second, and this effectively means re-sampling. As a result arbitrary edits of the audio are not necessarily seamless, so splitting back to reels requires care. The practical solution is to ensure that the time-code or footages of the original reel breaks for the movie are supplied. These should have been picked appropriately to minimise the possibility of the reel change being heard on 35mm, for instance avoiding sustained musical tones or dialogue. By making the reel edits in these places, the risk of them being audible after re-sampling is minimised. If this information is not available, an educated choice for the reel breaks has to be made. The picture will not be affected since it is frame based, so the only consideration is the sound. The best place is usually between scenes which do not have dialogue or music across the transition, preferably with only low level ambience or best of all, silence. Regardless of method, it is very important to note where reel breaks are and pay close attention to the audio here during the QC of the DCP to ensure they are clean.

Time Stretching

The audio will require time-stretching from the original length to 24fps. This is to ensure that the original pitch of the audio is retained. This can be either done through a real time device upon capture, or non-real time in an audio editing system. Either way, it is essential that the quality of this process is high, as a poor quality pitch shift or time stretch can be quite objectionable to even the untrained ears of the average audience. In the case of a 23.98fps tape, it is usually possible to run the tape deck at 24fps for capture, thus "gearboxing" the audio to the right length. In this case the pitch change will not be noticeable, but it is essential the capture device and replay tape deck are locked to the same reference clock to avoid any sample glitches.

Bit Depth and Sample Rate

Digital Cinema audio must be 24bit and may have a sample rate of either 48kHz or 96kHz. In this case, best practice for a studio would be to use one of these combinations, should their equipment support it. In the event that the dubbing equipment or delivery format does not support the full 24bits, the audio will be justified to the Most Significant Bit (MSB) in the final file, with the Least Significant Bits (LSB) being zero. It is essential to use the correct sample rate however, as any variation from 48kHz or 96kHz will cause problems downstream, either in synchronisation or with audio "glitches" in the server. The principle for these two sample rates is to have a fixed known number of audio samples per picture frame upon replay. This ensures that reel breaks are completely seamless and also allows arbitrary edits to be made using the Composition Play List (CPL) (see fig 1). This may be for instance because of foreign language text inserts, or censor cuts. The advantage is that the original picture source for a movie can be used for multiple international releases, and only the new picture and sound elements along with a new

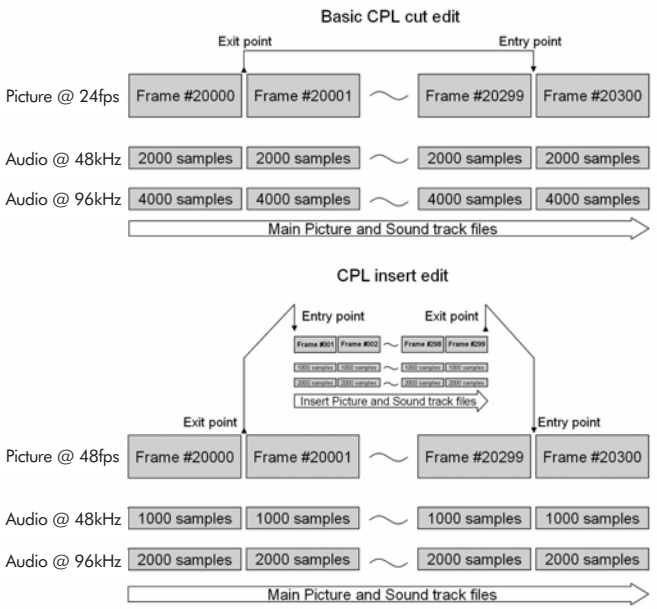


Figure 1. Audio samples per picture frame and CPL edit examples

CPL need to be added to the DCP, rather than re-making a whole reel of the movie. The presence of glitches in the soundtrack of a DCP either continuous throughout the movie, or at reel boundaries, usually indicates a sample rate problem with the audio.

Channel Assignment

The DCP allows for 16 channels of audio to be carried, although typically soundtracks are currently 5.1. Since there is currently no audio metadata support in most playback servers for channel identification DCI have defined channel mapping for 6 (i.e. 5.1) and 8 (i.e. 7.1) channels (see tables 1 and 2). It is only important that these are followed in the DCP since the DCDM calls for mono wav files, which can easily be re-organised during mastering. When supplying mono wav files, it is safest to name them by channel rather than number. For instance: *movietitle_reel1_left.wav*
movietitle_reel1_right.wav etc.

Table 1
– DCI Six channel mapping (first 8 channels shown only)

Channel Number	Channel Assignment
1	Left
2	Right
3	Centre
4	LFE
5	Ls
6	Rs
7	Unused
8	Unused

Table 2
– DCI Eight channel mapping (first 8 channels shown only)

Channel Number	Channel Assignment
1	Left
2	Right
3	Centre
4	LFE
5	Ls
6	Rs
7	Left Centre
8	Right Centre

It is common in the UK to have an audio description track (commonly known as the "AD track") to help visually-impaired people. The DCI specification allows that undefined channels may contain such channels as AD and/or a hearing impaired (HI) channel. However, in practice this can be problematic. Most Digital Cinema servers only actually support 8 audio output channels, so tracks 9 to 16 in the DCP cannot be used. This leaves channels 7 and 8 (assuming the movie carries a 5.1 soundtrack). This is fine in the DCP, but some cinemas may have a 7.1 sound system and if their Digital Cinema server has been connected according to the eight channel mapping above, then AD can come from the Left and/or Right centre speakers. This is discussed further in the Playback section.

DCDM Definition

The Audio DCDM should be delivered as mono tracks, split by reels according to the Image DCDM. The tracks should be 24bit, 48kHz or 96kHz mono Broadcast Wave (.wav) files. Each audio track should have an 8 second (196 frame) leader with a synchronisation pip/pop at 2 seconds (48 frames) before the First Frame of Action (FFOA).

DCP Audio Mastering Process

If both the Image DCDM and Audio DCDM have been correctly supplied, the mono .wav files will marry to the picture correctly. However, it is commonly the case that the picture and sound have come from different facilities, or a non DCDM source, and therefore may need to be synchronised at the DCP creation stage. This requires that the system being used to build the reels and CPL for the DCP has the facility to slip the audio track with reference to the picture track. Once sync is determined and correct, in and out points need to be defined to have each reel play out missing the leader, starting at the FFOA and ending at the LFOA. This should be defined in the CPL rather than cutting any leader and footer from the picture and sound files.

Once all the reels are set up, the play-list is defined and finally the project is committed. At this point the audio is interleaved into a single wav file, encrypted (if desired) and MXF wrapped.

Metadata

Metadata is a term that means "data about data". In the case of Digital Cinema it usually refers to information about, and carried with, a track file. For the audio track, there is currently no standard metadata schema which can be used. However DCI have defined some elements they require in the audio metadata when it is standardised. It is not important to list them all here, but two of these metadata fields will together have a significant impact on Digital Cinema audio when they are implemented, those being:

• Channel mapping label • Dynamic down mixing

The reason these are important is that there are currently 21 SMPTE defined cinema surround channels, and there is no reason why this number could not increase in the future. How should a lowly 5.1 cinema deal with the 15 channels it doesn't have, if some of them appear in one the 16 channels in the DCP? The answer is **Down-mixing**. Down-mixing using metadata will take place automatically either in the server or in the cinema sound processor. This metadata is generated at the mixing stage of the movie, by the mixer themselves. They can then decide the best way to take a large number of channels and add them together into a smaller number of channels. Taking for instance a 7.1 soundtrack being played in a 5.1 theatre, the left centre channel to be added to the normal left screen channel. Because the metadata is dynamic, the level at which the left centre is added to the left channel is at the discretion of the mixer and can be changed as the movie plays, thus being artistically appropriate to the sound track at any given moment. Metadata is a powerful tool, and is essential to Digital Cinema in order to provide backwards compatibility as the technology and cinema theatres move on.

Playback

Inevitably, problems may arise after the DCP arrives at the cinema theatre, despite a perfect QC at the mastering facility. It is important to understand the various aspects of the cinemas being supplied. Although most Digital Cinema servers are to the greater extent interoperable, they all have different capabilities and features. Furthermore, each cinema is different and in Europe there is a healthy mix of brand new cinemas with all digital installations, and old 35mm cinemas which have added digital capabilities to their existing systems. It is important to understand in some detail the setup of all the cinemas being supplied, since this can impact how you choose to master the DCP.

Taking the case of an Audio Description (AD) track discussed earlier, there is a legal requirement for Cinemas in the UK to offer a certain percentage of screenings that cater for disability groups. This usually entails captioned screenings, the provision of a hearing impaired (HI) induction loop for people with hearing aids, and a visually impaired AD channel available by wireless headphones (usually using an infra-red system). For these cinemas one of channel 7 or 8 is used for the AD track (The HI track is derived from the main soundtrack within the cinema processor and fed to the induction loop). The distributor then requests that the audio track for both the captioned and normal versions of their movie, include an AD track. Since it is not possible to know which cinemas have their AD connected to track 7 and which to track 8, the AD is placed on both channels. As mentioned earlier, some cinemas do not have an AD system installed, but do have 7.1 sound system. They would immediately have problems if they have connected up all eight channels of their Digital Cinema server to the sound system. In this case, the fix would be fairly easy, simply switch off the amplifiers for the Left Centre and Right Centre channels.

In practice most cinemas in Europe do not have 7.1 sound systems, but even when this is the case, there may be analogue cross talk issues that result in AD dialogue breaking out in auditorium speaker channels. This is more difficult for

the cinema because they cannot simply switch this problem off. The crosstalk may be taking place in the analogue outputs of a server, or the cinema audio processor or the power amplifiers. In this case, it is an installation issue, which needs to be addressed by the installers/equipment suppliers.

This is a very specific example, but as Digital Cinema proliferates and as channel counts increase, such problems will become more frequent and more complex. It will fall to the mastering facility to understand these issues and ensure their product plays perfectly in all cinemas they supply.

Distribution

One of the huge advantages of Digital Cinema is the possibility of distributing a single picture version with multiple soundtrack languages. Because of the ability to also include inserts, on screen text can also be changed for different languages without having a completely new picture version for the whole movie. In theory all language versions, dubbed and subtitled could be included in a single DCP containing multiple CPLs and single distribution inventory could be used globally, although in practice this has not happened yet.

When dealing with multiple language versions, the common practice is to have a full 5.1 audio track and play-list for each language version. However, there is the possibility of having only the Music and Effects track (M&E) as the 5.1 and including multiple language versions on the other 10 tracks available in the DCP, along with a single play-list. The appropriate language could then be selected, and mixed into the appropriate channels using dynamic metadata. This has two fundamental limitations however. Firstly, there is no server support for such a system. It would require significant software changes in servers to allow the selection of the appropriate language, not to mention the current lack of a dynamic metadata schema. Secondly, a modern 5.1 sound mix will often use effects such as reverb on dialogues and place them in different speakers such as surrounds to give a more natural feel to the sound of the dialogue in a particular scene. This type of complexity in the mix would not be supported using dynamic metadata. That said, this method is of value for special event screenings, for instance an international press screening, where the multiple dialogue languages can be fed over a multi-channel headphone system to the audience. The audience then simply selects the language they want to hear. This technique has been used to great effect already by Disney for a number of international screening events, and is a great example of the flexibility offered by Digital Cinema.

Richard Welsh
Dolby Laboratories

Richard Welsh joined Dolby Laboratories in 1999, after graduating with a BSc (Hons) in Media Technology from Southampton Solent University. Richard started as a Sound Consultant in the Production Services Group and began working in Digital Cinema in 2002. He now manages Digital Cinema services at Dolby including the Digital Cinema Mastering facility at its European Headquarters. The facility provides mastering and distribution services for clients worldwide, as well as being a test-bed for new Dolby Digital Cinema technologies.

4. Keys for Digital Cinema - Devices, Certificates, KDMs and Contracts

Nick Mitchell
Technicolor

During the Digital Cinema mastering process, when a track file is encrypted, a unique key is generated for it. The key is used during the track files encryption process and is the "secret password" required to decrypt it.

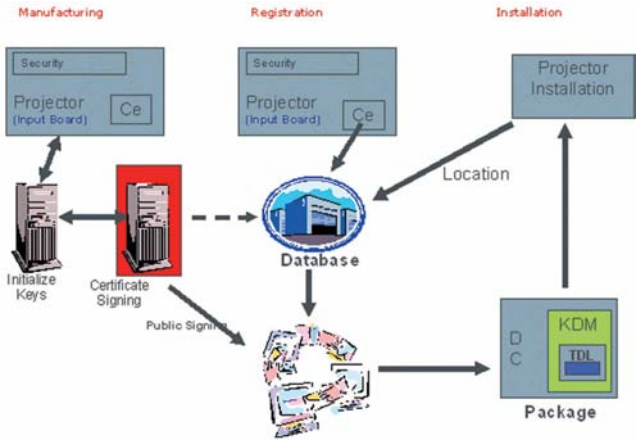
There is a need to securely deliver these keys to a number of recipients, such as theatres, distributors, or other mastering facilities. However, in their native state, each track file key is separate from another and can be used to decrypt its respective track file at any time, by virtually anyone who possesses it. This is an undesirable delivery format, due to the number of keys that may exist for a given composition and the relative ease with which unwanted acquisition and misuse of these keys may occur.

The Key Delivery Message

A key delivery message (KDM) allows the key(s) for one or more track files in a composition to be wrapped up and encrypted in an XML file format that only allows a specific trusted device, or set of trusted devices, controlled access to them. I refer to this as controlled access because the KDM also contains a reference to a specific CPL and the validity date range of the KDM. The CPL reference provides a way to prevent the content from being played in any way other than that which the content creator intended. The validity date range allows for greater enforcement of contractual agreements, as they relate to release and run-through dates.

A KDM is generated targeting a certificate containing the public key of a device the content rights owner specifies. Only the device(s) that have the private key, whose associated public key information was referenced in the KDM, can decrypt the secret keys, thereby obtaining the ability to decrypt the content or generate more KDMs for distribution. If the device certificate is for a Digital Cinema server, that server is able to play back the encrypted content, as specified by the information contained in the CPL with the ID referenced in the KDM. If the device certificate is for a capable mastering system, that mastering system can decrypt the track files and use them just like any other essence files of the same type, prior to encryption.

If the device certificate is for another KDM generation device, that device can decrypt and extract the keys from the KDM, then use them to generate KDMs for the devices for which it has certificates. This is common when one entity or device encrypts and masters content and another creates and distributes the keys for it.



Understanding the Mechanism for Certificates

All of the new Digital Cinema servers, mastering systems, and key generation devices, no matter where they are installed, have a unique set of certificates that relate directly to them. These certificates (based on the X.509 format) provide a mechanism to establish a level of trust between a content provider, distributor, and a vendor's device(s), by using a system of public and private keys. The public keys are contained within the certificate, while the private key is kept by the device. Certificates are essentially descriptions of the devices signed by the vendor that convey the make, model, serial number, role of the device, and most importantly, the proof that the certificate comes from a trusted source.

This proof is acquired by validating the signature chain of a certificate to the root (primary) certificate. A vendor will provide a content provider with the root and signer (intermediate) certificates for each of its device's leaf (end) certificates. The public key in the root certificate is used to issue and verify the validity of the signer certificate, and the signer certificate's public key is used to issue and verify the validity of the playback device's leaf certificates. Additional tiers of the signer (intermediate) certificates may exist in the chain, based upon the vendors security needs, but the method of validation is the same.

Using this signature validation, a content provider can acquire a small number of root and signer certificates and have the ability to validate the very large number of mastering and playback device certificates before importing them into the database used for KDM generation.

The Importance of Validation

If a rogue certificate were to make it into the database of certificates KDMs are generated against, the consequences of the piracy that may result could mean hundreds of millions of dollars in lost revenue. This loss affects every business involved in the provision of content.

When a KDM is generated, it targets one of these certificates. This is most often a leaf certificate for a playback device in a theater, or the certificate for a mastering or KDM generation device in another facility. In either case, the recipient of the KDM, given it has the private key correlating to the public key in the certificate the KDM is referencing, has the ability to decrypt the content. Therefore, each entity that wishes to acquire KDMs for their devices must provide their certificate chain.

A typical certificate database consists of a (relatively) small number of root and signer certificates, and a large number of device or leaf certificates. Managing a certificate database can be a challenge. Servers are constantly being moved around. Some get sent in for repair and are replaced with new ones, while others are being shuffled between cinemas. Tracking these changes requires constant communication with the exhibitors, essentially making a site survey a weekly task rather than a one time event. The industry is also currently in a transitional period in which we are moving from the JPEG-interop compliant certificates and KDMs (Ad-Hoc) to the standardized SMPTE 430-1 certificates and KDMs. During this period, servers can have as many as 3 separate certificate chains associated with them (one for MPEG KDMs, one for JPEG-Interop KDMs, and one for SMPTE KDMs.) By way of example only, the Technicolor certificate database currently contains over 7000 certificates, each one associated with a particular device and each device associated with a particular theater ID. That association may change rapidly, based on the growth and maturation of the Digital Cinema chain. That's just the nature of the business as the deployment of Digital Cinema systems continues its rapid pace.

Certificates were previously exchanged under circumstances that were less than ideal in maintaining a secure environment. This was due in large part to the relatively small community of vendors and integrators involved. However, this is quickly changing. As the industry grows, root and signer certificates will be exchanged under heavy contract, while the leaf certificates may be exchanged freely. This is also an important commercial component of the architecture of the certificates, as it allows last minute, new venue bookings to be accommodated quickly, without ever compromising security.

Nick Mitchell
Technicolor

Nick Mitchell serves as Head Production Engineer at Technicolor Digital Cinema, a division of Technicolor. He has been involved in the development of Digital Cinema Mastering, Packaging and Distribution related technologies for over 10 years, beginning at Entertainment Technology Associates Inc.

Nick assisted in the development manufacturing of the Vecta Digital StillStore which led to the creation of the Avica Technology Corp. and the FilmStore Digital Cinema platform. He was involved in the development, installation and support of servers worldwide, as well as the company's mastering services. Nick joined Technicolor in 2005, and continues to work towards making Digital Cinema successful.

5. Incorporating Subtitle Files into the Digital Cinema Package

Mazin Al-Jumaili - Head of Operations, Visiontext

Subtitles are usually the last thought on anyone's mind when packaging a media format for mass distribution. Multi language audio dubbing is classed as the sexy part of localized enhancement to a product, particularly movies.

I am forever getting last minute phone calls and pleas for a quick turnaround on translation work to meet final deliverables for film, DVD and more recently Blu-ray and internet ready transcodes. Don't get me wrong, distributors do not take subtitles lightly. The need for accurate, intelligent and compelling storytelling is of paramount importance when selling their product to subtitle only territories.

The off-putting feature of subtitling is the cost. There is an outside service premium that cannot be avoided. An expertise that cannot be replicated by the likes of online translator sites or getting your brother's mate to provide a translation just because he happens to have a degree in Italian. Our translators – and they are in their hundreds, based far and worldwide – are vetted and tested incessantly before being taken on. Our priority. 'Tell the story without us noticing we are reading subtitles.' That is art. We don't use machines.

We have been creating and delivering our 'Art' for over twelve years now to the TV, advertising, movie and Internet world at what we consider to be a very high level of quality. Clients pay to maintain that threshold and indeed it needs to be maintained to ensure the world gets a fair and inventive translation of every product that requires interpretation.

Digital Cinema, like DVD and Hi-Definition in its wake, has been through its trials on specification change throughout its conception and rollout. There are very basic similarities that combine the traditional ways of delivery against film print and home entertainment formats with the DC package. A revision in delivery data compilation has been necessary with subtitle generation packages. Working closely with either your internal developers or third party software manufacturers is essential in keep up with the ever changing environment.

Lets use a multi language project as a template
- A widely distributed feature film for a major film Studio.

Timing

Another art. Your translation will be originated in all territories as closely as possible to a final lock reel to reel version of the movie. The ideal scenario would be to have the ability to create a 'Genesis' document that incorporates all aspects of the onscreen visual and audio information. This would accurately document the feet and frame timings of dialogue as well as the duration of each on screen caption. The template would also include scene descriptions, translator and dubbing notes, subtitle spotting and continuity.

Extracting a timed subtitle file matching your Digital Cinema master is then a process of time code conversion. A DCM will be a married up version. i.e. a one or two part master originating at 24fps. The ongoing process then takes on two parts:

Retiming subtitles

Your existing file, whether originated in house or from a supplied foreign language theatrical subtitle list will need conforming to the new master. Your subtitle software package should do most of the import work but you still need a human eye to ensure timing, a comfortable reading speed and placement are at adhered to.

Building your output file

Back when we were first asked about providing subtitles for DC the request was for purely text based deliveries, known as XML. This is always a massive source of confusion in our industry, especially for our clients, so we refer to it specifically as the 'DCSubtitle' as there are several other XML based subtitle formats.

XML

This consists of the header and the body. The header carries key information regarding the Movie asset (name, reel number, language) as well as critical information for the correct presentation of the subtitles, namely the font, font size, colour and style.

Sample header

```
<MovieTitle>Visiontext – A True Story</MovieTitle>
<ReelNumber>1</ReelNumber>
<Language>English</Language>
<LoadFont Id="Font1" URI="Arial Narrow.ttf" />
- <Font Color="FFFFFFFF" Size="28" Id="Font1" Italic="yes"
EffectColor="FF000000" Effect="border">
```

The body then contains a host of information for each subtitle. For each sub, as well as the text itself there is information on in and out times, positioning and fade in/out timing. Extra information relating to each individual subtitle, such as font style can also be stored.

```
- <Subtitle SpotNumber="1" TimeIn="00:01:01:208" TimeOut="00:01:06:052"
    FadeUpTime="0" FadeDownTime="0">
  <Text VAlign="bottom" VPosition="14.00"> - Hello everyone!,</Text>
  <Text VAlign="bottom" VPosition="7.00"> - Hello Maz! </Text>
  </Subtitle>
- <Subtitle SpotNumber="6" TimeIn="00:01:24:229" TimeOut="00:01:27:208"
    FadeUpTime="0" FadeDownTime="0">
- <Text VAlign="bottom" VPosition="14.00">
  <Font Italic="no">- Move it, out of the way.</Font>
  </Text>
- <Text VAlign="bottom" VPosition="7.00">
  <Font Italic="no">- Oh, careful.</Font>
  </Text>
  </Subtitle>
```

One of the drawbacks of delivering this way is that we don't have full control of the appearance of our subtitles. Each different model of projection system can vary slightly in how it displays any given font. Whilst a font should in theory be universal, we've come across instances in the past where either by corruption or modification, two supposedly identical fonts are not. This can be something as minor as differences in the kerning table to actual missing or miss-assigned characters. Whilst improperly justified text may go unnoticed, squares in the middle of words or incorrect characters rarely do!
A problem with either the font or the data file in the form of a corruption can easily mean that no subtitles will be projected at all.

The benefit of this format is essentially the size of the asset and it's compactness. A 90 minute, 1000 caption movie excluding the font will be around 300k in size and requires only 2 files to work, insignificant compared to the bandwidth required for the media itself.

PNG

The other method for displaying subs is the sub picture method, using PNG (Portable Network Graphic images) These are high quality compressed, but lossless raster files with the useful feature of having an alpha channel setting for each colour in their palette. In basic terms, it means each colour can also be transparent to a different degree. Very useful for producing smooth, easy to read subtitles with no aliasing.

In supplying sub pictures, rather than relying on the DC hardware to generate the images 'live' from text, the images are pre-rendered in house. This option gives us much more control over the final look of the subtitles.

This is a more complex and much larger delivery (15-20Mb for a 90minute, 1000 caption movie) but removes any variation in font reproduction and in the unlikely event of any file corruption; only a single caption should be affected.

Rather than 2 files, a delivery will contain a PNG image for each subtitle and a control file very much along the lines of the normal XML delivery, but in place of the subtitle text and style information there's a reference to the image file name and the co-ordinates at which it should be displayed. No transparency information is required as this is held in the image itself.

Summary

The beauty of reformatting subtitle files for Digital Cinema packaging use for suppliers such as ourselves will initially be the additional reformat revenue that is now available outside of traditional delivery requirements of Distributors.

As and when more territories require subtitled packages per title - and at this point there are only a handful that have a sole requirement – we can see the attraction of the 'Genesis package template' being more and more useful for Distributors especially with the onset of more variable formats utilizing the same content.

Once Digital Cinema Packages are the norm for Studio releases, saturating every territory with local dubbing and subtitling requirements - replacing traditional print, we as translation and subtitling services can add to our main arm of revenue by taking advantage of the reformatting needs. We will be a required partner rather than an outside service to a DCP creator. As DVD disappears over the next few years we can move to Digital Cinema as a worthy replacement.

At last, subtitling services take a step out of the shadows.

Mazin Al-Jumaili has worked with Major Studios such as Paramount and Universal in Video and DVD Distribution for the last ten years. Mainly overseeing creation and distribution of Multilanguage DVDs. He has worked closely with DVD Authoring, Post Production and Subtitle houses worldwide. Now Head of Operations at Visiontext, Ascent Media's subtitling arm, Mazin's remit is to balance traditional subtitle delivery methods with new media demands which include the emerging Digital Cinema domain.

6. MXF Primer

Peter Wilson
Director of the
EDCF Technical Support Group and Board Member

What is MXF?

MXF stands for Material Exchange Format, its origin stretches back to the mid 1990s when it was realized that there was a need for a standardized File structure for program production and exchange. The initial work was carried out by a task force of EBU and SMPTE members who created a table of user requirements. A substantial team of people then developed MXF with the end result that a series of SMPTE standards was produced, with the core standard, SMPTE 377M.

The general concept of MXF is that of a file wrapper enclosing both the content and its associated metadata. The simplest way to look at MXF is to describe a typical piece of complex confectionery.

We start with the wrapper
The wrapper contains human readable text with:
• The brand • The product
• The ingredients • Extra data
The wrapper encloses the confectionery with:
• The ingredients • A chocolate covering
Within the chocolate covering are the ingredients, which include:

• A layer of nuts • A layer of caramel • A biscuit layer
The confectionery wrapper can have a description that includes:
• The ingredients • The Dimensions • The energy value
• The 'sell-by' date.

MXF is:

- A file Interchange format
- An extensible wrapper format
- A compression agnostic file format
- A versatile file format
- A metadata aware file format
- A Streamable file format

MXF also allows editable packages with simple cuts.

How does Digital Cinema use MXF?

In the case of Digital Cinema files we start with a list of elements to be assembled. The list contains human readable text and includes a key item called a **Universally Unique Identifier (UUID)** which is a number that is unique to the list. The list includes:
• **The composition playlist** to explain to the media block / server how to playback the large number of files at the required time.
• **The picture files** with relevant **metadata**.
• The individual **audio track files** with relevant **metadata**
• Other payloads such as **XML subtitle files**
Digital Cinema files can be encrypted for security.

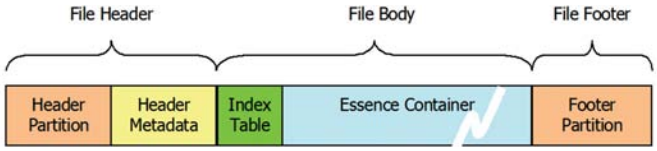
MXF structure

At the lowest level

MXF ensures extensibility by using KLV coding throughout the file where:
K= Key: a unique identifier
L= Length: how long is the field
V= Value: what is the value of the field
N.B. The key in KLV does not have a connection with the security keys.

At the highest level

MXF contains basic file components in the form of **Partition Packs**, **Header Metadata**, **Essence Container(s)** and **Index Tables**. A typical configuration of components in an MXF file is illustrated below:



Unique Identifiers

MXF uses unique identifiers exclusively and uses two general forms:
• **Universal labels (UL)** which are registered numbers. ULs in MXF are registered by SMPTE.
• **Universal Unique Identifiers (UUID)** are numbers having no meaning, but are unique.

ULs and UUIDs are both 16 bytes long (128bits) and can be used together, with no possibility of being confused for one another. If generated according to one of the approved algorithms, any UUID should be different from all other UUIDs generated until 3400 A.D.

XML - eXtensible Markup Language

This is now a common computer language which defines a generic syntax used to mark up data with simple, human-readable tags. MXF does not use XML as such, but the Header Metadata can be exported from (and imported to) MXF files.

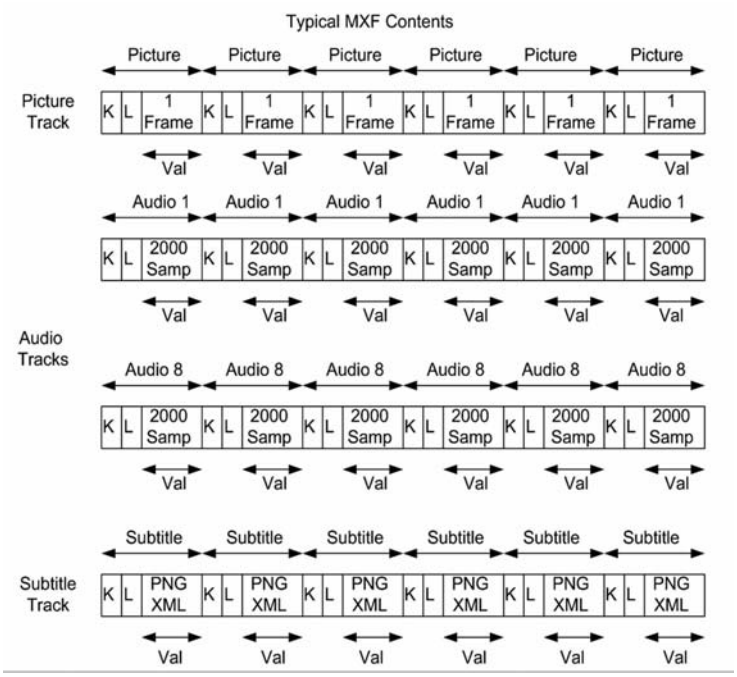
Operational Patterns

Operational Patterns (OP) are used to define the complexity of the MXF files. The coloured table opposite shows some of the more common patterns.
• MP stands for Media Package • FP stands for File Package
Reading across the top you have the OP number and reading down the left side you have the OP suffix.
The simplest pattern is OP1a which equates to a file version of the humble VCR. To date this is the predominant OP used by MXF equipment.
• OP1 is used for single items and would typically consist of a file containing a complete set of Picture, Audio and metadata tracks with a fixed length which fills up the file package.
• OP1a allows for 1 set of material packages in one file package
• OP1b allows for there to be more than one ganged file package
• OP1c allows there to be alternative material packages
• OP2 allows a timeline to be built up from several concatenated OP1 file packages

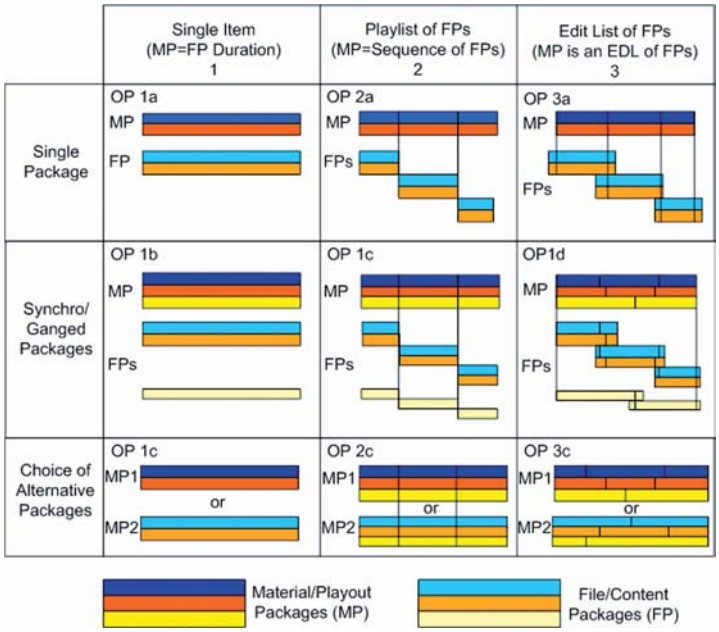
• OP3 allows playout of overlapping file packages according to an internal cut list.

In fact Digital Cinema uses a constrained version of a pattern called OP Atom. OP Atom was originally invented for non linear editing where there is a jumble of possible files.

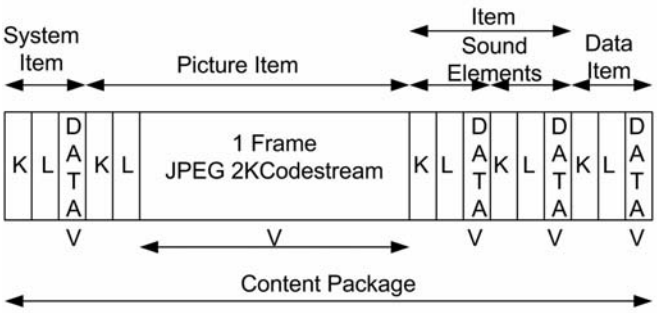
The original picture, sound and Subtitle data is called **Essence.** The essence is wrapped in the above mentioned KLV package. An MXF file may contain more than one essence container and each essence container may contain different essence types.



In the example above the file contains six frames of picture essence, audio track 1, audio track 8 and the subtitles, which may be Portable Network Graphics (PNG) or XML files.
Any number of tracks defined in the Operational Pattern can be used. In addition to the main essence there can also be a significant amount of metadata carried to, for example, control Dynamic sound mixing. How MXF carries this downmix metadata is controversial and still not resolved.



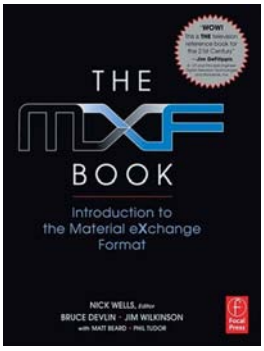
While the above drawing represents a selection of time coincident data this is not how it is carried within the outer wrappers. The Picture and sound essence are placed into content packages, these files are joined together in a sequential manner called interleaving with additional metadata files.



DC28 in fact decided not to interleave except when interleaving a single essence type (e.g. L-R pictures and 16-channel audio). Pictures, Sound and Subtitles are separate Track Files that are played out according to the Composition Playlist. Multiple Content Packages are combined into **Track Files**. Track files are self contained elements but must be associated with a reel. A reel is conceptually the same as a Film reel. It can be variable length with the proviso that the length is in integer frames. Track files cannot cross over a reel boundary.

At a higher level is the **Composition Playlist**. This is a file which contains all the information on how the movie package is constructed for playout. The Composition Playlist is generated as part of the mastering process and comprises metadata that defines the composition of the movie. The XMl composition playlist uses a form of Timecode embedded in the MXF and instructs the media block / server how to playback the reels (i.e. the Track Files) in the right sequence and render the essence in the right temporal space to assure picture, sound and subtitle synchronism. A secondary benefit of the Composition Playlist is that it can contain more than one way to render the essence (playback) to, for example, support different censor versions or audio tracks.

This primer is of necessity somewhat simplified, for those readers who wish to study the detail there is The MXF Book which has 390 Pages of detail. ISBN 13: 9780240806938 Parts of the DC 28 standardisation work are published as SMPTE-429; it is possible to join the SMPTE DC 28 work as an observer or participant if one is a member.



Thanks to Jim Wilkinson for his help with this section.

Peter Wilson
Director of the
EDCF Technical Support Group and Board Member

7. Dealing with Specialist content

Rich Philips
Arts Alliance Media

The DCI specification and the related standardisation work taking place within SMPTE has provided the industry with the foundations of a truly interoperable and secure system for mastering, distributing, and reproducing faithfully very high quality presentations to match the capability of today's and tomorrow's digital cinema projectors.

Understandably the standards are biased towards the studios' requirements for new content and have been conceived to fit in well with the Digital Intermediate post production process, providing a ready source for the X'Y'Z' colour space converted TIFF files that make up the Digital Cinema Distribution Master (DCDM) defined by DCI.

It is notable also that the standards only officially support the two main aspect ratios in common use today for new feature films – 1:1.85, known as "flat" and 1:2.39 – "scope". For audio, it is expected that content will be supplied as a 5.1 audio mix as a minimum. The frame rate is expected to be 24fps for 2K and 4K (with the addition of 48fps for 2K only so that enhanced temporal resolution may be supported in the future)

There is of course, a vast library of content that doesn't neatly fit these specifications. Digital cinema has the potential to increase access to "specialised" titles including archive content and low budget drama and documentaries. The reduced distribution costs allow a limited print budget to reach a much wider audience, and the capability to easily re-package foreign language versions with different audio tracks or subtitle languages allows for a wider release. Older titles for which only a handful of prints still exist can potentially enjoy renewed theatrical interest. Making these titles available as Digital Cinema Packages means working within the specification set by DCI as far as possible, adapting its use to specialised content.

The assumption of a digital intermediate post process with a possible re-grade for digital cinema presents high barrier costs. Some major archive titles may have been through a digital intermediate system during their restoration, making it relatively easy to produce the DCDM Tiff files requires, but most will not have done. The cost of rescanning and re-grading a film version to produce a DCDM may not be worthwhile. HD video masters can be used as an input source, but it is preferable if they have been graded using a digital cinema projector as reference, and within a wide colour gamut. It is more likely that an existing HD video master graded in Rec.709 on a CRT monitor is all that will be available. In either case, the material needs to be converted into X'Y'Z' colour space using appropriate look up tables (LUTs), paying close attention to gamma. This can be done either by capturing the HD video and generating the DCDM Tiff files frame by frame, or, for some mastering systems, by generating the JPEG2000 compressed files directly from the HD video capture, applying the colour space transformations and gamma conversions in real time. In some cases that will include spatial resolution conversion. Using HD video is a compromise compared to an uncompressed 12 bit X'Y'Z' Tiff file source, but the results can still be very good.

Many other aspect ratios have been used in the past, such as 1:1.33, 1:1.37, 1:1.66 and the specifications do not deal directly with the question of how these should be supported. Following the spirit of the DCI specification, the logical approach would be to represent the active pixels in image containers to suit the aspect ratios. However, this is not currently practicable as mastering systems do not typically support this approach, and not all playback servers will support playback on picture assets in non-standard image containers. The alternatives are either to use the "flat" DCI image container of 1998x1080, or to adopt the HD image container of 1920x1080 pixels and pad out the unused parts of the image container with black pixels. 1920x1080, although not directly specified by DCI, is supported by most playback servers.

Frame rates other than 24fps are often encountered, particularly in Europe where video originated material, or material intended primarily for video release may only be available in 25fps. No playout servers currently support 25fps JPEG2000 playback, so these must be retimed to 24fps, with audio stretched and possibly pitch corrected to compensate, and care taken with retiming and resynchronisation of subtitle files. Interlaced material must be avoided.

[Note from Peter Wilson: At Cinema Expo 2006 the formation of a SMPTE DC 28 study group was authorised to evaluate the need to add Additional Frame Rates to the Digital Cinema system. The study group has produced a document supporting the need for additional Frame Rates including 25 & 50 FPS complimenting the 24 and 48 FPS initially selected by the DCI. The next step is to form an AD Hoc group to generate the standards documents.]

For audio, many older titles may not have a 5.1 mix available at all. Some will be stereo. Some might be mono. Experience has shown that mono titles are best handled by routing the mono audio track to the centre channel rather than using the left and right. This locks the dialogue to the middle of the screen much better. In any case, it is important that the standard current 5.1 channel mapping arrangement is followed.

Specialised content, as well as mainstream content, can be prepared for digital theatrical release to be interoperable with all digital systems meeting the DCI specification. Input materials other than DCI specification DCDM files can be used as source material, and aspect ratios, frame rates and audio configurations other than those specified by DCI can be accommodated. Digital cinema unlocks considerable potential for archive and non-mainstream content.

Rich joined Arts Alliance Media in February 2003 as Head of Technical Operations for Digital Cinema to oversee early digital cinema trials across the City Screen cinema circuit, and to provide the technical expertise to deliver AAM's successful bid for the UK Film Council's Digital Screen Network, their initiative for using digital cinema technology to increase access to specialised film. Since the award of that project Rich has been responsible for delivering the theatre systems integration, and content mastering and distribution systems to support that contract. He is also responsible for all technical aspects of AAM's other digital cinema activities, including research and development for future projects, and has built the content preparation pipeline to support AAM's Digital Home and VOD operations.

Before joining AAM Rich ran a consultancy designing and building technical systems for broadcasters and post production houses, including the BBC, Channel 4, MPC and Ascent Media. Prior to that he cut his teeth working as an editor and then as an engineer for 10 years in broadcast post-production.

Rich has a B.Eng in Electrical and Electronic Engineering from Nottingham University, sits on the BKSTS Cinema Technology Committee, and is a member of SMPTE.

8. Digital Cinema Mastering
Where it is at - Summary

Digital Cinema mastering is in its infancy, and interoperability issues still rear their ugly heads regularly.

There are several approaches to this from a technology perspective, you may wish to purchase a proprietary mastering station which may be based on a server system with some additional horse power available from hardware / software coprocessors or you may wish to carry out the process completely in software if you already have a large render farm facility as part of your existing DI business.

Storage systems and their licences can be a significant cost as can be physical upgrades to your premises to support Digital Cinema Projection for the QA process.

Though many of the preparation processes are similar to current Digital processing for film and audio much care is needed with the detail of content preparation.

Another issue is the manpower profile - are the current staff suited to the new job, how will you retrain them?.

Is the business worthwhile? Most early players have entered the market to secure an existing client base as much as invest in a new business area.

So to conclude, it is early days, but the train has well and truly left the station heading for commodityville.

Peter Wilson

Peter Wilson, who set up his company High Definition and Digital Cinema Ltd. in 2005, specialising in hi-tech consultancy and training, has had a fascinating and wide-ranging career, constantly managing to be at the forefront of pioneering technical developments in television and film.

After an electronic and mechanical apprenticeship, he worked in TV studio engineering, before joining Sony Broadcast, working on TV and recording developments. He moved into High Definition TV early on, working on demo production at Channel 5 in Italy, where he was technical facilitator, and later worked on the ground breaking RAI feature movie Julia and Julia, which used HDTV production techniques for eventual transfer to 35mm for distribution. Peter's role as technical facilitator was to bring together all the then new technologies involved in HD production and the subsequent transfer to film using the Sony Electron beam recorder.

He developed a reputation as a practical engineer who can make things work, which provided the openings enabling him to work on the 1986-1990 Montreux Jazz Festival HD Recordings, the first regular musical productions captured in HDTV, and on the HD production for the 1987 Genesis at Wembley concert, the first ever multi-camera live concert captured on the High Definition Video System, transferred to 35mm using the Electron Beam recording process and then blown up to 70mm.

Digital Cinema has long been part of his life. Peter organised the technical facilities for the first Digital Cinema Demonstration at IBC Brighton in 1988, and was technical facilitator for the 1989 BBC NHK HD Co-production "Ginger Tree", using the High Definition Video System.

Working for Sony Europe he set up Europe's first HD - 35mm Film-out facility using Electron Beam recording technology, and got himself involved in numerous HD car product launches including Fiat, Mercedes and BMW. He joined Snell and Wilcox as Product Manger and Product Planner for HD and Display Products. He was chosen as co-facilitator for the UK DTI 'Celluloid or Silicon' road show in 2001, and in 2003 became Chairman of the EDCF Technical Module, where he continues to work hard on Digital Cinema interoperability matters. Somehow he also manages to carry out training on HD and Digital Cinema matters, and is a respected lecturer in several European countries.

9. EDCF Glossary of Digital Cinema Terms

Angelo D'Alessio,
Cine Design Group

The Beautiful Chaos of Digital Cinema terminology.

The use of digital technology and digital processes through the "film" chain is modifying the workflow and changing the terminology used by professionals. After a century of celluloid, the whole business model and the Art of "film" features is now changing.

Digital projection has already shown the benefits of digital techniques and the whole digital film business is moving forward. To understand the potential of digital cinema, this glossary includes terminology about the Mastering, Distribution and Exhibition of D-Cinema supply chain. Digital cinema can offer viable benefits if everyone involved in the supply chain understands and has a basic knowledge of both sections.

The key purpose of this EDCF Glossary is to facilitate and help new professionals entering into the "Beautiful Chaos" of digital Cinema!

EDCF DIGITAL CINEMA GLOSSARY

Active picture
The area of video frame which carries image information.
Adaptive white
A color that an observer, adapted to a set of viewing conditions, would judge to be white.
Alternative Content
Content available through a digital cinema system that would typically occur on a "one-off" basis or "off-peak hours" run basis. Sometimes referred as "non-traditional content".
Alternative Content Fee (ACF)
This is a fee that is paid when alternative content is played.
Answer print
A print made from the cut original (camera) negative with proposed final color timing and soundtracks, furnished by the printing lab to the producer for acceptance of image and sound before screenings and manufacturing begin. The check print is similar, but is made from the internegative. A black track answer print has no soundtracks.
Asset
Audio and video material complete with rights of ownership or for publication. Material without rights has no commercial value. The following figure represents the Media Asset and its components.
Artefact
Particular visible effects which are a direct result of some technical limitation.
Bit Depth
The total number of bits available to represent each pixel or color sample in a digital imaging system, or the bits available to represent each sample in a digital audio system. Using linear binary coding, the total number of resolution steps available is equal to 2 raised to the power of the bit depth.
Brightness
The property of a surface emitting or reflecting light. In lighting, it is our impression of the amount of light received from a surface. It is measured in candelas per square metre and is called luminosity in the USA.
Cataloguing
Adding meaningful metadata to a stored asset to ensure that it will be easy to find in future with any relevant searches. This involves adding cross-references as the asset may be important to a number of separate subjects and generally creating the metadata needed to allow maximum us of the asset.
Calibration
The process by which a device or system is brought into the condition whereby a defined input produces a defined output.
Checkerboard contrast
The intra-frame contrast in which the black and white patches in an image are arranged in alternating pattern. In this case, the white luminance is measured as the sum of the white luminance of each white patch and the black luminance is measured as the sum of the black luminance of each black patch as long as the number of white and black patches is the same.
Chromaticity diagram
A plot of the x and y chromaticity coordinates in which the x coordinate is plotted on the abscissa and the y coordinate is plotted on the ordinate. There is a similar u', v' chromaticity diagram, but it is not used in this guideline.
CIE
Commission Internationale de l'Eclairage, an international organization responsible for photometry and colorimetry.
CIE Standard Colorimetric Observer
An observer with spectral sensitivities that exactly match the CIE 1931 color matching functions.
CIE tristimulus values
The X, Y, and Z values determined by the data and equations defined in 1931 by the CIE for the Standard Colorimetric Observer.
Colour appearance
What a colour looks like to an observer. Colour appearance depends in many factors including absolute luminance, surround luminance, adaptation of the observer, etc. Colour appearance differs from colour measurements in that the same measured colour will change its appearance as the environment in which the colour is observed changes.
Colour decoding
The definition of a relationship between colour information and numbers. Decoding is the conversion of the numbers, also called code values, into colour information.
Colour encoding
The definition of a relationship between color information and numbers. Encoding is the conversion of the colour information into the numbers, also called the code values.
Colour gamut
The limits of the colours that can be displayed by a system. Also the limits of the colours that belong to a set of colours that are mathematically defined.
Contouring
An image artefact in which there is the appearance of steps or bands where only a continuous or smooth gradient is expected.
Central Storage
A central location where the packaged Digital Cinema content is stored for a multiple
screen installation.
Composition
A motion picture, trailer, advertisement, etc. Composition consist of Metadata Composition Play List along with the

Essence and other Metadata track files that define the work.

Conform
Making the final frame or image sequence according to a prepared scheme or EDL.

Chromaticity
The color aspect of light which includes hue and saturation, but not brightness.

Chrominance
The part of the video signal which conveys color hue and saturation information as distinct from luminance. Also called chroma.

Color correction
Changing the color balance or other characteristics of an image to improve the subjective image quality.

Color gamut
The range of colors allowed in a specific system, as defined within a triangular area located on the CIE color locus diagram whose corners are the three primaries of the system.

Conditional access
An entitlement control system that permits access to information only when specific cryptographically enforced conditions are met.

Cryptosystem
The entirely of methods and equipment used to protect content by cryptographic means, including scrambling and encryption, conditional access, key management, physical security of equipment (but not premises), and watermarking. It may also refer to all associated plaintexts and ciphertexts.

CineFence®
Video forensic marking technology developed by Philips.

CineLink(TM)2
The technology that encrypts the link between the media player and the projector. This technology supports the DCI specifications for strong link encryption.

CPL – Composition Playlist
A Composition Playlist consists of all of the essence and metadata required for a single presentation of a feature, trailer, advertisement, or logo. A single CPL contains all of the information on how the files are to be played, at the time of a presentation. There is a separate CPL for each version of a motion picture/feature (composition).

Digital image
An image defined by code values.

DCP – Digital Cinema Package
The DCP is the set of files that result from the encoding, encryption and packaging processes. A DCP may contain multiple CPLs.

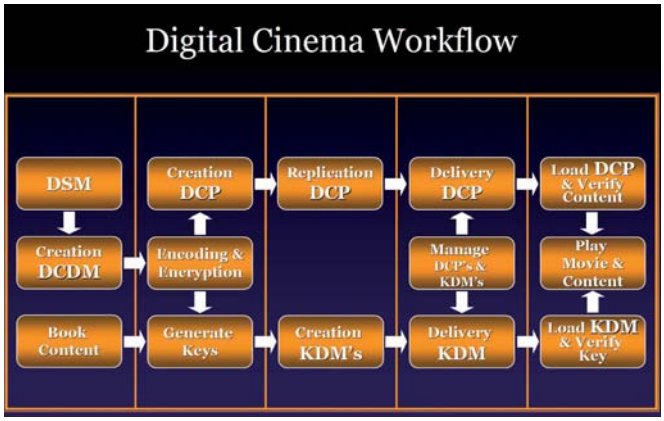
D-Cinema
A contraction of digital cinema. In the classic model the entire production chain from scene to screen is a digital process, with images first captured and processed digitally before then being compressed, encrypted and transmitted via satellite, broadband or disc to cinema theater for digital projection. Standard work is addressed by SMPTE DC28 Task Force on Digital Cinema

DC28
A standards committee composed of members from the Society of Motion Pictures and Television Engineers (SMPTE). The 28 refers to the number of groups required to oversee the various components of the digital cinema transition.

DCDM - Digital Cinema Distribution Master
A master set of files that have not been compressed, encrypted, or packaged for Digital Cinema distribution. The DCDM contains all of the elements required to provide a Digital Cinema presentation.

DCP - Digital Cinema Package. The set of files that are the result of the encoding, encryption and packaging process.

Definition
A description of sharpness or clarity of a picture. High definition pictures portray a lot of detail, while low definition pictures look soft and less clear. See also resolution.



Digital image
An image defined by code values.

Digital Cinema Projector
A Digital Cinema Projector is one that conforms to the DCI specifications. The available options in the marketplace today are those equipped with Texas Instrument's DLP Cinema® chip or Sony's SXRD® technology.

Distribution Package
The collection of files delivered by the distributor to the exhibitor. A distribution package may contain pieces of a composition, a complete composition, replacement/update files, etc.

DSM – Digital Source Master
The Digital Source Master is created in Post-Production and can be used to convert into a DCDM (Digital Cinema Distribution Master). The DSM can also be used to convert to a film duplication master, a home video master, and/or a master for archival purposes.

DLP
Texas Instrument's Digital Light Processing digital projectors, which use arrays of tiny mirrors mounted on DMDs (Digital Micromirror Devices) to project the image. Currently over one million DLP-Based systems have been sold worldwide (though very few of this number to date have been cinema projectors).

DPX
SMPTE file format for digital film images (extension .dpx) – ANSI/SMPTE 268M-1994. This uses the same raster formats as Cineon and only differs in its file header.

Encode (Compression)
In order for the digital cinema file to be a manageable size, it is compressed. A typical uncompressed feature can be approximately 2 Terabytes (TB) in size. After the compression process, those files may range between 150-250 Gigabytes (GB). This size file, while still large, is more easily delivered.

Encryption
Encryption can be considered as putting a lock on the content. The content is transformed by applying the encryption algorithm in conjunction with the encryption key. During the encoding process files must be encrypted to allow for secure transport of feature content. DCI adopted the AES (Advanced Encryption Standard) 128 bit encryption. AES 128 is the standard approved for U.S. government information classified to the SECRET level. Encryption is thus Hollywood's primary concern (fear) when it comes to digital cinema.

End-to-end Security
The consistent application of security measures across an entire process or system (the cryptosystem) such that the most vulnerable elements are sufficiently strong to maintain the desired level of security overall.

Essence
That part of the program data representing the image, audio or text that is directly presented to the audience.

Event Play List
A play list of compositions, describing an assembly of compositions in sequence. An event play list is typically created by content distributor and transferred to exhibition.

Expert viewing test
An assessment session based on the opinions of expert assessors, in which judgements are provided on visual quality and/or impairment visibility.

File
A structured collection of data characterized by a metadata header and a single body of data payload.

Frame rate
The number of pictures presented or recorded each second. It is measured in frames per second.

Gamut mapping
A process by which one color, which a device cannot produce, is replaced by another color, which the device can produce.

Gray scale
The series of achromatic colors from the lowest luminance to the highest luminance.

HVDLT
Human Vision Delta Luminance Threshold. This is the minimum change in luminance that a group of people can correctly identify 50% of the time. See also HVMT from which this is derived.

HVMT
Human Visual Modulation Threshold. This is the minimum modulation that a group of people can correctly identify 50% of the time.

Image State Diagram
A diagram showing the various states in which an encoded image can exist. There are three states, the Scene Referred State, the Output Referred State, and the Input Referred State. An image can be transformed between any two states.

Integration
Making one system, application or set of data work very closely with others. Ideally, the distinctions and boundaries and barriers between the separate parts should disappear as the integrated system or information works seamlessly - as one. This is a very 'deep' form of interfacing and goes a great deal further than simply interchanging information with a third party. The use of industry-wide standards is essential if extensive integration is to be achieved.

Interface
A means of passing on information from one application to another. Interfaces can either be proprietary, in which case only one or a chosen few applications can use it, or open with the interface details publicly available and, best of all, complying with the appropriate international standards.

Interoperability
The ability of systems to interoperate – to understand and work with information passed from one to another. Applied to television this means video, audio and metadata from one system can be used directly by another. Digital signals may be originated in various formats and subjected to different types of compression so care is needed to maintain interoperability.

Intra-frame contrast
The ratio of the luminance of the white divided by the luminance of the black, normalized to a denominator of 1,when the white and black that are measured are projected onto the screen in the same image. This is usually expressed as number:1, for example 2000:1. See also checkerboard contrast.

ISDCF Voluntary Naming Convention
The most significant information about the DCP is contained in the first 40 characters of the CPL text fields due to limited display space of certain DC servers. Additional information is included for servers that can display more than 40 characters.

JPEG 2000
A wavelet-based image compression standard. It was created by the Joint Photographic Expert Group (JPEG) committee with the intention of superseding their original discrete cosine transform-based JPEG standard. It is the compression method specified by DCI for digital cinema picturetracks.

KDM – Key Delivery Message
The KDM provides the method for securely delivering content and key elements. A KDM contains the 'keys' to unlock the elements of a CPL for a specific device. If a DCP contains multiple CPLs, a unique KDM is required for each different CPL, and can only be generated for devices on the Trusted Device List (TDL).

Kell Factor
The vertical definition of a scanned image is only around 70% (the Kell Factor) of the line count due to a scan's inability to show detail occurring between the lines. Note that, for interlaced scans, vertical definition is further reduced by the Interlace Factor to 50% or less overall during most vertical image movement.

Legacy
Something that is influenced by or a part of the past. As much as new applications and technologies spring up, most times even these bright new ideas are steeped in legacy - they are not a clean break from the past.

Library Management Server® (LMS)
A group of servers and networking components that are integrated and tested to create a powerful central hub for all communication needs in the multiplex. It allows central storage of all movies, alternative content, trailers, advertising and more. This component networks the theatre, increasing the value of the individual components on each screen.

Local Storage
A storage device that is associated with the individual playout device.

LSDI
Large Screen Digital Imagery. Is a family of digital imagery systems applicable to programs such as dramas, plays, sporting events, concerts, cultural events, etc, from capture to large screen presentation in high resolution quality in appropriately equipped theaters, halls and other venues.

Luminance
A measure of the energy being reflected or emitted by a surface and in which the energy is weighted by the CIE V(λ), also called the CIE y-bar color matching function. Luminance is an approximate correlate of brightness. The Y value in the set of CIE XYZ tristimulus values is the luminance.

Luminance factor
The ratio of the luminance of a sample divided by the luminance of a perfectly reflecting or transmitting object when both are illuminated identically.

Mastering
Mastering indicates the set of those technical activities that lead to the finished edited master of a program, which normally materializes the creative intent of its authors.

Media Server
Each digital cinema projector requires a media player to decompress and decrypt Digital Cinema Packages (DCP), allowing the content to be played on the associated projector. There is one media server for every projector in a multiplex.

Metadata
Data about data. For programme material this might include the title, duration, time and date, copyright details, location or type of programme. Metadata has become a vital part of storing digital content, image and audio, in large archives to enable it to be found again easily. Information that is considered ancillary to or otherwise directly complementary to Essence. Any information that a content provider considers useful or of value when associated with the Essence being provided.

MXF
The Material Exchange Format is aimed at the exchange of program material between file servers and is a format for tape streamers and digital archives. It usually contains one complete sequence but this may comprise a sequence of clips and program segments. MXF bridges file and streaming transfers, helping to move material between AAF file-based post production and streaming program reply using standard networks. The MXF body carries the content that can include MPEG, DV and uncompressed video and contains an interleaved sequence of picture frames, each with audio and data essence plus frame-based metadata.

NexGuard®
Video forensic marking technology developed by Thomson.

Redundancy
In order to offer 24/7 uptime, there has to be protection against equipment failure. A good way to provide this is to provide redundancy that avoids any single point which could cause an unrecoverable system failure. As many may be relying on the continuous running of a server, the extra cost of redundancy is often justified.

Primary
A color from which other colors are made by addition or subtraction. The Reference Projector primaries are red, green, and blue and all other colors are made by addition of light from each of these primaries. The DCDM encoding primaries are X, Y, and Z, which are imaginary primaries, and by which all other colors are defined.

Rights
Material can only become a valuable asset if it has rights to its use. Such information which defines the allowable circumstances of its use needs to be associated with the material as a part of its linked metadata. For example, rights may be granted for broadcast on a certain channel at a particular time. At the same Rights Protection prevents the use of the asset where it is not licensed.

Review room
A theatre in which decisions are made about images projected onto a screen.

RPGB
Reference Projector Gamut Boundary, the limits of the colors that can be displayed by the Reference Projector.

Saturation
The colorfulness of an area judged in proportion to its brightness. On a chromaticity diagram, the saturation of a color increases as its distance from the white point on the diagram increases. Also, on a chromaticity diagram, the points that plot at the same xy coordinates, but have different Y values, form a series in colors that have the same saturation, but different brightness.

Sequential contrast
The ratio of the luminance of the white divided by the luminance of the black, normalized to a denominator of 1,when the white and black that are measured are projected onto the screen as full frame images. This is usually expressed as number:1, for example 2000:1.

Show Play List - SPL
A Play List of Compositions, Play lists and Event Play lists, describing a sequence that occurs at a particular screen. A Show Play List is typically created by exhibition using theatre management software to transfer screen ads, trailers, features to the equipment controlling a particular screen..

StEM
Standard Evaluation Material. Also called the ASC/DCI Standard Evaluation Material or the DCI-ASC Mini-Movie. Motion content that was shot on film, scanned, and used for D-Cinema and image quality testing. The material is available from SMPTE as of the writing of this guideline.

Transfer function
The equation that shows luminance as a function of the DCDM Y′ code value, Y = f(Y′), Equation 6-5.

TDL – Trusted Device List
The TDL is list comprised of digital equipment installed in theatres for which studios or other rights owners have given their approval to these 'trusted' devices to play their content. KDMs are only created for devices on the list. This adds another level of security to the DC process.

Transport and Delivery
Digital Cinema Packages (DCPs) and Key Delivery Messages (KDMs) are transported either physically on media (such as hard drives) or electronically via satellite. When the DCP arrives at the theater and is loaded, it is unpackaged, decrypted and decompressed for play out by the projection equipment.

Watermark
Watermarking refers to the type of technology used to embed information, including content usage rules, securely into a video or audio signal. Watermarks are designed to be imperceptible by the audience, and they travel with the content even over analog interfaces. Watermarks are directly embedded into the actual content itself and therefore are difficult to remove. Furthermore, watermarks survive and "travel with" content as it is converted from digital to analog form or is re-digitized from analog back into digital. While watermark technology permits content protection rules to "stay with" content, watermarks do not, in and of themselves, protect the content. Watermarking is simply a technology for signaling information and usage rights to devices that may receive the content.

Wrapper
A digital container that contains program Content and also defines and describes the structure of the Content.

Visually Lossless
An image is considered visually lossless when the processed image is indistinguishable from the unprocessed image under normal theatrical viewing conditions.

XYZ
A shorthand notation for the CIE tristimulus values.

X′Y′Z′
A shorthand notation for the DCDM encoded code values. Notably, the DCDM encoded code values are normalized to a maximum code value of 4095 and have a non-linear transfer function of 1/2.6.

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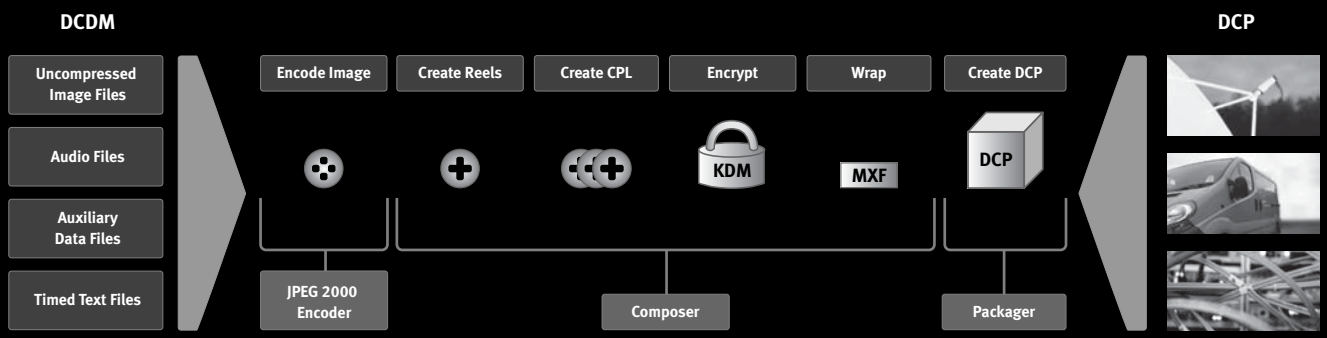
He is President of MIC – Media Innovation Center, for research, innovation, application and training methodologies for advanced media applications and is a Consultant and Teacher for the Digital Cinema Section at the National Cinema School, Italy, and Teacher of Digital Cinema at the International Academy for the Art and Science of Images.

Angelo is SMPTE Director, International Sections, and Chair of the EDCF Educational & Training Module. He is Consultant for the ANEC – National Association of Theater Exhibitors
He is a participant at the National Commission - Ministry for Communication for ITU R 6 & 9 working group, and Coordinator at Istituto Luce-Cinecittà for the Digital Film Archive and related MAM.

"In a word, Impressive."

PETER DOYLE, SUPERVISING DIGITAL COLOURIST – *HARRY POTTER AND THE ORDER OF THE PHOENIX.*

Harry Potter and the Order of the Phoenix — total DCP size 60 GB
JPEG2000 encoded and packaged using the Dolby SCC2000



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