CinemaDNG
Image Data Format Specification

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Revision History

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September 2011 Version 1.1. Major changes include: revised MXF structure and key values to match ST 2055; removed irrelevant TIFF tags from Annex; demoted file structure to Annex. Added details on time code. Added Reel Name and Camera Label tags. Added notation on recommended metadata tags. Added Annexes on initiative, format evolution, application notes. Minor corrections to all sections. Removed unused normative references.

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Introduction (Informative)

This document defines the CinemaDNG image data format.

The CinemaDNG format is designed for storing high-resolution image streams in camera raw format.

Key Features

CinemaDNG is an open, documented format leveraging standard formats for video and imaging — DNG, TIFF, TIFF/EP, MXF, XMP. Each image is encoded using the DNG image format. The image stream can be stored in one of two formats: either as video essence in an MXF file, or as a sequence of image files in a file directory.

CinemaDNG can be used with stereoscopic cameras and multiple audio channels.

The CinemaDNG format offers several benefits:

- The CinemaDNG format is standards-based. The image encoding is based on the DNG specification, compliant with current DNG readers, compatible with the TIFF6 and TIFF/EP specifications, using published TIFF6, TIFF/EP and DNG tags;
- For a high level of compatibility with existing tools, CinemaDNG images can be stored in a directory structure, in an MXF wrapper, or transformed between these wrapping formats;
- The camera sensor output can be stored directly into the CinemaDNG format with minimal in-camera pixel processing and no repackaging of the raw image data;
- The CinemaDNG format typically adds less than 1 kbytes to the raw sensor data per image;
- There are no known intellectual property encumbrances or license requirements for CinemaDNG or its underlying formats DNG, TIFF, XMP, or MXF;
- SDKs are available from several parties for DNG, TIFF, XMP, and MXF.

DNG options supported in CinemaDNG include:

- Single-chip (mosaiced) and multi-chip (RGB only) image data;
- Integer sensor values of any bit depth from 8 to 32 bits;
- Arbitrary size color filter arrays with up to seven color channels;
- Lossless Huffman JPEG compression;
- Black level, white level, and linearization parameters for scaling of sensor values;
- TIFF, EXIF and XMP metadata;
- Preview images;
- Color-processing parameters for mapping camera RGB to CIE XYZ color space;
- Scale factors to convert original image size to, for example, HD image size;

Document structure

Section 1 describes the scope of this document.

Section 2 provides a list of normative references.

Section 3 defines terms used in the document.

Section 4 specifies compliance requirements for encoders and decoders.

Section 5 defines the requirements for encoding images in the CinemaDNG format.

Section 6 defines the requirements for storing the CinemaDNG essence in an image sequence directory.

Section 7 defines the requirements for the CinemaDNG picture essence wrapped in the SMPTE Material Exchange Format (MXF).

Section 8 defines the requirements for associating optional descriptive metadata with the CinemaDNG essence.

Annex A lists the TIFF tags applicable to DNG image processing under CinemaDNG.

Annex B provides the background for the CinemaDNG initiative and discusses future enhancements to the specification.

Annex C provides some tips for applications using CinemaDNG.

Annex D describes a data structure for storing multiple CinemaDNG clips or clips with audio.

Acknowledgements

This CinemaDNG specification was made possible through contributions from members of the SMPTE Technical Committee 31FS, ISO TC42/WG 18, and the CinemaDNG developers network.

1 Scope

This document defines the data structure of the CinemaDNG file format for the exchange of image streams in raw format, to use on storage media for exchange and for network transport.

The document does not describe how to create or process such images.

2 Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

Digital Negative (DNG) Specification, *Version 1.3*, Adobe Systems Incorporated, 2009

ISO 12234-2, *Photography — Electronic still-picture imaging — Removable memory — Part 2: TIFF/EP image data format*

SMPTE 12M-1-2008 Television — *Time and Control Code*

SMPTE 309M-1999 Television – *Transmission of Date and Time Zone Information in Binary Groups of Time and Control Code*

SMPTE 331M-2004 Television — *Element and Metadata Definitions for the SDTI-CP*

SMPTE 377-1-2009 Television — *Material Exchange Format (MXF) – File Format Specification*

SMPTE 379-2-2009 Television — *Material Exchange Format (MXF) – MXF Constrained Generic Container*

SMPTE ST 2055-201X - *Mapping TIFF/EP Profile 2 Essence into MXF Generic Container* (At this writing, ST 2055 has not been published)

TIFF, Revision 6.0 Final, Adobe Systems, 1992

XMP Specification, Adobe Systems, 2010

3 Terms and definitions

3.1
essence

image, video, audio, or data stream

3.2
frame

single image within a video stream

3.3
raw image

unprocessed image taken from a digital camera's image sensor

4 Compliance Requirements

4.1 General Requirements

A CinemaDNG dataset is a dataset that meets all requirements specified in this document using "shall". When an optional feature is used, the CinemaDNG dataset shall meet all requirements specified using "shall" for the optional feature.

4.2 Baseline Encoder Requirements

A CinemaDNG encoder shall have the capability to create a CinemaDNG dataset. A CinemaDNG encoder using an optional feature shall meet all requirements for the optional feature.

4.3 Baseline Decoder Requirements

A CinemaDNG decoder shall have the capability to read the full resolution image sequence of a CinemaDNG dataset.

A CinemaDNG decoder shall have the capability to:

- Decode both CinemaDNG MXF files and CinemaDNG image sequences.
- Handle gaps in the image sequence in a directory.
- Convert full resolution images in the CinemaDNG image-encoding format to scene-referred images.

A CinemaDNG decoder is not required to:

- Read proxy images.
- Select or order images using, for example, an EDL.
- Read metadata that's not required for image conversion.

5 CinemaDNG Image-Encoding Format

5.1 Encoding images in DNG format

Each image in the CinemaDNG image stream shall be encoded individually as a single dataset, here called a DNG dataset. An image shall not be encoded as subdivided into fields.

5.2 The Full-Resolution Image In DNG Format

Each image shall be stored in the DNG format as defined in the DNG Specification.

Compliant decoders shall support DNG version 1.1. Support of later versions is optional.

The DNG dataset shall include the image as a raw image at full resolution.

NOTE Per the DNG format specification, the full resolution image has NewSubfileType = 0. The raw image can be stored in strips or tiles. The image can be of any size, with a bit depth in the range 8 to 32 bits. The data can be uncompressed, or compressed using lossless Huffman JPEG. The PhotometricInterpretation values can be 32803 = CFA (Color Filter Array) for one sample per pixel, or 34892 = LinearRaw for Red, Green and Blue samples per pixel. When sample values are encoded using log, gamma, or other encoding function, the inverse decoding function is expected in the LinearizationTable.

5.3 Consistency From Image To Image

Unless otherwise specified, all images in a CinemaDNG clip shall be encoded similarly, using the same option values, additional images, parameter values, encodings, IFD structure, and image dimensions.

The locations of data elements within encoded images should remain constant across all encoded images. This allows for performance optimizations when reading the CinemaDNG dataset.

5.4 Including Additional Images In The Same DNG Data Set

The DNG dataset may include additional images, such as rendered previews, thumbnails, or reduced resolution versions, all of which can be used as proxies when editing. A compliant CinemaDNG decoder should ignore these images.

5.5 Including Additional Tags For Optional TIFF/EP Compliance

The DNG dataset may include additional tags for compliance with TIFF/EP. Compliance with TIFF/EP is not required. See Annex A for a list of relevant TIFF tags.

5.6 Including Metadata In DNG Datasets

The DNG format allows for storing metadata in the XMP metadata tag, in an EXIF IFD, or as other TIFF tags.

NOTE Metadata specified for the DNG dataset takes priority over similar metadata specified for the clip, possibly interfering with global metadata edits. See Section 8 "CinemaDNG Descriptive Metadata" for details.

5.7 Specifying Time Code, Frame Rate, T-Stop, Reel Name, Camera Label

5.7.1 Metadata items specific for CinemaDNG

The DNG dataset may include CinemaDNG-specific TIFF tags TimeCodes, FrameRate, TStop, ReelName, CameraLabel, defined below, or, when available, corresponding XMP entries.

5.7.2 TimeCodes

5.7.2.1 Tag Structure

Tag 51043 (C763.H)

Type BYTE

Count 8 * number of time code values in the tag

Default None

Usage IFD 0

5.7.2.2 Description

The optional TimeCodes tag shall contain an ordered array of time codes. All time codes shall be 8 bytes long and in binary format. The tag may contain from 1 to 10 time codes. When the tag contains more than one time code, the first one shall be the default time code. This specification does not prescribe how to use multiple time codes.

Each time code shall be as defined for the 8-byte time code structure in SMPTE 331M-2004, Section 8.3. See also SMPTE 12-1-2008 and SMPTE 309-1999.

NOTE 1 When a DNG dataset is embedded in an MXF file, EBU Recommendation R122 recommends that the time code in the DNG essence file be omitted or ignored.

NOTE 2 *Table 1 - Time code data structure* provides a brief summary of the format defined in SMPTE 331. Flags 1 to 4 encode field, parity, and type of Binary Group (BG) contents. With certain flag settings, the date, and time zone can be carried in the BG fields. All flags and BG nibbles can be 0. Drop flag is 1 only for drop frame rate 29.97.

Table 1 - Time code data structure

	Bit (MSB)							(LSB)
Byte	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	0	Drop flag	Tens of Frames		Units of Frames			
1	Flag 1	Tens of Seconds			Units of Seconds			
2	Flag 2	Tens of Minutes			Units of Minutes			
3	Flag 3	Flag 4	Tens of Hours		Units of Hours			
4	BG 2				BG 1			
5	BG 4				BG 3			
6	BG 6				BG 5			
7	BG 8				BG 7			

EXAMPLE

Hex tag value …	decodes as time code
07.49.53.02.00.00.00.00	02:53:49:07
00.37.54.d6.98.01.24.10	1998-01-24T16:54:37:00-10:00
21.35.38.d2.54.51.05.83	2009-11-19T12:38:35:21-03:00

5.7.3 FrameRate

5.7.3.1 Tag Structure

Tag 51044 (C764.H)

Type SRATIONAL

Count 1

Default None

Usage IFD 0

5.7.3.2 Description

The optional FrameRate tag shall specify the video frame rate in number of image frames per second, expressed as a signed rational number. The numerator shall be non-negative and the denominator shall be positive. This field value is identical to the sample rate field in SMPTE 377-1-2009.

EXAMPLE The NTSC 29.97 frame rate is specified as 30 000 / 1001.

5.7.4 TStop

5.7.4.1 Tag Structure

Tag 51058 (C772.H)

Type RATIONAL

Count 1 or 2

Default None

Usage IFD 0

5.7.4.2 Description

The optional TStop tag shall specify the T-stop of the actual lens, expressed as an unsigned rational number. T-stop is also known as T-number or the photometric aperture of the lens. (F-number is the geometric aperture of the lens.) When the exact value is known, the T-stop shall be specified using a single number. Alternately, two numbers shall be used to indicate a T-stop range, in which case the first number shall be the minimum T-stop and the second number shall be the maximum T-stop.

5.7.5 ReelName

5.7.5.1 Tag Structure

Tag 51081 (C789.H)

Type ASCII

Count 2 to 32 including the terminating NUL character

Default None

Usage IFD 0

5.7.5.2 Description

The optional ReelName tag shall specify a name for a sequence of images, where each image in the sequence has a unique image identifier (including but not limited to file name, frame number, date time, time code).

NOTE The tag value is often a reel name, tape name, clip name, or reel number, and can be used as a source identifier in an EDL (Edit Decision List). Some EDL systems require that the value is restricted to 1-8 alphanumeric characters (A..Z, a..z, 0..9) or underscore (_) followed by NUL. A new tag value can be assigned whenever the image identifiers are reused in a new sequence, for example, time code after a clock reset, time code during a second day of shooting, or a second folder of images. This tag is similar to TapeName in XMP.

5.7.6 CameraLabel

5.7.6.1 Tag Structure

Tag 51105 (C7A1.H)

Type ASCII

Count 2 to 32 including the terminating NUL character

Default None

Usage IFD 0

5.7.6.2 Description

The optional CameraLabel tag shall specify a text label for how the camera is used or assigned in this clip. This tag is similar to CameraLabel in XMP.

EXAMPLES Camera 1 Left, B Camera, POV

6 Storing CinemaDNG Essence As Image Files In A Directory

6.1 Images in a Sequence

The CinemaDNG essence may be stored in a file directory, in which case the following requirements apply.

The CinemaDNG essence shall be stored with one file per image. The file extension shall be ".DNG" or ".dng".

All images shall be encoded as defined in section 5 "CinemaDNG Image-Encoding Format". All images shall be encoded similarly, using the same option values, additional images, parameter values, encodings, IFD structure, and image dimensions.

6.2 A Sequence Of Image Files

The CinemaDNG essence shall be stored as sequence of images with filenames in numerical order.

For a sequence of image files the following conditions shall be met:

- The files shall be in the same directory. Other directories and files, including XMP metadata files, may exist in the same directory.
- The filenames shall include a sequencing field that is at the same position and of the same length for all filenames.
- A file's sequence number shall be stored as a decimal integer in the sequence field.
- The sequencing field shall contain characters 0 through 9 only. A file whose filename contains other characters in the location of the sequencing field (including sign, period, comma, or space) shall not be part of this sequence.
- The sequencing field shall be a run of at least four decimal characters in the filename. When more than one such run exists in the filename, the sequencing field shall be the run closest to the end of the filename.
- Except for the sequencing field, the files shall have the same filename, name length, and file extension.
- The sequence shall include at least one file. The playback shall start with the file having the lowest sequence number and end with the file having the highest sequence number. Omitted intermediate numbers shall indicate corresponding missing frames.

NOTE The sequencing field can be determined from any filename in the sequence.

EXAMPLE In bridge_0812.1136.day13.dng, 1136 is the sequencing field.

7 Mapping CinemaDNG Essence to MXF

7.1 Mapping The CinemaDNG Picture Data To The MXF Generic Container

The CinemaDNG essence may be stored in an MXF wrapper, in which case the following requirements apply.

The CinemaDNG picture essence shall be stored in MXF as specified in SMPTE ST 2055.

The file extension shall be ".MXF" or ".mxf".

SMPTE ST 2055 is a picture essence container specification for storing TIFF/EP Profile 2 images in the MXF Constrained Generic Container (SMPTE 379-2). The following is an overview of using ST 2055 for CinemaDNG. The implementer should consult the SMPTE document for the complete details.

7.2 The CinemaDNG Picture Element

The picture element can be stored using frame-based or clip-based wrapping.

When frame-wrapping is used, each picture is wrapped in a content package. The content packages can also contain other elements, such as fill, system, sound, or data.

In clip-based wrapping, a single contents package contains the entire clip, with no other elements present. Indexing is always used with clip-based wrapping.

Each picture element is KLV coded as defined in SMPTE 379-2.

The picture element key as specified in SMPTE 379-2 indicates the Essence Element Type and wrapping in Byte 15. For TIFF/EP Byte 15 has one of the following values:

- 0Eh for Frame-wrapped TIFF/EP Picture Element
- 0Fh for Clip-wrapped TIFF/EP Picture Element

Thus, the picture element key for a frame-wrapped element, when no other picture elements are present in the container, is 06.0E.2B.34.01.02.0101.0D.01.03.01.15.01.0E.01h, and the Track Number is 15.01.0E.01h.

The picture element value field contains one CinemaDNG image, when the container is frame-wrapped, and all images of the clip, when the container is clip-wrapped.

7.3 MXF Header Metadata

7.3.1 Essence Container Label

The essence container label specified in SMPTE 379-2 indicates the Essence Container Mapping and Content Kind in Bytes 14 and 15. SMPTE ST 2055 defines the following values for TIFF/EP for Bytes 14 and 15:

- 14.01h for Frame-wrapped TIFF/EP Profile 2 Pictures
- 14.02h for Clip-wrapped TIFF/EP Profile 2 Pictures

The essence container UL for frame-wrapped essence is thus 06.0E.2B.34.04.01.01.0B.0D.01.03.01.02.14.01.00h.

7.3.2 Picture Essence Descriptor

For CinemaDNG, SMPTE ST 2055 defines a TIFF Picture Essence Descriptor. The set key for the TIFF Picture Essence Descriptor is 06.0E.2B.34.02.53.01.01.0D.01.01.01.01.01.69.00h.

The TIFF Picture Essence Descriptor extends the Generic Picture Descriptor with the following items:

Table 2 TIFF Picture Essence Descriptor items

Item Name	Type	Len	UL	Req ?	Meaning	Default
TIFF Byte Order	UInt16	2	06.0E.2B.34.01.01.01.0D 04.01.06.05.01.00.00.00	E/Req	Byte order of the essence data: - 'MM' = Big endian - 'II' = Little endian	
TIFF Bits Per Sample Array	UInt16 Array	8 + 2 *n*	06.0E.2B.34.01.01.01.0D 04.01.06.05.02.00.00.00	Opt	Number of bits per sample in an uncompressed pixel. *n* = SamplesPerPixel.	
TIFF Compression Kind	UInt16	2	06.0E.2B.34.01.01.01.0D 04.01.06.05.03.00.00.00	E/Req	Compression scheme: - 1 = No compression - 7 = Lossless Huffman JPEG	
TIFF Photometric Interpretation Kind	UInt16	2	06.0E.2B.34.01.01.01.0D 04.01.06.05.04.00.00.00	E/Req	Color space and order of pixel data: - 32803 = Color Filter Array - 34892 = Linear Raw	
TIFF Orientation	UInt16	2	06.0E.2B.34.01.01.01.0D 04.01.06.05.05.00.00.00	Opt	Orientation of the image	1
TIFF Samples Per Pixel	UInt16	2	06.0E.2B.34.01.01.01.0D 04.01.06.05.06.00.00.00	E/Req	Number of samples (*n*) per pixel: - 1 for Photometric Interpretation = 32083 - 3 for PhotometricInterpretation = 34892	
TIFF Light Source Kind	UInt16	2	06.0E.2B.34.01.01.01.0D 04.01.06.05.07.00.00.00	Opt	Light source or its color temperature	0

The code values for the above items are defined in the TIFF/EP specification.

In the Generic Picture Descriptor, Frame Layout is always 0 = full frame.

The Picture Essence Coding UL is 06.0E.2B.34.04.01.01.0B.04.01.02.02.03.02.01.0nh, where n indicates the essence format. Bytes 14, 15, 16 specify TIFF/EP Profile 2 codings, as follows:

- 02.01.01h TIFF/EP Profile 2 in CFA format, uncompressed
- 02.01.02h TIFF/EP Profile 2 in LinearRaw format, uncompressed
- 02.01.03h TIFF/EP Profile 2 in CFA format, compressed
- 02.01.04h TIFF/EP Profile 2 in LinearRaw format, compressed

7.3.3 Populating The TIFF Picture Essence Descriptor

The TIFF Picture Essence Descriptor can be populated from CinemaDNG image parameter values as shown below.

Table 3 - Mapping DNG Image Parameters To Picture Essence Descriptor Items

Descriptor Item	DNG image parameter
Stored Width	ImageWidth
Stored Height	ImageLength
Sampled Width	ActiveArea [4] – ActiveArea [2]
Sampled Height	ActiveArea [3] – ActiveArea [1]
Sampled X Offset	ActiveArea [2]

Sampled Y Offset	ActiveArea [1]
Display Height	DefaultCropSize [2]
Display Width	DefaultCropSize [1]
Display X Offset	DefaultCropOrigin [1]
Display Y Offset	DefaultCropOrigin [2]
Aspect Ratio	DefaultCropSize [1] / DefaultCropSize [2]
Picture Essence Coding	Derived from Compression and PhotometricInterpretation
TIFF Byte Order	Bytes 0 and 1 from the TIFF file
TIFF Bits Per Sample Array	BitsPerSample
TIFF Compression Kind	Compression
TIFF Photometric Interpretation Kind	PhotometricInterpretation
TIFF Orientation	Orientation
TIFF Samples Per Pixel	SamplesPerPixel
TIFF Light Source Kind	LightSource

7.4 Application Notes

Index tables should be implemented whenever possible. A complete index in the header partition allows for quick read access to any part of the file, and enables streaming support.

A fixed Edit Unit size encoded as a non-zero Edit Unit Byte Count (with Index Duration = 0 and no Index Entry Array) can provide several benefits, especially for CBR or near-CBR uncompressed images:

- The encoder can store the complete index in the header when the recording starts.
- A single index table segment covers the entire clip, regardless of its duration.

A fixed Edit Unit size can be achieved for near-CBR uncompressed images through appending a Fill element.

A carefully selected KAG, for example, 16384, can provide disk sector alignment, which can provide faster read access when indexing to frames.

This essence mapping can be used with any operational pattern.

8 CinemaDNG Descriptive Metadata

8.1 Metadata Storage Locations

XMP metadata files may be present in an image sequence directory. The XMP metadata file (also known as sidecar file) shall be associated with the image file with the corresponding file name. The XMP metadata file associated with the first image file in the clip shall be associated with the entire clip. Other XMP files should not be present, as a large number of XMP files can degrade playback performance.

Metadata is stored as header metadata in the video essence MXF file. This metadata is associated with the corresponding clip.

XMP, TIFF, and EXIF metadata may be present within a DNG dataset, and shall be associated with the DNG dataset. If this is the first image in the clip, the metadata shall be associated with the entire clip.

To facilitate editing performance, if a metadata item is constant for the clip, could be subject to change in edit, and is not required to be stored within each DNG dataset, then the metadata item should not be stored in each DNG dataset.

8.2 Metadata Formats

XMP metadata items may be present. These shall comply with the XMP specification.

MXF metadata items may be present. These shall comply with the MXF specifications.

Optional TIFF and EXIF tags may be present in a DNG dataset. EXIF is a metadata standard for image files, widely used by digital cameras. This includes camera settings, such as exposure, lens, ISO, and GPS location.

The usage of metadata shall comply with the specification in Annex A .

8.3 Metadata Priority

When an image is associated with multiple instances of the same metadata property, and the instances don't have identical property values, the following descending-priority order should be used to resolve which property value to apply to this image.

For image sequence directories the following descending-priority order should be used:

1. The image's DNG, TIFF, and EXIF parameters
2. The image's corresponding XMP file
3. The image's DNG XMP item
4. The user-selected rendering parameters for the clip
5. The clip's first image's sidecar XMP file
6. The XMP metadata file for the clip
7. The clip's first image's DNG, TIFF, and EXIF parameters
8. The clip's first image's DNG XMP item
9. The default rendering parameters for the application

For MXF video essence files the following descending-priority order should be used:

1. The image's DNG, TIFF, and EXIF parameters
2. The image's DNG XMP item
3. The user-selected rendering parameters for the clip
4. The XMP metadata file for the clip
5. The MXF header metadata
6. The clip's first image's DNG, TIFF, and EXIF parameters
7. The clip's first image's DNG XMP item
8. The default rendering parameters for the application

Annex A (Normative) TIFF Tags For DNG Datasets

The following table, *Table 4 - TIFF tags for CinemaDNG essence*, lists the TIFF tags applicable to DNG image processing under CinemaDNG. This table does not apply to tags for other images, such as thumbnails, that may be included in DNG datasets.

The tag name and short description values are from the applicable TIFF, EXIF, and DNG specifications. The Code column provides the tag's decimal code in a TIFF IFD entry.

NOTE The letter "**y**" in any of the columns headed DNG, EXIF, TIFF/EP, or XMP indicates that the tag is included in the corresponding specification. The corresponding specification prescribes how and where the tag is stored. Some XMP tags, such as tiff:DateTime, are combinations of several TIFF/EP or EXIF tags. TIFF tags with codes 51043, 51044, 51058, and 51081, are defined in this specification, and are stored in IFD 0 of the DNG dataset.

When the letter "**y**" is present in several columns DNG, EXIF, TIFF/EP, or XMP, the tag can be stored in multiple locations according to the corresponding specifications. The letter "**c**" in the XMP column indicates that a copy of the tag can be stored in an XMP dataset, and the original value is stored as indicated by "**y**".

The Encoder column prescribes the Encoder behavior for the raw image in a DNG dataset. Seventeen tags are marked **Mandatory**.

The encoder shall provide the tags marked "**Mandatory**" in the Encoder column in each DNG dataset. The encoder should also provide tags marked "**Recommended**".

As stated in the TIFF/EP specification, the Encoder may use tags 322, 323, 324, 325 for tile storage (marked "**Alt to strips**") instead of tags 273, 278, 279 for strip storage (marked "**Mandatory (1)**"). However, a single strip is recommended.

The Decoder column prescribes the Decoder behavior for the raw image in a DNG dataset. 37 tags are marked **Mandatory**.

For image rendering, the decoder shall process tags marked "**Mandatory**" in the Decoder column, and should process tags marked "**Recommended**", when these tags are present. The value of the tag DNGBackwardVersion shall determine whether the decoder is required to process the tags (marked "**Optional**") for DNG sets 1.2 and 1.3.

The decoder should also utilize or carry forward the metadata tags marked "**Rec MD**", although they don't apply to image rendering.

Tags marked "**Ignore**" should not affect the decoder's image rendering.

Tags marked "**Not allowed**" and "**Error**" shall not be present in a compliant CinemaDNG dataset, and should be treated as an error case when seen by the decoder, as the decoder behavior is undefined for these tags in raw images.

The remaining tags are allowed.

Other descriptive metadata tags not listed here but defined in the mentioned specifications may be used. The decoder's image rendering by default should ignore these tags.

Table 4 - TIFF tags for CinemaDNG essence

Encoder	*Decoder*	*DNG*	*EXIF*	*TIFF / EP*	*XMP*	*Tag Name*	*Code*	*Short description*
Mandatory	Mandatory	y		y		NewSubFileType	254	General indication of the kind of data contained in this subfile.
Mandatory	Mandatory	y		y	c	ImageWidth	256	Number of columns in the image, i.e., the number of pixels per row.
Mandatory	Mandatory	y		y	c	ImageLength	257	Number of rows of pixels in the image.
Mandatory	Mandatory	y		y	c	BitsPerSample	258	Number of bits per component.
Mandatory	Mandatory	y		y	c	Compression	259	Compression scheme used on the image data.
Mandatory	Mandatory	y		y	c	PhotometricInterpretation	262	Color space of the image data.
Allowed	Mandatory	y				FillOrder	266	Logical order of bits within a byte.
Recommended	Rec MD			y	y	Make	271	Camera manufacturer.
Recommended	Rec MD			y	y	Model	272	Camera model name or number.
Mandatory (1)	Mandatory	y		y		StripOffsets	273	Byte offsets to each strip
Mandatory	Mandatory	y		y	c	Orientation	274	Orientation of the image with respect to the rows and columns.
Mandatory	Mandatory	y		y	c	SamplesPerPixel	277	Number of components per pixel.
Mandatory (1)	Mandatory	y		y		RowsPerStrip	278	Number of rows per strip.
Mandatory (1)	Mandatory	y		y		StripByteCounts	279	Number of bytes in each strip after compression
Mandatory	Mandatory	y		y	c	PlanarConfiguration	284	How the components of each pixel are stored.
Not allowed	Error				y	TransferFunction	301	Transfer function for the image in tabular style.
Recommended	Rec MD			y	y	Software	305	Name and version number of the software package(s) used to create the image.
Recommended	Rec MD			y	y	Artist	315	Person who created the image.
Not allowed	Error				y	WhitePoint	318	Chromaticity of the white point of the image.
Not allowed	Error				y	PrimaryChromaticities	319	Chromaticities of the primaries of the image.
Not allowed	Error					ColorMap	320	Color map for palette color images.
Alt to strips	Mandatory			y		TileWidth	322	Tile width in pixels. This is the number of columns in each tile.
Alt to strips	Mandatory			y		TileLength	323	Tile length (height) in pixels. This is the number of rows in each tile.
Alt to strips	Mandatory			y		TileOffsets	324	Byte offsets to each tile, as compressed and stored on disk.
Alt to strips	Mandatory			y		TileByteCounts	325	Number of (compressed) bytes in each tile.
Allowed	Mandatory	y		y		SubIFDs	330	Offsets to child IFDs.
Not allowed	Error			y		JPEGTables	347	JPEG quantization and/or Huffman tables.
Not allowed	Error			y	y	YCbCrCoefficients	529	Transformation from RGB to YCbCr image data.
Not allowed	Error			y	y	YCbCrSubSampling	530	Subsampling factors used for the chrominance components of a YCbCr image.
Not allowed	Error			y	y	YcbCrPositioning	531	Positioning of subsampled chrominance components relative to luminance samples.
Not allowed	Error			y	y	ReferenceBlackWhite	532	Pair of headroom and footroom image data values (codes) for each pixel component.
Allowed	Rec MD	y				XMP	700	XML packet containing XMP metadata
Mandatory	Mandatory	y		y		CFARepeatPatternDim	33421	Number of pixels horizontally and vertically in CFA Pattern
Mandatory	Mandatory	y		y		CFAPattern	33422	Color filter array (CFA) geometric pattern of the image sensor when a one-chip color area sensor is used.
Recommended	Rec MD			y	y	Copyright	33432	Copyright notice.
Recommended	Rec MD		y	y	y	ExposureTime	33434	Exposure time, given in seconds.
Recommended	Rec MD		y	y	y	FNumber	33437	F-number.
Not allowed	Error			y		InterColorProfile	34675	ICC profile data.
Recommended	Rec MD		y	y		GPS IFD	34853	Offset to the Exif-related GPS Info IFD.
Recommended	Rec MD		y	y	y	ISOSpeedRatings	34855	ISO Speed and ISO Latitude of the camera or input device as specified in ISO 12232.
Not allowed	Error		y	y	y	OECF	34856	Opto-Electric Conversion Function (OECF)
Recommended	Rec MD			y	y	TimeZoneOffset	34858	Time zone of DateTimeOriginal values

Recommended	Rec MD		y	y	y	DateTimeOriginal	36867	Date and time when the original image data was generated.
Not allowed	Error		y		y	ComponentsConfiguration	37121	Specifies the channels and complements PhotometricInterpretation
Recommended	Rec MD		y	y	y	ShutterSpeedValue	37377	Shutter speed as APEX value.
Recommended	Rec MD		y	y	y	ApertureValue	37378	Lens aperture as APEX value.
Recommended	Rec MD		y	y	y	SubjectDistance	37382	Distance to the subject, given in meters.
Recommended	Rec MD		y	y	y	LightSource	37384	Kind of light source.
Recommended	Rec MD		y	y	y	FocalLength	37386	Actual focal length of the lens, in mm.
Recommended	Rec MD			y		ExposureIndex	37397	Exposure index (ISO) selected on the camera or input device at the time the image is captured.
Allowed	Ignore			y		TIFF/EPStandardID	37398	Version of this TIFF/EP file
Recommended	Rec MD		y		y	SubsecTimeOriginal	37521	Fractions of seconds for the DateTimeOriginal tag.
Not allowed	Error		y		y	ColorSpace	40961	Color space information tag is always recorded as the color space specifier.
Not allowed	Error		y		y	CFAPattern	41730	Color filter array (CFA) geometric pattern of the image sensor when a one-chip color area sensor is used. Use 33422 instead
Not allowed	Error		y		y	CustomRendered	41985	Use of special processing on image data, such as rendering geared to output.
Mandatory	Mandatory	y				DNGVersion	50706	DNG version intended for this image.
Allowed	Mandatory	y				DNGBackwardVersion	50707	Lowest DNG version required to support this image
Mandatory	Mandatory	y				UniqueCameraModel	50708	Unique, non-localized name for the camera model that created the image
Allowed	Mandatory	y				CFAPlaneColor	50710	
Allowed	Mandatory	y				CFALayout	50711	
Recommended	Mandatory	y				LinearizationTable	50712	Lookup table that maps stored values into linear values
Recommended	Mandatory	y				BlackLevelRepeatDim	50713	Repeat pattern size for the blacklevel tag
Recommended	Mandatory	y				BlackLevel	50714	Zero light (a.k.a. Thermal black or black current) level in linear values, stored as a repeating pattern
Allowed	Mandatory	y				BlackLevelDeltaH	50715	Difference between the zero light level for each column and the baseline zero light level
Recommended	Mandatory	y				BlackLevelDeltaV	50716	Difference between the zero light level for each row and the baseline zero light level
Recommended	Mandatory	y				WhiteLevel	50717	Fully saturated encoding level for linearized raw sample values
Allowed	Mandatory	y				DefaultScale	50718	
Recommended	Mandatory	y				DefaultCropOrigin	50719	Origin of final image area, in raw image coordinates
Recommended	Mandatory	y				DefaultCropSize	50720	Size of final image area, in raw image coordinates
Mandatory	Mandatory	y				ColorMatrix1	50721	Transformation matrix that converts XYZ values to reference camera native color space values, under the first calibration illuminant
Recommended	Mandatory	y				ColorMatrix2	50722	Transformation matrix under the second calibration illuminant
Recommended	Mandatory	y				CameraCalibration1	50723	Calibration matrix that transforms reference camera native space values to individual camera native space values under the first calibration illuminant
Recommended	Mandatory	y				CameraCalibration2	50724	Calibration matrix under the second calibration illuminant
Recommended	Mandatory	y				AsShotNeutral	50728	Selected white balance at time of capture, as coordinates of a neutral color in linear reference space
Allowed	Mandatory	y				AsShotWhiteXY	50729	Selected white balance at time of capture, as xy chromaticity coordinates of a neutral color
Allowed	Mandatory	y				BaselineExposure	50730	Amount (in EV units) by which to brighten the image
Allowed	Recommended	y				BaselineNoise	50731	
Allowed	Recommended	y				BaselineSharpness	50732	
Allowed	Mandatory	y				BayerGreenSplit	50733	

Allowed	Mandatory	y		LinearResponseLimit	50734	
Recommended	Rec MD	y		CameraSerialNumber	50735	Camera serial number
Allowed	Rec MD	y		LensInfo	50736	Min and Max focal length and F-stop
Allowed	Recommended	y		AntiAliasStrength	50738	
Recommended	Mandatory	y		CalibrationIlluminant1	50778	Illuminant used for the first set of color calibration tags
Recommended	Mandatory	y		CalibrationIlluminant2	50779	Illuminant used for the second set
Allowed	Mandatory	y		BestQualityScale	50780	
Discouraged	Ignore	y		OriginalRawFileData	50828	
Recommended	Mandatory	y		ActiveArea	50829	Rectangle of the active (non-masked) pixels of the sensor
Allowed	Ignore	y		MaskedAreas	50830	Rectangles of masked pixels of the sensor
Allowed	Optional	y		ProfileToneCurve	50940	
Allowed	Optional	y		ProfileEmbedPolicy	50941	
Allowed	Optional	y		ProfileCopyright	50942	
Allowed	Optional	y		OpcodeList1	51008	
Allowed	Optional	y		OpcodeList2	51009	
Allowed	Optional	y		OpcodeList3	51022	
Allowed	Optional	y		NoiseProfile	51041	
Recommended	Rec MD		y	TimeCodes	51043	Multiple time codes.
Recommended	Rec MD		y	FrameRate	51044	Video frame rate in image frames per second
Recommended	Rec MD			TStop	51058	T-stop or T-number, the photometric aperture of the lens
Recommended	Rec MD		y	ReelName	51081	Reel name, tape name, or reel number
Recommended	Rec MD		y	CameraLabel	51105	Camera assignment for this clip

Annex B (Informative) An Evolving Format

B.1 The CinemaDNG Initiative

In the closing of the 20th century, photography experienced a technological shift with the proliferation of digital cameras. As photographers embraced digital cameras, their desire to access low-level image data increased, resulting in a shift towards raw image capture. Unfortunately, the Digital Still Image RAW workflow brought with it a slew of file formats (over 200 for still cameras) that are proprietary, closed, and sometimes even encrypted.

Today, the cinema industry is experiencing a similar transition as many filmmakers are foregoing film in favor of digital cinema cameras and workflows. Digital cinema cameras have increased the use of RAW workflows and proprietary RAW formats. Proprietary RAW formats lock participants, both vendors and users, into walled gardens with limited interoperability and longevity.

At NAB 2008, Adobe with industry partners announced the CinemaDNG initiative to improve interoperability in Digital Cinema RAW workflows.

The CinemaDNG Initiative offers a solution by defining an open file format for digital cinema files to streamline workflows and ensure that digital cinema files can be easily archived and exchanged. The first CinemaDNG format specification was released at IBC in September 2009.

By providing a unified, open, publicly documented, file format, the CinemaDNG Initiative offers several core advantages for camera manufacturers, software vendors, and filmmakers.

Advantages for Camera and Software Vendors

- Reduce costs and time to market by eliminating the need to develop and maintain proprietary formats and conversion utilities.
- Remove a key obstacle to the adoption of new products by providing instant interoperability with existing workflows.

Advantages for Filmmakers

- Avoid roadblocks caused by incompatibilities in workflows that involve multiple devices, vendors, and file formats.

Industry Support for CinemaDNG

A broad range of industry-leading companies are supporting the CinemaDNG effort, including:

Aaton	Advanced Architectures	Adobe Systems	Apertus
Avid	Blackmagic Design	Cineraw	Cine-tal
Fraunhofer IIS	Gamma & Density	Ikonoskop	Image Engineering
INDIECAM	IRIDAS	MXF4mac	RadiantGrid Technologies
Silicon Imaging	Synthetic Aperture	The Foundry	ViewPLUS
Vision Research	WEISSCAM		

B.2 Standardization Progress

ISO TC42 is standardizing DNG for inclusion in the next revision of ISO 12234-2 TIFF/EP. The expectation is that CinemaDNG will be updated to adopt the revised ISO 12234-2.

SMPTE's MXF standard was chosen as the preferred wrapping format for CinemaDNG. In 2009, no standards existed for mapping camera raw images into the MXF format, so SMPTE agreed to specify the mapping of DNG or

TIFF/EP raw essence into the MXF Generic Container. In 2011, SMPTE completed ST 2055 "*Mapping TIFF/EP Profile 2 Essence into MXF Generic Container"*, summarized in this specification.

B.3 Lossy Image Compression

The CinemaDNG interest group is considering adding lossy compression.

The current CinemaDNG format supports only lossless compression, giving about 2.5:1 reduction in size. Lossless compression does not guarantee a constant bit rate.

Some use cases call for lossy compression (8:1 or better) and constant bit rate. This would reduce storage needs and transfer times. Candidate methods for lossy compression would have to be evaluated against requirements such as performance, power consumption, complexity, licensing, availability, and standardization.

B.4 CinemaDNG versus DNG

The CinemaDNG 1.1 essence format is a DNG-compliant subset of DNG, currently version 1.1. Thus, DNG 1.1-compliant image processors can be used in CinemaDNG workflows.

The web site http://www.barrypearson.co.uk/articles/dng/products.htm lists about 200 applications that can read DNG files.

CinemaDNG also adds five optional cinema-oriented metadata tags, which are not used for image processing.

Annex C (Informative) Application Notes

C.1 Camera Calibration

Accurate camera calibration and on-set white balance are essential for efficient and predictable look management on set and in post-production.

The tags ColorMatrix1 and AsShotNeutral and other optional tags allow for this calibration data to be embedded with the image essence at capture time, assuring that all post facilities get the same initial view. The CinemaDNG encoder is strongly encouraged to provide accurate metadata. This is preferred over calibrating at each post facility.

Practical use with DNG and digital still cameras shows that it is often sufficient with two calibration points. Still cameras are typically calibrated for tungsten and daylight illumination.

C.2 Look Management

Look management is outside the scope of the CinemaDNG file format. The ideal look management system is format-agnostic, unrelated to the specifics of the CinemaDNG format.

The look transform is not applied to the (highly device-specific) Camera RGB values, but rather after the image has been converted to a standard color space (such as ACES, Academy's working space in the IIF workflow) in a workflow providing a predictable preview transform (such as Academy's RRT). Through using a standard color space and preview transform, the effect of the look transform will be predictable, regardless of the underlying device color space.

Look data ideally is not stored in or referenced from the master essence file, as this causes edit and backup issues when the look changes or alternate looks are used. Look data could be in a folder for each clip or a sidecar file with same name as the clip.

C.3 Stereoscopy

Stereo contents can be managed without new CinemaDNG format features, for example, using file or folder names to indicate left and right eye as in current practice. The image essence files can also include a left or right camera indicator using the CameraLabel tag.

As SMPTE develops standards for Stereo 3D Metadata in MXF files, CinemaDNG workflows can leverage these without changes in the CinemaDNG format specification.

C.4 Audio

Audio is outside the scope of the CinemaDNG file format. MXF can combine audio with CinemaDNG essence.

Annex D (Informative) File Structure of CinemaDNG Contents

D.1 General

At this writing, the most commonly used format for CinemaDNG contents is the CinemaDNG file sequence described in section 6.

This Annex presents an optional, more complex file structure to be considered for future recommendations with multiple CinemaDNG clips. The structure is based on SMPTE RP 2002. The file structure has not been evaluated in practice and is not yet recommended for use with CinemaDNG.

A CinemaDNG file structure contains one or more CinemaDNG clips.

A clip has at least one MXF video essence file or one image sequence directory. All other files are optional.

A clip contains image essence, in two tracks for stereoscopic images, and otherwise in one track.

The tracks of the image essence are stored either as video essence in MXF files or as directories with a sequence of image files.

Individual images in the image essence are encoded in the CinemaDNG image-encoding format.

Optionally, the clip can include audio essence, metadata, a proxy file, and a thumbnail image.

The audio essence can include up to 16 channels. The audio essence is stored as MXF files.

All essence in the clip has the same duration.

Metadata can be associated with the clip. Metadata can also be associated with individual images.

D.2 CinemaDNG Directory Structure

The files for one or more CinemaDNG clips are organized (by media type) in a directory structure. This is illustrated in *Table 5*.

Table 5 - CinemaDNG File Structure Example

```
MyMovie/
        CONTENTS/
                CLIP/
                                0001AB.XMP
                                0002CD.XMP
                VIDEO/
                                0001AB.MXF
                AUDIO/
                                0001AB.MXF
                                0002CD00.MXF
                                0002CD01.MXF
                IMAGE/
                                0002CD/
                                        00020001.DNG
                                        00020002.DNG
                                        0002……..DNG
                ICON/
                                0001AB.JPG
                PROXY/
                                0001AB.MP4
```

The topmost directory is named 'CONTENTS', and can contain a 'CLIP' metadata directory, a 'VIDEO' essence directory, an 'AUDIO' essence directory, an 'IMAGE' essence directory, an 'ICON' thumbnail directory, and a 'PROXY' directory.

The 'CLIP' directory contains all XMP metadata files.

The 'VIDEO' directory contains all video essence files.

The 'AUDIO' directory contains all audio essence files. If a clip's video essence file contains audio, a separate audio essence file is not present for that clip. Otherwise, for each clip, there is either one audio essence file that includes all audio channels or one audio essence file per audio channel.

The 'IMAGE' directory contains all image sequence directories. If a clip has a video essence file, an image sequence directory is not present for that clip.

The 'ICON' directory contains all thumbnail files.

The 'PROXY' directory contains all proxy files.

Directories can be empty. Additional files can be present.

In SMPTE RP2002, a clip is limited to one video essence file and multiple single-channel audio essence files. This specification supports the following file combinations for a clip:

- One video essence file that includes all audio essence, or
- One video essence file without audio essence, or
- One video essence file and one multi-channel audio essence file, or
- One video essence file and multiple single-channel audio essence files, or
- Two (stereo) video essence files without audio essence, or
- Two (stereo) video essence files and one multi-channel audio essence file, or
- Two (stereo) video essence files and multiple single-channel audio essence files, or
- One image sequence directory, or
- One image sequence directory and one multi-channel audio essence file, or
- One image sequence directory and multiple single-channel audio essence files, or
- Two (stereo) image sequence directories, or
- Two (stereo) image sequence directories and one multi-channel audio essence file, or
- Two (stereo) image sequence directories and multiple single-channel audio essence files.

A clip has either video essence files or image sequence directories, but not both. A clip's audio essence is stored either in a video essence file or in one or more audio essence files. For stereoscopic clips, the audio is always stored in audio essence files.

D.3 CinemaDNG Structure Subsets

The file structure is section D.2 "CinemaDNG Directory Structure" is optional, when a clip is composed solely of one video essence file, or one image sequence directory. Two subsets of CinemaDNG have been identified for these common cases:

- CinemaDNG/MXF for a clip composed solely of an MXF video essence file
- Cinema/DNG/Seq for a clip composed solely of an image sequence directory

CinemaDNG/MXF Structure

A CinemaDNG/MXF dataset is an MXF video essence file as defined in section 7 "Mapping CinemaDNG Essence to MXF ".

All metadata is contained in the MXF file, and meets the requirements of section 8 "CinemaDNG Descriptive Metadata".

A CinemaDNG/MXF encoder has the capability to create a CinemaDNG/MXF dataset. A CinemaDNG/MXF decoder has the capability to read the full-resolution image stream of a CinemaDNG/MXF dataset.

A module compliant with CinemaDNG/MXF can use the CinemaDNG/MXF designator to indicate compliance.

CinemaDNG/Seq Structure

A CinemaDNG/Seq dataset is an image sequence directory as defined in section 6 "Storing CinemaDNG Essence As Image Files In A Directory".

All metadata is contained in the image sequence directory, and meets the requirements of section 8 "CinemaDNG Descriptive Metadata".

A CinemaDNG/Seq encoder has the capability to create a CinemaDNG/Seq dataset. A CinemaDNG/Seq decoder has the capability to read the full-resolution image stream of a CinemaDNG/Seq dataset.

A module compliant with CinemaDNG/Seq can use the CinemaDNG/Seq designator to indicate compliance.

D.4 File Formats

This section defines the required file formats.

XMP Metadata File

XMP metadata files can be present in the 'CLIP' directory. This is the recommended location for XMP files. Metadata in such files is associated with the clips with the corresponding clip names.

An XMP metadata file in the 'CLIP' directory contains XMP metadata applicable to the entire clip.

The XMP metadata file complies with the XMP specification, using the XMP schemas and properties described in section 10 below.

XMP metadata files can appear also in image sequence directories.

Video Essence File

A video essence file contains one track of image essence. The video essence file comply with MXF, using the mapping to MXF described in section 7 "Mapping CinemaDNG Essence to MXF " below.

For monoscopic pictures, the video essence file can contain all channels of audio essence.

Audio Essence File

An audio essence file complies with MXF using the AES3 audio mapping defined in SMPTE 382M.

The audio essence file contains either one audio channel or all audio channels of the clip.

Image Sequence Directory

An image sequence directory contains the image files of one track of image essence. Its contents be as defined in section 6 "Storing CinemaDNG Essence As Image Files In A Directory" below.

An image sequence directory can also contain XMP metadata files for specified frames.

Thumbnail File

A thumbnail file stores a thumbnail image of the clip. The image is up to 512x512 pixels in size encoded in the JPEG image format.

Proxy File

A proxy file is compliant with the MP4 format as defined in ISO/IEC 14496-14:2003.

D.5 File Naming Rules

The file names in the 'CLIP', 'VIDEO', 'AUDIO', 'IMAGE', and 'PROXY' directories are six, seven, or eight characters and an extension.

All files of a given clip have the same first six characters.

The first six characters represent a (local) clip name.

The first four characters of the clip name is a four-digit integer number, uniquely identifying the clip within the CONTENTS structure.

The next two characters of the clip name is upper case alphanumeric and is derived from the UMID of the clip's material package, as described in RP2002-2009, section 8.3.3.

For stereoscopic image essence, character seven represents the image channel, using 'L' or 'R' for left and right channels respectively. The image channel letter is omitted otherwise.

For single-channel audio essence files, characters seven and eight represent the audio channel number as a decimal number in the range "00" to "15". The channel number is omitted for multi-channel audio essence.

The file name for an XMP metadata file in the 'CLIP' directory is the clip name followed by the extension ".XMP" or “.xmp”.

The file name for an XMP metadata file in an image sequence directory is the image file name followed by the extension ".XMP" or “.xmp”.

The video essence file name is the clip name followed by the optional image channel letter and the extension ".MXF" or “.mxf”.

The audio essence file name is the clip name followed by the optional audio channel number and the extension ".MXF" or “.mxf”.

The image sequence directory name is the clip name followed by the optional image channel letter.

The thumbnail file name is the clip name followed by the extension ".JPG" or “.jpg”.

The proxy file name is the clip name followed by the extension ".MP4" or “.mp4”.

Bibliography (Informative)

The following documents describe the DNG and TIFF image format.

Digital Negative (DNG) Specification, Adobe Systems Incorporated

ISO 12234-2, *Photography — Electronic still-picture imaging — Removable memory — Part 2: TIFF/EP image data format*

TIFF, Revision 6.0 Final, Adobe Systems, 1992

TIFF Tag Reference, http://www.awaresystems.be/imaging/tiff/tifftags.html

The following documents describe the MXF format and related features.

The MXF Book — Introduction to the Material eXchange Format, editor Nick Wells, principal authors Bruce Devlin, and Jim Wilkinson, contributing authors Matt Beard and Phil Tudor, Focal Press, 2006.

SMPTE 377-1 Television — *Material Exchange Format (MXF) – File Format Specification*

SMPTE 379-2 Television — *Material Exchange Format (MXF) – MXF Constrained Generic Container*

SMPTE 382M Television — *Material Exchange Format - Mapping AES3 and Broadcast Wave Audio into the MXF Generic Container*

SMPTE ST 2055 - *Mapping TIFF/EP Profile 2 Essence into MXF Generic Container* (Not yet published)

SMPTE RP 210 — *Metadata Dictionary Registry of Metadata Element Descriptions*

SMPTE RP 224 *SMPTE Labels Registry*

SMPTE RP 2002 *Content Specification on Solid State Media Card for DV/DV-Based Essence*

The following documents describe metadata options.

JEITA CP-3451, *Exchangeable image file format for digital still cameras: Exif*

XMP Specification, Adobe Systems

The following documents describe lossless JPEG compression.

Adobe Photoshop TIFF Technical Notes, March 22, Adobe Systems, 2002

ITU-T Recommendation T.81 (1992) | ISO/IEC 10918-1:1994, Information technology — *Digital compression and coding of continuous-tone still images – Requirements and guidelines (for JPEG compression)*

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