

CinemaDNG

Image Data Format Specification

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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.

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 supports 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. For 16 or 32 bits, the byte ordering of the CinemaDNG data can be big-endian or little-endian as needed, to match the sensor output;
- The CinemaDNG format typically adds less than 1 kbytes overhead 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;
- Time codes and frame rate (new with CinemaDNG).

MXF options supported in CinemaDNG include Operational Patterns OP-1A and OP Atom, time codes and audio

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1 Scope

This document defines the data structure of the CinemaDNG 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

EBU Recommendation R122-2007 — *Material Exchange Format Timecode Implementation*

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

ISO/IEC 14496-14:2003 Information technology — *Coding of audio-visual objects — Part 14: MP4 file format*

ITU-T Recommendation X.690 | ISO/IEC 8825-1, Information technology — *ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)*.

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

SMPTE 326M-2000 Television — *SDTI Content Package Format (SDTI-CP)*

SMPTE 330M-2004, Television — *Unique Material Identifier (UMID)*

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

SMPTE 336M-2007 Television — *Data Encoding Protocol Using Key-Length-Value*

SMPTE 377M-2004 Television — *Material Exchange Format (MXF) – File Format Specification*

SMPTE 378M-2004 Television — *Material Exchange Format (MXF) Operational Pattern 1a (Single Item, Single Package)*

SMPTE 379M-2004 Television — *Material Exchange Format (MXF) – MXF Generic Container*

SMPTE 382M-2007 Television — *Material Exchange Format - Mapping AES3 and Broadcast Wave Audio into the MXF Generic Container*

SMPTE 390M-2004 Television — *Material Exchange Format (MXF) – Specialized Operational Pattern “Atom” (Simplified Representation of a Single Item)*

SMPTE 405M-2006, Television — *Material Exchange Format (MXF) — Elements and Individual Data Items for the MXF Generic Container System Scheme 1*

SMPTE RP 210.10-2007 *Metadata Dictionary Registry of Metadata Element Descriptions*

SMPTE RP 224.9-2008 *SMPTE Labels Registry*

SMPTE RP 2002-2006 *Content Specification on Solid State Media Card for DV/DV-Based Essence*

TIFF, Revision 6.0 Final, Adobe Systems, 1992

XMP Specification, Adobe Systems, 2008

3 Terms and definitions

essence	image, video, audio, or data stream
frame	single image within a video stream
raw image	unprocessed image taken from a digital camera's image sensor

4 Compliance Requirements

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

4.1 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.

4.2 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, as described in the DNG Specification, 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 Data Structure of CinemaDNG Contents

This section defines the data structure requirements for CinemaDNG.

A CinemaDNG file structure shall contain one or more CinemaDNG clips.

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

A clip shall contain 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 may include audio essence, metadata, a proxy file, and a thumbnail image.

The audio essence may include up to 16 channels.

The audio essence is stored as MXF files.

All essence in the clip shall have the same duration.

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

5.1 CinemaDNG Directory Structure

The files for one or more CinemaDNG clips shall be organized (by media type) in a directory structure. This is illustrated below. This file structure may be omitted, when a clip is composed solely of one video essence file, or one image sequence directory.

MyMovie/	
CONTENTS/	
CLIP/	
	0001AB.XMP
	0002CD.XMP
VIDEO/	
	0001AB.MXF
AUDIO/	
	0001AB.MXF
	0002CD00.MXF
	0002CD01.MXF
IMAGE/	
	0002CD/
	00020001.DNG
	00020002.DNG
	00020003.DNG
	00020004.DNG
	00020005.DNG
	00020006.DNG
	00020007.DNG
ICON/	
	0001.AB.JPG
PROXY/	
	0001AB.MP4

The topmost directory shall be named 'CONTENTS', and may 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 should contain all XMP metadata files.

The 'VIDEO' directory shall contain all video essence files.

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

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

The 'ICON' directory shall contain all thumbnail files.

The 'PROXY' directory shall contain all proxy files.

Directories may be empty. Additional files may be present.

NOTES:

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.

6 File Formats

This section defines the required file formats and file names.

6.1 XMP Metadata File

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

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

NOTE: XMP metadata files can appear also in image sequence directories.

6.2 Video Essence File

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

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

6.3 Audio Essence File

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

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

6.4 Image Sequence Directory

An image sequence directory shall contain the image files of one track of image essence. Its contents shall be as defined in section 8 "Storing CinemaDNG Essence As Image Files In A Directory" below.

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

6.5 Thumbnail File

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

6.6 Proxy File

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

6.7 File Naming Rules

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

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

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

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

The next two characters of the clip name shall be upper case alphanumeric and should be 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 shall represent the image channel, using 'L' or 'R' for left and right channels respectively. The image channel letter shall be omitted otherwise.

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

The file name for an XMP metadata file in the 'CLIP' directory shall consist of the clip name followed by the extension ".XMP" or ".xmp".

The file name for an XMP metadata file in an image sequence directory shall consist of the image file name followed by the extension ".XMP" or ".xmp".

The video essence file name shall consist of the clip name followed by the optional image channel letter and the extension ".MXF" or ".mxf".

The audio essence file name shall consist of the clip name followed by the optional audio channel number and the extension ".MXF" or ".mxf".

The image sequence directory name shall consist of the clip name followed by the optional image channel letter.

The thumbnail file name shall consist of the clip name followed by the extension ".JPG" or ".jpg".

The proxy file name shall consist of the clip name followed by the extension ".MP4" or ".mp4".

7 Mapping CinemaDNG Essence to the MXF Format

This section defines the requirements for storing the CinemaDNG essence in the SMPTE Material Exchange Format (MXF, SMPTE 377M).

An MXF-based CinemaDNG dataset should use one of the MXF Operational Patterns 1a (SMPTE 378M) or Atom (SMPTE 390M). The use of other Operational Patterns is outside the scope of this document. A compliant CinemaDNG decoder may ignore Operational Patterns other than OP 1a and OP Atom.

Audio may be present. Audio, when present, shall be encoded as defined in SMPTE 382M, Mapping AES3 and Broadcast Wave Audio into the MXF Generic Container, using AES3 or Broadcast Wave Audio.

Timecodes should be present. Timecode, when present, shall be encoded as defined in EBU Recommendation R122-2007 "Material Exchange Format Timecode Implementation".

7.1 Mapping The CinemaDNG Picture Data To The MXF Generic Container

The essence shall be stored using the MXF Generic Container (SMPTE 379M).

A picture element shall be present in the content package.

Other elements, such as fill, system, sound, or data, may be present in the content package.

7.1.1 The CinemaDNG Picture Element

The CinemaDNG picture element shall use frame-based wrapping, see figure. Each picture is wrapped in a content package, optionally with other elements in the package.

NOTE Clip-based wrapping cannot be used for TIFF-based essence such as DNG, as the dataset size cannot be determined from the TIFF dataset. The TIFF dataset does not include a dataset length field, and the possible presence of dark metadata of unknown size and location in a TIFF dataset precludes determining the size.

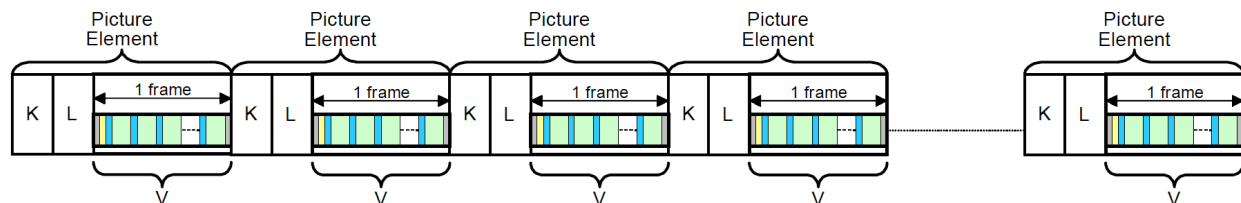


Figure – Frame-based wrapping (from SMPTE 384M)

7.1.1.1 KLV Encoding Of The Picture Element

Each picture element is KLV coded as defined in SMPTE Data Encoding Protocol Using Key-Length-Value (SMPTE 336M).

7.1.1.2 Picture Element Key

The key for the picture element shall be set to the essence element key value as defined in MXF Generic Container, extended for the CinemaDNG type.

Byte No.	Description	Value (hex)	Meaning
1-12	See MXF Generic Container Specification		
13	Item Type Identifier	15h	Generic Container Picture Item (SMPTE 326M)
14	Essence Element Count	xxh	Count of Picture Elements in this Item
15	Essence Element Type	42h	Frame Wrapped TIFF Picture Element
16	Essence Element Number	zzh	The Number (used as an Index) of this Picture Element in

			this Item
--	--	--	-----------

When no other picture elements are present in the container, xx and zz shall both be 01. In such case, the key is 06.0E.2B.34.01.02.01.01.0D.01.03.01.15.01.42.01

7.1.1.3 Picture Element Length

The length field shall be BER long-form encoded.

7.1.1.4 Picture Element Value

The value field shall comprise a single picture, encoded as defined in this document in section 9 "CinemaDNG image-encoding format".

7.1.2 Fill Elements

Fill elements may be used between elements, for example, for KAG alignment. The KLV filler metadata element shall be encoded as defined in MXF (SMPTE 377M). The UL is 06.0E.2B.34.01.01.01.01.03.01.02.10.01.00.00.00.

7.1.3 System Elements

Timecode, when present, shall be encoded as defined in EBU Recommendation R122-2007 "Material Exchange Format Timecode Implementation".

7.1.4 Sound Elements

Audio, when present, shall be encoded as defined in SMPTE 382M.

7.2 MXF Header Metadata

7.2.1 Label For Essence Container Identification

The value for the essence container UL should be as defined in Table 3 in SMPTE 379M MXF Generic Container.

The CinemaDNG essence container UL shall be defined as follows:

Byte No.	Description	Value (hex)	Meaning
1	Object Identifier	06h	
2	Label size	0Eh	
3	Designator	2Bh	ISO, ORG
4	Designator	34h	SMPTE
5	Registry Category Designator	04h	Labels
6	Registry Designator	01h	Labels Registry
7	Structure Designator	01h	Labels Structure
8	Version Number	01h	Version of the Registry
9	Item Designator	0Fh	Experimental
10		0Ah	Unique ID for Adobe Systems
11		0Dh	
12		0Bh	
13	Essence Container Kind	02h	MXF Generic Container
14	Mapping Kind	7Fh	Raw Image Picture Element
15	Content kind	01h	Frame-wrapped DNG Picture Element in CFA format

		02h	Frame-wrapped DNG Picture Element in LinearRaw format
16	Reserved	00h	Reserved

Byte 14 (Mapping Kind) is set to 7Fh to indicate Raw Image encoding.

Byte 15 (Content Kind) identifies how the image is encoded, and is set to 01h for CinemaDNG pictures with PhotometricInterpretation = 32803 for CFA (Color Filter Array), or to 02h for CinemaDNG pictures with PhotometricInterpretation = 34892 for LinearRaw.

Thus, the following essence container ULs are used to indicate frame-wrapped DNG picture element and format:

06.0E.2B.34.04.01.01.01.0F.0A.0D.0B.02.7F.01.00 Frame-wrapped DNG Picture Element in CFA format

06.0E.2B.34.04.01.01.01.0F.0A.0D.0B.02.7F.02.00 Frame-wrapped DNG Picture Element in LinearRaw

7.2.2 Picture Essence Descriptors

For CinemaDNG pictures, the MXF file shall include the RGBA Picture Essence Descriptor (See SMPTE 377M Annex D.2 and Annex E for details).

The picture essence descriptor shall describe the image returned by the essence decoder, not the encoded image, as the latter includes samples that are discarded in the decoding process.

7.2.2.1 Generic Picture Essence Descriptor

The RGBA Picture Essence Descriptor is a subclass of the Generic Picture Essence Descriptor.

The Frame Layout in the Generic Picture Essence Descriptor shall be 0 = full frame.

The stored rectangle shall be present.

The displayed rectangle should be present.

Other Items in the Generic picture essence descriptor shall be as defined in SMPTE 377M, and should be present when values are known.

7.2.2.2 Label for Picture Essence Coding

A Picture Essence Coding UL is optional.

If the file package's picture essence descriptor parameter values are set to values specified in a registered parameter configuration for CinemaDNG, the configuration's Picture Essence Coding UL should be present in the file. No configurations are registered as of July 2009.

7.2.2.3 RGBA Picture Essence Descriptor

The items Component Max Ref and PixelLayout in the RGBA Picture Essence Descriptor shall be present. The number of bits per pixel in the decoded image should be set to 16 bits per component regardless of the bit depth of the sensor.

Other items in the RGBA Picture Essence Descriptor should be present when values are known.

7.2.3 Cross-Referencing Parallel MXF Files

There should be one Material Package and ID for a clip's video and audio essence, also when the audio essence is stored in files separate from the video essence.

The SourceClip of the Picture Track set in the Video Essence files and Audio Essence files should reference the Source packages in the Video Essence files via the PackageID values.

The SourceClip of the Sound Track set in the Video Essence file and Audio Essence files should reference the Source packages in the Audio Essence files via the PackageID values.

This is further described in Section 5.2.7 in RP2002-2006.

7.2.4 Mapping Track Numbers To Generic Container Elements

Each track number value for an essence element defined in this standard shall be derived as described in the MXF generic container specification (SMPTE 379M).

NOTE This gives a Track Number of 15.01.42.01 for the above picture element key.

7.3 Application Issues

7.3.1 Key Alignment Grid (KAG)

KAG should be 16384 or a multiple thereof. A carefully selected KAG can provide disk sector alignment, which can provide faster read access when indexing to frames.

7.3.2 Index Table Usage

Index tables should be implemented whenever possible. Index tables are required with Operational pattern OP Atom.

The complete index should be stored in the header partition. This is strongly recommended as it allows for quick read access to any part of the file, and enables streaming support.

A non-zero Edit Unit Byte Count (with Index Duration = 0), indicating a fixed Edit Unit size, should be stored instead of an Index Entry Array. This is strongly recommended for uncompressed images. This provides several benefits:

- The encoder can store the complete index in the header as the recording starts.
- A single index table covers the entire clip, regardless of its duration.
- The duration of a partition can exceed 5957 frames, the limit imposed by the 65535-byte size limit for the Index Entry Array.

NOTE A fixed Edit Unit size can be achieved through padding the DNG data set or using a Fill element.

7.3.3 Operational Pattern Usage

This essence mapping may be used by any operational pattern. A compliant decoder shall support OP 1a and OP Atom and may support any other operational pattern.

7.4 Provisional Values For ULs

The SMPTE *Metadata Dictionary Registry of Metadata Element Descriptions* (SMPTE RP 210.10-2007) and the *SMPTE Labels Registry* (SMPTE RP 224.9-2008) define ULs for use in MXF.

The following keys are not yet defined in these SMPTE Registries:

- MXF Picture Element Key, Byte 15, the Essence Element Type code for CinemaDNG
- MXF Essence Container ULs for CinemaDNG
- Picture Essence Coding ULs for specific configurations of CinemaDNG

This specification provides provisional values. The MXF Picture Element Key uses the TIFF type defined in SMPTE *Element and Metadata Definitions for the SDTI-CP* (SMPTE 331M). The MXF Essence Container UL is an unregistered label from the range of experimental codes. The specification will be revised when the final key values are assigned by SMPTE.

8 Storing CinemaDNG Essence As Image Files In A Directory

This section defines the requirements for storing the CinemaDNG essence in an image sequence directory.

All images shall be encoded as defined in section 9 "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.

The CinemaDNG essence shall be stored as sequence of images in a directory with one image data file per image and with filenames in numerical order. The file extension shall be ".DNG" or ".dng".

8.1 A Sequence Of Image Files

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. For example, in `bridge_0812.1136.day13.dng`, 1136 is the sequencing field.

9 CinemaDNG Image-Encoding Format

This section defines the requirements for encoding images in the CinemaDNG 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.

9.1 The Full-Resolution Image In DNG Format

Each image shall be stored in the DNG format. See 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 using log encoding of sample values, the anti-log decoding function shall be included in the `LinearizationTable`.

9.2 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.

9.3 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 may ignore these images.

Including proxy images other than thumbnails in the full resolution DNG dataset is generally not recommended, as playback performance can be poor.

When additional images are used, all DNG datasets in a CinemaDNG clip should include the same set of additional images with the same dimensions, parameters, and IFD structure.

9.4 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 TIFF tags.

9.5 Including Metadata In DNG Datasets

The DNG format allows for storing metadata in the XMP metadata tag, in an EXIF IFD, or as 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 10 for details.

9.6 Specifying Time Code, Frame Rate, And T-Stop

The DNG dataset may include time codes, frame rate and T-stop values, using the TIFF tags `TimeCodes`, `FrameRate`, and `TStop`, defined below, or, when available, corresponding XMP entries.

9.6.1 *TimeCodes*

9.6.1.1 Tag Structure

Tag	51043 (C763.H)
Type	BYTE
Count	8 * number of time codes
Default	None
Usage	IFD 0

9.6.1.2 Description

This optional tag is an ordered array of Time codes. Each value in the array is of 8 bytes length and has the format and byte order as defined for the first 8 bytes in SMPTE 331M-2004, section 8.2, titled "SMPTE 12M time code metadata". This field is identical to the Time Code Array field in SMPTE 405M-2006.

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.

9.6.2 *FrameRate*

9.6.2.1 Tag Structure

Tag	51044 (C764.H)
Type	SRATIONAL
Count	1
Default	None
Usage	IFD 0

9.6.2.2 Description

This optional tag specifies the video frame rate in number of image fields or frames per second, expressed as a signed rational number. For example, the NTSC 29.97 frame rate is specified as 30000/1001. This field is identical to the sample rate field in SMPTE 377M-2004.

9.6.3 *TStop*

9.6.3.1 Tag Structure

Tag	51058 (C772.H)
Type	RATIONAL
Count	1 or 2
Default	None
Usage	IFD 0

9.6.3.2 Description

This optional tag specifies 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. When the exact value is known, the T-stop shall be specified using a single number. Alternately, two numbers may 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.

10 CinemaDNG Descriptive Metadata

This section defines the requirements for associating optional descriptive metadata with the CinemaDNG essence.

10.1 Metadata Storage Locations

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

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

XMP metadata files may be present in an image sequence directory, although this is not recommended. The existence of XMP files in this location may double the number of files to access, degrading performance. Metadata in such files (also known as sidecar files) shall be associated with the image files with the corresponding file names. If this is the first image file in the clip, the metadata shall be associated with the entire 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, 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 be stored in the MXF header or in the XMP file in the 'CLIP' directory, not in the DNG dataset.

10.2 XMP Metadata Format

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

The usage of XMP items listed in Annex A shall comply with the specification in Annex A.

10.3 TIFF and EXIF Metadata Formats

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 TIFF and EXIF tags shall comply with the specification in Annex A.

10.4 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 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

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

11 CinemaDNG Subsets

The file structure in section 5.1 "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 defined for these special 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

Picture Essence Coding ULs for specific configurations of CinemaDNG may define additional subsets.

11.1 CinemaDNG/MXF Structure

A CinemaDNG/MXF dataset shall be an MXF video essence file as defined in section 6.3 "Video Essence File".

All metadata shall be contained in the MXF file, and shall meet the requirements of section 10 "CinemaDNG Descriptive Metadata".

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

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

11.2 CinemaDNG/Seq Structure

A CinemaDNG/Seq dataset shall be an image sequence directory as defined in section 6.5 "Image Sequence Directory".

All metadata shall be contained in the image sequence directory, and shall meet the requirements of section 10 "CinemaDNG Descriptive Metadata".

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

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

Annex A (Normative)

TIFF Tags For DNG Datasets

The following table 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. The table is available as an Excel file.

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 to be stored. Some XMP tags, such as tiff:DateTime, are combinations of several TIFF/EP or EXIF tags. TIFF tags with codes 51043, 51044, and 51058 are defined in this specification, and may be 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 may be stored in multiple locations according to the corresponding specifications. The letter "c" in the XMP column indicates that a copy of the tag may be stored in an XMP dataset, and the original value shall be stored as indicated by "y".

The first 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)").

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

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.

Tags marked "Not allowed" shall not be utilized by the encoder, 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. Tags marked "Ignore" should not affect the decoder's image rendering.

Encoder	Decoder	DNG	EXIF	TIFF / EP	XMP	Tag Name	Code	Short description
Allowed	Ignore	y	y			GPSTimeStamp	0	Version of GPSInfoIFD.
Allowed	Ignore	y	y			GPSLatitudeRef	1	Indicates whether the latitude is north or south latitude.
Allowed	Ignore	y	y			GPSLatitude	2	Latitude.
Allowed	Ignore	y	y			GPSLongitudeRef	3	Indicates whether the longitude is east or west longitude.

Allowed	Ignore	y	y	GPSTimeStamp	4	Longitude.
Allowed	Ignore	y	y	GPSSatellites	5	Altitude used as the reference altitude.
Allowed	Ignore	y	y	GPSSpeedRef	6	Altitude based on the reference in GPSSpeedRef.
Allowed	Ignore	y	y	GPSSpeed	7	Time as UTC (Coordinated Universal Time).
Allowed	Ignore	y	y	GPSTimeStamp	8	GPS satellites used for measurements.
Allowed	Ignore	y	y	GPSTimeStamp	9	Status of the GPS receiver when the image is recorded.
Allowed	Ignore	y	y	GPSTimeStamp	10	GPS measurement mode.
Allowed	Ignore	y	y	GPSTimeStamp	11	GPS DOP (data degree of precision).
Allowed	Ignore	y	y	GPSTimeStamp	12	Unit used to express the GPS receiver speed of movement.
Allowed	Ignore	y	y	GPSTimeStamp	13	Speed of GPS receiver movement.
Allowed	Ignore	y	y	GPSTimeStamp	14	Reference for giving the direction of GPS receiver movement.
Allowed	Ignore	y	y	GPSTimeStamp	15	Direction of GPS receiver movement.
Allowed	Ignore	y	y	GPSTimeStamp	16	Reference for giving the direction of the image when it is captured.
Allowed	Ignore	y	y	GPSTimeStamp	17	Direction of the image when it was captured.
Allowed	Ignore	y	y	GPSTimeStamp	18	Geodetic survey data used by the GPS receiver.
Allowed	Ignore	y	y	GPSTimeStamp	19	Indicates whether the latitude of the destination point is north or south latitude.
Allowed	Ignore	y	y	GPSTimeStamp	20	Latitude of the destination point.
Allowed	Ignore	y	y	GPSTimeStamp	21	Indicates whether the longitude of the destination point is east or west longitude.
Allowed	Ignore	y	y	GPSTimeStamp	22	Longitude of the destination point.
Allowed	Ignore	y	y	GPSTimeStamp	23	Reference used for giving the bearing to the destination point.
Allowed	Ignore	y	y	GPSTimeStamp	24	Bearing to the destination point.
Allowed	Ignore	y	y	GPSTimeStamp	25	Unit used to express the distance to the destination point.
Allowed	Ignore	y	y	GPSTimeStamp	26	Distance to the destination point.
Allowed	Ignore	y	y	GPSTimeStamp	27	Character string recording the name of the method used for location finding.
Allowed	Ignore	y	y	GPSTimeStamp	28	Character string recording the name of the GPS area.
Allowed	Ignore	y	y	GPSTimeStamp	29	Character string recording date and time information relative to UTC (Coordinated Universal Time).
Allowed	Ignore	y	y	GPSTimeStamp	30	Indicates whether differential correction is applied to the GPS receiver.
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	Ignore		y	y ImageDescription	270	String that describes the subject of the image.
Recommended	Ignore		y	y Make	271	Scanner manufacturer.
Recommended	Ignore		y	y Model	272	Scanner 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
Allowed	Ignore		y	y	XResolution	282	Number of pixels per ResolutionUnit in the ImageWidth direction.
Allowed	Ignore		y	y	YResolution	283	Number of pixels per ResolutionUnit in the ImageLength direction.
Mandatory	Mandatory	y	y	c	PlanarConfiguration	284	How the components of each pixel are stored.
Allowed	Ignore		y	y	ResolutionUnit	296	Unit of measurement for XResolution and YResolution.
Not allowed	Ignore		y		TransferFunction	301	Transfer function for the image in tabular style.
Recommended	Ignore		y	y	Software	305	Name and version number of the software package(s) used to create the image.
Allowed	Ignore		y	y	DateTime	306	Date and time of image creation.
Recommended	Ignore		y	y	Artist	315	Person who created the image.
Allowed	Ignore				HostComputer	316	Computer and/or operating system in use at the time of image creation.
Not allowed	Ignore		y		WhitePoint	318	Chromaticity of the white point of the image.
Not allowed	Ignore		y		PrimaryChromaticities	319	Chromaticities of the primaries of the image.
Not allowed	Ignore				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	Ignore		y		JPEGTables	347	JPEG quantization and/or Huffman tables.
Not allowed	Ignore		y	y	YCbCrCoefficients	529	Transformation from RGB to YCbCr image data.
Not allowed	Ignore		y	y	YCbCrSubSampling	530	Subsampling factors used for the chrominance components of a YCbCr image.
Not allowed	Ignore		y	y	YcbCrPositioning	531	Positioning of subsampled chrominance components relative to luminance samples.
Not allowed	Ignore		y	y	ReferenceBlackWhite	532	Pair of headroom and footroom image data values (codes) for each pixel component.
Allowed	Ignore	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.
Allowed	Ignore		y		BatteryLevel	33423	Camera's battery level relative to full
Recommended	Ignore		y	y	Copyright	33432	Copyright notice.
Recommended	Ignore	y	y	y	ExposureTime	33434	Exposure time, given in seconds.
Recommended	Ignore	y	y	y	FNumber	33437	F-number.

Allowed	Ignore	y			IPTC/NAA	33723	IPTC (International Press Telecommunications Council) meta data.
Allowed	Ignore	y	y		Exif IFD	34665	Offset to the Exif IFD.
Not allowed	Ignore		y		InterColorProfile	34675	ICC profile data.
Allowed	Ignore	y	y	y	ExposureProgram	34850	Class of the program used by the camera to set exposure when the picture is taken.
Allowed	Ignore	y	y	y	SpectralSensitivity	34852	Spectral sensitivity of each channel of the camera used.
Recommended	Ignore	y	y		GPS IFD	34853	Offset to the Exif-related GPS Info IFD.
Recommended	Ignore	y	y	y	ISOSpeedRatings	34855	ISO Speed and ISO Latitude of the camera or input device as specified in ISO 12232.
Not allowed	Ignore	y	y	y	OECF	34856	Opto-Electric Conversion Function (OECF) specified in ISO 14524.
Allowed	Ignore		y		Interlace	34857	Field number of multi-field images
Recommended	Ignore		y	y	TimeZoneOffset	34858	Time zone of DateTimeOriginal value
Allowed	Ignore		y		SelfTimerMode	34859	Number of seconds in delay between image capture and button press
Recommended	Ignore	y		y	ExifVersion	36864	Version of the supported Exif standard.
Recommended	Ignore	y	y	y	DateTimeOriginal	36867	Date and time when the original image data was generated.
Allowed	Ignore	y		y	DateTimeDigitized	36868	Date and time when the image was stored as digital data.
Not allowed	Ignore	y		y	ComponentsConfiguration	37121	Specific to compressed data; specifies the channels and complements PhotometricInterpretation
Allowed	Ignore	y	y	y	CompressedBitsPerPixel	37122	Specific to compressed data; states the compressed bits per pixel.
Recommended	Ignore	y	y	y	ShutterSpeedValue	37377	Shutter speed.
Recommended	Ignore	y	y	y	ApertureValue	37378	Lens aperture.
Allowed	Ignore	y	y	y	BrightnessValue	37379	Value of brightness.
Allowed	Ignore	y	y	y	ExposureBiasValue	37380	Exposure bias.
Allowed	Ignore	y	y	y	MaxApertureValue	37381	Smallest F-number of the lens.
Recommended	Ignore	y	y	y	SubjectDistance	37382	Distance to the subject, given in meters.
Allowed	Ignore	y	y	y	MeteringMode	37383	Metering mode.
Allowed	Ignore	y	y	y	LightSource	37384	Kind of light source.
Allowed	Ignore	y	y	y	Flash	37385	Status of flash when the image was shot.
Recommended	Ignore	y	y	y	FocalLength	37386	Actual focal length of the lens, in mm.
Allowed	Ignore		y		FlashEnergy	37387	Flash energy at the time the image is captured, as measured in Beam Candle Power Seconds. See also 41483
Allowed	Ignore		y		SpatialFrequencyResponse	37388	Spatial frequency response (SFR) of the camera or capture device. See also 41484
Allowed	Ignore		y		Noise	37389	Camera noise measurements
Allowed	Ignore		y		FocalPlaneXResolution	37390	Number of pixels in the image width (X) direction per FocalPlaneResolutionUnit on the camera focal plane. See also 42486
Allowed	Ignore		y		FocalPlaneYResolution	37391	Number of pixels in the image height (Y) direction per FocalPlaneResolutionUnit on the camera focal plane. See also 41487
Allowed	Ignore		y		FocalPlaneResolutionUnit	37392	Unit for measuring FocalPlaneXResolution and FocalPlaneYResolution. See also 41488
Allowed	Ignore		y		ImageNumber	37393	Number assigned to the image
Allowed	Ignore		y		SecurityClassification	37394	Level of security classification
Allowed	Ignore		y		ImageHistory	37395	Record of what has been done to the image

Allowed	Ignore	y	y	y	SubjectArea	37396	Location and area of the main subject in the overall scene in pixels
Allowed	Ignore	y			ExposureIndex	37397	Exposure index selected on the camera or input device at the time the image is captured. See also 41493
Allowed	Ignore	y			TIFF/EPStandardID	37398	Version of this TIFF/EP file
Allowed	Ignore	y			SensingMethod	37399	Type of image sensor used in the camera or image capturing device
Allowed	Ignore	y			MakerNote	37500	Manufacturer specific information.
Allowed	Ignore	y	y		UserComment	37510	Keywords or comments on the image; complements ImageDescription.
Allowed	Ignore	y	y		SubsecTime	37520	Fractions of seconds for the DateTime tag.
Recommended	Ignore	y	y		SubsecTimeOriginal	37521	Fractions of seconds for the DateTimeOriginal tag.
Allowed	Ignore	y	y		SubsecTimeDigitized	37522	Fractions of seconds for the DateTimeDigitized tag.
Allowed	Ignore	y	y		FlashpixVersion	40960	Flashpix format version supported by a FPXR file.
Not allowed	Ignore	y	y		ColorSpace	40961	Color space information tag is always recorded as the color space specifier.
Allowed	Ignore	y	y		PixelXDimension	40962	Specific to compressed data; the valid width of the meaningful image.
Allowed	Ignore	y	y		PixelYDimension	40963	Specific to compressed data; the valid height of the meaningful image.
Allowed	Ignore	y	y		RelatedSoundFile	40964	Name of an audio file related to the image data.
Allowed	Ignore				Interoperability IFD	40965	Offset to the Exif-related Interoperability IFD.
Allowed	Ignore	y	y		FlashEnergy	41483	Strobe energy at the time the image is captured, as measured in Beam Candle Power Seconds
Allowed	Ignore	y	y		SpatialFrequencyResponse	41484	Camera or input device spatial frequency table and SFR values in the direction of image width, image height, and diagonal direction, as specified in ISO 12233.
Allowed	Ignore	y	y		FocalPlaneXResolution	41486	Number of pixels in the image width (X) direction per FocalPlaneResolutionUnit on the camera focal plane.
Allowed	Ignore	y	y		FocalPlaneYResolution	41487	Number of pixels in the image height (Y) direction per FocalPlaneResolutionUnit on the camera focal plane.
Allowed	Ignore	y	y		FocalPlaneResolutionUnit	41488	Unit for measuring FocalPlaneXResolution and FocalPlaneYResolution.
Allowed	Ignore	y	y		SubjectLocation	41492	Location of the main subject in the scene as a pixel position.
Recommended	Ignore	y	y		ExposureIndex	41493	Exposure index selected on the camera or input device at the time the image is captured.
Allowed	Ignore	y	y		SensingMethod	41495	Image sensor type on the camera or input device.
Allowed	Ignore	y	y		FileSource	41728	Image source.
Allowed	Ignore	y	y		SceneType	41729	Type of scene.
Not allowed	Ignore	y	y		CFA Pattern	41730	Color filter array (CFA) geometric pattern of the image sensor when a one-chip color area sensor is used. See 33422 instead

Not allowed	Ignore	y	y	CustomRendered	41985	Use of special processing on image data, such as rendering geared to output.
Allowed	Ignore	y	y	ExposureMode	41986	Exposure mode set when the image was shot.
Allowed	Ignore	y	y	WhiteBalance	41987	White balance mode set when the image was shot.
Allowed	Ignore	y	y	DigitalZoomRatio	41988	Digital zoom ratio when the image was shot.
Recommended	Ignore	y	y	FocalLengthIn35mmFilm	41989	Equivalent focal length assuming a 35mm film camera, in mm.
Allowed	Ignore	y	y	SceneCaptureType	41990	Type of scene that was shot.
Recommended	Ignore	y	y	GainControl	41991	Degree of overall image gain adjustment.
Allowed	Ignore	y	y	Contrast	41992	Direction of contrast processing applied by the camera when the image was shot.
Allowed	Ignore	y	y	Saturation	41993	Direction of saturation processing applied by the camera when the image was shot.
Allowed	Ignore	y	y	Sharpness	41994	Direction of sharpness processing applied by the camera when the image was shot.
Allowed	Ignore	y	y	DeviceSettingDescription	41995	Information on the picture-taking conditions of a particular camera model.
Allowed	Ignore	y	y	SubjectDistanceRange	41996	Distance to the subject.
Allowed	Ignore	y	y	ImageUniqueID	42016	Identifier assigned uniquely to each image.
Mandatory	Mandatory	y		DNGVersion	50706	Used in IFD 0 of DNG files.
Allowed	Mandatory	y		DNGBackwardVersion	50707	Used in IFD 0 of DNG files.
Mandatory	Mandatory	y		UniqueCameraModel	50708	Used in IFD 0 of DNG files.
Allowed	Ignore	y		LocalizedCameraModel	50709	Used in IFD 0 of DNG files.
Allowed	Mandatory	y		CFAPlaneColor	50710	Used in Raw IFD of DNG files.
Allowed	Mandatory	y		CFALayout	50711	Used in Raw IFD of DNG files.
Recommended	Mandatory	y		LinearizationTable	50712	Used in Raw IFD of DNG files.
Recommended	Mandatory	y		BlackLevelRepeatDim	50713	Used in Raw IFD of DNG files.
Recommended	Mandatory	y		BlackLevel	50714	Used in Raw IFD of DNG files.
Allowed	Mandatory	y		BlackLevelDeltaH	50715	Used in Raw IFD of DNG files.
Recommended	Mandatory	y		BlackLevelDeltaV	50716	Used in Raw IFD of DNG files.
Recommended	Mandatory	y		WhiteLevel	50717	Used in Raw IFD of DNG files.
Allowed	Mandatory	y		DefaultScale	50718	Used in Raw IFD of DNG files.
Recommended	Mandatory	y		DefaultCropOrigin	50719	Used in Raw IFD of DNG files.
Recommended	Mandatory	y		DefaultCropSize	50720	Used in Raw IFD of DNG files.
Mandatory	Mandatory	y		ColorMatrix1	50721	Used in IFD 0 or Camera Profile IFD of DNG files.
Recommended	Mandatory	y		ColorMatrix2	50722	Used in IFD 0 or Camera Profile IFD of DNG files.
Recommended	Mandatory	y		CameraCalibration1	50723	Used in IFD 0 of DNG files.
Recommended	Mandatory	y		CameraCalibration2	50724	Used in IFD 0 of DNG files.
	Ignore	y		ReductionMatrix1	50725	Used in IFD 0 or Camera Profile IFD of DNG files.
	Ignore	y		ReductionMatrix2	50726	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Mandatory	y		AnalogBalance	50727	Used in IFD 0 of DNG files.
Recommended	Mandatory	y		AsShotNeutral	50728	Used in IFD 0 of DNG files.
Allowed	Mandatory	y		AsShotWhiteXY	50729	Used in IFD 0 of DNG files.
Allowed	Mandatory	y		BaselineExposure	50730	Used in IFD 0 of DNG files.
Allowed	Recommended	y		BaselineNoise	50731	Used in IFD 0 of DNG files.
Allowed	Recommended	y		BaselineSharpness	50732	Used in IFD 0 of DNG files.
Allowed	Mandatory	y		BayerGreenSplit	50733	Used in Raw IFD of DNG files.
Allowed	Mandatory	y		LinearResponseLimit	50734	Used in IFD 0 of DNG files.
Recommended	Ignore	y		CameraSerialNumber	50735	Used in IFD 0 of DNG files.

Allowed	Ignore	y	LensInfo	50736	Used in IFD 0 of DNG files. Min and Max focal length and F-stop
Allowed	Ignore	y	ChromaBlurRadius	50737	Used in Raw IFD of DNG files.
Allowed	Recommended	y	AntiAliasStrength	50738	Used in Raw IFD of DNG files.
Allowed	Ignore	y	ShadowScale	50739	Used in IFD 0 of DNG files.
Allowed	Ignore	y	DNGPrivateData	50740	Used in IFD 0 of DNG files.
Allowed	Ignore	y	MakerNoteSafety	50741	Used in IFD 0 of DNG files.
Recommended	Mandatory	y	CalibrationIlluminant1	50778	Used in IFD 0 or Camera Profile IFD of DNG files.
Recommended	Mandatory	y	CalibrationIlluminant2	50779	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Mandatory	y	BestQualityScale	50780	Used in Raw IFD of DNG files.
Allowed	Ignore	y	RawDataUniqueID	50781	Used in IFD 0 of DNG files.
Allowed	Ignore	y	OriginalRawFileName	50827	Used in IFD 0 of DNG files.
Discouraged	Ignore	y	OriginalRawFileData	50828	Used in IFD 0 of DNG files.
Recommended	Mandatory	y	ActiveArea	50829	Used in Raw IFD of DNG files.
Allowed	Ignore	y	MaskedAreas	50830	Used in Raw IFD of DNG files.
Allowed	Mandatory	y	AsShotICCProfile	50831	Used in IFD 0 of DNG files.
Allowed	Mandatory	y	AsShotPreProfileMatrix	50832	Used in IFD 0 of DNG files.
Allowed	Mandatory	y	CurrentICCProfile	50833	Used in IFD 0 of DNG files.
Allowed	Mandatory	y	CurrentPreProfileMatrix	50834	Used in IFD 0 of DNG files.
Allowed	Optional	y	ColorimetricReference	50879	Used in IFD 0 of DNG files.
Allowed	Optional	y	CameraCalibrationSignature	50931	Used in IFD 0 of DNG files.
Allowed	Optional	y	ProfileCalibrationSignature	50932	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ExtraCameraProfiles	50933	Used in IFD 0 of DNG files.
Allowed	Optional	y	AsShotProfileName	50934	Used in IFD 0 of DNG files.
Allowed	Optional	y	NoiseReductionApplied	50935	Used in Raw IFD of DNG files.
Allowed	Optional	y	ProfileName	50936	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ProfileHueSatMapDims	50937	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ProfileHueSatMapData1	50938	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ProfileHueSatMapData2	50939	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ProfileToneCurve	50940	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ProfileEmbedPolicy	50941	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ProfileCopyright	50942	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ForwardMatrix1	50964	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ForwardMatrix2	50965	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Ignore	y	PreviewApplicationName	50966	Used in Preview IFD of DNG files.
Allowed	Ignore	y	PreviewApplicationVersion	50967	Used in Preview IFD of DNG files.
Allowed	Ignore	y	PreviewSettingsName	50968	Used in Preview IFD of DNG files.
Allowed	Ignore	y	PreviewSettingsDigest	50969	Used in Preview IFD of DNG files.
Allowed	Ignore	y	PreviewColorSpace	50970	Used in Preview IFD of DNG files.
Allowed	Ignore	y	PreviewDateTime	50971	Used in Preview IFD of DNG files.
Allowed	Ignore	y	RawImageDigest	50972	Used in IFD 0 of DNG files.
Allowed	Ignore	y	OriginalRawFileDigest	50973	Used in IFD 0 of DNG files.
Allowed	Optional	y	SubTileBlockSize	50974	Used in Raw IFD of DNG files.

Allowed	Optional	y	RowInterleaveFactor	50975	Used in Raw IFD of DNG files.
Allowed	Optional	y	ProfileLookTableDims	50981	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	ProfileLookTableData	50982	Used in IFD 0 or Camera Profile IFD of DNG files.
Allowed	Optional	y	OpcodeList1	51008	Used in Raw IFD of DNG files.
Allowed	Optional	y	OpcodeList2	51009	Used in Raw IFD of DNG files.
Allowed	Optional	y	OpcodeList3	51022	Used in Raw IFD of DNG files.
Allowed	Optional	y	NoiseProfile	51041	Used in Raw IFD of DNG files.
Recommended	Ignore		TimeCodes	51043	Multiple time codes. Each is an 8-byte quantity as defined in SMPTE 12M
Recommended	Ignore	y	FrameRate	51044	Video frame rate in image frames per second
Recommended	Ignore		TStop	51058	T-stop or T-number, the photometric aperture of the lens

Annex B (Informative)

Bibliography

The following documents describe the DNG and TIFF image format.

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*

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.

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 298M-1997 Television — *Universal Labels for Unique Identification of Digital Data*

SMPTE 330M-2004, Television — *Unique Material Identifier (UMID)*

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

SMPTE 336M-2007 Television — *Data Encoding Protocol Using Key-Length-Value*

SMPTE 377M-2004 Television — *Material Exchange Format (MXF) – File Format Specification*

SMPTE 378M-2004 Television — *Material Exchange Format (MXF) Operational Pattern 1a (Single Item, Single Package)*

SMPTE 379M-2004 Television — *Material Exchange Format (MXF) – MXF Generic Container*

SMPTE 382M-2007 Television — *Material Exchange Format - Mapping AES3 and Broadcast Wave Audio into the MXF Generic Container*

SMPTE 390M-2004 Television — *Material Exchange Format (MXF) – Specialized Operational Pattern “Atom” (Simplified Representation of a Single Item)*

SMPTE 405M-2006, Television — *Material Exchange Format (MXF) — Elements and Individual Data Items for the MXF Generic Container System Scheme 1*

SMPTE RP 210.10-2007 — *Metadata Dictionary Registry of Metadata Element Descriptions*

SMPTE RP 224.9-2008 *SMPTE Labels Registry*

SMPTE RP 2002-2006 *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 Version 2.2*

XMP Specification, Adobe Systems, 2008

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)*