

# HDR/WCG Metadata Encoding Best Practice

This practice defines how to encode High Dynamic Range (HDR) and Wide Color Gamut (WCG) metadata values such as Mastered Color Volume, MaxFALL and MaxCLL.



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## REVISION HISTORY

Version	Date	Description
1.0	November 1, 2018	Initial publication

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## 1 DIGITAL ASSET METADATA

Digital Asset Metadata related to High Dynamic Range (HDR) and Wide Color Gamut (WCG) is typically encoded as part of the Media Manifest Inventory. In this case, Inventory/Video/Picture.

### 1.1 Color Subsampling

Video/PictureColorSubsampling is defined in Section 5.2.6.3. The following values are allowed:

- ‘4:1:1’
- ‘4:2:0’
- ‘4:2:2’
- ‘4:4:4’

For the formal definition, see Common Metadata, Section 5.2.6.3.

### 1.2 Colorimetry

For P3D65, use “P3”. Other values will be defined as needed.

### 1.3 Mastered Color Volume

Mastered Color Volume is defined in Image/Picture/MasteredColorVolume which is defined in Section 5.2.6.5. The definitions are from SMPTE ST 2086.

Note that by convention, when LuminanceMin is unknown, it’s set to ‘0.0’.

Following are some common examples of encoding.

The following example represents master of P3-D65 with a Luminance range from .005 cd/m<sup>2</sup> to 1000 cd/m<sup>2</sup>.

```
<md:MasteredColorVolume>
  <md:PrimaryRChromaticity>
    <md:ChromaticityCIEx>0.68</md:ChromaticityCIEx>
    <md:ChromaticityCIEy>0.32</md:ChromaticityCIEy>
  </md:PrimaryRChromaticity>
  <md:PrimaryGChromaticity>
    <md:ChromaticityCIEx>0.265</md:ChromaticityCIEx>
    <md:ChromaticityCIEy>0.69</md:ChromaticityCIEy>
  </md:PrimaryGChromaticity>
  <md:PrimaryBChromaticity>
    <md:ChromaticityCIEx>0.15</md:ChromaticityCIEx>
    <md:ChromaticityCIEy>0.06</md:ChromaticityCIEy>
  </md:PrimaryBChromaticity>
  <md:WhitePointChromaticity>
    <md:ChromaticityCIEx>0.3127</md:ChromaticityCIEx>
    <md:ChromaticityCIEy>0.329</md:ChromaticityCIEy>
```

---

```
</md:WhitePointChromaticity>  
<md:LuminanceMin>0.005</md:LuminanceMin>  
<md:LuminanceMax>1000</md:LuminanceMax>  
</md:MasteredColorVolume>
```

## 1.4 Color Encoding

Color Encoding is expressed in Picture/ColorEncoding, as described in Section 5.2.6.6.

It consists of three parts: Primaries, TransferFunction and ColorDifferencing. These all have controlled vocabularies described in the spec.

For HDR, Primaries is typically ‘BT2020’ and TransferFunction is ‘ST2084’ (for PQ). ColorDifferencing is usually not encoded and is entered like this:

```
<md:ColorDifferencing/>
```

## 1.5 MaxFALL and MaxCLL

MaxFALL and MaxCLL are encoded in Picture/LightLevel as described in Section 6.2.6.8. ContentMax holds MaxCLL and FrameAverageMax holds MaxFALL.

```
<md:LightLevel>  
  <md:ContentMax interpretation="MaxCLL">1000</md:ContentMax>  
  <md:FrameAverageMax interpretation="MaxFALL">399</md:FrameAverageMax>  
</md:LightLevel>
```

Noting that @interpretation defaults to MaxCLL and MaxFALL respective, so it is unnecessary to include in the XML as shown here:

```
<md:LightLevel>  
  <md:ContentMax>1000</md:ContentMax>  
  <md:FrameAverageMax>399</md:FrameAverageMax>  
</md:LightLevel>
```

If values are not known, the convention is to set values to zero (‘0’):

```
md:LightLevel>  
  <md:ContentMax>0</md:ContentMax>  
  <md:FrameAverageMax>0</md:FrameAverageMax>  
</md:LightLevel>
```

## 2 MAPPING TO/FROM OTHER SYSTEMS

This section describes how to translate values between Common Metadata, IMF (Application #2E) and HEVC.

### 2.1 IMF

Data are defined in SMPTE ST-2067-21. Data are encoded in KLV format in accordance with MXF (SMPTE ST 377-1), Generic Picture Essence Descriptor (Section F.4.1).

Mastered Display Color Volume is defined in Annex C, with parameters in Table C.1.

- Chromaticity is encoded as Mastering Display Primaries and Mastering Display White Point Chromaticity. Units in IMF are 0.00002, so IMF values must be multiplied by 0.00002 when translating from IMF to Common Metadata.
- LuminanceMin and LuminanceMax correspond with Mastering Display Minimum Luminance and Mastering Display Maximum Luminance respectively. Note that units in IMF are 0.0001, so IMF values must be multiplied by 0.0001 when translating from IMF to Common Metadata.

ColorEncoding/Primaries and ColorEncoding/ColorDifferencing and ColorEncoding/TransferFunction come from Color Primaries (also part of Generic Picture Essence Descriptor). This is defined in ST 2067-20 Section 6.1.2.17 and ST 2067-21 Annex D. These are encoded as follows (ST 2067-20 reference, ST 2067-21 reference):

UL Associated with...	Primaries (6.1.2.17, 6.1.3)	ColorDifferencing (6.1.2.1.6, 6.1.2?)	TransferFunction (6.1.2.15, 6.1.1)
COLOR.1 or COLOR.2	'BT601'	'BT601'	'BT601'
COLOR.3	'BT709'	'BT709'	'BT701'
COLOR.4	'BT709'	'xvYCC709'	'BT709'
COLOR.5	'BT2020'	'BT2020'	'BT2020'
COLOR.6	'DCIP3'	'BT2020'	'ST2084'
COLOR.7	'BT2020'	'BT2020'	'ST2084'

LightLevel/ContentMax (i.e., MaxCLL) and LightLevel/FrameAverageMax (i.e., MaxFALL) are defined in ST 2067-21, Section 7.2. Values of 0 should be used if these values are not present.

Colorimetry is determined by the color system. I don't believe this is encoded directly, but can be inferred from the fields above.

Color model	Colorimetry
COLOR.1 or COLOR.2	'601'
COLOR.3	'709'
COLOR.4	'xvYCC709'
COLOR.5	'2020'
COLOR.6	'P3'
COLOR.7	'2020'

## 2.2 H.265/HEVC

Reference rec.ITU-T H.265 v2 or ISO 23008.

Data are encoded in SEI messages.

Mastered Display Color Volume is in mastering\_display\_colour\_volume as defined in Section D.2.27. Encoding instructions are found in Section D.3.27. Note that units are 0.00002, so H.265 values must be multiplied by 0.00002 when translating from IMF to Common Metadata.

Colorimetry is encoded from color\_primaries in VUI parameters, defined in H.265, Section E.2.1. Note that Table E.3 in H.265 does not include P3D65 values. However, this is extended in

ITU-T H.273, Table 2. P3D65 has the value of '11' in this table. color primaries maps to Colorimetry as follows:

color primaries	Colorimetry
1	'709'
6 or 7	'601'
9	'2020'
11	'P3'

MaxFALL and MaxCLL are in

## 3 EXAMPLE

Following is an example of an Picture element

### 3.1 P3 D65

```
<md:Picture>
  <md:ColorSubsampling>4:4:4</md:ColorSubsampling >
  <md:MasteredColorVolume>
    <md:PrimaryRChromaticity>
      <md:ChromaticityCIEx>0.68</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.32</md:ChromaticityCIEy>
    </md:PrimaryRChromaticity>
    <md:PrimaryGChromaticity>
      <md:ChromaticityCIEx>0.265</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.69</md:ChromaticityCIEy>
    </md:PrimaryGChromaticity>
    <md:PrimaryBChromaticity>
      <md:ChromaticityCIEx>0.15</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.06</md:ChromaticityCIEy>
    </md:PrimaryBChromaticity>
    <md:WhitePointChromaticity>
      <md:ChromaticityCIEx>0.3127</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.329</md:ChromaticityCIEy>
    </md:WhitePointChromaticity>
    <md:LuminanceMin>0.005</md:LuminanceMin>
    <md:LuminanceMax>1000</md:LuminanceMax>
  </md:MasteredColorVolume>
  <md:ColorEncoding>
    <md:Primaries>DCIP3</md:Primaries>
    <md:TransferFunction>ST2084</md:TransferFunction>
    <md:ColorDifferencing/>
  </md:ColorEncoding>
  <md:LightLevel>
    <md:ContentMax>1000</md:ContentMax>
    <md:FrameAverageMax>399</md:FrameAverageMax>
  </md:LightLevel>
</md:Picture>
```

## 3.2 SDR HDR Conversion

If one started with an SDR mastered content and converted to HDR in accordance with *MovieLabs Best Practices for Mapping BT.709 to HDR10 for Consumer Distribution* (<https://movielabs.com/solutions-specifications/ultra-hd-and-hdr/>), you would end up with:

```
<md:Picture>
  <md:ColorSubsampling>4:2:0</md:ColorSubsampling>
  <md:MasteredColorVolume>
    <md:PrimaryRChromaticity>
      <md:ChromaticityCIEx>0.64</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.33</md:ChromaticityCIEy>
    </md:PrimaryRChromaticity>
    <md:PrimaryGChromaticity>
      <md:ChromaticityCIEx>0.30</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.60</md:ChromaticityCIEy>
    </md:PrimaryGChromaticity>
    <md:PrimaryBChromaticity>
      <md:ChromaticityCIEx>0.15</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.06</md:ChromaticityCIEy>
    </md:PrimaryBChromaticity>
    <md:WhitePointChromaticity>
      <md:ChromaticityCIEx>0.3127</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.329</md:ChromaticityCIEy>
    </md:WhitePointChromaticity>
    <md:LuminanceMin>0.0</md:LuminanceMin>
    <md:LuminanceMax>200</md:LuminanceMax>
  </md:MasteredColorVolume>
  <md:ColorEncoding>
    <md:Primaries>BT709</md:Primaries>
    <md:TransferFunction>ST2084</md:TransferFunction>
    <md:ColorDifferencing/>
  </md:ColorEncoding>
  <md:LightLevel>
    <md:ContentMax>200</md:ContentMax>
    <md:FrameAverageMax>0</md:FrameAverageMax>
  </md:LightLevel>
</md:Picture>
```

## 4 DETERMINING IF A TRACK IS SDR OR HDR

There is no strict definition of SDR or HDR. Generally, if video has either a higher-than-usual dynamic range or a wider-than-usual color gamut it is HDR.

It's a little trickier than that because the most straightforward data is in an optional element: Picture/MasteredColorVolume. Fortunately, there are other parameters that indicate one or the other. As noted, some of these aren't definitive so using more than one is preferred.

- Content is HDR if
  - Picture/Primaries is *not* "BT601" or "BT709". Note one could hypothetically use BT.2020 and master to SDR.

- Picture/TransferFunction is ‘ST2084’ or ‘BT2100HLG’. Again, it is possible to have SDR with these EOTFs, but unlikely
- ColorDifferencing is *not* ‘BT601’ or ‘BT709’
- Picture/MasteredColorVolume/LuminanceMax or LuminanceMin is outside of an SDR range (you decide what this is)
- Picture/MasteredColorVolume primaries are outside of Rec.709 range.
- Otherwise it is SDR

Note that when dynamic metadata is included (i.e., Dynamic Metadata Color Volume Transform), there can be two or more gradings from the same video track. Each can be SDR or HDR.

## 5 DYNAMIC METADATA

‘Dynamic Metadata’ refers to metadata synchronized to video that defines a color volume transfer. Sometimes, this is referred to DMCVT (Dynamic Metadata for Color Volume Transform). The means to identify the DMCVT method used is part of the Video/Picture description, and can be found in Common Metadata, Section 5.2.6.13

DMCVT data can be carried in a video track, typically in an MPEG SEI Message or in specialized ISO Base Media File Format (ISOBMFF) boxes. DMCVT can also be carried outside of a video track. We include this in the category of Ancillary Tracks.

Following is an example of DMCVT metadata with a HDR10 P3 D65 base layer.

```
<md:Picture>
  <md:ColorSubsampling>4:4:4</md:ColorSubsampling >
  <md:MasteredColorVolume>
    <md:PrimaryRChromaticity>
      <md:ChromaticityCIEx>0.68</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.32</md:ChromaticityCIEy>
    </md:PrimaryRChromaticity>
    <md:PrimaryGChromaticity>
      <md:ChromaticityCIEx>0.265</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.69</md:ChromaticityCIEy>
    </md:PrimaryGChromaticity>
    <md:PrimaryBChromaticity>
      <md:ChromaticityCIEx>0.15</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.06</md:ChromaticityCIEy>
    </md:PrimaryBChromaticity>
    <md:WhitePointChromaticity>
      <md:ChromaticityCIEx>0.3127</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.329</md:ChromaticityCIEy>
    </md:WhitePointChromaticity>
    <md:LuminanceMin>0.005</md:LuminanceMin>
    <md:LuminanceMax>1000</md:LuminanceMax>
  </md:MasteredColorVolume>
```

```
<md:ColorEncoding>
  <md:Primaries>DCIP3</md:Primaries>
  <md:TransferFunction>ST2084</md:TransferFunction>
  <md:ColorDifferencing/>
</md:ColorEncoding>
<md:LightLevel>
  <md:ContentMax>1000</md:ContentMax>
  <md:FrameAverageMax>399</md:FrameAverageMax>
</md:LightLevel>
<md:ColorTransformMetadata>
  <md:ColorVolumeTransform>DolbyVision</md:ColorVolumeTransform>
  <md:ApplicationIdentifier ApplicationVersion="0">1</md:ApplicationIdentifier>
  <md:TargetSystemDisplay>
    <md:PrimaryRChromaticity>
      <md:ChromaticityCIEx>0.68</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.32</md:ChromaticityCIEy>
    </md:PrimaryRChromaticity>
    <md:PrimaryGChromaticity>
      <md:ChromaticityCIEx>0.265</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.69</md:ChromaticityCIEy>
    </md:PrimaryGChromaticity>
    <md:PrimaryBChromaticity>
      <md:ChromaticityCIEx>0.15</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.06</md:ChromaticityCIEy>
    </md:PrimaryBChromaticity>
    <md:WhitePointChromaticity>
      <md:ChromaticityCIEx>0.3127</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.329</md:ChromaticityCIEy>
    </md:WhitePointChromaticity>
    <md:LuminanceMin>0.0005</md:LuminanceMin>
    <md:LuminanceMax>4000</md:LuminanceMax>
  </md:TargetSystemDisplay>
  <md:FrameAverageMax>399</md:FrameAverageMax>
</md:ColorTransformMetadata>
</md:Picture>
```

## 5.1 Dolby Vision

Dolby Vision (DoVi) can be encoded as part of a video track or as an Ancillary Track. If DoVi is part of the video track (i.e., SEI Message, ISOBMFF box, etc.), the video track will contain both the base layer and enhancement metadata. See Section 5.4 for information on Ancillary tracks.

The base layer color volume is captured in Video/Picture/MasteredColorVolume.

Then only metadata for the DolbyVision metadata is ColorTransformMetadata. ColorVolumeTransform is “DolbyVision”. ApplicationIdentifier is “1”. TargetSystemDisplay is the ST 2094 metadata for the base + enhancement.

For example, if the base is HDR10 at 1000 nits and the enhancement takes it to 10,000 nits, MasteredColorVolume/LuminanceMax would be 1000, and ColorTransformMetadata/TargetSystemDisplay/LuminanceMax would be 10000.



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If there is more than one enhancement defined, there could be multiple instances of ColorTransformMetadata. For example, one DoVi enhancement path might take an HDR10 base layer to a color volume with wider gamut and more dynamic range; and another enhancement path might take the same base layer to SDR.

Note that in Ancillary tracks, rather than using Picture/ColorTransformMetadata, you use Inventory/Ancillary/CombinedMetadata/Video/Picture/ColorTransformMetadata.

## 5.2 HDR10+

HDR10+ dynamic metadata is included in the video track. Accordingly, metadata for the is included in ColorTransformMetadata. ColorVolumeTransform is “HDR10PLUS”. ApplicationIdentifier is “2”. TargetSystemDisplay is the ST 2094 metadata for the base + enhancement.

We are not aware of HDR10+ in ancillary tracks.

## 5.3 SL-HDR1/2/3

There are three variations of SL-HDR who differ primarily by base layer type. SL-HDR1 has an SDR base layer, SL-HDR2 has an HDR10 base layer and SL-HDR3 has an HLG base layer. At time of this document’s publication, SL-HDR3 is not fully specified.

Dynamic metadata is included in the video track. Accordingly, metadata for the is included in ColorTransformMetadata. ColorVolumeTransform is “SL-HLG”. This is the encoding for any variant

ApplicationIdentifier is “4”. TargetSystemDisplay is the ST 2094 metadata for the base + enhancement.

We are not aware of SL-HLG in ancillary tracks.

## 5.4 Encoding DMCVT data in Ancillary Tracks

If dynamic metadata is packaged outside of the video track, it is described in an MMC Ancillary Track. That is, there would an Inventory/Ancillary instance for the DMCVT data.

- Ancillary/Type is “enhancement”
- Ancillary/SubType is the ColorVolumeTransform values as defined in CM, Section 5.2.6.13. For example, “DolbyVision” for Dolby Vision
- Ancillary/BaseTrackReference is the VideoTrackID of the base layer video track
- Ancillary/CombinedMetadata/Video/Picture/ColorTransformMetadata is the same encoding as Picture/ColorTransformMetadata for DMCVT embedded in the video track.

## 5.5 Preventing Base or Enhancement Transcoding

Studios and service providers will sometimes delivery base layers and specific enhancements that are not intended for transcoding. This section describes how to signal those tracks or enhancements should not be used for transcoding (i.e., do not generate output files from these tracks or metadata).

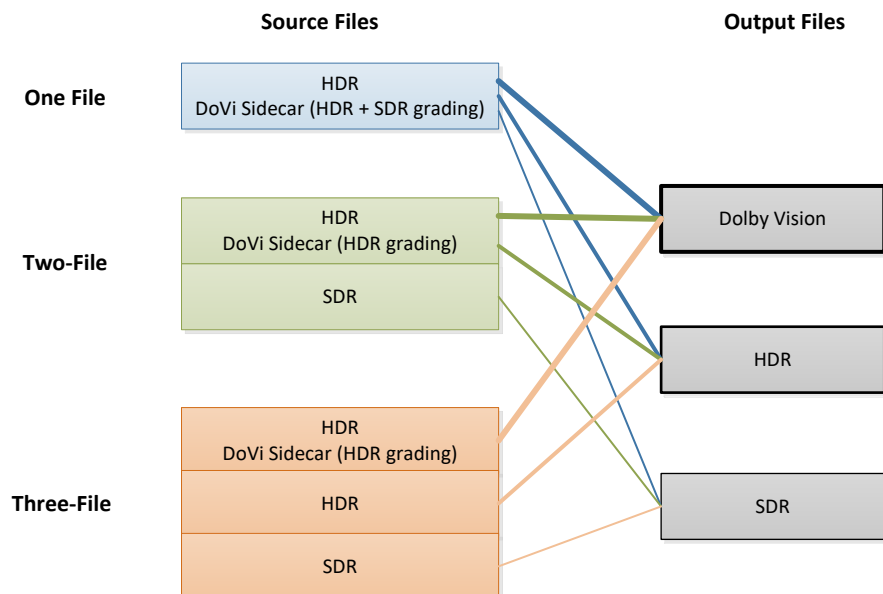
Consider the use case where a 4,000 nit graded HDR10 base layer is provided for use with DMCVT enhancement. However, there is no intent to distribute a 4,000 nit HDR10 version. Instead, a 1000 nit HDR10 encode is provided in a separate file. Or, there might be and HDR to SDR DMCVT enhancement that is not intended for use, because there is a separate SDR encode provided.

If there is no intent to use a DMCVT, do not include the Picture/ColorTransformMetadata instance for that metadata. Retailers should only use the enhancement metadata for which ColorTransformMetadata is provided.

If there is no intent to use the base layer, encode Picture/ColorTransformMetadata/DoNotTranscodeBase="true". This is the signal that the base track is unusable on its own.

## 5.6 Packaging Combinations with Dynamic Metadata

This section describes how to encode metadata given different source file and transcoded file combinations. Consider the following cases:



All cases result in similar output files (Dolby Vision, HDR10 and SDR), but have different input files. Notably in the first case, the source with HDR + Sidecar DoVi outputs Dolby Vision, but not HDR10—that comes from a separate source. Note that although Dolby Vision is used in these

examples, the same principles apply to other dynamic metadata such as HDR10+ or SL-HDR1. Note also that principles also apply whether dynamic metadata is embedded or in a sidecar.

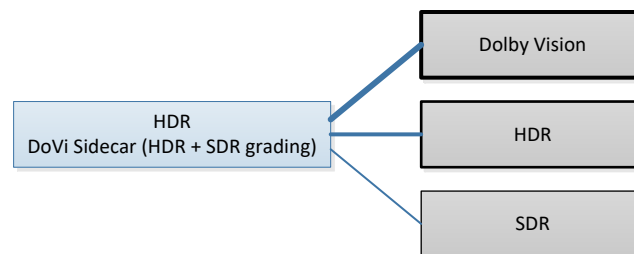
Note that one should avoid sending two files that produce equivalent outputs. For example, one should not deliver a file that produces SDR with Dolby Vision, and also deliver a standalone SDR file.

## 5.6.1 One-source example

Note that the one-file scenario is included for completeness, although we are not aware of anyone currently using this approach.

The one-source example works as follows:

- Source 1 (HDR + Sidecar DoVi) → Dolby Vision, HDR, SDR



Implicit in this example is the assumption that the DoVi sidecar includes grading for Dolby Vision HDR and for SDR.

This is encoded in accordance with the example in the beginning of Section 5 as with sidecar modification in accordance with Section 5.4. However since there are two gradings, there are two instances of ColorTransformMetadata, one for HDR (as shown in the example), and one for SDR.

Note that when transcoding HDR to SDR, this is signaled by including a TargetSystemDisplay with SDR (i.e., Rec.709) values. It would look something like this:

```

<md:ColorTransformMetadata>
  <md:ColorVolumeTransform>DolbyVision</md:ColorVolumeTransform>
  <md:ApplicationIdentifier ApplicationVersion="0">1</md:ApplicationIdentifier>
  <md:TargetSystemDisplay>
    <md:PrimaryRChromaticity>
      <md:ChromaticityCIEx>0.64</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.33</md:ChromaticityCIEy>
    </md:PrimaryRChromaticity>
    <md:PrimaryGChromaticity>
      <md:ChromaticityCIEx>0.30</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.60</md:ChromaticityCIEy>
    </md:PrimaryGChromaticity>
    <md:PrimaryBChromaticity>
      <md:ChromaticityCIEx>0.15</md:ChromaticityCIEx>
      <md:ChromaticityCIEy>0.06</md:ChromaticityCIEy>
    </md:PrimaryBChromaticity>
  </md:TargetSystemDisplay>
</md:ColorTransformMetadata>
  
```

```

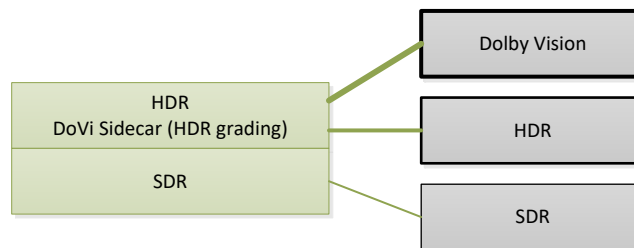
<md:WhitePointChromaticity>
  <md:ChromaticityCIEx>0.3127</md:ChromaticityCIEx>
  <md:ChromaticityCIEy>0.329</md:ChromaticityCIEy>
</md:WhitePointChromaticity>
<md:LuminanceMin>0</md:LuminanceMin>
<md:LuminanceMax>100</md:LuminanceMax>
</md:TargetSystemDisplay>
<md:ColorTransformMetadata>

```

## 5.6.2 Two-source example

The two-source example works as follows:

- Source 1 (HDR + Sidecar DoVi) → Dolby Vision, HDR
- Source 2 (SDR) → SDR



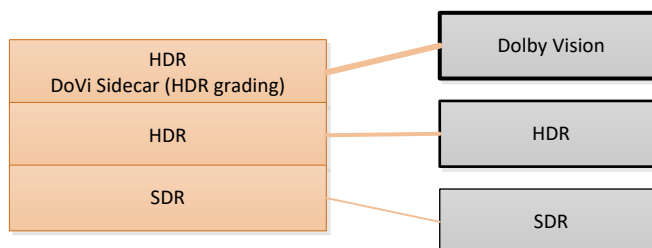
Source 1 is encoded in accordance with the example in the beginning of Section 5 as with sidecar modification in accordance with Section 5.4.

Source 2 is a standard SDR file.

## 5.6.3 Three-source example

The three-source example works as follows:

- Source 1 (HDR + Sidecar DoVi) → Dolby Vision
- Source 2 (HDR) → HDR10
- Source 3 (SDR) → SDR



Source 1 is encoded in accordance with the example in the beginning of Section 5 as with sidecar modification in accordance with Section 5.4; with one important exception. At end of ColorTransformMetadata, DoNotTranscodeBase="true" must be added to avoid generating

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HDR10 from the base layer. Note that there is nothing to describe SDR, so SDR is implicitly not generated.

...

```
<md:LuminanceMin>0.0005</md:LuminanceMin>
<md:LuminanceMax>4000</md:LuminanceMax>
</md:TargetSystemDisplay>
<md:FrameAverageMax>399</md:FrameAverageMax>
</md:ColorVolumeTransform>
<md:DoNotTranscodeBase>true</md:DoNotTranscodeBase>
<md:ColorTransformMetadata>
```

Sources 2 and 3 are encoded as any other HDR or SDR file, respectively, with no dynamic metadata.