COMMITTEE DRAFT

SMPTE STANDARD

Interoperable Master Format — Application #2E

Approved - 2025-06-17

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Foreword

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This document was prepared by Technology Committee 35PM.

The following summarizes the changes from the previous edition of this document:

- Adds 8K resolution support
- Adds example JPEG 2000 encoder commands

1 Scope

This specification defines IMF Application #2E. It is a specialization of the IMF Framework. Application #2E is meant for studio applications where a TV or movie title is transformed into multiple content versions (airline edits, special edition, languages...) that are made available to multiple consumer distribution channels (Internet, optical media, broadcast...) across multiple territories and over the span of many months to over a year. It uses image essence coded as a JPEG 2000 codestream and audio essence coded as linear PCM.

2 Conformance

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any clause explicitly labeled as "Informative" or individual paragraphs that start with "Note:"

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword "reserved" indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; tables shall be next; then formal languages; then figures; and then any other language forms.

3 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

SMPTE ST 377-1:2011, Material Exchange Format (MXF) - File Format Specification

SMPTE ST 379-1:2009, Material Exchange Format (MXF) - MXF Generic Container

SMPTE ST 422:2019, Material Exchange Format — Mapping JPEG 2000 Codestreams into the MXF Generic Container

SMPTE ST 2067-2:2020, Interoperable Master Format - Core Constraints

SMPTE ST 2084:2014, High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays

SMPTE ST 2086:2018, Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images

SMPTE ST 2113:2018, Colorimetry of P3 Color Spaces

Recommendation ITU-R BT.601-7, Studio Encoding Parameters of Digital Television for Standard 4:3 and Wide-Screen 16:9 Aspect Ratios

Recommendation ITU-R BT.709-6, Parameter Values for the HDTV Standards for Production and International Programme Exchange

Recommendation ITU-R BT.2020-2, Parameter Values for Ultra-High Definition Television Systems for Production and International Programme Exchange

Recommendation ITU-R BT.2100-2, Image parameter values for high dynamic range television for use in production and international programme exchange

CTA 861-G, A DTV Profile for Uncompressed High Speed Digital Interfaces (November 2016)

IEC 61966-2-4 Edition 1.0, Multimedia Systems and Equipment - Colour Measurement and Management — Part 2-4: Colour Management — Extended-Gamut YCC Colour Space for Video Applications — xvYCC

ISO/IEC 15444-1:2019, Information Technology — JPEG 2000 Image Coding System: Core Coding System

ISO/IEC 15444-15:2019, Information technology — JPEG 2000 image coding system — Part 15: High Throughput JPEG 2000

ISO 11664-3:2012 (CIE S014-3/E:2011), Colorimetry — Part 3: CIE Tristimulus Values

World Wide Web Consortium (W3C) (2004, October 28). XML Schema Part 1: Structures (Second Edition)

4 Terms and definitions

No terms and definitions are listed in this document.

5 Overall

5.1 General

All provisions of SMPTE ST 2067-2 shall apply.

5.2 Format

Track Files shall conform to SMPTE ST 379-1:2009.

5.3 Shim Parameters

Table 1 — Shim Parameter Values Definitions

Shim Parameter	Value
shim_id	http://www.smpte-ra.org/schemas/2067-21/2016
picture_bitrate	ST 2067-21
picture_format	ST 2067-21
gc_type	379-1-gc
picture_family	JPEG2000
picture_custom_ANC	false
picture_render_ANC	false

5.4 XML Schema and Namespace

XML elements defined by this specification shall conform to the XML schema definitions (see World Wide Web Consortium (W3C) (2004, October 28). XML Schema Part 1: Structures (Second Edition)) found in this specification. In the event of a conflict between schema definitions and the prose, the prose shall take precedence.

The XML schema root element shall be as defined in Figure 1

```
<xs:schema targetNamespace="http://www.smpte-ra.org/schemas/2067-21/2016"
    xmlns:app2e="http://www.smpte-ra.org/schemas/2067-21/2016"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    elementFormDefault="qualified"
    attributeFormDefault="unqualified">
    <!-- schema definitions found in this document -->
</xs:schema>
```

Figure 1 — XML Schema root element definition

Element a is an XML schema document as specified in World Wide Web Consortium (W3C) (2004, October 28). XML Schema Part 1: Structures (Second Edition). It collects the XML schema definitions defined in this specification. Element a is informative and, in case of conflict, the main prose element takes precedence.

6 Image Essence

6.1 General

Image essence shall consist of image frames, each a rectangular pixel array.

6.2 Constraints

6.2.1 General

Each image frame shall conform to one of the permitted combinations of image frame characteristics listed in Table 2.

The notation a..b indicates that any value between a and b, including a and b, is allowed. For instance, the range 1..4096 includes the value 3840 and the range 1..3112 includes the value 2160.

Table 2 — Image Characteristics

Characteristic	Constraint								
Image Frame Width	1...1920			1...3840	1...7680			1...8192	
Image Frame Height	1...1080			1...2160	1...4320			1...6224	
Colorimetry	COLOR.1 COLOR.2 COLOR.3			COLOR.4	COLOR.3	COLOR.5 COLOR.8	COLOR.7	COLOR.3	COLOR.5 COLOR.8	COLOR.6 COLOR.7
Pixel Bit Depth	8 10				8 10 12 16	10 12	10 12 16	8 10 12 16	10 12	10 12 16
Frame Structure	Interlaced	Progressive	Progressive	Progressive						
Stereoscopy	Monoscopic	Stereoscopic Monoscopic								
Frame Rate	25 30 30000/1001	24 24000/1001 25 30 30000/1001 50 60 60000/1001						24 24000/1001 25 30 30000/1001 50 60 60000/1001 120		
Sampling	4:2:2		4:4:4	4:2:2				4:4:4		
Quantization	QE.1							QE.1 QE.2		
Color Components	$Y'C'_BC'_R$		$Y'C'_BC'_R$ R'G'B'	$Y'C'_BC'_R$				R'G'B'		

EXAMPLE 1 — An image frame that combines COLOR.6 colorimetry with $Y'C'_BC'_R$ color components is not supported.

EXAMPLE 2 — A monoscopic progressive R'G'B' 4:4:4 image frame with dimensions 3840x2160 that combines COLOR.7 colorimetry with 12-bit pixel bit depth, 60 Hz frame rate, and QE.2 quantization is supported

NOTE 1 — This specification does not support the $Y'_CC'_{BC}C'_{RC}$ (constant luminance) color components specified in Recommendation ITU-R BT.2020-2.

NOTE 2 — IEC 61966-2-4 Edition 1.0> uses $Y'C'_BC'_R$ and YCC (luma-chroma-chroma) interchangeably.

NOTE 3 — Image formats defined in this document do not necessarily correspond to image formats defined in other standards or recommendations.

6.2.2 Frame Dimensions

The width and height of the frame are defined as the number of horizontal and vertical pixels, respectively.

6.2.3 Frame Structure

6.2.3.1 General

Implementations shall support image frames with either a progressive or interlaced structure.

6.2.3.2 Progressive Structure

An image frame with progressive structure shall consist of a complete image frame, scanned progressively left to right and from top to bottom.

6.2.3.3 Interlaced Structure

An image frame with interlaced structure shall consist of a pair of fields, a first field then a second field. The lines of each field shall have twice the vertical spatial sampling pitch of the frame. Lines in the second field shall be displaced vertically by the vertical sampling pitch and the line timing shall be delayed temporally by half the frame time from the lines in the first field.

The temporal order and relative line positions of the two fields are indicated by the Field Dominance and DisplayF2Offset items described in 7.2, Table 7.

6.2.3.4 Frame Size

The height and width of the image frame shall be an integer.

Image frames with an interlaced image structure shall have an even number of vertical pixels.

6.2.3.5 Frame Rate

When interlaced frame structure is used, the field rate, i.e. the number of image fields per second, shall be twice the frame rate.

6.2.3.6 Color Components

Implementations shall support image frames sampled using either R'G'B' or $Y'C'_BC'_R$ color component triplets.

6.2.3.7 Pixel Bit Depth

Implementations shall support the color component of each pixel being represented by an integer in the set $\{0..2^n - 1\}$, with n being the pixel bit depth.

6.2.3.8 Sampling

In 4:4:4 sampling, each component shall be sampled once at each image frame pixel.

In 4:2:2 $Y'C'_BC'_R$ sampling, the Y' component shall be sampled at each pixel, but the C'_B and C'_R components shall be horizontally subsampled by a factor of two with respect to the Y component, co-sited with evennumbered Y' samples

6.2.3.9 Stereoscopic and Monoscopic Image Essence

Monoscopic essence consists of a single sequence of image frames.

Stereoscopic essence consists of a sequence of pairs of image frames, a left eye frame and a right eye frame, for stereoscopic viewing. The two images of a pair shall be coincident in time.

6.3 Colorimetry

Implementations shall support the mappings of component signals to red, green and blue tristimulus values listed in Table 3.

Table 3 — Colorimetry Systems

System	Description
COLOR.1	Mapped as specified for 625-line systems in Section 2.6 of Recommendation ITU-R BT.601-7.
COLOR.2	Mapped as specified for 525-line systems in Section 2.6 of Recommendation ITU-R BT.601-7.
COLOR.3	Mapped as specified in Section 1 of Recommendation ITU-R BT.709-6
COLOR.4	Mapped using method xvYCC709 as specified in IEC 61966-2-4 Edition 1.0>.
COLOR.5	Mapped as specified in Recommendation ITU-R BT.2020-2. R'G'B' components are mapped to Y'C'$_B$C'$_R$ components using the (non-constant luminance) derivation of Y' and color difference signals specified in Table 4 of Recommendation ITU-R BT.2020-2.
COLOR.6	Mapped using the P3D65 color system color primaries and white point specified in SMPTE ST 2113:2018 and the transfer function specified in SMPTE ST 2084:2014
COLOR.7	R'G'B' components are mapped using the color primaries and white point specified in Recommendation ITU-R BT.2020 and the transfer function specified in SMPTE ST 2084:2014 R'G'B' components are mapped to Y'C'$_B$C'$_R$ components using the (non-constant luminance) derivation of Y' and color difference signals specified in Table 4 of Recommendation ITU-R BT.2020-2.
COLOR.8	R'G'B' components are mapped using the color primaries and white point specified in Recommendation ITU-R BT.2020-2 and the Hybrid Log-Gamma (HLG) reference non-linear transfer function specified in Recommendation ITU-R BT.2100-2. R'G'B' components are mapped to Y'C'$_B$C'$_R$ components using the (non-constant luminance) derivation of Y' and color difference signals specified in Table 4 of Recommendation ITU-R BT.2020-2.

NOTE — In Recommendation ITU-R BT.601-7 and Recommendation ITU-R BT.709-6, the signals R', G', B', Y', C'$_B$ and C'$_R$ are referred to as signals E'$_R$, E'$_G$, E'$_B$, E'$_Y$, E'$_{CB}$ and E'$_{CR}$ respectively, i.e. they correspond to gamma pre-corrected signals.

6.4 Quantization

Implementations shall support R'G'B' or Y'C'$_B$C'$_R$ component signals being quantized according to one of the systems specified in Table 4.

Table 4 — Quantization Systems

System	Component Triplet	Quantization equations (n is the pixel bit depth)	Notes
QE.1	R'G'B' $Y'C'_BC'_R$	$D'_R = INT((219 \cdot R' + 16) \cdot 2^{n-8})$ $D'_G = INT((219 \cdot G' + 16) \cdot 2^{n-8})$ $D'_B = INT((219 \cdot B' + 16) \cdot 2^{n-8})$ $D'_Y = INT((219 \cdot Y' + 16) \cdot 2^{n-8})$ $D'_{CB} = INT((224 \cdot C'_B + 128) \cdot 2^{n-8})$ $D'_{CR} = INT((224 \cdot C'_R + 128) \cdot 2^{n-8})$	Equivalent to quantization equations of Section 3 of Recommendation ITU-R BT.709-6, and Table 3 and Table 4 of Recommendation ITU-R BT.601-7.
QE.2	R'G'B'	$D'_R = INT(R' \cdot (2^{n-8} - 1))$ $D'_G = INT(G' \cdot (2^{n-8} - 1))$ $D'_B = INT(B' \cdot (2^{n-8} - 1))$	The mapping of components signals using the QE.2 system onto interfaces such as HD-SDI is defined in other specifications.

6.5 Encoding Profile

6.5.1 Single Codestream

Each frame, in the case of progressive structure, or field, in the case of interlaced structure, shall be encoded as a single codestream.

6.5.2 JPEG 2000 Encoding Constraints

Implementations shall support the combinations of JPEG 2000 profiles (as specified in ISO/IEC 15444-1:2019), constraints on HTJ2K Codestreams, and image frame dimensions listed in Table 5.

NOTE 1 — See 6.2 for a definition of the notation *a…b*.

Table 5 — JPEG 2000 Encoding Constraints

Image Frame Width	1...3840			1...2048			2049...4096			4097...8192		
Image Frame Height	1...2160			1...1556			1...3112			1...6224		
JPEG 2000 Profile	Broadcast Contribution Single Tile Profile	Broadcast Contribution Multi-tile Reversible Profile		2k IMF Single/Multi Tile Reversible Profile	2k IMF Single Tile Lossy Profile		4k IMF Single/Multi Tile Reversible Profile	4k IMF Single Tile Lossy Profile		8k IMF Single/Multi Tile Reversible Profile	8k IMF Single Tile Lossy Profile	
JPEG 2000 Operating Levels	Level 1 Level 2 Level 3 Level 4 Level 5	Level 6 Level 7	APP2.HT.REV or APP2.HT.IRV	Mainlevel 1 Mainlevel 2 Mainlevel 3 Mainlevel 4 Mainlevel 5 Mainlevel 6		APP2.HT.REV or APP2.HT.IRV	Mainlevel 1 Mainlevel 2 Mainlevel 3 Mainlevel 4 Mainlevel 5 Mainlevel 6 Mainlevel 7 Mainlevel 8		APP2.HT.REV or APP2.HT.IRV	Mainlevel 1 Mainlevel 2 Mainlevel 3 Mainlevel 4 Mainlevel 5 Mainlevel 6 Mainlevel 7 Mainlevel 8 Mainlevel 9 Mainlevel 10		A o A
JPEG 2000 Operating Sublevels	n/a			Sublevel 0 only	All allowed at a given Mainlevel with the exception of Sublevel 0		Sublevel 0 only	All allowed at a given Mainlevel with the exception of Sublevel 0		Sublevel 0 only	All allowed at a given Mainlevel with the exception of Sublevel 0	

NOTE 2 — The JPEG 2000 Broadcast Contribution profiles do not support either 16-bit Pixel Bit Depth or a Maximum Components Sampling Rate greater than $520 \cdot 10^6$ samples $\cdot$ s^{-1}. In both cases, JPEG 2000 IMF profiles are used instead.

NOTE 3 — The JPEG 2000 profiles, operating level and sublevel in Table 5 are selected as described in Annex E

NOTE 4 — The APP2.HT.REV or APP2.HT.IRV constraints are specified in Annex H.

Example encoder commands that generate JPEG 2000 Part-1 and JPEG 2000 Part-15 (HTJ2K) codestreams that satisfy these constraints are included in Annex I.

6.5.3 Component Ordering

In a codestream, color components shall be ordered as specified in Table 6.

Table 6 — JPEG 2000 Component Ordering

Component Index	R'G'B'	$Y'C'_BC'_R$
0	R'	Y'
1	G'	C'_B
2	B'	C'_R

7 Image Track Files

7.1 Essence

7.1.1 General

Image Track Files shall contain image essence conforming to Clause 6

7.1.2 Wrapping

Image Track Files shall conform to SMPTE ST 422:2019

In the case of progressive frame structure, the image essence shall be wrapped according to mode P1 specified in SMPTE ST 422:2019 ("Frame-wrapping").

In the case of interlaced frame structure, the image essence shall be wrapped according to mode I1 specified in SMPTE ST 422:2019 ("Interlaced Frame, 1 field per KLV Element")

The Top-Level File Package of Image Track File shall reference:

- a CDCI Picture Essence Descriptor if the image uses $Y'C'_BC'_R$ color components; or
- an RGBA Picture Essence Descriptor if the image essence uses R'G'B' color components.

7.2 Generic Picture Essence Descriptor

7.2.1 General

7.2.1.1 General

The Generic Picture Essence Descriptor items (including those specified in SMPTE ST 2067-2:2020) shall be constrained as specified in Table 7.

Table 7 — Generic Picture Essence Descriptor Items

Generic Picture Essence Descriptor Item	Constraints
Sample Rate	See Annex A of SMPTE ST 422:2019
Signal Standard	Shall be ignored
Frame Layout	See 7.2.1.4
Stored Width	See 7.2.1.2
Stored Height	See 7.2.1.2
StoredF2Offset	Shall not be present
Sampled Width	Shall not be present or shall be equal to Stored Width
Sampled Height	Shall not be present or shall be equal to Stored Height
SampledXOffset	Shall not be present or shall be 0.
SampledYOffset	Shall not be present or shall be 0.
DisplayHeight	See Annex G for illustrative examples. NOTE — Unless explicitly set, the Active Area Rectangle is by default equal to the Display Rectangle — see SMPTE ST 2067-2:2020.
DisplayWidth	
DisplayXOffset	
DisplayYOffset	
ActiveHeight	
ActiveWidth	
ActiveXOffset	
ActiveYOffset	
DisplayF2Offset	Shall be present if interlaced structure is used and should not be present if progressive structure is used.
AspectRatio	See 7.2.1.3
Active Format Descriptor	Shall be ignored
Video Line Map	Shall be ignored
Alpha Transparency	Shall be ignored
Transfer Characteristic	Shall be present. See 7.2.2
Image Alignment Offset	Shall not be present
Image Start Offset	Shall not be present
Image End Offset	Shall not be present
FieldDominance	Shall be present if interlaced structure is used and shall not be present if progressive structure is used
Picture Essence Coding	Shall be present. See 7.2.5
Coding Equations	Shall be present if $Y'C'_BC'_R$ sampling is used. See 7.2.3 Shall be ignored if R'G'B' sampling is used
Color Primaries	Shall be present. See 7.2.4

7.2.1.2 Stored Width and Stored Height

The values of the Stored Width and Stored Height items shall be set according to the image frame structure, as specified in Table 8.

Table 8 — Stored Width and Stored Height

Frame Structure	Progressive	Interlaced
Stored Width	Image Frame Width	Image Frame Width
Stored Height	Image Frame Height	Image Frame Height / 2

7.2.1.3 Aspect Ratio

The value of the Aspect Ratio item shall be the ratio of width to height of the rectangular area into which the pixels within the Display Rectangle are intended to be displayed.

NOTE — For interlaced image structure, the *rectangular area into which the pixels within the Display Rectangle are intended to be displayed* is the rectangular area resulting from the interlacing of the pixel elements within the Display Rectangle of each of the two fields of the image frame.

EXAMPLE — Illustrative examples are presented in Annex G.

7.2.1.4 Frame Layout

The value of the Frame Layout item shall be equal to:

- 00h (FULL_FRAME) if the image structure is progressive.
- 01h (SEPARATE_FIELDS) if the image structure is interlaced.

7.2.2 Transfer Characteristic

The value of the Transfer Characteristic item shall be equal to:

- `06.0E.2B.34.04.01.01.01.04.01.01.01.01.02.00.00` if COLOR.1, COLOR.2 or COLOR.3 systems are used.
- `06.0E.2B.34.04.01.01.0D.04.01.01.01.01.08.00.00` if COLOR.4 system is used
- `06.0E.2B.34.04.01.01.0E.04.01.01.01.01.09.00.00` (see Annex A) if COLOR.5 system is used.
- `06.0E.2B.34.04.01.01.0D.04.01.01.01.01.0A.00.00` (see Annex C) if COLOR.6 or COLOR.7 systems are used.
- `06.0E.2B.34.04.01.01.0D.04.01.01.01.01.0B.00.00` if COLOR.8 system is used.

7.2.3 Coding Equations

The value of the Coding Equations item shall be equal to:

- `06.0E.2B.34.04.01.01.01.04.01.01.01.02.01.00.00` if COLOR.1 or COLOR.2 systems are used.
- `06.0E.2B.34.04.01.01.01.04.01.01.01.02.02.00.00` if COLOR.3 or COLOR.4 systems are used.

- `06.0E.2B.34.04.01.01.0D.04.01.01.01.02.06.00.00` (see Annex D) if COLOR.5, COLOR.7 or COLOR.8 systems are used.

7.2.4 Color Primaries

The value of the Color Primaries item shall be equal to:

- `06.0E.2B.34.04.01.01.06.04.01.01.01.03.02.00.00` if the COLOR.1 system is used.
- `06.0E.2B.34.04.01.01.06.04.01.01.01.03.01.00.00` if the COLOR.2 system is used.
- `06.0E.2B.34.04.01.01.06.04.01.01.01.03.03.00.00` if the COLOR.3 or COLOR.4 systems are used.
- `06.0E.2B.34.04.01.01.0D.04.01.01.01.03.04.00.00` if the COLOR.5, COLOR.7 or COLOR.8 systems are used.
- `06.0E.2B.34.04.01.01.0D.04.01.01.01.03.06.00.00` if the COLOR.6 system is used.

7.2.5 Picture Essence Coding

The value of the Picture Essence Coding item shall reflect the JPEG 2000 profile and operating level used to encode the image essence if ISO/IEC 15444-1 image encoding is used, or the UL `06.0E.2B.34.04.01.01.0D.04.01.02.02.03.01.08.01` if ISO/IEC 15444-15 image encoding is used.

NOTE — See 6.5.2 for list of JPEG 2000 Encoding Constraints.

7.2.6 Alternative Center Cuts

The Alternative Center Cuts item is specified in SMPTE ST 2067-2:2020.

An empty Alternative Center Cuts item shall be ignored. Any Alternative Center Cut value not specified in SMPTE ST 2067-2:2020 may be safely ignored.

7.2.7 Mastering Display Color Volume Metadata

If COLOR.3, COLOR.5, COLOR.6, COLOR.7 or COLOR.8 system is used then:

- either all or none of the items specified in Annex B shall be present;
- the items specified in Annex B should characterize the mastering display; and
- if the items specified in Annex B are absent, no ST 2086 metadata values are assumed.

If neither COLOR.3, COLOR.5, COLOR.6, COLOR.7 nor COLOR.8 system is used, then no item specified in Annex B shall be present.

NOTE 1 — Clause B.6 contains selected examples values for Mastering Display Color Volume Metadata. Other values, not specified in these examples, are also permitted.

NOTE 2 — Although COLOR.8 does not use Master Display Color Volume Metadata, the option to include it is intended to facilitate downstream conversion to formats that do require this data. General information on conversion between high dynamic range systems defined by Recommendation ITU-R BT.2100-2 can be found in Report ITU-R BT.2390-8.

7.3 RGBA Picture Essence Descriptor

7.3.1 General

The RGBA Picture Essence Descriptor items shall be constrained as specified in Table 9.

Table 9 — RGBA Essence Descriptor Items

RGBA Picture Essence Descriptor Item	Constraints
Component Max Ref	Shall be present. See 7.3.2.
Component Min Ref	Shall be present. See 7.3.2.
Alpha Max Ref	Shall not be present.
Alpha Min Ref	Shall not be present.
ScanningDirection	Shall be present and shall be equal to 00h.
PixelLayout	Shall be ignored.
Palette	Shall not be present.
PaletteLayout	Shall not be present.

7.3.2 Component Max Ref and Component Min Ref

The values of the Component Max Ref and Component Min Ref items shall be set according to the pixel bit depth and quantization system used, as specified in Table 10.

Table 10 — Component Max Ref and Component Min Ref values

System	QE.1				QE.2			
Pixel Bit Depth	8	10	12	16	8	10	12	16
Component Min Ref	16	64	256	4096	0	0	0	0
Component Max Ref	235	940	3760	60160	255	1023	4095	65535

7.4 CDCI Picture Essence Descriptor

7.4.1 General

The CDCI Picture Essence Descriptor items shall be constrained as specified in Table 11.

Table 11 — CDCI Picture Essence Descriptor

CDCI Picture Essence Descriptor Item	Constraints
Component Depth	Shall be present and shall be equal to the Pixel Bit Depth used (see 6.2.3.7).
Horizontal Subsampling	See 7.4.2.
Vertical Subsampling	Shall be 01h.
Color Siting	Shall be present and shall be 00h.
ReversedByteOrder	Shall not be present.
PaddingBits	Shall not be present.
Alpha Sample Depth	Shall not be present.
Black Ref Level	Shall be present. See 7.4.3.
White Ref Level	Shall be present. See 7.4.3.
Color Range	Shall be present. See 7.4.3.

7.4.2 Horizontal Subsampling

The value of Horizontal Subsampling item shall be equal to:

- 01h if 4:4:4 sampling is used per 6.2.3.8.
- 02h if 4:2:2 Y'C'$_B$C'$_R$ sampling is used per 6.2.3.8.

7.4.3 Black Ref Level, White Ref Level and Color Range Values

If COLOR.1, COLOR.2, COLOR.3, COLOR.4, COLOR.5, COLOR.7 or COLOR.8 is used, the values of the Black Ref Level, White Ref level and Color Range items shall be set according to Table 12.

Table 12 — Black Ref Level, White Ref level and Color Range values for COLOR.1, COLOR.2, COLOR.3, COLOR.4, COLOR.5, COLOR.7 and COLOR.8

Colorimetry	COLOR.1 COLOR.2				COLOR.4		COLOR.5 COLOR.7		
	COLOR.3						COLOR.8		
Pixel Bit Depth	8	10	12	16	8	10	10	12	16
Black Ref Level	16	64	256	4096	16	64	64	256	4096
White Ref Level	235	940	3760	60160	235	940	940	3760	60160
Color Range	225	897	3585	57345	254	1013	897	3585	57345

NOTE 1 — The White Ref level item applies only to the Y' component, and the Color Range item to the C'$_B$ and C'$_R$ components.

NOTE 2 — In the case of COLOR.7 or COLOR.8, "White Ref" is occasionally referred to as "Nominal Peak".

7.5 JPEG 2000 Picture Sub Descriptor

7.5.1 General

The Top-Level File Package of the Image Track File shall reference a JPEG 2000 Picture Sub Descriptor SMPTE ST 422:2019 as constrained by Table 13.

Table 13 — JPEG 2000 Picture Subdescriptor items

JPEG 2000 Picture Subdescriptor Item	Constraints
Coding Style	Shall be present.
J2CLayout	Shall be present. See 7.5.2
J2KExtendedCapabilities	Shall be present if ISO/IEC 15544-15 coding is used.

7.5.2 J2CLayout

The value of the J2CLayout item shall be equal to:

- `{ 'R', x, 'G', x, 'B', x, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 }` if R'G'B' sampling is used, where x is the pixel bit depth; or
- `{ 'Y', x, 'U', x, 'V', x, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 }` if Y'C'$_B$C'$_R$ sampling is used where x is the pixel bit depth, respectively

8 Composition

8.1 ApplicationIdentification

The ApplicationIdentification element (see SMPTE ST 2067-2:2020) shall include the value listed in Figure 2.

```
http://www.smpte-ra.org/ns/2067-21/5ED
```

Figure 2 — Application Identification

8.2 Homogeneous Image Essence

Within a given composition, the following shall remain constant:

- all image essence characteristics specified in Clause 6.
- the JPEG 2000 Encoding Constraints as specified in 6.5.2.

8.3 Virtual Tracks

8.3.1 Main Image Virtual Track

All Image Track Files referenced by Resource elements of type StereoImageTrackFileResourceType and type TrackFileResourceType shall conform to Clause 7.

8.3.2 Segment Duration

If the average number of audio samples per Composition Edit Unit is not an integer, the duration of each Segment shall be an integer multiple of 5/Composition Edit Rate.

8.3.3 MaxCLL and MaxFALL

If MainImage conforms to COLOR.6 or COLOR.7, the ExtensionProperties element of the Composition Playlist instance shall include:

- zero or one instance of the MaxCLL element specified in Figure 3; and
- zero or one instance of the MaxFALL element specified in Figure 3.

```
<xs:element name="MaxCLL" type="xs:unsignedShort"/>
<xs:element name="MaxFALL" type="xs:unsignedShort"/>
```

Figure 3 — MaxCLL and MaxFALL elements

The MaxCLL and MaxFALL values may be calculated as specified in Annex P.1 and P.2 of CTA 861-G, respectively. This calculation shall use the MainImage Virtual Track image essence contained:

- within the area specified by the Active Area Rectangle; and
- only from the First Frame of Composition to the Last Frame of Composition, if specified.

If the MaxCLL (MaxFALL) value is unknown, then the MaxCLL (MaxFALL) element shall be (i) absent or (ii) set to 0.

The MaxCLL and MaxFALL values shall be represented in units of 1 cd/m^2.

Annex A
ITU-R BT.2020 Transfer Characteristic Label (Normative)

Table A.1 — ITU-R BT.2020 Transfer Characteristic Label

Byte No.	Description	Value (hex)	Meaning
1-7	(see Transfer Characteristic node)		
8	Version Number	0Eh	Registry Version at the point of registration of this label
9-13	(see Transfer Characteristic node)		
14	ITU-R BT.2020 Transfer Characteristic	09h	Identifies ITU-R BT.2020 transfer characteristic
15-16		00h	

Annex B
Mastering Display Color Volume Metadata (Normative)

B.1 General

Table B.1 specifies optional items for the Generic Picture Essence Descriptor (see SMPTE ST 377-1:2011) based on the metadata parameters specified in SMPTE ST 2086:2018

Table B.1 — Color Volume Metadata

Item Name	Item Symbol	Type	Len	Local Tag	Item UL	Req	Meaning
Mastering Display Primaries	MasteringDisplayPrimaries	ThreeColorPrimaries	12	dyn	urn:smpte:ul:060e2b34.0101010e.04200401.0101000	Opt	Display Primaries metadata as specified in SMPTE ST 2086:2018
Mastering Display White Point Chromaticity	MasteringDisplayWhitePointChromaticity	ColorPrimary	4	dyn	urn:smpte:ul:060e2b34.0101010e.04200401.0102000	Opt	Chromaticity of White Point metadata as specified in SMPTE ST 2086:2018
Mastering Display Maximum Luminance	MasteringDisplayMaximumLuminance	UInt32	4	dyn	urn:smpte:ul:060e2b34.0101010e.04200401.0103000	Opt	Maximum Display Mastering Luminance metadata as specified in SMPTE ST 2086:2018
Mastering Display Minimum Luminance	MasteringDisplayMinimumLuminance	UInt32	4	dyn	urn:smpte:ul:060e2b34.0101010e.04200401.0104000	Opt	Minimum Display Mastering Luminance metadata as specified in SMPTE ST 2086:2018

NOTE — The quantization of the metadata parameters match that specified in Section D.2.28 of Recommendation ITU-T H.265 (11/2019).

B.2 Mastering Display Primaries

If present, the Mastering Display Primaries item shall be equal to the Display Primaries metadata specified in SMPTE ST 2086:2018.

The ColorPrimary type shall consist of two UInt16 elements, in order, the normalized x and y chromaticity coordinates of the color primary in units of 0.00002.

EXAMPLE — The color primary characterized by the (x, y) chromaticity coordinates of (0.6800, 0.3200) is represented by a ColorPrimary value of {34000, 16000}.

NOTE 1 — The elements of a ColorPrimary instance that conforms to the precision specified in SMPTE ST 2086:2018 (four decimal places) are multiples of 5 (0.0001 = 0.00002 · 5).

The ThreeColorPrimaries type shall be a fixed-size sequence of 3 instances of the ColorPrimary type, for a total of 12 bytes. The ColorPrimary instances should be ordered as follows: (i) instance with the largest x chromaticity coordinate, (ii) instance with the largest y chromaticity coordinate, and (iii) instance with neither the largest y nor the largest x chromaticity coordinate.

NOTE 2 — The recommended ordering of the ColorPrimary instances corresponds to RGB ordering in many common cases.

B.3 Mastering Display White Point Chromaticity

If present, the Mastering Display White Point Chromaticity item shall be equal to the Chromaticity of White Point metadata specified in SMPTE ST 2086:2018.

The ColorPrimary type is specified in Clause B.2.

B.4 Mastering Display Maximum Luminance

If present, the Mastering Display Maximum Luminance item shall be equal to the Maximum Display Mastering Luminance metadata specified in SMPTE ST 2086:2018.

The value Mastering Display Maximum Luminance item shall be expressed in units of 0.0001 cd/m^2.

B.5 Mastering Display Minimum Luminance

If present, the Mastering Display Minimum Luminance item shall be equal to the Minimum Display Mastering Luminance metadata specified in SMPTE ST 2086:2018.

The value Mastering Display Minimum Luminance item shall be expressed in units of 0.0001 cd/m^2.

B.6 Examples (Informative)

Table B.2 lists example values for the items specified in Table B.1.

Table B.2 — Example values for the Mastering Display Color Volume Metadata (Informative)

Item	Example Values	
Mastering Display White Point Chromaticity	Illuminant D65 specified in SMPTE RP 177:1993	{ 15635, 16450 }
Mastering Display Primaries	Color primaries specified in Recommendation ITU-R BT.709-6	{ 32000, 16500 } { 15000, 30000 } { 7500, 3000 }
	Color primaries specified in Recommendation ITU-R BT.2020-2	{ 35400, 14600 } { 8500, 39850 } { 6550, 2300 }
	Color primaries of the P3D65 system specified in SMPTE ST 2113:2018	{ 34000, 16000 } { 13250, 34500 } { 7500, 3000 }
Mastering Display Maximum Luminance	Reference white in Recommendation ITU-R BT.2035	1000000
	Mastering display with a maximum luminance of 4000 cd/m^2	40000000
Mastering Display Minimum Luminance	Reference black in Recommendation ITU-R BT.2035	100
	Mastering display with a minimum luminance of 0.005 cd/m^2	50

Annex C
SMPTE ST 2084 Transfer Characteristic Label (Normative)

Table C.1 — SMPTE ST 2084 Transfer Characteristic Label

Byte No.	Description	Value (hex)	Meaning
1-7	(see Transfer Characteristic node)		
8	Version Number	0Dh	Registry Version at the point of registration of this label
9-13	(see Transfer Characteristic node)		
14	SMPTE ST 2084 Transfer Characteristic	0Ah	Identifies the transfer characteristics as specified in SMPTE ST 2084:2014
15-16		00h	

Annex D
ITU-R BT.2020 Non-Constant Luminance Coding Equations Label
(Normative)

Table D.1 — ITU-R BT.2020 Non-Constant Luminance Coding Equations Label

Byte No.	Description	Value (hex)	Meaning
1-7	(see Coding Equations node)		
8	Version Number	0Dh	Registry Version at the point of registration of this label
9-13	(see Coding Equations node)		
14	ITU-R BT.2020 Non-Constant Luminance Coding Equations	06h	Identifies ITU-R BT.2020 coding equations for non-constant luminance
15-16		00h	

Annex E
Recommended selection of JPEG 2000 Profiles (Informative)

This annex provides guidance for selecting the appropriate JPEG 2000 profiles based on the characteristics of the image essence.

If image essence conforms to the following parameters, a broadcast application profile (as defined in ISO/IEC 15444-1:2019) might be used. Refer to Table E.1. If any of these are exceeded, an IMF profile is the appropriate choice. Refer to Table E.2 and Table E.3.

Broadcast application profiles support:

- a maximum frame dimension of 3840 x 2160 pixels;
- a maximum 12-bit color depth;
- a maximum compressed bit rate of 800 Mbit/s for non-reversible profile;
- a maximum components sampling rate of 520 MSamples/s

Note that in this standard there are many combinations of image characteristics where a profile from either the broadcast application profile sets or IMF profile sets might be applicable.

To determine maximum components sampling rate:

M = (W x H x F x A) / 1,000,000

where:

M is MegaSamples per second (Msamples/s)

W is Frame Width, in pixels

H is Image Frame Height, in pixels

F is Frame Rate, per second

A is average number of color components per pixel (2 for 4:2:2, 3 for 4:4:4)

EXAMPLE — (3840 x 2160 x 24000/1001 x 2) / 1,000,000 = 397.7330688 MSamples/s.

In this example, a user might select either BCP Level 5 or 4k IMF Single Tile Lossy Profile Mainlevel 5 for nonreversible workflows or either BCP Level 7 or 4k IMF Single/Multi-tile Reversible Profile Mainlevel 5 (Sublevel 0) for reversible workflows.

Table E.1 — Broadcast Contribution Profile Levels used in IMF App2E

Levels	Max. Sampling Rate (MSamples/s)	Max. compressed Bit Rate (Mbits/s)
Broadcast Single Tile Profile Level 1	65	200
Broadcast Single Tile Profile Level 2	130	200
Broadcast Single Tile Profile Level 3	195	200
Broadcast Single Tile Profile Level 4	260	400
Broadcast Single Tile Profile Level 5	520	800
Broadcast Multi-Tile Reversible Profile Level 7	520	Unspecified *

*Reversible compression

Table E.2 — IMF Profile Mainlevels used by IMF App2E

Mainlevel	Max. Sampling Rate (MSamples/s)	Available Sublevels for lossy profiles
Mainlevel 1	65	Sublevel 1
Mainlevel 2	130	Sublevel 1
Mainlevel 3	195	Sublevel 1
Mainlevel 4	260	Sublevels 1-2
Mainlevel 5	520	Sublevels 1-3
Mainlevel 6	1200	Sublevels 1-4
Mainlevel 7	2400	Sublevels 1-5
Mainlevel 8	4800	Sublevels 1-6
Mainlevel 9	9600	Sublevels 1-7
Mainlevel 10	19200	Sublevels 1-8

Table E.3 — IMF Profile Sublevels used by IMF App2E

Sublevels	Max. compressed Bit Rate (Mbit/s)
Sublevel 1	200
Sublevel 2	400
Sublevel 3	800
Sublevel 4	1600
Sublevel 5	3200
Sublevel 6	6400
Sublevel 7	12800
Sublevel 8	25600
Sublevel 0	Unspecified *

*only used for reversible profiles in IMF App2E

Users are encouraged to select the smallest level, for broadcast application profiles, or Mainlevel and Sublevel, for IMF profiles, that meets the requirements for image frame dimensions, color depth, components sampling rate and, for non-reversible compression, compressed bit rate. This allows implementations to optimally allocate resources when processing the image essence.

It is recommended that the sampling rate and maximum bit rate used in determining the profiles be increased by 5% to allow for speed-up of the image, e.g. 24fps to 25fps, without having to update profile metadata in both the codestream and Track File.

Annex F
Additional JPEG 2000 Picture Essence Compression Labels (Normative)

Table F.1 — Additional JPEG 2000 Picture Essence Compression Labels

Byte No.	Description	Value (hex)	Meaning
1-7	See SMPTE ST 422:2019		
8	Version Number	0Dh	Registry Version at the point of registration of this label
9-15	See SMPTE ST 422:2019		
16	Broadcast Contribution Single Tile Profile Level 1	11h	Broadcast Contribution Single Tile Profile Level 1 as specified in ISO/IEC 15444-1:2019
	Broadcast Contribution Single Tile Profile Level 2	12h	Broadcast Contribution Single Tile Profile Level 2 as specified in ISO/IEC 15444-1:2019
	Broadcast Contribution Single Tile Profile Level 3	13h	Broadcast Contribution Single Tile Profile Level 3 as specified in ISO/IEC 15444-1:2019
	Broadcast Contribution Single Tile Profile Level 4	14h	Broadcast Contribution Single Tile Profile Level 4 as specified in ISO/IEC 15444-1:2019
	Broadcast Contribution Single Tile Profile Level 5	15h	Broadcast Contribution Single Tile Profile Level 5 as specified in ISO/IEC 15444-1:2019
	Broadcast Contribution Multitile Reversible Profile Level 6	16h	Broadcast Contribution Multi-tile Reversible Profile Level 6 as specified in ISO/IEC 15444-1:2019
	Broadcast Contribution Multitile Reversible Profile Level 7	17h	Broadcast Contribution Multi-tile Reversible Profile Level 7 as specified in ISO/IEC 15444-1:2019

Annex G
Image Frame And Active Area Rectangle Examples (Informative)

This specification allows the user to choose which rectangular subset of an input image to store and which portion of the resulting stored image to identify as the Active Area Rectangle.

Figure G.1 and Table G.1 depict selected examples using HD progressive image frames. As shown in (a) and (b), two different users or the same user in different circumstances can elect to identify different portions of the same image as the Active Area Rectangle. In (c), only the Active Area Rectangle is stored. As illustrated by (b), the extent of the Display Rectangle is not specified and left to users: Table G.1 lists two valid sets of Display Rectangle and Active Area Rectangle values for (b).

The process by which the dimensions of the stored image and active area are set depends on individual workflows and can include a combination of manual and automated processing during and after ingest.

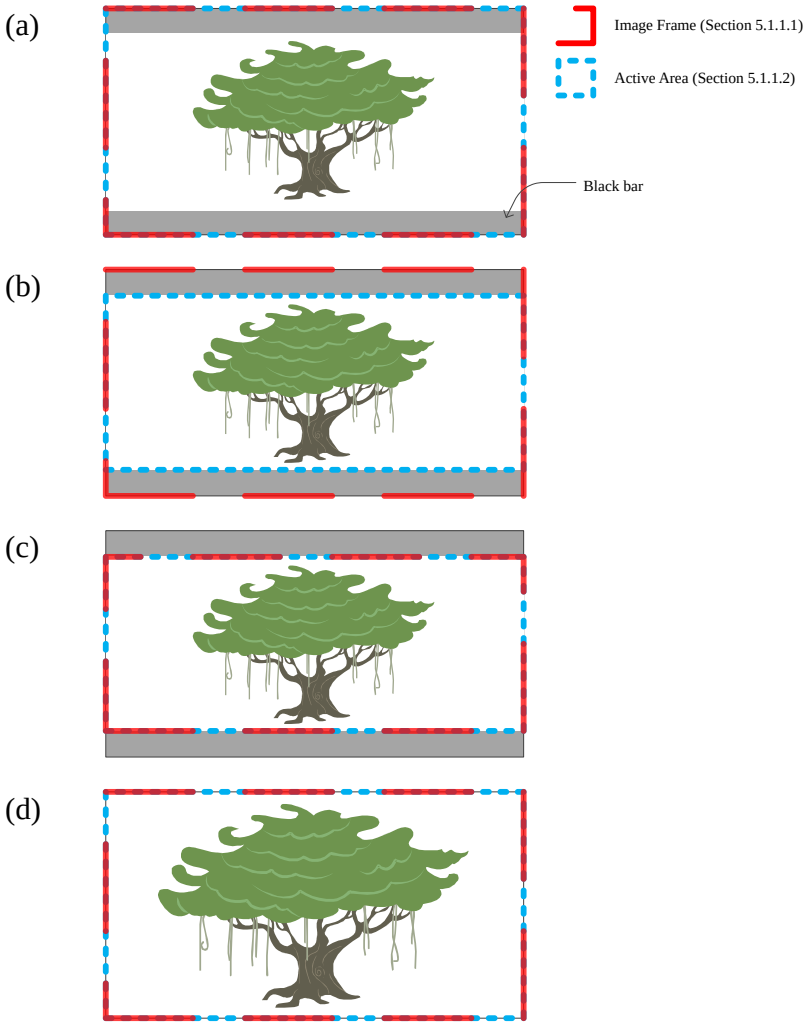

Figure G.1 — High-Definition Progressive Frame Active Area Rectangle Examples

Table G.1 — Selected Property Values for the Examples of Figure G.1

	Figure G.1a	Figure G.1b	Figure G.1b	Figure G.1c	Figure G.1d
Stored Height	1080	1080	1080	800	1080
Stored Width	1920	1920	1920	1920	1920
Sampled Height	1080	1080	1080	800	1080
Sampled Width	1920	1920	1920	1920	1920
Sampled X Offset	0	0	0	0	0
Sampled Y Offset	0	0	0	0	0
Display Height	1080	800	1080	800	1080
Display Width	1920	1920	1920	1920	1920
Display X Offset	0	0	0	0	0
Display Y Offset	0	140	0	0	0
Aspect Ratio	16/9	12/5	16/9	12/5	16/9
Active Height	1080	800	800	800	1080
Active Width	1920	1920	1920	1920	1920
Active X Offset	0	0	0	0	0
Active Y Offset	0	0	140	0	0

Figure G.2 and Table G.2 depict three means of storing the same source SD interlaced anamorphic image frame. The source image frame contains a 720x576 container as well as vertical blanking interval (VBI) information. The container is intended to be displayed at a 16:9 aspect ratio and contains a 2.40 Active Area Rectangle. In (a), the entire source image frame is ingested, including VBI information, which is not included in the Display Rectangle, as specified by SMPTE ST 377-1:2011. In contrast to (a), the VBI information is not stored in (b). In (c), the Aspect Ratio property value is computed to preserve the exact pixel aspect ratio of the source image.

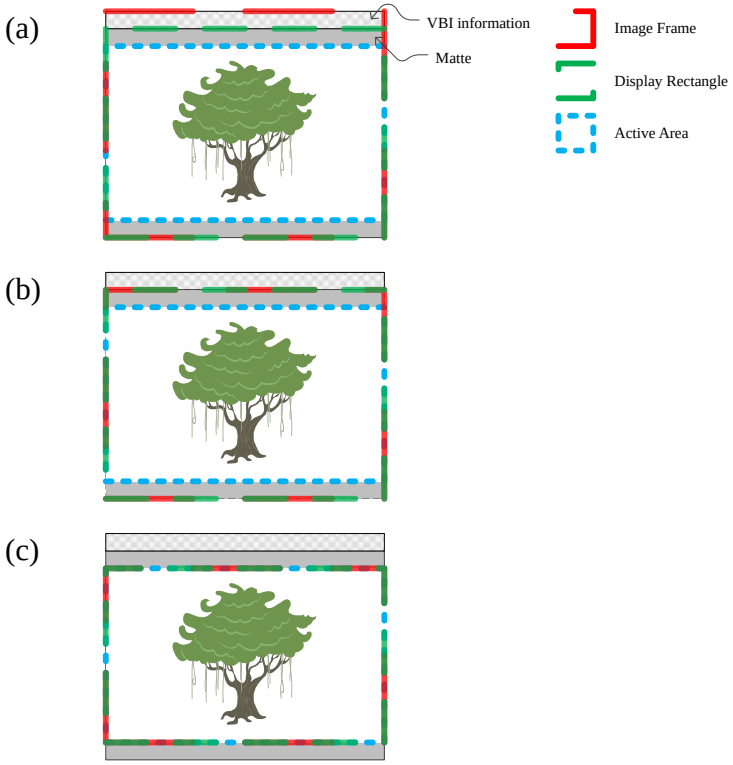

Figure G.2 — Standard Definition Interlaced Frame Examples

Table G.2 — Selected Property Values for the Examples of Figure G.2

	Figure G.2a	Figure G.2b	Figure G.2c
Stored Height	304	288	213
Stored Width	720	720	720
Sampled Height	304	288	213
Sampled Width	720	720	720
Sampled X Offset	0	0	0
Sampled Y Offset	0	0	0
Display Height	288	288	213
Display Width	720	720	720
Display X Offset	0	0	0
Display Y Offset	16	0	0
Aspect Ratio	16/9	16/9	512/213
Active Height	213	213	213
Active Width	720	720	720
Active X Offset	0	0	0
Active Y Offset	37	37	0

Annex H
ISO/IEC 15444-15 HT-J2K Codestream Constraints (Normative)

The HT-J2K encoding shall follow the constraints listed in Table H.1.

Table H.1 — Additional JPEG 2000 Picture Essence Compression Labels

Item	IMF App2e HTJ2K Reversible Constraints (APP2.HT.REV)	IMF App2e HTJ2K Irreversible Constraints (APP2.HT.IRV)
Codestream	Shall be an HTJ2K codestream as defined in ISO/IEC 15444-15:2019	
Capabilities	No capabilities other than those specified in ISO/IEC 15444-1:2019 and ISO/IEC 15444-15:2019 $Pcap^i$ is 1 for i = 15, and 0 otherwise.	
	Bits of $Ccap^{15}$ corresponding to the selected constrained codestream sets must be set. Bits 14-15 of $Ccap^{15}$ shall be zero (HTONLY) Bit 13 of $Ccap^{15}$ shall be zero (SINGLEHT) Bit 12 of $Ccap^{15}$ shall be zero (RGNFREE) Bit 11 of $Ccap^{15}$ shall be zero (HOMOGENEOUS) Bits 0-4 of $Ccap^{15}$ shall be set according to the $MAGB_P$ parameter	
	Bit 5 of $Ccap^{15}$ shall be zero (HTREV)	Bit 5 of $Ccap^{15}$ shall be one (HTIRV)
Tile	One tile for the whole image, with YTsiz + YTOsiz ≥ Ysiz XTsiz + XTOsiz ≥ Xsiz	
Image and tile origin	XOsiz = YOsiz = XTOsiz = YTOsiz = 0	
Sub-sampling	($XRsiz^i$ = 1 for all i) or ($Xrsiz^i$=2 for i = {2,3} and $XRsiz^i$=1 for other i) $YRsiz^i$=1 for all i	
Number of components	Csiz ≤ 4	
Bitdepth	7 ≤ $Ssiz^i$ ≤ 15 Within a codestream, all components shall have identical $Ssiz^i$	
PPM marker	Shall not be present	
Number of layers	Shall be exactly 1	
Number of decomposition levels	$1 \le N_L \le 5$ for max(Xsiz,Ysiz) ≤ 2048 $1 \le N_L \le 6$ for 2049 ≤ max(Xsiz,Ysiz) ≤ 4096 $1 \le N_L \le 7$ for 4097 ≤ max(Xsiz,Ysiz) ≤ 8192 Within a codestream, all components shall have the same number of decomposition levels	
Code-block size	5 ≤ xcb ≤ 7 and 5 ≤ ycb ≤ 6 Within a codestream, all components shall have identical codeblock sizes.	
Code-block style	0100 0000	
Transformation	5-3 reversible transform	9-7 irreversible transform
Precinct size	PPx = PPy = 7 for N_LLL band, else 8	
Progression order	RPCL	
Tile-parts	one tile part per resolution	
TLM marker	Shall be present	

POC marker	Shall not be present	
Constrained codestream sets	Shall belong to the following sets: HTONLY, SINGLEHT, RGNFREE, HOMOGENEOUS, LOCAL	
	HTREV $MAGB_P$ per parameter B calculated according to Table H.2	HTIRV $MAGB_P$ per parameter B shall be equal to or less than 31 $MAGB_P$ per parameter B should be equal to or less than the values calculated according to Table H.3

Table H.2 — Parameter B for APP2.HT.REV Constraints

$Ssiz^i$	**Parameter B**		
	SGcod.C = 0 $N_L \leq 5$	**SGcod.C = 0 $N_L > 5$** **SGcod.C = 1 $N_L \leq 5$**	**SGcod.C = 1 $N_L > 5$**
7	11	12	13
9	13	14	15
11	15	16	17
15	19	20	21

Table H.3 — Parameter B for APP2.HT.IRV Constraints

	Parameter B	
$Ssiz^i$	**SGcod.C = 0**	**SGcod.C = 1**
7	9	9
9	11	11
11	13	14
15	17	18

NOTE 1 — As specified at ISO/IEC 15444-1:2019, SGcod.C indicates whether the multiple component transformation is used.

NOTE 2 — Table 4 at ISO/IEC 15444-15:2019 specifies the relationship between parameter B and $MAGB_P$ codestream sets.

NOTE 3 — Using RPCL progression order allows reduced-resolution decoding of codestreams in throughput-limited and -varying environments with a single contiguous read operation of a partial codestream.

NOTE 4 — Conformance to the constrained codestream set LOCAL is implied by the signaling of other HTJ2K constraints Precinct Size = [PPx = PPy = 7 for N_LLL band, else 8] and Number of layers = 1

NOTE 5 — A decoder can increase throughput by using a hardware-accelerated implementation if the HT cleanup magnitudes are below a given threshold, i.e., if the HTJ2K codestream belongs to a set where parameter B is below a certain threshold; and reverting to a slower software implementation otherwise. Thus HTJ2K encoders are encouraged to use a value of parameter B that is as small as possible, like those values described in Table H.3

Example encoder commands that generate JPEG 2000 Part-15 (HTJ2K) codestreams that satisfy these constraints are included in Annex I.

Annex I
Example JPEG 2000 encoder commands (Informative)

I.1 General

The tables in this Annex contain example encoder commands that generate compressed JPEG 2000 codestreams. In the examples, the filename represented by `${INPUT_TIF_FILE}` is a 16bit TIF file.

The examples were generated with the most current version of each encoder library available at the time of publication and these versions are listed in the caption of each table.

I.2 Kakadu

Kakadu is a commercial software libary that supports encoding and decoding JPEG 2000 Part-1 and JPEG 2000 Part-15 (HTJ2K) codestreams.

Table I.1 — Example JPEG 2000 Part-1 encoder commands for Kakadu Software demo app `kdu_compress` version 8.4.1

Description	Example Command
HD 4:4:4 10bit Lossless	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 10M Sbroadcast="{7,multi,rev}"`
HD 4:4:4 Lossy 10bit VBR with 250Mbs Maximum @ 24fps	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 10M Sbroadcast="{4,single,irrev}" Creslengths=1302083 -slope 41808 Qstep=0.0009765625`
4K 4:4:4 12bit Lossless	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 12M Simf="{6,0,rev}"`
8K 4:4:4 16bit Lossless	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 16M Simf="{8,0,rev}"`

Table I.2 — Example JPEG 2000 Part-15 (HTJ2K) encoder commands for Kakadu Software demo app `kdu_compress` version 8.4.1

Description	Example Command
HD 4:4:4 Lossy 10bit VBR HTJ2K	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 10M Creversible=no Corder=RPCL Cblk="{32,128}" Cmodes=HT ORGtparts=R Clevels=5 ORGgen_tlm=6 Cprecincts="{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{128,128}" Qfactor=95`
HD 4:4:4 Lossless 10bit HTJ2K	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 10M Creversible=yes Corder=RPCL Cblk="{32,128}" Cmodes=HT ORGtparts=R Clevels=5 ORGgen_tlm=6 Cprecincts="{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{128,128}"`
4K 4:4:4 12bit Lossless HTJ2K	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 12M Creversible=yes Corder=RPCL Cblk="{32,128}" Cmodes=HT ORGtparts=R Clevels=6 ORGgen_tlm=7 Cprecincts="{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{128,128}"`
4K 4:4:4 12bit Lossy VBR HTJ2K	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 12M Creversible=no Corder=RPCL Cblk="{32,128}" Cmodes=HT ORGtparts=R Clevels=6 ORGgen_tlm=7 Cprecincts="{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{128,128}" Qfactor=95`
8K 4:4:4 12bit Lossless HTJ2K	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 12M Creversible=yes Corder=RPCL Cblk="{32,128}" Cmodes=HT ORGtparts=R Clevels=7 ORGgen_tlm=8 Cprecincts="{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{128,128}"`
8K Lossy 12bit CBR HTJ2K	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 12M Creversible=no Corder=RPCL Cblk="{32,128}" Cmodes=HT ORGtparts=R Clevels=7 ORGgen_tlm=8 Cprecincts="{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{128,128}" Cplex="{6,EST,0.25,-1}" -rate 2.0`
8K Lossy 12bit VBR HTJ2K	`kdu_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -fprec 12M Creversible=no Corder=RPCL Cblk="{32,128}" Cmodes=HT ORGtparts=R Clevels=7 ORGgen_tlm=8 Cprecincts="{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{256,256},{128,128}" Qfactor=95`

I.3 OpenJPH

OpenJPH is an open-source library that supports encoding and decoding JPEG 2000 Part-15 (HTJ2K) codestreams.

Table I.3 — Example JPEG 2000 Part-15 (HTJ2K) encoder commands for OpenJPH demo app `ojph_compress` version 0.21.2

Description	Example Command
HD 4:4:4 10bit Lossless	`ojph_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -reversible true -prog_order RPCL -block_size "{128,32}" -num_decomps 5 -tlm_marker true -precincts "{128,128},{256,256}" -tileparts R -bit_depth 10`
4K 4:4:4 12bit Lossless	`ojph_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -reversible true -prog_order RPCL -block_size "{128,32}" -num_decomps 6 -tlm_marker true -precincts "{128,128},{256,256}" -tileparts R -bit_depth 12`
8K 4:4:4 12bit Lossless	`ojph_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -reversible true -prog_order RPCL -block_size "{128,32}" -num_decomps 7 -tlm_marker true -precincts "{128,128},{256,256}" -tileparts R -bit_depth 12`

I.4 OpenJPEG

OpenJPEG is an open-source library that supports encoding JPEG 2000 Part-1 codestreams and decoding JPEG 200 Part-1 and JPEG 2000 Part-15 (HTJ2K) codestreams.

Table I.4 — Example JPEG 2000 Part-1 encoder commands for OpenJPEG demo app `opj_compress` version 2.5.3

Description	Example Command
HD 4:4:4 10bit Lossless	`opj_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -TargetBitDepth 10 -IMF 2K_R,mainlevel=3,sublevel=0,framerate=24`
4K 4:4:4 12bit Lossless	`opj_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -TargetBitDepth 12 -IMF 4K_R,mainlevel=6,sublevel=0,framerate=24`
8K 4:4:4 12bit Lossless	`opj_compress -i ${INPUT_TIF_FILE} -o ${OUTPUT_J2C_FILE} -TargetBitDepth 12 -IMF 8K_R,mainlevel=7,sublevel=0,framerate=24`

Additional elements

The following are the non-prose elements of this document:

a. Consolidated Schema (informative). file: <st2067-21a-2023.xsd>.

Bibliography

SMPTE RP 177:1993, Derivation of Basic Television Color Equations

Recommendation ITU-R BT.2035, A Reference Viewing Environment for Evaluation of HDTV Program Material or Completed Programmes

Recommendation ITU-T H.265 (11/2019), High Efficiency Video Coding

Report ITU-R BT.2390-8, High dynamic range television for production and international programme exchange

Kakadu, commercial software library,
url: https://kakadusoftware.com/documentation-downloads/

OpenJPH, open source library,
url: https://github.com/aous72/OpenJPH

OpenJPEG, open source library,
url: https://www.openjpeg.org/

