SMPTE ST 2067-40:2021
Revision of SMPTE ST 2067-40:2016

SMPTE STANDARD

Interoperable Master Format — Application #4 Cinema Mezzanine

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Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices, and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual.

SMPTE ST 2067-40 was prepared by Technology Committee 35PM.

The following summarizes the substantive changes made from SMPTE ST 2067-40:2016, as amended by ST 2067-40:2016 Am1:2017, to this edition:

- support is added for image and timed text essence that conform to the D-Cinema Distribution Master as specified in the SMPTE ST 428 family of documents (sub-clause 5.2 and 6.3);
- the SMPTE labels identifying the image transfer characteristics supported by this document are modified (sub-clause 6.1.3.1.2);
- constraints on the Composition timeline and contents are relaxed (clause 7); and
- constraints on Display Mastering Metadata are clarified and relaxed (sub-clause 6.1.3.1.5)
- Pixel Color Schemes for OPL processing are added (Annex C)
- shim_id for image track files is modified and now include a complete URL with fragment part to accord to new other identifiers defined in the document (Table 6)
- reference to SMPTE ST 2067-20 is suppressed, and SMPTE ST 2067-21 is now referenced to define Mastering Display elements (subclause 6.1.3.1.5)
- the application identifiers changed and use new SMPTE namespace (subclause 7.1)
- The PixelLayout in RGBA Picture Essence Descriptor is now marked as "shall be ignored". The prose defining the former RGBA PixelLayout has been transposed for the J2C Layout (subclause 6.1.3.3.2).
- Add constraints on markers for DCDM characteristics #15. A constraint on the authorized markers scope URI and content for DCDM characteristics is added (subclause 7.8).
- Add constraint on authorized ContentKind for DCDM characteristics #19. A constraint on the authorized ContentKind scope URI and content for DCDM characteristics is added (subclause 7.3).
- HT-J2K block encoding support is added (subclause 5.4.2)
- JPEG 2000 profiles table moved to Annex D

Intellectual Property

At the time of publication no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

1 Scope

This document specifies compositions for IMF Application #4. IMF Application #4 is a specialization of the IMF Framework. It is intended for the exchange and preservation of cinematographic content after digital postproduction, either sourced from film or from digital media. In particular, it supports Digital Cinema Distribution Master (DCDM) content as specified in the ST 428 family of specifications.

To simplify implementation, IMF Application #4 reuses constraints from IMF Application #2 whenever appropriate.

2 Conformance Notation

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 section 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; followed by formal languages; then figures; and then any other language forms.

3 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision,

and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

SMPTE ST 400:2012, SMPTE Labels Structure

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 428-1:2019 - D-Cinema Distribution Master — Image Characteristics

SMPTE ST 428-7:2014 - Digital Cinema Distribution Master — Subtitle

SMPTE ST 428-10:2008 - D-Cinema Distribution Master — Closed Caption and Closed Subtitle

SMPTE ST 428-11:2013 - Additional Frame Rates for D-Cinema

SMPTE ST 428-21:2011 - Archive Frame Rates for D-Cinema

SMPTE ST 429-5:2017 - D-Cinema Packaging — Timed Text Track File

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

SMPTE ST 2067-21:2020, Interoperable Master Format — Application 2E

SMPTE ST 2067-101:2018, Interoperable Master Format – Output Profile List – Common Image Definitions and Macros

SMPTE ST 2067-102:2017, Interoperable Master Format - Common Image Pixel Color Schemes

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

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

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

World Wide Web Consortium (W3C) (2004, October 28). XML Schema Part 2: Datatypes (Second Edition)

4 Overall

4.1 **General**

All provisions of SMPTE ST 2067-2 shall apply.

4.2 **Format**

Track Files shall conform to SMPTE ST 379-1.

4.3 XML Schema and Namespace

XML elements defined by this specification shall conform to the XML schema definitions (see W3C XML Schema Part 1: Structures) 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 Table 1.

Table 1 – XML Schema root element definition.

```
<xs:schema targetNamespace="http://www.smpte-ra.org/ns/2067-40/2020"
    xmlns:app4="http://www.smpte-ra.org/ns/2067-40/2020"
    xmlns:xs="http://www.w3.org/2001/XMLSchema"
    elementFormDefault="qualified" attributeFormDefault="unqualified">
  <!-- schema definitions found in this document -->
</xs:schema>
```

5 Image Essence

5.1 General

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

5.2 Constraints

Image frames shall conform to the combinations of characteristics allowed in Table 2, either following linear characteristics constraints or DCDM characteristics constraints.

Table 2 – Image Characteristics

		Linear characteristics			DCDM characteristics
Image Frame Width		1..2048	1..4096	1..8192	See 5.3.1
Image Frame Height		1..1556	1..3112	1..6224	
Pixel Bit Depth		16			12
Frame Structure		Progressive			
Stereoscopy		Monoscopic Stereoscopic			
Frame Rate		16 200/11 20 240/11 24 25 30 48 50 60 100 120			See 5.3.2
Sampling		4:4:4			
Color Components	§5.3.3	$X_{TC}Y_{TC}Z_{TC}$			
Colorimetry	§5.3.4	COLOR.APP4.1			COLOR.APP4.2
Quantization	§5.3.5	QE.APP4			

5.3 Characteristics

5.3.1 DCDM characteristics size constraints

For the DCDM characteristics, combinations of image height and width shall be as specified at SMPTE ST 428-1.

5.3.2 DCDM characteristics Frame Rate

For the DCDM characteristics, the frame rate values shall be as specified at SMPTE ST 428-1, SMPTE ST 428-11 and SMPTE ST 428-21.

5.3.3 Color Components

The image shall be sampled using $X_{TC}Y_{TC}Z_{TC}$ component triplets, as defined in 5.3.4.

5.3.4 Colorimetry

The $X_{TC}Y_{TC}Z_{TC}$ components triplet shall be mapped to the XYZ tristimulus values specified in ISO 11664-3, as specified in Table 3.

For linear characteristics, COLOR.APP4.1 shall be used, for DCDM characteristics, COLOR.APP4.2 shall be used.

Table 3 – Colorimetry systems

System	Description
COLOR.APP4.1	$X_{TC} = X \times 10^3 \div 65535, X \in [0, 52.37]$ $Y_{TC} = Y \times 10^3 \div 65535, Y \in [0, 48]$ $Z_{TC} = Z \times 10^3 \div 65535, Z \in [0, 52.37]$
COLOR.APP4.2	$X_{TC} = \left(\frac{X}{L_{vw}}\right)^{1/2.6}, X \in [0,52.37]$ $Y_{TC} = \left(\frac{Y}{L_{vw}}\right)^{1/2.6}, Y \in [0,52.37]$ $Z_{TC} = \left(\frac{Z}{L_{vw}}\right)^{1/2.6}, Z \in [0,52.37]$ where L_{vw} = 52.37 cd/m^2

NOTE: The combination of the COLOR.APP4.2 colorimetry system and the QE.APP4 quantization system is mathematically equivalent to the color encoding specified at Section 4 of SMPTE ST 428-1:2019.

5.3.5 Quantization

The $X_{TC}Y_{TC}Z_{TC}$ components triplet shall use the quantization equation as specified in Table 4.

Table 4 – Quantization Systems

System	Quantization equations
QE.APP4	$CV(X_{TC}) = \mathrm{ROUND}[(2^n - 1) \times X_{TC}]$ $CV(Y_{TC}) = \mathrm{ROUND}[(2^n - 1) \times Y_{TC}]$ $CV(Z_{TC}) = \mathrm{ROUND}[(2^n - 1) \times Z_{TC}]$ where *n* is the pixel bit depth

The ROUND(x) operator returns the largest integral value not greater than x if the fractional part of x is less than 0.5; or the smallest integral not less than x, if the fractional part of x is greater or equal to 0.5.

5.4 Encoding

5.4.1 Single Codestream

Each frame shall be a single codestream, as specified in ISO/IEC 15444-1.

5.4.2 Block encoding

The codestream blocks shall be encoded as specified in ISO/IEC 15444-1 or ISO/IEC 15444-15.

5.4.3 Profile and Operating Levels

If ISO/IEC 15444-1 is used, the ISO/IEC 15444-1 JPEG 2000 profile and operating level for each image frame dimension shall conform to Annex D, if ISO/IEC 15444-15 block encoding is used, the constraints specified in Annex E shall apply.

5.4.4 Component Ordering

In a codestream, color components shall be ordered as specified in Table 5.

Table 5 – JPEG 2000 Color Component Ordering

Component Index	$X_{TC}Y_{TC}Z_{TC}$ Component
0	X_{TC}
1	Y_{TC}
2	Z_{TC}

6 Track Files

6.1 Image Track Files

6.1.1 Essence

Image Track Files shall contain image essence conforming to Section 5.

6.1.2 Shim Parameters

Track Files shall be associated with the shim parameter values specified in Table 6.

Table 6 – Image track file Shim Parameter Values Definitions

Shim Parameter	Value
shim_id	http://www.smpte-ra.org/ns/2067-40/2020/shims#image
gc_type	379-1-gc
picture_family	JPEG2000
picture_bitrate	ST 2067-40
picture_format	ST 2067-40
picture_custom_ANC	false
picture_render_ANC	false

6.1.3 Wrapping

Image Track Files shall conform to SMPTE ST 422.

The image essence shall be wrapped according to mode P1 specified in SMPTE ST 422 ("Frame-wrapping").

The Top-Level File Package of Image Track Files shall reference an RGBA Picture Essence Descriptor.

6.1.3.1 Generic Picture Essence Descriptor

6.1.3.1.1 General

The Generic Picture Essence Descriptor items (including those specified in SMPTE ST 2067-2) 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.
Signal Standard	Shall be ignored by the decoder.
Frame Layout	00h (FULL_FRAME)
Stored Width	Shall be equal to Image Frame Width. See Table 2.
Stored Height	Shall be equal to Image Frame Height. See Table 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.
DisplayWidth	Shall not be present or shall be equal to Stored Width.
DisplayHeight	Shall not be present or shall be equal to Stored Height.
DisplayXOffset	Shall not be present or shall be 0.
DisplayYOffset	Shall not be present or shall be 0.
ActiveWidth	Annex B of this specification and Annex G in SMPTE ST 2067-2 provide examples.
ActiveHeight	
ActiveXOffset	

ActiveYOffset	Note: Unless explicitly set, the Active Area Rectangle is by default equal to the Display Rectangle, as specified in SMPTE ST 2067-2.
DisplayF2Offset	Shall not be present.
Aspect Ratio	Shall be present. Annex B provides examples.
Active Format Descriptor	Shall be ignored by the decoder
Video Line Map	Shall be ignored by the decoder.
Alpha Transparency	Shall not be present.
Transfer Characteristic	Shall be present. See Section 6.1.3.1.2.
Image Alignment Offset	Shall not be present.
Image Start Offset	Shall not be present.
Image End Offset	Shall not be present.
FieldDominance	Shall not be present.
Picture Essence Coding	Shall be present. See Section 6.1.3.1.4.
Coding Equations	Shall not be present.
Color Primaries	Shall be present. See Section 6.1.3.1.3.
Alternative Center Cuts	Shall be ignored by the decoder.
Mastering Display Primaries	Should be present. See Section 6.1.3.1.5.
Mastering Display White Point Chromaticity	Should be present. See Section 6.1.3.1.5.

6.1.3.1.2 Transfer Characteristic

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

- the label specified at Table A.2 if the COLOR.APP4.1 system is used.
- the label specified at Table A.3 if the COLOR.APP4.2 system is used.

6.1.3.1.3 Color Primaries

The value of the Color Primaries item shall be equal to the label specified at Table A.1.

6.1.3.1.4 Picture Essence Coding

The value of the Picture Essence Coding item shall indicate the JPEG 2000 Picture Coding Variant and Constraints reflecting the JPEG 2000 profile and operating level of the image essence if ISO/IEC 15444-1 image encoding is used, or the UL for ISO/IEC 15444-15 if this encoding is used.

NOTE: The SMPTE Labels register defined by SMPTE ST 400 defines a UL for each of the JPEG 2000 profiles and operating levels listed in Annex D.

6.1.3.1.5 Mastering Display Color Volume Metadata

Either none or both of the Mastering Display Primaries and Mastering Display White Point Chromaticity items as defined in SMPTE ST 2067-21 shall be present.

If the items are absent, no information on the mastering display is available.

Example 1: Table 8 lists example values of the Mastering Display Primaries item.

Table 8 – Commonly used values of the Mastering Display Primaries item (Informative)

Value	Notes

{
{ 34000, 16000 },
{ 13250, 34500 },
{ 7500, 3000 }
}
	Corresponds to the RGB color primaries, in order, of the reference projector defined in SMPTE ST 2113 :
	Red (0.6800, 0.3200),
	Green (0.2650,0.6900),
	Blue (0.1500,0.0600)

Example 2: Table 9 lists example value of the Mastering Display White Point Chromaticity item.

Table 9 – Commonly used values of the Mastering Display White Point Chromaticity item (Informative)

Value	Notes
{ { 15700, 17550 } }	Corresponds to the white chromatic coordinates referenced as P3DCI in SMPTE ST 2113 : White (0.3140,0.3510).
{ { 15635, 16450 } }	Corresponds to the white chromatic coordinates referenced as P3D65 in SMPTE ST 2113 : White (0.3127, 0.3290).
{ { 15990, 16800 } }	Corresponds to the white chromatic coordinates as defined in SMPTE EG 432-1 : D61 White {0.3198, 0.3360}
{ { 16085, 16890 } }	Corresponds to the white chromatic coordinates referenced as P3D60 in SMPTE ST 2113 : D60 White (0.32168,0.33767).
{ { 16620, 17370 } }	Corresponds to the white chromatic coordinates as defined in SMPTE EG 432-1 : D55 White (0.3324,0.3474)

6.1.3.2 RGBA Picture Essence Descriptor

6.1.3.2.1 General

The RGBA Picture Essence Descriptor items shall be constrained as specified in Table 10.

Table 10 – RGBA Essence Descriptor items

RGBA Picture Essence Descriptor Item	Constraints
Component Max Ref	Shall be present. See Section 6.1.3.2.2.
Component Min Ref	Shall be present. See Section 6.1.3.2.2.
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.

6.1.3.2.2 Component Max Ref and Component Min Ref

The values of the Component Max Ref and Component Min Ref items shall be as specified in Table 11.

Table 11 – Component Max Ref and Component Min Ref values

Pixel Bit Depth	16	12
Component Min Ref	0	0
Component Max Ref	65535	4095

6.1.3.3 JPEG 2000 Picture Sub Descriptor

6.1.3.3.1 General

The Top-Level File Package of the Image Track File shall reference a JPEG 2000 Picture Sub Descriptor SMPTE ST 422 as constrained by Table 12.

Table 12 – JPEG 2000 Picture Subdescriptor items

JPEG 2000 Picture Subdescriptor Item	Constraints
Coding Style Default	Shall be present.
J2CLayout	Shall be present. See Section 6.1.3.3.2.

6.1.3.3.2 J2CLayout

The value of the J2CLayout item shall be equal to { D8h, n, D9h, n, DAh, n, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 } where n is the pixel bit depth.

6.2 Audio Track Files

Each Audio Track File shall contain at least one audio channel.

6.3 DCDM Timed Text Track Files

6.3.1 General

A DCDM Timed Text Track File is a Track File that conforms to Section 6.3 of this document.

A Timed Text Track File primarily contains timed Text essence, e.g. subtitle and caption.

The DataEssenceCoding item shall not be present in a Timed Text Track File.

6.3.2 Shim Parameters

A DCDM Timed Text Track Files is associated with the shim parameter values specified in Table 13.

Table 13 – DCDM Timed-text track file Shim Parameter Values Definitions

Shim Parameter	Value
shim_id	http://www.smpte-ra.org/ns/2067-40/2020/shims#timed-text
gc_type	379-1-gc
data_family	ST 428-7, ST 428-10
data_file_arrangement	ST 429-5

6.3.3 Wrapping

DCDM Timed Text Track Files shall conform to SMPTE ST 429-5.

The Timed Text Resource shall contain a single Document Instance that conforms to SMPTE ST 428-7.

6.3.4 NamespaceURI

The NamespaceURI item of the Timed Text Descriptor shall be equal to the XML namespace name of the top-level XML element of the Document Instance.

6.3.5 RFC 5646 Language Tag List

The Timed Text Descriptor may contain the RFC 5646 Language Tag List property specified at SMPTE ST 2067-2. The value of the property shall indicate the languages associated with the data essence within the Data Essence Track File. Absence of the property shall indicate that no language is associated with the Data Essence Track File.

If the Language element of the SubtitleReel element of the Timed Text Resource is present, the RFC 5646 Language Tag List property shall be present and shall include one instance of the value of the Language element.

6.3.6 ResourceID

The ResourceID property of the Timed Text Descriptor shall be equal to the Id element of the SubtitleReel element of the Timed Text Resource.

6.3.7 Image Resources

For each Image element in the Timed Text Resource, an Ancillary Resource shall exist in the Track File such that the AncillaryResourceID of Ancillary Resource is equal to the value of the Image element. This Ancillary Resource contains the external image resource referenced by the Image element.

6.3.8 Font Resources

For each LoadFont element in the Timed Text Resource, an Ancillary Resource shall exist in the Track File such that the AncillaryResourceID of Ancillary Resource is equal to the ID attribute of the LoadFont element. This Ancillary Resource contains the font resource referenced by the LoadFont element.

7 Composition

7.1 Application Identification

The ApplicationIdentification element (as defined in SMPTE ST 2067-2) shall include exactly one instance of one of the values listed in Table 14.

Table 14 – Application Identification

Characteristics	*Identifier*
Linear characteristics	http://www.smpte-ra.org/ns/2067-40-linear/2020
DCDM characteristics	http://www.smpte-ra.org/ns/2067-40-DCDM/2020

A DCDM Composition is intended to be transformed into a Composition specified in SMPTE ST 429-2.

7.2 Homogeneous Essence

Within a given composition, the following shall remain constant:

- all image essence characteristics specified in Section 5.2, 5.3 and 5.4.2.

7.3 ContentKind

The ContentKind element shall be present in the Composition Playlist.

For compositions conforming to DCDM characteristics, the scope attribute of the ContentKind element should be present and should use one of the URI values listed in Table 15:

Table 15 – Recommended ContentKind scope attribute values for DCDM characteristics

URI	*Defining standard*
http://www.smptera.org/schemas/429-7/2006/CPL#standard-content	SMPTE ST 429-7:2006
http://www.smptera.org/schemas/429-16/2014/CPL-Metadata#scope/content-kind	SMPTE ST 429-16:2014

The value of the ContentKind element itself shall be one of the values associated with the scope.

7.4 Creator

The Creator element shall be present in the Composition Playlist.

7.5 Issuer

The Issuer element shall be present in the Composition Playlist.

7.6 CompositionTimecode

If Composition edit rate is equal to one of the values listed in Table 16, the CompositionTimecode element of the Composition Playlist instance shall not be present.

Table 16 – Edit rates not suitable for use with the CompositionTimecode element.

Frame Rate
16
200/11
20
240/11

NOTE: The frame rates listed in Table 16 cannot be represented by the CompositionTimecode element.

7.7 DCDM Timed Text Virtual Tracks

A Composition shall contain zero or more DCDM Timed Text Virtual Tracks.

Each DCDM Timed Text Virtual Track shall consist of one or more instances of one of the element specified in Table 17.

Table 17 – DCDM Timed Text Sequence schema definition.

```
<xs:element name="DCDMMainSubtitleSequence" type="cpl:SequenceType"/>
<xs:element name="DCDMMainCaptionSequence" type="cpl:SequenceType"/>
<xs:element name="DCDMClosedSubtitleSequence" type="cpl:SequenceType"/>
<xs:element name="DCDMClosedCaptionSequence" type="cpl:SequenceType"/>
```

Each Resource elements within a DCDM Timed Text Virtual Track:

- shall be of type TrackFileResourceType.
- shall reference a DCDM Timed Text Track File that conforms to Section 6.3 and is constrained according to Table 18.
- shall have a native start point corresponding to time coordinate 0 in the timeline of the underlying Track File.
- shall have a native duration equal to or larger than the time coordinate after which no element will be active in the timeline of the underlying Track File.

Table 18 – DCDM Timed Text Sequence essence constraints kind

Sequence Element	Constraints	Description
DCDMMainSubtitleSequence	SMPTE ST 428-7	Subtitle essence to be reproduced on the main screen in the auditorium.
DCDMMainCaptionSequence	SMPTE ST 428-10	Open Caption essence to be reproduced on the main screen of the auditorium.
DCDMClosedSubtitleSequence	SMPTE ST 428-10	Closed Subtitle essence to be reproduced on closed-style displays in the auditorium.
DCDMClosedCaptionSequence	SMPTE ST 428-10	Closed Caption essence to be reproduced on closed-style displays in the auditorium.

7.8 **Markers**

For compositions conforming to DCDM characteristics, the marker elements should be constrained with the presence of a scope attribute, with the URI value listed in Table 19. The content of the element shall be limited to the values listed in the defining section accordingly.

Table 19 –Recommended Marker scope values for DCDM characteristics

URI	Defining standard
http://www.smpte-ra.org/schemas/429-7/2006/CPL#standard-markers	SMPTE ST 429-7

NOTE: The markers for IMF have a different default namespace name (scope="http://www.smpte-ra.org/schemas/2067-3/2013#standard-markers") that is not used in this case.

8 Pixel Color Schemes

Annex C defines Pixel Color Schemes, as specified in SMPTE ST 2067-101, for the use with IMF Application #4.

NOTE: Annex C is for the sole purpose of enabling Output Profile List (OPL) processing of Application #4 IMF packages.

Annex A SMPTE Label definitions (Normative)

Table A.1 – Cinema Mezzanine Color Primaries

Name	Cinema Mezzanine Color Primaries
Symbol	ColorPrimaries_CinemaMezzanine
Namespace	http://www.smpte-ra.org/reg/400/2012
Item UL	urn:smpte:ul:060e2b34.0401010d.04010101.03080000
Definition	Colors are sampled as the X, Y and Z tristimulus values specified in ISO 11664-3 (No color primaries are specified)

Table A.2 – Cinema Mezzanine Linear Transfer Characteristic

Name	Cinema Mezzanine Linear Transfer Characteristic
Symbol	TransferCharacteristic_CinemaMezzanineLinear
Namespace	http://www.smpte-ra.org/reg/400/2012
Item UL	urn:smpte:ul:060e2b34.0401010d.04010101.01120000
Definition	Identifies the COLOR.APP4.1 transfer characteristic specified in SMPTE ST 2067-40

Table A.3 – Cinema Mezzanine DCDM Transfer Characteristic

Name	Cinema Mezzanine DCDM Transfer Characteristic
Symbol	TransferCharacteristic_CinemaMezzanineDCDM
Namespace	http://www.smpte-ra.org/reg/400/2012
Item UL	urn:smpte:ul:060e2b34.0401010d.04010101.01130000
Definition	Identifies the COLOR.APP4.2 transfer characteristic specified in SMPTE ST 2067-40

Annex B Active Area Rectangle Examples (Informative)

Table B.1 provides examples of the use of active area and aspect ratio for selected image frame sizes.

Table B.1 – Example Image Frame Size

	1.85 aspect ratio image within a 2K container (with black bands)	1.85 aspect ratio image within a 4K container (with black bands)	16/9 aspect ratio image within a 2K container (without black bands)	2.39 aspect ratio image within a 2K container (without black bands)
Stored Width	2048	4096	1920	2048
Stored Height	1556	3112	1080	858
StoredF2FOffset	0	0	0	0
Sampled Width	2048	4096	1920	2048
Sampled Height	1556	3112	1080	858
Sampled X Offset	0	0	0	0
Sampled Y Offset	0	0	0	0
Display Width	2048	4096	1920	2048
Display Height	1556	3112	1080	858
Display X Offset	0	0	0	0
Display Y Offset	0	0	0	0
Aspect Ratio	2048/1556	4096/3112	16/9	1024/429
Active Width	2048	4096	1920	2048
Active Height	1106	2212	1080	858
Active X Offset	0	0	0	0
Active Y Offset	215	430	0	0

Annex C Pixel Color Schemes Definition (Normative)

C.1 XML Schema Definition

The XML schema root element for Pixel Color Schemes shall be as defined in Table C.1.

Table C.1 – XML Schema root element definition

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://www.smpte-ra.org/ns/2067-40/2020/opl-color-
                scheme"
            xmlns:oplcs="http://www.smpte-ra.org/ns/2067-101/2018/color-schemes"
            xmlns:oplc="http://www.smpte-ra.org/ns/2067-102/2017/
            xmlns:app4cs="http://www.smpte-ra.org/ns/2067-40/2020/opl-color-
                scheme"
            xmlns:xs="http://www.w3.org/2001/XMLSchema"
            elementFormDefault="qualified" attributeFormDefault="unqualified">
    <xs:import namespace="http://www.smpte-ra.org/ns/2067-101/2018/color-schemes"/>
    <xs:import namespace="http://www.smpte-ra.org/ns/2067-102/2017"/>
<!-- schema definitions found in this document excluding this one -->
</xs:schema>
```

C.2 APP4-XYZ-12

The APP4-XYZ-12 color scheme shall be as specified in Table C.2. The mathematical functions "floor(x)" and "clamp(a, b, x)" in Table C.2 shall be as defined in SMPTE ST 2067-102. The XML datatype Integer4096TripletType shall be as defined in SMPTE ST 2067-102.

Table C.2 – APP4-XYZ-12 Color Scheme

Name	APP4-XYZ-12
URI	`http://www.smpte-ra.org/ns/2067-40/2020/opl-color-scheme#APP4-XYZ-12`
Description	X_{TC}, Y_{TC} and Z_{TC} components as specified in Section 5.3.4, using 12-bit bit depth, COLOR.APP4.2 colorimetry and QE.APP4 quantization system.
Mapping from Reference Image Pixel	X_{TC} = floor(4095 • clamp(0, 1, P1) + 0.5) Y_{TC} = floor(4095 • clamp(0, 1, P2) + 0.5) Z_{TC} = floor(4095 • clamp(0, 1, P3) + 0.5)
Mapping to Reference Image Pixel	$P_1 = X_{TC} / 4095$ $P_2 = Y_{TC} / 4095$ $P_3 = Z_{TC} / 4095$ $P_4 = 1.0$

Pixel Encoding Type	`<xs:complexType name="APP4-XYZ-12-ColorEncodingType">`
	`  <xs:simpleContent>`
	`  <xs:restriction base="oplcs:ColorEncodingType">`
	`  <xs:simpleType>`
	`  <xs:restriction base="oplc:Integer4096TripletType"/>`
	`  </xs:simpleType>`
	`  </xs:restriction>`
	`  </xs:simpleContent>`
	`</xs:complexType>`

	The three elements of the triplet shall correspond to the X_{TC}, Y_{TC} and Z_{TC} components.

C.3 APP4-XYZ-16

The APP4-XYZ-16 color scheme shall be as specified in Table C.3. The mathematical functions "floor(x)" and "clamp(a, b, x)" in Table C.3 shall be as defined in ST 2067-102. The XML datatype Integer65536TripletType shall be as defined in ST 2067-102.

Table C.3 – APP4-XYZ-16 Color Scheme

Name	APP4-XYZ-16
URI	`http://www.smpte-ra.org/ns/2067-40/2020/opl-color-scheme#APP4-XYZ-16`
Description	X_{TC}, Y_{TC} and Z_{TC} components as specified in Section 5.3.4, using 16-bit bit depth, COLOR.APP4.1 colorimetry and QE.APP4 quantization system.
Mapping from Reference Image Pixel	X_{TC} = floor(65535 • clamp(0, 1, P1) + 0.5) Y_{TC} = floor(65535 • clamp(0, 1, P2) + 0.5) Z_{TC} = floor(65535 • clamp(0, 1, P3) + 0.5)
Mapping to Reference Image Pixel	$P_1 = X_{TC} / 65535$ $P_2 = Y_{TC} / 65535$ $P_3 = Z_{TC} / 65535$ $P_4 = 1.0$

Pixel Encoding Type	`<xs:complexType name="APP4-XYZ-16-ColorEncodingType">`
	`  <xs:simpleContent>`
	`  <xs:restriction base="oplcs:ColorEncodingType">`
	`  <xs:simpleType>`
	`  <xs:restriction base="oplc:Integer65536TripletType"/>`
	`  </xs:simpleType>`
	`  </xs:restriction>`
	`  </xs:simpleContent>`
	`</xs:complexType>`
	The three elements of the triplet shall correspond to the X_{TC}, Y_{TC} and Z_{TC} components.

Annex D ISO/IEC 15444-1 JPEG 2000 profiles and operating levels (Normative)

The JPEG 2000 profile should be selected such that its maximum supported image frame dimensions (as specified in Table D.1 are the smallest encompassing the image frame dimensions. Similarly, the JPEG 2000 operating level should be selected such that the image essence does not conform to any lower operating level.

Table D.1 – JPEG 2000 Profiles

Image Frame Width	1..2048	1..4096	1..8192
Image Frame Height	1..1556	1..3112	1..6224
JPEG 2000 Profile	2k IMF single/multi-tile reversible profile	4k IMF single/multi-tile reversible profile	8k IMF single/multi-tile reversible profile
JPEG 2000 Operating Levels	Mainlevel 1 Sublevel 0 Mainlevel 2 Sublevel 0 Mainlevel 3 Sublevel 0 Mainlevel 4 Sublevel 0 Mainlevel 5 Sublevel 0 Mainlevel 6 Sublevel 0	Mainlevel 1 Sublevel 0 Mainlevel 2 Sublevel 0 Mainlevel 3 Sublevel 0 Mainlevel 4 Sublevel 0 Mainlevel 5 Sublevel 0 Mainlevel 6 Sublevel 0 Mainlevel 7 Sublevel 0 Mainlevel 8 Sublevel 0	Mainlevel 1 Sublevel 0 Mainlevel 2 Sublevel 0 Mainlevel 3 Sublevel 0 Mainlevel 4 Sublevel 0 Mainlevel 5 Sublevel 0 Mainlevel 6 Sublevel 0 Mainlevel 7 Sublevel 0 Mainlevel 8 Sublevel 0 Mainlevel 9 Sublevel 0 Mainlevel 10 Sublevel 0

Annex E ISO/IEC 15444-15 HT-J2K codestream constraints (Normative)

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

Table E.1– HT-J2K constraints

Item	Constraints
Codestream	Shall be an HTJ2K codestream as defined in ISO/IEC 15444-15
Capabilities	No capabilities other than those specified in ISO/IEC 15444-1 and ISO/IEC 15444-15 $Pcap^i$ is be 1 for i = 15, and 0 otherwise.
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	N_L ≤ 4 for XTsiz ≥ 1024 N_L ≤ 5 for XTsiz ≥ 2048 N_L ≤ 6 for XTsiz ≥ 4096 N_L ≤ 7 for XTsiz ≥ 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
Precinct size	PPx = PPy = 7 for N_LLL band, else 8
Progression order	LRCP, RLCP, RPCL, PCRL, CPRL
Tile-parts	if the progression order is: LRCP, one tile part per resolution RLCP: one tile part per resolution RPCL: one tile part per resolution PCRL: one tile part per position such that there is 8 tile-parts per image CPRL: one tile part per component
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 E.2

Table E.2 – Parameter B

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

NOTE 1 – As specified at ISO/IEC 15444-1, 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.

Annex F Additional elements (Informative)

This annex lists non-prose elements of this document.

F.1 Consolidated Schema

This specification is accompanied by the following element, which is an XML schema document as specified in W3C XML Schema Part 1: Structures.

st2067-40a-2020.xsd

This element collects the XML schema definitions defined in this specification. It is informative and, in case of conflict, this specification takes precedence.

Bibliography (Informative)

SMPTE EG 432-1:2010, Digital Source Processing — Color Processing for D-Cinema

SMPTE RP 431-2:2011, D-Cinema Quality — Reference Projector and Environment

SMPTE ST 2113:2018, Colorimetry of P3 Color Spaces