SMPTE REGISTERED DISCLOSURE DOCUMENT

Material Exchange Format — Mapping ARRIRAW Bitstreams into the MXF Generic Container

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Every attempt has been made to ensure that the information contained in this document is accurate. Errors in this document should be reported to the proponent identified below, with a copy to eng@smpte.org.

This document is intended to support the development of applications that read and process ARRIRAW essence. It is not intended to support the development of hardware or software applications that create MXF files containing ARRIRAW essence 'from scratch', that is, MXF files containing ARRIRAW essence that did not originate in an ARRI camera. Creation of such MXF files is reserved to individuals and organizations that have entered into agreements with the proponent identified below for such file creation.

All other inquiries in respect of this document, including inquiries as to intellectual property requirements that may be attached to use of the disclosed technology, should be addressed to the proponent identified below.

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1 Introduction

This clause is entirely informative and does not form an integral part of this Registered Disclosure Document.

ARRI cameras can generate sequences of frames containing captured image essence in photomosaic form, metadata, and, optionally, audio and/or data essence. The photomosaic data are encoded in a way that approximates a logarithmic function, and, optionally, this approximately logarithmic data can be losslessly compressed using the algorithm described in SMPTE RDD 51. This document describes how ARRIRAW image essence from frame sequences is mapped into the MXF Constrained Generic Container. It also describes certain metadata present in the container that carry information required for correct transformation of the ARRIRAW essence from photomosaic to tristimulus data.

2 Scope

This Registered Disclosure Document (RDD) specifies the mapping of ARRIRAW image essence as a Picture Essence track of the MXF Constrained Generic Container in frame-wrapped form. It defines the ARRIRAW image bitstream, the KLV coding, essence container label values, essence coding labels, and SubDescriptor values describing the mapping, as well as the composition of the content package. It also states the layout of MXF files containing ARRIRAW essence, and constraints on applications producing such files.

3 Conformance Notation

This RDD uses the conformance notation specified in SMPTE ST 377-1.

4 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this RDD. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this RDD are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

SMPTE ST 377-1:2019, Material Exchange Format (MXF) — File Format Specification

SMPTE ST 378:2004, Material Exchange Format (MXF) — Operational Pattern 1a

SMPTE ST 379-2:2010, Material Exchange Format (MXF) — MXF Constrained Generic Container

SMPTE ST 382:2007, Material Exchange Format (MXF) — Mapping AES3 and Broadcast Wave Audio into the MXF Generic Container

SMPTE RDD 51:2020, High Density Image Encoding for ARRIRAW Files

SMPTE RDD 55:2022, Material Exchange Format (MXF) — Carriage of ARRI Camera System Metadata

5 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

5.1
ARRIRAW MXF File

file conforming to the provisions of this Registered Disclosure Document, containing ARRIRAW Picture Essence and associated metadata, and, optionally, audio and/or data essence

5.2
ARRIRAW Picture Essence

12- or 13-bit approximately logarithmic (AL) representation of 16- or 18-bit linear photosite data

5.3
HDE-encoded ARRIRAW Picture Essence

ARRIRAW Picture Essence that has been encoded in the manner described in SMPTE RDD 51

5.4
least-significant-byte-first order

byte ordering where 32-bit words are represented by a sequence of 4 bytes with the first byte representing the least-significant bits (bits 7:0) of the word, the second byte representing bits 15:8 of the word, the third byte representing bits 23:16 of the word and the fourth byte representing bits 31:24 of the word

5.5
Packed ARRIRAW Picture Essence

ARRIRAW Picture Essence that has been packed into 32-bit words such that all bits of the essence are present and every bit in each 32-bit word is used to carry that essence

5.6
photosite

individual element of an image sensor’s photomosaic array

5.7
sensor traversal order

progression of positions on the image sensor’s photomosaic array from topmost row to bottom row, and within each row from leftmost column to rightmost column

6 ARRIRAW Picture Essence

6.1 Introduction (informative)

ARRIRAW Picture Essence is a single-channel representation of sensor photomosaic data produced by an ARRI digital camera.

There are four types of photosite values: $Green_{Red}$, Red, Blue, and $Green_{Blue}$.

The sensor can be considered as being comprised of rows of photosites, the columns of which are made up either of alternating of green-covered and red-covered photosites or alternating green-covered and blue-covered photosites. Whereas the values associated with the red-covered and blue-covered photosites are simply termed ‘Red photosite values’ and ‘Blue photosite values’, the values associated with the green-covered values are treated differently depending on whether their neighbors in the row are red-covered or blue-covered, leading to the terms ‘$Green_{Red}$ photosite values’ and ‘$Green_{Blue}$ photosite values’.

There are four color filter array layouts of rows of alternating Red or $Green_{Red}$ photosites and rows of alternating Blue or $Green_{Blue}$ rows, differing in which type of photosite value ($Green_{Red}$, Red, Blue, or $Green_{Blue}$) anchors the row-and-column array of the sensor at its uppermost, leftmost photosite. Metadata identifies which of the layouts was used to capture imagery.

An area incorporating this uppermost, leftmost photosite is shown, with the pattern anchored by a $Green_{Red}$ photosite, is shown in Figure 1.

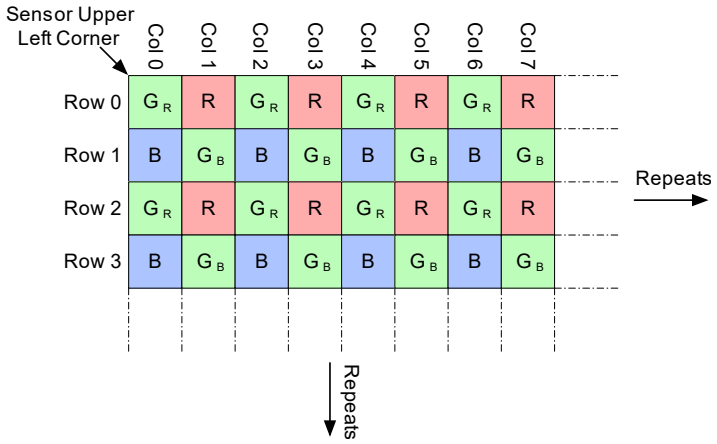

Figure 1 — Example Sensor Photosite Layout

6.2 ARRIRAW Picture Essence encoding

ARRIRAW Picture Essence shall represent ARRIRAW images as 16-bit or 18-bit photosite response values, with the values stored into a file after undergoing a transformation to a 12-bit or 13-bit approximately logarithmic (AL) representation, respectively.

The 12- or 13-bit representations of the AL values shall be stored either as Packed ARRIRAW Picture Essence by applying a tight packing into a stream of 32-bit words, or as HDE-encoded ARRIRAW Picture Essence by applying the lossless high density image encoding specified in SMPTE RDD 51.

The unpacking of Packed ARRIRAW Picture Essence shall be as specified in 6.2.1.

The bitstream format and decoding of HDE-encoded ARRIRAW Picture Essence shall be as specified in 6.2.2.

Approximation of the original 16-bit or 18-bit photosite response value from a 12-bit or 13-bit AL value shall be as specified in 6.2.3.

6.2.1 Packed ARRIRAW Picture Essence

6.2.1.1 Packing Illustrations Conventions (informative)

The packing illustrations in this clause contain 12- or 13-element collections of trapezoids or triangles representing the 12- or 13-bit AL values. The tallest trapezoid represents the highest-order bit of the AL value. The shortest trapezoid represents the next-to-lowest-order bit of the AL value. A triangle (the sole occurrence of a triangle in any 12- or 13-element representation of an AL value) represents the lowest-order bit.

The packing illustrations in this clause use the color of the fill of the trapezoid or triangle to indicate the position of the AL value in sensor traversal order as shown in Figure 2.

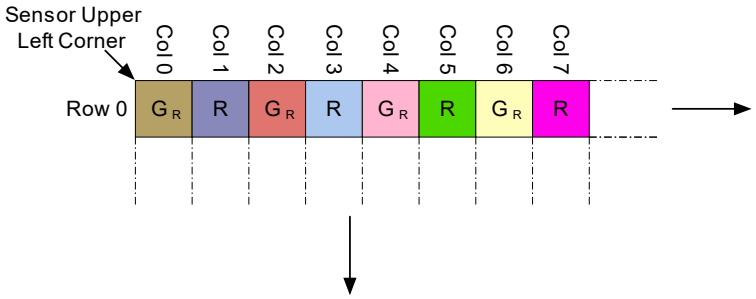

Figure 2 — Photosite Ordering Key for Unpacking Figures in this Clause (Informative)

6.2.1.2 Packed ARRIRAW Picture Essence representing 16-bit photosite response values

When a packed representation of ARRIRAW Picture Essence is chosen, one of two packing methods shall be used to store ARRIRAW Picture Essence as 12-bit AL values representing 16-bit photosite response values. The first packing method shall be termed '12-bit reverse packed'; the second packing method shall be termed '12-bit packed'.

6.2.1.2.1 Unpacking 12-bit reverse packed data into a sensor-traversal-ordered sequence of 16-bit words

Unpacking 12-bit reverse packed AL values shall proceed in two steps.

1. The ARRIRAW Picture Essence shall be interpreted as a sequence of 32-bit words in least-significant-byte-first order.

2. Starting from the most significant bit of the first 32-bit word and continuing through successive 32-bit words, packed 12-bit values shall be unpacked sequentially into 16-bit words. Each 12-bit value shall be stored in the least-significant bits of the corresponding 16-bit word with higher-order bits of the word set to zero.

NOTE If the 8-bit bytes in the 12-bit reverse packed ARRIRAW Picture Essence were processed to produce AL values in sensor traversal order, as described in the immediately preceding two paragraphs, the step-by-step mapping of the bitstream from a sequence of 8-bit bytes into AL values in 16-bit words would be as shown in Figure 3.

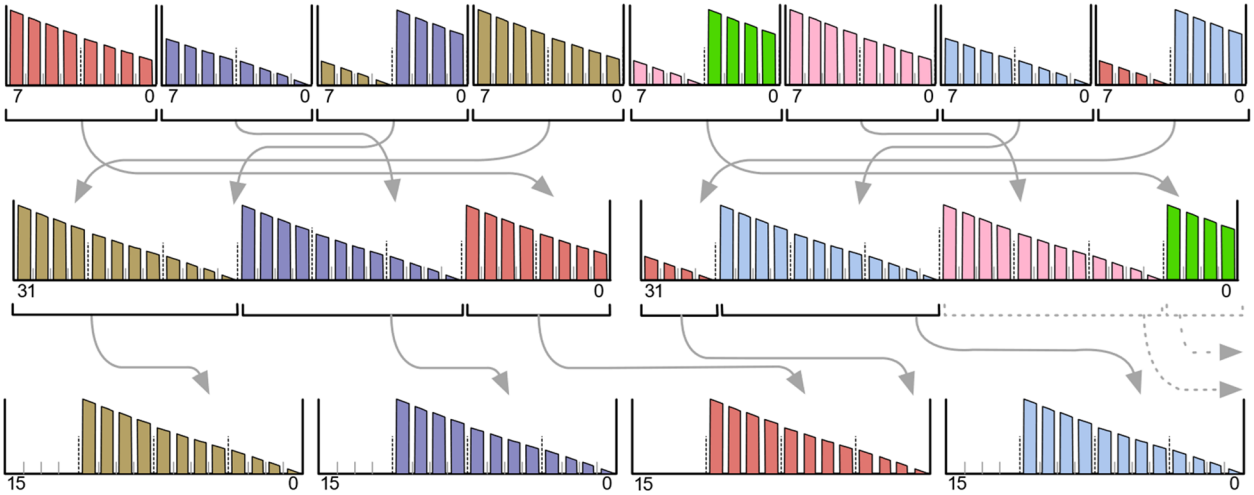

Figure 3 — Obtaining sensor-traversal-order AL values from 12-bit reverse packed ARRIRAW Picture Essence

6.2.1.2.2 Unpacking 12-bit packed AL values into a sensor-traversal-ordered sequence of 16-bit words

Unpacking 12-bit packed AL values shall proceed in three steps.

1. The ARRIRAW Picture Essence shall be interpreted as a sequence of 32-bit words in least-significant-byte-first order.

2. Starting from the most significant bit of the first 32-bit word and continuing through successive 32-bit words, packed 12-bit values shall be unpacked sequentially into 16-bit words. Each 12-bit value shall be stored in the least-significant bits of the corresponding 16-bit word with higher-order bits of the word set to zero.

3. Starting with the first 16-bit word, the two values in each successive pair of words shall be swapped.

NOTE If the 8-bit bytes in the 12-bit packed ARRIRAW Picture Essence were processed to produce AL values in sensor traversal order, as described in the immediately preceding three paragraphs, the step-by-step mapping of the bitstream from a sequence of 8-bit bytes into AL values in 16-bit words would be as shown in Figure 4.

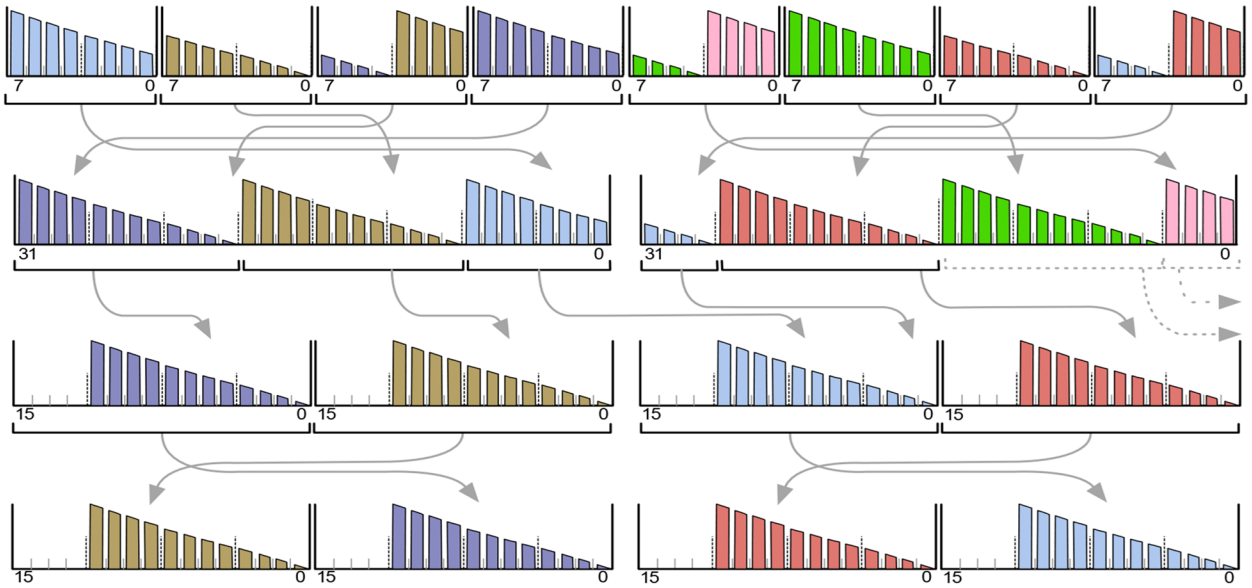

Figure 4 — Obtaining sensor-traversal-order AL values from 12-bit packed ARRIRAW Picture Essence

6.2.1.3 Packed ARRIRAW Picture Essence representing 18-bit photosite response values

When a packed representation of ARRIRAW Picture Essence is chosen, ARRIRAW Picture Essence representing 18-bit photosite response values shall be stored as packed 13-bit approximately logarithmic (AL) values.

Unpacking 13-bit packed AL values shall proceed in two steps.

1. The ARRIRAW Picture Essence shall be interpreted as a sequence of 32-bit words in least-significant-byte-first order.

2. Starting from the most significant bit of the first 32-bit word and continuing through successive 32-bit words, packed 13-bit values shall be unpacked sequentially into 16-bit words. Each 13-bit value shall be stored in the least-significant bits of the corresponding 16-bit word with higher-order bits of the word set to zero.

NOTE If the 8-bit bytes in the 13-bit packed ARRIRAW Picture Essence were processed to produce AL values in sensor traversal order, as described in the immediately preceding two paragraphs, the step-by-step mapping of the bitstream from a sequence of 8-bit bytes into AL values in 16-bit words would be as shown in Figure 5.

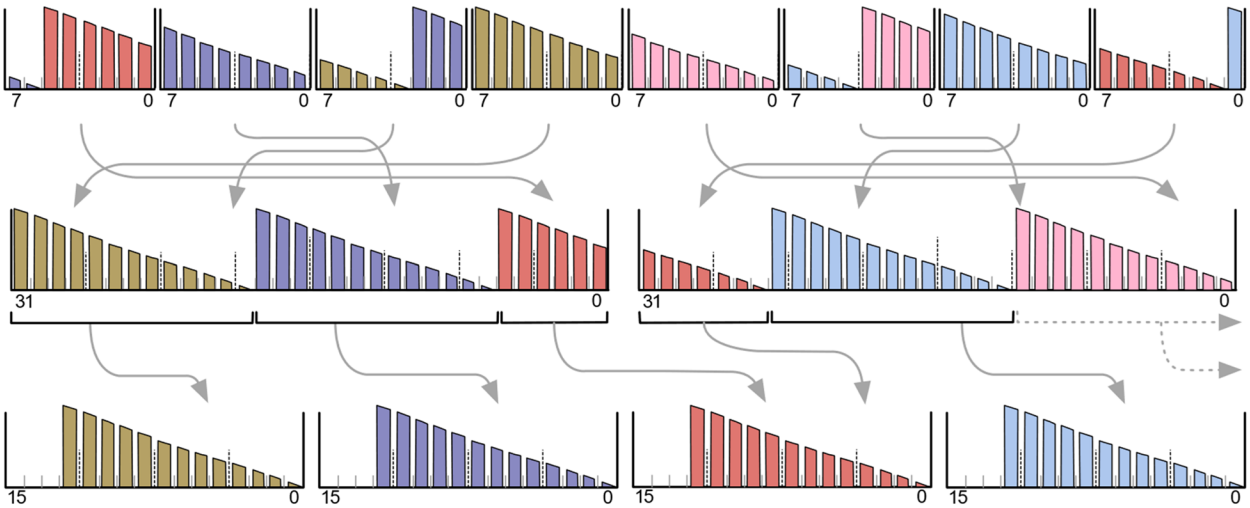

Figure 5 — Obtaining sensor-traversal-order AL values from 13-bit packed ARRIRAW Picture Essence

6.2.2 HDE-encoded ARRIRAW Picture Essence

When HDE is chosen to encode ARRIRAW Picture Essence, the stored data represent 12- or 13-bit AL values encoded as specified in RDD 51.

6.2.2.1 Decoding HDE-encoded ARRIRAW Picture Essence

The stored data shall be decoded using the inverse of the encoding process specified in RDD 51. The output of the decoding process shall be interpreted as a sequence of 16-bit unsigned integers holding 12- or 13-bit AL values, depending on whether the original photosite data held 16- or 18-bit photosite response values, respectively.

6.2.3 Approximation of original linear photosite response values

The stored data represent either 16-bit linear photosite response values stored as 12-bit AL values, or 18-bit linear photosite response values stored as 13-bit AL values using a method that approximates a logarithmic encoding, but emphasizes the preservation of deep shadow detail.

The following, Formula (1), shall be used to produce a linear photosite response value r from a stored 12-bit or 13-bit AL value v:

$$r = \begin{cases} v, & v < 1024 \\ ((1024 + 2\,o + 1) \ll (q - 2)) - 1, & v \geq 1024 \end{cases} \quad (1)$$

where

q is the value represented by the three most significant bits of v for 12-bit AL value input, or the four most significant bits of v for 13-bit AL value input (i.e., $v \gg 9$ for both 12-bit and 13-bit AL value input);

o is the value represented by the nine least significant bits of v (i.e., $v \,\&\, (2^9 - 1)$);

$\ll$ is the left-shift operator, shifting its operand to the left by the specified number of bits, with bit positions vacated at the right being zero-filled;

$\gg$ is the right-shift operator, shifting its operand to the right by the specified number of bits;

& is the bitwise AND operator.

7 ARRIRAW Essence Container

7.1 ARRIRAW Picture Element KLV Coding

7.1.1 Element Key

ARRIRAW Picture Essence shall be Frame Wrapped, and shall be identified with the ARRIRAW Picture Element Key as specified in Table 1. Bytes 1-13 of the label are defined in SMPTE ST 379-2.

Table 1 — ARRIRAW Picture Element Keys

Item Name	Symbol	Kind	Item UL
ARRIRAW Picture Element	ARRIRAWPictureElement	LEAF	060e2b34.01020101.0d010301.15kk1cnn

The symbol ‘kk’ is the count of Picture Elements in the Picture Item, and the symbol ‘nn’ is the number (used as an Index) of this Picture Element in the Picture Item.

7.1.2 Element Length

The BER length field of the KLV triple for ARRIRAW Picture Essence shall be 8 bytes long.

7.1.3 Element Value

The KLV value is an encoding of a single frame of ARRIRAW Picture Essence, prepended by some amount of Pre-Picture Essence Padding. This padding is shown in Figure 6 with O_s representing the ImageStartOffset.

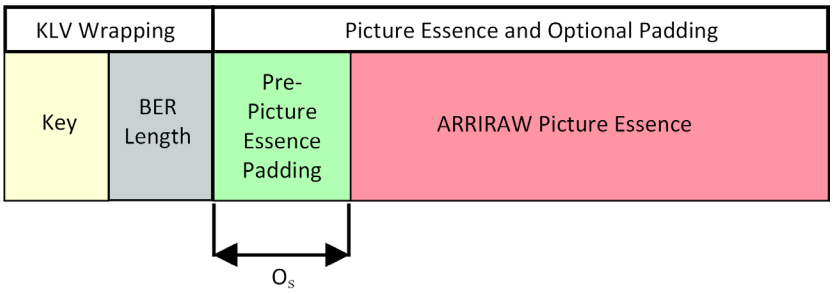

Figure 6 — ARRIRAW Picture Essence Element Layout

NOTE Valid values of O_s in an ARRIRAW MXF File are constrained as described in 8.5.1.

7.2 ARRIRAW Essence Container Labels

The ARRIRAW Essence Container Labels shall be as specified in Table 2. Bytes 1-13 of the labels are defined in SMPTE ST 379-2.

Table 2 — ARRIRAW Essence Container Labels

Item Name	Symbol	Kind	Item UL
ARRIRAW Frame-Wrapped Packed Essence Container	MXFGCARRIRAWFrameWrappedPacked	LEAF	060e2b34.0401010d.0d010301.02220100
ARRIRAW Frame-Wrapped HDE-Encoded Essence Container	MXFGCARRIRAWFrameWrappedHDEEncoded	LEAF	060e2b34.0401010d.0d010301.02220200

7.3 ARRIRAW Picture Essence Coding Labels

The ARRIRAW Picture Essence Coding Labels shall be as specified in Table 3.

For Packed ARRIRAW Picture Essence, the presence of 12-bit packed, 12-bit reverse packed, and 13-bit packed essence shall be indicated by the ARRIRAW Essence 12-bit Coding label, ARRIRAW Essence 12-bit Reverse Coding label, or ARRIRAW Essence 13-bit Coding label, respectively.

For HDE-encoded ARRIRAW Picture Essence, 12-bit essence shall be indicated by the ARRIRAW Essence 12-bit High Density Coding label and 13-bit essence is indicated by the ARRIRAW Essence 13-bit High Density Coding label.

Table 3 — ARRIRAW Picture Essence Coding Labels

Item Name	Symbol	Kind	Item UL
ARRIRAW Essence 12-bit Coding	ARRIRAWCoding12bit	LEAF	060e2b34.0401010d.04010201.02010101
ARRIRAW Essence 12-bit Reverse Coding	ARRIRAWCoding12bitReverse	LEAF	060e2b34.0401010d.04010201.02010102
ARRIRAW Essence 13-bit Coding	ARRIRAWCoding13bit	LEAF	060e2b34.0401010d.04010201.02010103
ARRIRAW Essence 12-bit High Density Coding	ARRIRAWCodingHighDensity12bit	LEAF	060e2b34.0401010d.04010201.02010201
ARRIRAW Essence 13-bit High Density Coding	ARRIRAWCodingHighDensity13bit	LEAF	060e2b34.0401010d.04010201.02010202

7.4 Metadata

Storage of metadata applicable to all frames in the ARRIRAW MXF File (static metadata) generic to both ARRIRAW Picture Essence and other essence created by ARRI camera systems shall be as specified in RDD 55.

Static metadata specific to the processing and interpretation of ARRIRAW Picture Essence and other picture essence stored in clips recorded by ARRI camera systems shall be stored in the ARRIRAW Picture Essence Processing SubDescriptor as specified in 7.4.1.

Metadata that potentially can change from frame to frame (dynamic metadata) shall be stored in the System Item and in the Supplemental Data Essence Container elements as specified in SMPTE RDD 55.

7.4.1 ARRIRAW Picture Essence Processing

Metadata concerning processing of the picture essence in ways specific to ARRIRAW shall be carried by an ARRIRAW Picture Essence Processing SubDescriptor, a subclass of the Picture Essence Processing SubDescriptor that is defined in SMPTE RDD 55.

In an ARRIRAW MXF File the following Boolean items of PictureEssenceProcessingSubDescriptor shall always have the value FALSE:

- WhiteBalanceApplied
- ColorLookApplied
- TextureApplied

7.4.1.1 ARRIRAW Color Filter Array Layout ULs

There are four possible layouts of the color filter array covering the photosite array, distinguished by the placement of the red, green and blue filter material over the four photosites closest to the origin. The ULs identifying the possible layouts shall be as specified in Table 4. The four colors given are expressed in a coordinate system in which the origin is at the upper left of the photosite array and is designated as (0,0) and in which the coordinate notation indicates first the row and then the column. The colors correspond to the photosites at (0, 0), (0, 1), (1, 0) and (1, 1), in that order.

Table 4 — ARRIRAW Color Filter Array Layout ULs

Item Name	Symbol	Kind	Item UL
CFA Order Green, Red, Blue, Green	CFA_GRBG	LEAF	060e2b34.0401010d.0e170101.01010000
CFA Order Green, Blue, Red, Green	CFA_GBRG	LEAF	060e2b34.0401010d.0e170101.01020000
CFA Order Blue, Green, Green, Red	CFA_BGGR	LEAF	060e2b34.0401010d.0e170101.01030000
CFA Order Red, Green, Green, Blue	CFA_RGGB	LEAF	060e2b34.0401010d.0e170101.01040000

7.4.1.2 ARRIRAW Picture Essence Processing SubDescriptor ULs

The ULs of the ARRIRAW Picture Essence Processing SubDescriptor Key and of the ARRIRAW Picture Essence Processing items shall be as specified in Table 5.

Table 5 — ARRIRAW Picture Essence Processing SubDescriptor ULs

Item Name	Symbol	Kind	Item UL
ARRIRAW Picture Essence Processing SubDescriptor	ARRIRAWPictureEssenceProcessingSubDescriptor	LEAF	060e2b34.027f0101.0e170101.01000000
CFA Layout	CFALayout	LEAF	060e2b34.0101010e.0e170101.01010000
Unit Calibration Data	UnitCalibrationData	LEAF	060e2b34.0101010e.0e170101.01020000

7.4.1.3 ARRIRAW Picture Essence Processing SubDescriptor

The ARRIRAW Picture Essence Processing SubDescriptor shall be as specified in Table 6.

Table 6 — ARRIRAW Picture Essence Processing SubDescriptor

Symbol	Type	Len	Req ?	Meaning	Default
ARRIRAWPictureEssenceProcessingSubDescriptor	Set Key	16	Req	Defines image processing parameters specific to ARRIRAW camera system images.	
Length	BER Length	4	Req	Set Length.	
All items in PictureEssenceProcessingSubDescriptor except the Key or Group UL and the Length, if present					
CFALayout	AUID	16	Req	Layout of Color Filter Array material relative to the origin of the photosite array. The value shall be one of the ULs specified in Table 4.	
UnitCalibrationData	DataValue	var	Opt	Per-camera-sensor radiometric calibration data.	

8 Application Considerations

8.1 Partition Structure

An ARRIRAW MXF File shall not contain a Run-In.

An ARRIRAW MXF File shall include a Header Partition, zero or more triads of Body Partitions, a Footer Partition, and a Random Index Pack [RIP].

The Header Partition shall not contain an Index Table segment, nor shall the Header Partition contain ARRIRAW Picture Essence.

The Footer Partition shall contain Header Metadata and an Index Table.

Every edit unit shall be indexed.

The partition structure shall be as specified in Clauses 8.1.1 and 8.1.2 for the ARRIRAW Frame-Wrapped CBE Essence Container and for the ARRIRAW Frame-Wrapped VBE Essence Container, respectively.

When ARRIRAW Picture Essence is Packed, and the size of any sound essence and/or data essence is constant or can be readily made so by padding, the ARRIRAW Frame-Wrapped CBE Essence Container should be used.

When ARRIRAW Picture Essence is Packed, and the size of any sound essence is constant or can be readily made so by padding, but the data essence byte count is very non-uniformly distributed throughout the timeline, or the maximum size of such data essence cannot be established before the start of MXF file creation, the ARRIRAW Frame-Wrapped VBE Essence Container may be used.

When ARRIRAW Picture Essence is HDE-Encoded, the ARRIRAW Frame-Wrapped VBE Essence Container shall be used.

NOTE 1 The above implies that readers of ARRIRAW Packed Picture Essence should be prepared to process such essence carried in an ARRIRAW Frame-Wrapped VBE Generic Container as well as an ARRIRAW Frame-Wrapped CBE Generic Container.

NOTE 2 As RDD 54 builds on RDD 55, in accordance with the partition structure specified in that document, the value of the HeaderByteCount item in the Header Partition Pack shall be at least 16,777,216 (2^{24}) bytes.

8.1.1 Partition Structure for the ARRIRAW Frame-Wrapped CBE Generic Container

The arrangement of Header Partition, triads of Body Partitions, Footer Partition and Random Index Pack (RIP) shall be as shown in Figure 7, and the order of Body Partitions in a triad shall be first the Index Table, second the edit units and third the Header Metadata.

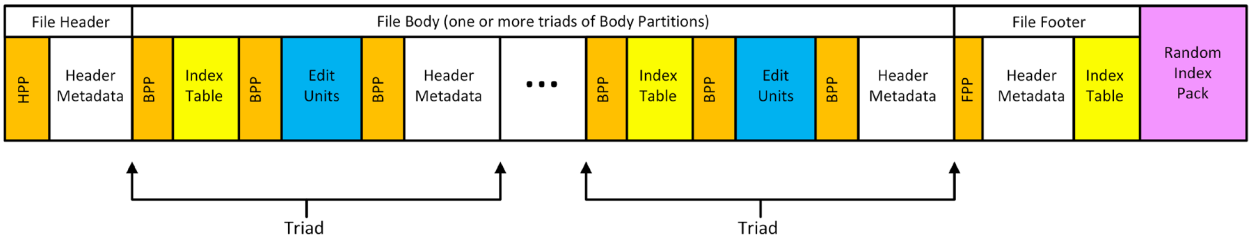

Figure 7 — ARRIRAW MXF File Partition Structure for ARRIRAW Frame-Wrapped CBE Generic Container

8.1.2 Partition Structure for the ARRIRAW Frame-Wrapped VBE Generic Container

The arrangement of Header Partition, triads of Body Partitions, Footer Partition and Random Index Pack (RIP) shall be as shown in Figure 8, and the order of Body Partitions in a triad shall be first the edit units, second the Index Table and third the Header Metadata.

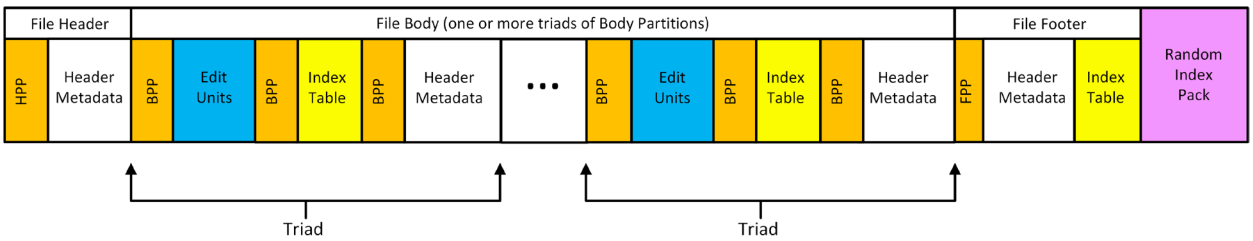

Figure 8 — ARRIRAW MXF File Partition Structure for ARRIRAW Frame-Wrapped VBE Generic Container

8.2 Partition Duration

The duration of all Body Partitions containing ARRIRAW Picture Essence shall be constant (measured in time or Edit Units), with the possible exception of the final Body Partition containing ARRIRAW Picture Essence. The duration should be approximately 10 seconds, and all Body Partitions containing ARRIRAW Picture Essence shall be less than or equal to 10.01 seconds in duration.

8.3 Operational Pattern

The Preface shall indicate the use of Operational Pattern 1a as described in SMPTE ST 378.

8.4 Mapping Track Numbers to Generic Container Elements

Each Track Number for a Picture Essence Element (and, if present, a Sound Essence Element) shall be derived as described in SMPTE ST 379-2. There may be zero or more Data Tracks in an ARRIRAW MXF File.

8.5 Essence Container Constraints

ARRIRAW Picture Essence shall be mapped into the Constrained Generic Container using Frame Wrapping.

An ARRIRAW MXF File shall use internal essence only.

Content Packages found in the ARRIRAW Essence Container shall contain a System Item, a Picture Item, and a Data Item. If an ARRIRAW MXF File includes Sound Essence, the Content Package shall also contain a Sound Item immediately after the Picture Item. The Data Item shall follow immediately after the Sound Item; if no Sound Item is present, the Data Item shall follow immediately after the Picture Item.

The layout of a Content Package from an ARRIRAW Essence Container, corresponding to camera operation when sound essence is also stored, shall be as shown in Figure 9.

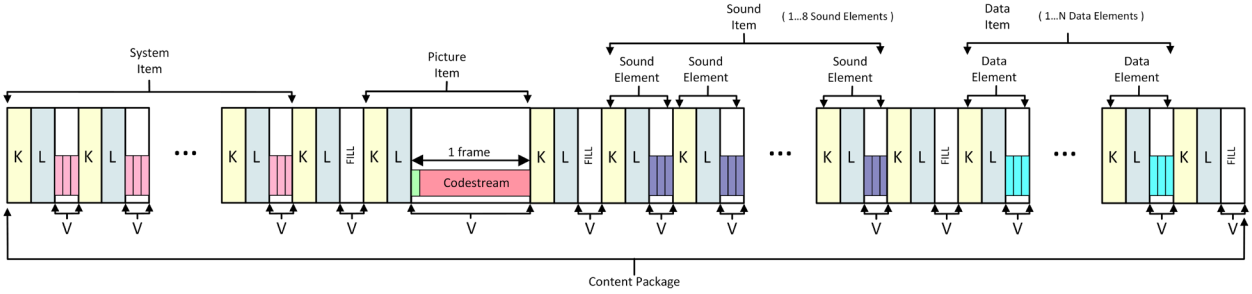

Figure 9 — ARRIRAW Content Package Layout

8.5.1 Picture Item

The ARRIRAW Picture Element Key shall be used to indicate the presence of ARRIRAW Picture Essence.

The Picture Item shall contain a single Picture Element.

The ImageStartOffset in the Generic Picture Essence Descriptor shall be a value such that the offset from the first byte of the Content Package to the first byte of ARRIRAW Picture Essence is an integral multiple of 64.

8.5.2 Sound Item

Sound essence, if present, shall be mapped into single channel SMPTE ST 382 Sound Essence Elements. The Sound Item may contain between 1 to 8 (inclusive) Sound Essence Elements.

8.5.3 Data Item

The Container shall contain a Supplemental Data Element that carries the time-varying metadata specified in SMPTE RDD 55.

There may be additional Data Elements in the Container.

8.5.4 KLV Alignment Grid

The KAG size for an ARRIRAW MXF File shall be 512.