INTERNATIONAL STANDARD

ISO/IEC 23008-2

Third edition
2017-10-15

AMENDMENT 3
2018-07

Information technology — High efficiency coding and media delivery in heterogeneous environments —

Part 2: High efficiency video coding

AMENDMENT 3: Additional supplemental enhancement information

Technologies de l'information — Codage à haute efficacité et livraison des medias dans des environnements hétérogènes —

Partie 2: Codage vidéo à haute efficacité

AMENDEMENT 3: Informations additionnelles supplémentaires pour amélioration

Reference number
ISO/IEC 23008-2:2017/Amd.3:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*, in collaboration with ITU-T. The identical text for ISO/IEC 23008-2 is published as ITU-T H.265.

A list of all parts in the ISO/IEC 23008 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Information technology — High efficiency coding and media delivery in heterogeneous environments —

Part 2:
High efficiency video coding

AMENDMENT 3: Additional supplemental enhancement information

General

Throughout the specification, replace all single-word instances of "nested" with "scalable-nested" (e.g., there is no single-word instance of "nested" in "non-nested"), and all instances of "non-nested" with "non-scalable-nested", except in 3.158 (which is kept unchanged) and Table F.4 in F.14.3.1 (for which a change is provided below).

Clause 3

Add the following term definitions (in alphabetical order within the current list) and correct all term numbering sequentially:

3.X
azimuth circle
circle on a sphere connecting all points with the same azimuth value

Note 1 to entry: An azimuth circle is always a *great circle* like a longitude line on the earth.

3.X
constituent picture
part of a spatially frame-packed stereoscopic video picture that corresponds to one view, or a picture itself when frame packing is not in use or the temporal interleaving frame packing arrangement is in use

3.X
elevation circle
circle on a sphere connecting all points with the same elevation value

Note 1 to entry: An elevation circle is similar to a lattitude line on the earth. Except when the elevation value is zero, an elevation circle is not a *great circle* like a longitude circle on the earth.

3.X
global coordinate axes
coordinate axes associated with *omnidirectional video* that are associated with an externally reference-able position and orientation

Note 1 to entry: The global coordinate axes may correspond to the position and orientation of a device or rig used for omnidirectional audio/video acquisition as well as the position of an observer's head in the three-dimensional space of the *omnidirectional video* rendering environment.

3.X
great circle
intersection of a sphere and a plane that passes through the centre point of the sphere

Note 1 to entry: A great circle is also known as an orthodrome or Riemannian circle.

3.X
local coordinate axes
coordinate axes having a specified rotation relationship relative to the *global coordinate axes*

3.X
omnidirectional video
video content in a format that enables rendering according to the user's viewing orientation, e.g., if viewed using a head-mounted device, or according to a user's desired *viewport*, reflecting a potentially rotated viewing position

3.X
packed region
region in a *region-wise packed picture* that is mapped to a *projected region* according to a *region-wise packing*

3.X
projected picture
picture that uses a *projection* format for *omnidirectional video*

3.X
projected region
region in a *projected picture* that is mapped to a *packed region* according to a *region-wise packing*

3.X
projection
specified correspondence between the colour samples of a *projected picture* and azimuth and elevation positions on a sphere

3.X
region-wise packed picture
decoded picture that contains one or more *packed regions*

Note 1 to entry: A packed picture may contain a *region-wise packing* of a *projected picture*.

3.X
region-wise packing
transformation, resizing, and relocation of *packed regions* of a *region-wise packed picture* to remap the *packed regions* to *projected regions* of a *projected picture*

3.X
sphere coordinates
azimuth and elevation angles identifying a location of a point on a sphere

3.X
sphere region
region on a sphere, specified either by four *great circles* or by two *azimuth circles* and two *elevation circles*, or such a region on a rotated sphere after applying yaw, pitch, and roll rotations

3.X
tilt angle
angle indicating the amount of tilt of a *sphere region*, measured as the amount of rotation of a *sphere region* along the axis originating from the sphere origin passing through the centre point of the *sphere region*, where the angle value increases clockwise when looking from the origin towards the positive end of the axis

3.X
viewport
region of *omnidirectional video* content suitable for display and viewing by the user

Clause 4

Add the following to the list of abbreviations (in alphabetical order):

MCTS motion-constrained tile set

5.8

Add the following function definitions:

Asin(x) the trigonometric inverse sine function, operating on an argument x that is in the range of −1.0 to 1.0, inclusive, with an output value in the range of −π ÷ 2 to π ÷ 2, inclusive, in units of radians (5-2)

Atan(x) the trigonometric inverse tangent function, operating on an argument x, with an output value in the range of −π ÷ 2 to π ÷ 2, inclusive, in units of radians (5-3)

$$\text{Atan2}(y,x)=\begin{cases}\text{Atan}\left(\frac{y}{x}\right) & ;\ \text{if } x > 0\\ \text{Atan}\left(\frac{y}{x}\right)+\pi & ;\ \text{if } x < 0 \ \&\ \&\ y >= 0\\ \text{Atan}\left(\frac{y}{x}\right)-\pi & ;\ \text{if } x < 0 \ \&\ \&\ y < 0\\ +\frac{\pi}{2} & ;\ \text{if } x == 0 \ \&\ \&\ y >= 0\\ -\frac{\pi}{2} & ;\ \text{otherwise}\end{cases} \quad (5\text{-}4)$$

Renumber the prior Formulae 5-2 through 5-15 as 5-5 to 5-18 to account for the added formulae.

Add the following function definition:

Sin(x) the trigonometric sine function operating on an argument x in units of radians (5-19)

Renumber the prior Formulae 5-19 through 5-20 as 5-20 to 5-21 to account for the added formulae.

Add the following function definition:

Tan(x) the trigonometric tangent function operating on an argument x in units of radians (5-22)

7.4.2.4.4 NOTE 2

Delete the sentence that says “Consequently, hypothetical reference decoder (HRD) parameters carried in non-nested buffering period, picture timing and decoding unit information SEI messages apply to access units based on such access unit boundary detection.”

7.4.4

Replace paragraph 6 (directly after NOTE 1) and NOTE 2 with the following:

general_non_packed_constraint_flag equal to 1 specifies that there are no frame packing arrangement SEI messages, segmented rectangular frame packing arrangement SEI messages, omnidirectional projection indication SEI messages, or cubemap projection SEI messages present in the CVS. general_non_packed_constraint_flag equal to 0 indicates that there may or may not be one or more frame packing arrangement SEI messages, segmented rectangular frame packing arrangement

SEI messages, omnidirectional projection indication SEI messages, or cubemap projection SEI messages present in the CVS.

NOTE 2 Decoders could ignore the value of general_non_packed_constraint_flag, as there are no decoding process requirements associated with the presence or interpretation of frame packing arrangement SEI messages, segmented rectangular frame packing arrangement SEI messages, equirectangular projection SEI messages, or cubemap projection SEI messages present in the CVS.

8.7.2.1

Replace paragraph 4 (directly after the NOTE) with the following:

The deblocking filter process is applied to all prediction block edges and transform block edges of a picture, except the following types of edges:

— Edges that are at the boundary of the picture;

— Edges that coincide with tile boundaries when loop_filter_across_tiles_enabled_flag is equal to 0;

— Edges that coincide with upper or left boundaries of slices with slice_loop_filter_across_slices_enabled_flag, equal to 0 or slice_deblocking_filter_disabled_flag equal to 1;

— Edges within slices with slice_deblocking_filter_disabled_flag equal to 1;

— Edges that do not correspond to 8 × 8 sample grid boundaries of the considered component;

— Edges within chroma components for which both sides of the edge use inter prediction;

— Edges of chroma transform blocks that are not edges of the associated transform unit.

C.1

Add the following NOTE 1 immediately before the sentence that says “Figure C.1 shows the types of bitstream conformance points checked by the HRD.”, and renumber the existing NOTEs in the clause accordingly:

NOTE 1 Decoders conforming to profiles specified in Annex A do not use NAL units with nuh_layer_id greater than 0 (e.g., access unit delimiter NAL units with nuh_layer_id greater than 0) for access unit boundary detection, except for identification of whether a NAL unit is a VCL or non-VCL NAL unit. Consequently, hypothetical reference decoder (HRD) parameters carried in non-scalable-nested buffering period, picture timing and decoding unit information SEI messages apply to access units that are identified based on such access unit boundary detection.

D.2.1

Replace this subclause with the following:

D.2.1 General SEI message syntax

sei_payload(payloadType, payloadSize) {	**Descriptor**
if(nal_unit_type = = PREFIX_SEI_NUT)	
if(payloadType = = 0)	
buffering_period(payloadSize)	
else if(payloadType = = 1)	
pic_timing(payloadSize)	
else if(payloadType = = 2)	
pan_scan_rect(payloadSize)	
else if(payloadType = = 3)	
filler_payload(payloadSize)	
else if(payloadType = = 4)	

user_data_registered_itu_t_t35(payloadSize)	
else if(payloadType = = 5)	
user_data_unregistered(payloadSize)	
else if(payloadType = = 6)	
recovery_point(payloadSize)	
else if(payloadType = = 9)	
scene_info(payloadSize)	
else if(payloadType = = 15)	
picture_snapshot(payloadSize)	
else if(payloadType = = 16)	
progressive_refinement_segment_start(payloadSize)	
else if(payloadType = = 17)	
progressive_refinement_segment_end(payloadSize)	
else if(payloadType = = 19)	
film_grain_characteristics(payloadSize)	
else if(payloadType = = 22)	
post_filter_hint(payloadSize)	
else if(payloadType = = 23)	
tone_mapping_info(payloadSize)	
else if(payloadType = = 45)	
frame_packing_arrangement(payloadSize)	
else if(payloadType = = 47)	
display_orientation(payloadSize)	
else if(payloadType = = 56)	
green_metadata(payloadsize) /* specified in ISO/IEC 23001-11 */	
else if(payloadType = = 128)	
structure_of_pictures_info(payloadSize)	
else if(payloadType = = 129)	
active_parameter_sets(payloadSize)	
else if(payloadType = = 130)	
decoding_unit_info(payloadSize)	
else if(payloadType = = 131)	
temporal_sub_layer_zero_index(payloadSize)	
else if(payloadType = = 133)	
scalable_nesting(payloadSize)	
else if(payloadType = = 134)	
region_refresh_info(payloadSize)	
else if(payloadType = = 135)	
no_display(payloadSize)	
else if(payloadType = = 136)	
time_code(payloadSize)	
else if(payloadType = = 137)	
mastering_display_colour_volume(payloadSize)	
else if(payloadType = = 138)	

segmented_rect_frame_packing_arrangement(payloadSize)	
else if(payloadType = = 139)	
temporal_motion_constrained_tile_sets(payloadSize)	
else if(payloadType = = 140)	
chroma_resampling_filter_hint(payloadSize)	
else if(payloadType = = 141)	
knee_function_info(payloadSize)	
else if(payloadType = = 142)	
colour_remapping_info(payloadSize)	
else if(payloadType = = 143)	
deinterlaced_field_identification(payloadSize)	
else if(payloadType = = 144)	
content_light_level_info(payloadSize)	
else if(payloadType = = 145)	
dependent_rap_indication(payloadSize)	
else if(payloadType = = 146)	
coded_region_completion(payloadSize)	
else if(payloadType = = 147)	
alternative_transfer_characteristics(payloadSize)	
else if(payloadType = = 148)	
ambient_viewing_environment(payloadSize)	
else if(payloadType = = 149)	
content_colour_volume(payloadSize)	
else if(payloadType = = 150)	
equirectangular_projection(payloadSize)	
else if(payloadType = = 151)	
cubemap_projection(payloadSize)	
else if(payloadType = = 154)	
sphere_rotation(payloadSize)	
else if(payloadType = = 155)	
regionwise_packing(payloadSize)	
else if(payloadType = = 156)	
omni_viewport(payloadSize)	
else if(payloadType = = 157)	
regional_nesting(payloadSize)	
else if(payloadType = = 158)	
mcts_extraction_info_sets(payloadSize)	
else if(payloadType = = 159)	
mcts_extraction_info_nesting(payloadSize)	
else if(payloadType = = 160)	
layers_not_present(payloadSize) /* specified in Annex F */	
else if(payloadType = = 161)	
inter_layer_constrained_tile_sets(payloadSize) /* specified in Annex F */	
else if(payloadType = = 162)	

bsp_nesting(payloadSize) /* specified in Annex F */	
else if(payloadType = = 163)	
bsp_initial_arrival_time(payloadSize) /* specified in Annex F */	
else if(payloadType = = 164)	
sub_bitstream_property(payloadSize) /* specified in Annex F */	
else if(payloadType = = 165)	
alpha_channel_info(payloadSize) /* specified in Annex F */	
else if(payloadType = = 166)	
overlay_info(payloadSize) /* specified in Annex F */	
else if(payloadType = = 167)	
temporal_mv_prediction_constraints(payloadSize) /* specified in Annex F */	
else if(payloadType = = 168)	
frame_field_info(payloadSize) /* specified in Annex F */	
else if(payloadType = = 176)	
three_dimensional_reference_displays_info(payloadSize) /* specified in Annex G */	
else if(payloadType = = 177)	
depth_representation_info(payloadSize) /* specified in Annex G */	
else if(payloadType = = 178)	
multiview_scene_info(payloadSize) /* specified in Annex G */	
else if(payloadType = = 179)	
multiview_acquisition_info(payloadSize) /* specified in Annex G */	
else if(payloadType = = 180)	
multiview_view_position(payloadSize) /* specified in Annex G */	
else if(payloadType = = 181)	
alternative_depth_info(payloadSize) /* specified in Annex I */	
else	
reserved_sei_message(payloadSize)	
else /* nal_unit_type = = SUFFIX_SEI_NUT */	
if(payloadType = = 3)	
filler_payload(payloadSize)	
else if(payloadType = = 4)	
user_data_registered_itu_t_t35(payloadSize)	
else if(payloadType = = 5)	
user_data_unregistered(payloadSize)	
else if(payloadType = = 17)	
progressive_refinement_segment_end(payloadSize)	
else if(payloadType = = 22)	
post_filter_hint(payloadSize)	
else if(payloadType = = 132)	
decoded_picture_hash(payloadSize)	
else if(payloadType = = 146)	
coded_region_completion(payloadSize)	
else	
reserved_sei_message(payloadSize)	

if(more_data_in_payload( )) {	
if(payload_extension_present( ))	
reserved_payload_extension_data	u(v)
payload_bit_equal_to_one /* equal to 1 */	f(1)
while(!byte_aligned( ))	
payload_bit_equal_to_zero /* equal to 0 */	f(1)
}	
}	

D.2.40

Renumber D.2.40 (Reserved SEI message syntax) as D.2.45.

Add new subclauses D.2.40 through D.2.44, as follows:

D.2.40 Content colour volume SEI message syntax

content_colour_volume(payloadSize) {	Descriptor
ccv_cancel_flag	u(1)
if(!ccv_cancel_flag) {	
ccv_persistence_flag	u(1)
ccv_primaries_present_flag	u(1)
ccv_min_luminance_value_present_flag	u(1)
ccv_max_luminance_value_present_flag	u(1)
ccv_avg_luminance_value_present_flag	u(1)
ccv_reserved_zero_2bits	u(2)
if(ccv_primaries_present_flag)	
for(c = 0; c < 3; c++) {	
ccv_primaries_x[c]	i(32)
ccv_primaries_y[c]	i(32)
}	
if(ccv_min_luminance_value_present_flag)	
ccv_min_luminance_value	u(32)
if(ccv_max_luminance_value_present_flag)	
ccv_max_luminance_value	u(32)
if(ccv_avg_luminance_value_present_flag)	
ccv_avg_luminance_value	u(32)
}	
}	

D.2.41 Syntax of omnidirectional video specific SEI messages

D.2.41.1 Equirectangular projection SEI message syntax

equirectangular_projection(payloadSize) {	Descriptor
erp_cancel_flag	u(1)
if(!erp_cancel_flag) {	
erp_persistence_flag	u(1)
erp_guard_band_flag	u(1)
erp_reserved_zero_2bits	u(2)
if(erp_guard_band_flag = = 1) {	
erp_guard_band_type	u(3)
erp_left_guard_band_width	u(8)
erp_right_guard_band_width	u(8)
}	
}	
}	

D.2.41.2 Cubemap projection SEI message syntax

cubemap_projection(payloadSize) {	Descriptor
cmp_cancel_flag	u(1)
if(!cmp_cancel_flag)	
cmp_persistence_flag	u(1)
}	

D.2.41.3 Sphere rotation SEI message syntax

sphere_rotation(payloadSize) {	Descriptor
sphere_rotation_cancel_flag	u(1)
if(!sphere_rotation_cancel_flag) {	
sphere_rotation_persistence_flag	u(1)
sphere_rotation_reserved_zero_6bits	u(6)
yaw_rotation	i(32)
pitch_rotation	i(32)
roll_rotation	i(32)
}	
}	

D.2.41.4 Region-wise packing SEI message syntax

regionwise_packing(payloadSize) {	Descriptor
rwp_cancel_flag	u(1)
if(!rwp_cancel_flag) {	
rwp_persistence_flag	u(1)
constituent_picture_matching_flag	u(1)
rwp_reserved_zero_5bits	u(5)
num_packed_regions	u(8)
proj_picture_width	u(32)
proj_picture_height	u(32)
packed_picture_width	u(16)
packed_picture_height	u(16)
for(i = 0; i < num_packed_regions; i++) {	
rwp_reserved_zero_4bits[i]	u(4)
rwp_transform_type[i]	u(3)
rwp_guard_band_flag[i]	u(1)
proj_region_width[i]	u(32)
proj_region_height[i]	u(32)
proj_region_top[i]	u(32)
proj_region_left[i]	u(32)
packed_region_width[i]	u(16)
packed_region_height[i]	u(16)
packed_region_top[i]	u(16)
packed_region_left[i]	u(16)
if(rwp_guard_band_flag[i]) {	

rwp_left_guard_band_width[i]	u(8)
rwp_right_guard_band_width[i]	u(8)
rwp_top_guard_band_height[i]	u(8)
rwp_bottom_guard_band_height[i]	u(8)
rwp_guard_band_not_used_for_pred_flag[i]	u(1)
for(j = 0; j < 4; j++)	
rwp_guard_band_type[i][j]	u(3)
rwp_guard_band_reserved_zero_3bits[i]	u(3)
}	
}	
}	
}	

D.2.41.5 Omnidirectional viewport SEI message syntax

omni_viewport(payloadSize) {	**Descriptor**
omni_viewport_id	u(10)
omni_viewport_cancel_flag	u(1)
if(!omni_viewport_cancel_flag) {	
omni_viewport_persistence_flag	u(1)
omni_viewport_cnt_minus1	u(4)
for(i = 0; i <= omni_viewport_cnt_minus1; i++) {	
omni_viewport_azimuth_centre[i]	i(32)
omni_viewport_elevation_centre[i]	i(32)
omni_viewport_tilt_centre[i]	i(32)
omni_viewport_hor_range[i]	u(32)
omni_viewport_ver_range[i]	u(32)
}	
}	
}	

D.2.42 Regional nesting SEI message syntax

regional_nesting(payloadSize) {	**Descriptor**
regional_nesting_id	u(16)
regional_nesting_num_rect_regions	u(8)
for(i = 0; i < regional_nesting_num_rect_regions; i++) {	
regional_nesting_rect_region_id[i]	u(8)
regional_nesting_rect_left_offset[i]	u(16)
regional_nesting_rect_right_offset[i]	u(16)
regional_nesting_rect_top_offset[i]	u(16)
regional_nesting_rect_bottom_offset[i]	u(16)
}	
num_sei_messages_in_regional_nesting_minus1	u(8)
for(i = 0; i <= num_sei_messages_in_regional_nesting_minus1; i++) {	
num_regions_for_sei_message[i]	u(8)

for(j = 0; j < num_regions_for_sei_message[i]; j++)	
regional_nesting_sei_region_idx[i][j]	u(8)
sei_message( )	
}	
}	

D.2.43 Motion-constrained tile sets extraction information sets SEI message syntax

mcts_extraction_info_sets( ) {	**Descriptor**
num_info_sets_minus1	ue(v)
for(i = 0; i <= num_info_sets_minus1; i++) {	
num_mcts_sets_minus1[i]	ue(v)
for(j = 0; j <= num_mcts_sets_minus1[i]; j++) {	
num_mcts_in_set_minus1[i][j]	ue(v)
for(k = 0; k <= num_mcts_in_set_minus1[i][j]; k++)	
idx_of_mcts_in_set[i][j][k]	ue(v)
}	
slice_reordering_enabled_flag[i]	u(1)
if(slice_reordering_enabled_flag[i]) {	
num_slice_segments_minus1[i]	ue(v)
for(j = 0; j <= num_slice_segments_minus1[i]; j++)	
output_slice_segment_address[i][j]	u(v)
}	
num_vps_in_info_set_minus1[i]	ue(v)
for(j = 0; j <= num_vps_in_info_set_minus1[i]; j++)	
vps_rbsp_data_length[i][j]	ue(v)
num_sps_in_info_set_minus1[i]	ue(v)
for(j = 0; j <= num_sps_in_info_set_minus1[i]; j++)	
sps_rbsp_data_length[i][j]	ue(v)
num_pps_in_info_set_minus1[i]	ue(v)
for(j = 0; j <= num_pps_in_info_set_minus1[i]; j++) {	
pps_nuh_temporal_id_plus1[i][j]	u(3)
pps_rbsp_data_length[i][j]	ue(v)
}	
while(!byte_aligned( ))	
mcts_alignment_bit_equal_to_zero	f(1)
for(j = 0; j <= num_vps_in_info_set_minus1[i]; j++)	
for(k = 0; k <= vps_rbsp_data_length[i][j]; k++)	
vps_rbsp_data_byte[i][j][k]	u(8)
for(j = 0; j <= num_sps_in_info_set_minus1[i]; j++)	
for(k = 0; k <= sps_rbsp_data_length[i][j]; k++)	
sps_rbsp_data_byte[i][j][k]	u(8)
for(j = 0; j <= num_pps_in_info_set_minus1[i]; j++)	
for(k = 0; k <= pps_rbsp_data_length[i][j]; k++)	

pps_rbsp_data_byte[i][j][k]	u(8)
}	
}	

D.2.44 Motion-constrained tile sets extraction information nesting SEI message syntax

mcts_extraction_info_nesting( ) {	**Descriptor**
all_mcts_flag	u(1)
if(!all_mcts_flag) {	
num_associated_mcts_minus1	ue(v)
for(i = 0; i <= num_associated_mcts_minus1; i++)	
idx_of_associated_mcts[i]	ue(v)
}	
num_sei_messages_in_mcts_extraction_nesting_minus1	ue(v)
while(!byte_aligned( ))	
mcts_nesting_zero_bit /* equal to 0 */	u(1)
for(i = 0; i <= num_sei_messages_in_mcts_extraction_nesting_minus1; i++)	
sei_message( )	
}	

D.3.1

Replace paragraphs 4, 5 and 6 (directly after NOTE 2) with the following:

The list SingleLayerSeiList is set to consist of the payloadType values 3, 6, 9, 15, 16, 17, 19, 22, 23, 45, 47, 56, 128, 129, 131, 132, 134 to 151, inclusive, and 154 to 159, inclusive.

The list VclAssociatedSeiList is set to consist of the payloadType values 2, 3, 6, 9, 15, 16, 17, 19, 22, 23, 45, 47, 56, 128, 131, 132, 134 to 151, inclusive, and 154 to 159.

The list PicUnitRepConSeiList is set to consist of the payloadType values 0, 1, 2, 6, 9, 15, 16, 17, 19, 22, 23, 45, 47, 56, 128, 129, 131, 132, 133, 135 to 151, inclusive, and 154 to 159, inclusive.

D.3.1, Table D.1

Replace the following rows in the table:

Scene information	The access unit containing the SEI message and up to but not including the next access unit, in decoding order, that contains a scene information SEI message
Green metadata	The CLVS containing the SEI message
Temporal motion-constrained tile sets	The CLVS containing the SEI message

with the following:

Scene information	The access unit containing the SEI message and up to but not including the next access unit, in decoding order, that contains a scene information SEI message or starts a new CLVS
Green metadata	Specified by the syntax of the SEI message
Temporal motion-constrained tile sets	The access unit containing the SEI message and up to but not including the next access unit, in decoding order, that contains an SEI message of the same type or starts a new CLVS

D.3.1, Table D.1

Add the following rows to the end of the table:

Content colour volume	Specified by the syntax of the SEI message
Equirectangular projection	Specified by the syntax of the SEI message
Cubemap projection	Specified by the syntax of the SEI message
Sphere rotation	Specified by the syntax of the SEI message
Region-wise packing	Specified by the syntax of the SEI message
Omnidirectional viewport	Specified by the syntax of the SEI message
Regional nesting	Depending on the region-nested SEI messages; each region-nested SEI message has the same persistence scope as if the SEI message was non-region-nested
Motion-constrained tile sets extraction information sets	The access unit containing the SEI message and up to but not including the next access unit, in decoding order, that contains an SEI message of the same type or starts a new CLVS
Motion-constrained tile sets extraction information nesting	The access unit containing the SEI message

D.3.1

Add the following paragraph immediately after Table D.1:

The values of some SEI message syntax elements, including pan_scan_rect_id, scene_id, second_scene_id, snapshot_id, progressive_refinement_id, tone_map_id, frame_packing_arrangement_id, mcts_id[i], knee_function_id, colour_remap_id, ilcts_id[i], and regional_nesting_id, are split into two sets of value ranges, where the first set is specified as "may be used as determined by the application", and the second set is specified as "reserved for future use by ITU-T | ISO/IEC". Applications should be cautious of potential "collisions" of the interpretation for values of these syntax elements belonging to the first set of value ranges. Since different applications might use these IDs having values in the first set of value ranges for different purposes, particular care should be exercised in the design of encoders that generate SEI messages with these IDs having values in the first set of value ranges, and in the design of decoders that interpret SEI messages with these IDs. This Specification does not define any management for these values. These IDs having values in the first set of value ranges might only be suitable for use in contexts in which "collisions" of usage (i.e., different definitions of the syntax and semantics of an SEI message with one of these IDs having the same value in the first set of value ranges) are unimportant, or not possible, or are managed – e.g., defined or managed in the controlling application or transport specification, or by controlling the environment in which bitstreams are distributed.

D.3.4

Replace paragraph 3 with the following:

Values of pan_scan_rect_id from 0 to 255, inclusive, and from 512 to $2^{31} - 1$, inclusive, may be used as determined by the application. Values of pan_scan_rect_id from 256 to 511, inclusive, and from 2^{31} to $2^{32} - 2$, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of pan_scan_rect_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, shall ignore it.

D.3.15

Replace paragraph 3 with the following:

Values of tone_map_id from 0 to 255, inclusive, and from 512 to $2^{31} - 1$, inclusive, may be used as determined by the application. Values of tone_map_id from 256 to 511, inclusive, and from 2^{31} to $2^{32} - 2$, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of tone_map_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, shall ignore it.

D.3.16

Replace the following sentence:

This SEI message informs the decoder that the output cropped decoded picture contains samples of multiple distinct spatially packed constituent frames that are packed into one frame using an indicated frame packing arrangement scheme.

with the following:

This SEI message informs the decoder that the output cropped decoded picture contains samples of multiple distinct spatially packed constituent frames that are packed into one frame, or that the output cropped decoded pictures in output order form a temporal interleaving of alternating first and second constituent frames, using an indicated frame packing arrangement scheme.

Replace paragraph 5 with the following:

Values of frame_packing_arrangement_id from 0 to 255, inclusive, and from 512 to $2^{31} - 1$, inclusive, may be used as determined by the application. Values of frame_packing_arrangement_id from 256 to 511, inclusive, and from 2^{31} to $2^{32} - 2$, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of frame_packing_arrangement_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, shall ignore it.

Replace Table D.8 with the following:

Value	Interpretation
3	Each colour component plane of the output cropped decoded picture contains a side-by-side packing arrangement of corresponding planes of two constituent frames as illustrated in Figure D.4, Figure D.5 and Figure D.8.
4	Each colour component plane of the output cropped decoded picture contains a top-bottom packing arrangement of corresponding planes of two constituent frames as illustrated in Figure D.6 and Figure D.7.
5	The colour component planes of the output cropped decoded pictures in output order form a temporal interleaving of alternating first and second constituent frames as illustrated in Figure D.9.

D.3.24

Replace the following sentence in paragraph 3:

It is a requirement of bitstream conformance that the following restrictions apply on nesting of SEI messages:

with the following:

It is a requirement of bitstream conformance that the following restrictions apply on the containing of SEI messages in a scalable nesting SEI message:

D.3.29

Replace the following:

Each component plane of the decoded frames contains a rectangular region frame packing arrangement of corresponding planes of two constituent frames as illustrated in Figure D.10.

with the following:

Each colour component plane of the output cropped decoded picture contains a rectangular region frame packing arrangement of corresponding planes of two constituent frames as illustrated in Figure D.10.

D.3.30

Replace paragraph 1 with the following:

The temporal motion-constrained tile sets SEI message indicates that the following constraints apply:

— No sample values outside each identified tile set or outside the picture are referenced for inter prediction.

— For PUs located directly left of the right tile boundary of each identified tile set except the last one at the bottom right, the following applies when CuPredMode[xPb][yPb] is equal to MODE_INTER, where (xPb, yPb) specifies the top-left sample of the corresponding luma prediction block relative to the top-left sample of the current picture:

  — With the number of spatial merging candidates numSpatialMergeCand derived as follows:

$$\text{numSpatialMergeCand} = \text{availableFlagA}_0 + \text{availableFlagA}_1 + \text{availableFlagB}_0 + \text{availableFlagB}_1 + \text{availableFlagB}_2 \quad \text{(D-42)}$$

  where availableFlagA_0, availableFlagA_1, availableFlagB_0, availableFlagB_1, and availableFlagB_2 are the output of the derivation process for spatial merging candidates specified in subclause 8.5.3.2.3, the following applies

    — If numSpatialMergeCand is equal to 0, merge_flag[xPb][yPb] is equal to 0.

    — Otherwise (numSpatialMergeCand is greater than 0), merge_idx[xPb][yPb] is in the range of 0 to numSpatialMergeCand − 1, inclusive.

  — With the number of spatial motion vector predictor candidates numSpatialMvpCand derived as follows:

```
if ( availableFlagLXA )
  numSpatialMvpCand = availableFlagLXA + ( ( mvLXA !=
  mvLXB ) ? availableFlagLXB : 0 )                    (D-43)
else
  numSpatialMvpCand = availableFlagLXB
```


where availableFlagLXA, availableFlagLXB, mvLXA, and mvLXB are the output of the derivation process for motion vector predictor candidates from neighbouring prediction unit partitions specified in subclause 8.5.3.2.7, the following applies:

— If numSpatialMvpCand is equal to 0, mvp_l0_flag[xPb][yPb] and mvp_l1_flag[xPb][yPb] is equal to 1.

— Otherwise (numSpatialMvpCand is greater than 0), mvp_l0_flag[xPb][yPb] and mvp_l1_flag[xPb][yPb] is in the range of 0 to numSpatialMvpCand − 1, inclusive.

NOTE 1 The first constraint restricts motion vectors to point to full-sample locations inside each identified tile set and to fractional-sample locations that require only full-sample locations inside each identified tile set for interpolation. The second constraint restricts the usage of motion vector candidates derived from blocks outside each identified tile set.

D.3.30

Renumber the subsequent NOTEs to account for the added NOTE.

D.3.30 (and subsequent subclauses of Annex D)

Renumber the subsequent formulae to account for the added formula.

D.3.30

Remove the original paragraph 8:

The number of temporal motion-constrained tile sets SEI messages applicable to the same nuh_layer_id value in each access unit shall not exceed 5.

D.3.30

Add the following paragraphs immediately before the semantics of mc_all_tiles_exact_sample_value_match_flag:

When a temporal motion-constrained tile sets SEI message is present, a slice segment that contains one or more tiles in any particular temporal motion-constrained tile set shall not be a dependent slice segment of an independent slice segment that contains one or more tiles that do not belong to that temporal motion-constrained tile set.

For purposes of referencing a particular temporal motion-constrained tile set that is identified in a temporal motion-constrained tile sets SEI message (e.g., for use with a motion-constrained tile sets extraction information sets SEI message or a motion-constrained tile sets extraction information nesting SEI message), an MCTS index is defined as follows:

— If the value of each_tile_one_tile_set_flag of the temporal motion-constrained tile sets SEI message is equal to 0, the MCTS index is the value of the variable i within the loop of the num_sets_in_message_minus1 + 1 sets of MCTS information specified by the temporal MCTS SEI message.

— Otherwise, the MCTS index of each MCTS is the tile position of the tile in tile raster scan order.

D.3.30

Replace the following sentence in the original paragraph 14:

Decoders shall ignore (remove from the bitstream and discard) those SEI messages containing a value of mcts_id[i] in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive.

with the following:

Decoders encountering a value of mcts_id[i] in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, shall ignore it.

D.3.30

Add the following sentence after the paragraph providing the semantics of top_left_tile_index[i][j] and bottom_right_tile_index[i][j]:

The value of top_left_tile_index[i][j] and bottom_right_tile_index[i][j] shall be in the range of 0 to (num_tile_columns_minus1 + 1) * (num_tile_rows_minus1 + 1) − 1, inclusive.

D.3.31

Add the following paragraph before the semantics of hor_chroma_filter_idc:

All chroma resampling filter hint SEI messages that apply to the same CLVS shall have the same content.

D.3.32

Replace the following sentence in paragraph 4:

Decoders shall ignore all knee function information SEI messages containing a value of knee_function_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, and bitstreams shall not contain such values.

with the following:

Decoders encountering a value of knee_function_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, shall ignore it.

D.3.33

Replace paragraph 4 with the following:

Values of colour_remap_id from 0 to 255, inclusive, and from 512 to $2^{31} - 1$, inclusive, may be used as determined by the application. Values of colour_remap_id from 256 to 511, inclusive, and from 2^{31} to $2^{32} - 2$, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of colour_remap_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, shall ignore it.

D.3.35

Add the following paragraph before the semantics of max_content_light_level:

All content light level information SEI messages that apply to the same CLVS shall have the same content.

D.3.40

Renumber subclause D.3.40 as D.3.45. Add new subclauses D.3.40 through D.3.44, as follows:

D.3.40 Content colour volume SEI message semantics

The content colour volume SEI message describes the colour volume characteristics of the associated pictures. These colour volume characteristics are expressed in terms of a nominal range, although deviations from this range may occur.

The variable transferCharacteristics is specified as follows:

— If an alternative transfer characteristics SEI message is present for the CLVS, transferCharacteristics is set equal to preferred_transfer_characteristics;

— Otherwise, (an alternative transfer characteristics SEI message is not present for the CLVS), transferCharacteristics is set equal to transfer_characteristics.

The content colour volume SEI message shall not be present, and decoders shall ignore it, when any of the following conditions is true:

— Any of the values of transferCharacteristics, colour_primaries, and matrix_coeffs has a value defined as unspecified.

— The value of transfer_characteristics is equal to 2, 4, or 5.

— The value of colour_primaries is equal to 2.

The following applies when converting the signal from a non-linear to a linear representation:

— If the value of transferCharacteristics is equal to 1, 6, 7, 14, or 15, the Rec. ITU-R BT.1886-0 reference electro-optical transfer function should be used to convert the signal to its linear representation, where the value of screen luminance for white is set equal to 100 cd/m^2, the value of screen luminance for black is set equal to 0 cd/m^2, and the value of the exponent of the power function is set equal to 2.4.

— Otherwise, if the value of transferCharacteristics is equal to 18, the hybrid log-gamma reference electro-optical transfer function specified in Rec. ITU-R BT.2100-1 should be used to convert the signal to its linear representation, where the value of nominal peak luminance of the display is set equal to 1 000 cd/m^2, the value of the display luminance for black is set equal to 0 cd/m^2, and the value of system gamma is set equal to 1.2.

— Otherwise (the value of transferCharacteristics is not equal to 1, 6, 7, 14, 15, or 18) when the content colour volume SEI message is present, the exact inverse of the transfer function specified in Table E.4 should be used to convert the non-linear signal to a linear representation.

ccv_cancel_flag equal to 1 indicates that the content colour volume SEI message cancels the persistence of any previous content colour volume SEI message in output order that applies to the current layer. ccv_cancel_flag equal to 0 indicates that content colour volume information follows.

ccv_persistence_flag specifies the persistence of the content colour volume SEI message for the current layer.

ccv_persistence_flag equal to 0 specifies that the content colour volume applies to the current decoded picture only.

Let picA be the current picture. ccv_persistence_flag equal to 1 specifies that the content colour volume SEI message persists for the current layer in output order until any of the following conditions are true:

— A new CLVS of the current layer begins.

— The bitstream ends.

— A picture picB in the current layer in an access unit containing a content colour volume SEI message that is applicable to the current layer is output for which PicOrderCnt(picB) is greater than PicOrderCnt(picA), where PicOrderCnt(picB) and PicOrderCnt(picA) are the PicOrderCntVal values of picB and picA, respectively, immediately after the invocation of the decoding process for the picture order count of picB.

ccv_primaries_present_flag equal to 1 specifies that the syntax elements ccv_primaries_x[c] and ccv_primaries_y[c] are present. ccv_primaries_present_flag equal to 0 specifies that the syntax elements ccv_primaries_x[c] and ccv_primaries_y[c] are not present.

ccv_min_luminance_value_present_flag equal to 1 specifies that the syntax element ccv_min_luminance_value is present. ccv_min_luminance_value_present_flag equal to 0 specifies that the syntax element ccv_min_luminance_value is not present.

ccv_max_luminance_value_present_flag equal to 1 specifies that the syntax element ccv_max_luminance_value is present. ccv_max_luminance_value_present_flag equal to 0 specifies that the syntax element ccv_max_luminance_value is not present.

ccv_avg_luminance_value_present_flag equal to 1 specifies that the syntax element ccv_avg_luminance_value is present. ccv_avg_luminance_value_present_flag equal to 0 specifies that the syntax element ccv_avg_luminance_value is not present.

It is a requirement of bitstream conformance that the values of ccv_primaries_present_flag, ccv_min_luminance_value_present_flag, ccv_max_luminance_value_present_flag, and ccv_avg_luminance_value_present_flag shall not all be equal to 0.

ccv_reserved_zero_2bits[i] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for reserved_zero_2bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of reserved_zero_2bits[i].

ccv_primaries_x[c] and **ccv_primaries_y**[c] specify the normalized x and y chromaticity coordinates, respectively, of the colour primary component c of the nominal content colour volume in normalized increments of 0.00002, according to the CIE 1931 definition of x and y as specified in ISO 11664-1 (see also ISO 11664-3 and CIE 15), in normalized increments of 0.00002. For describing colour volumes that use red, green, and blue colour primaries, it is suggested that index value c equal to 0 should correspond to the green primary, c equal to 1 should correspond to the blue primary, and c equal to 2 should correspond to the red colour primary (see also Annex E and Table E.3).

The values of ccv_primaries_x[c] and ccv_primaries_y[c] shall be in the range of −5 000 000 to 5 000 000, inclusive.

When ccv_primaries_x[c] and ccv_primaries_y[c] are not present, they are inferred to be equal to the normalized x and y chromaticity coordinates, respectively, specified by colour_primaries.

ccv_min_luminance_value specifies the normalized minimum luminance value, according to CIE 1931, that is expected to be present in the content, where values are normalized to L_o or L_c as specified in Table E.4 according to the indicated transfer characteristics of the signal. The values of ccv_min_luminance_value are in normalized increments of 0.0000001.

ccv_max_luminance_value specifies the maximum luminance value, according to CIE 1931, that is expected to be present in the content, where values are normalized to L_o or L_c as specified in Table E.4 according to the transfer characteristics of the signal. The values of ccv_max_luminance_value are in normalized increments of 0.0000001.

ccv_avg_luminance_value specifies the average luminance value, according to CIE 1931, that is expected to be present in the content, where values are normalized to L_o or L_c as specified in Table E.4 according to the transfer characteristics of the signal. The values of ccv_avg_luminance_value are in normalized increments of 0.0000001.

NOTE The resulting domain from this conversion process may or may not represent light in a source or display domain – it is merely a gamut representation domain rather than necessarily being a representation of actual light in either the scene or display domain. Therefore, the values corresponding to ccv_min_luminance_value, ccv_max_luminance_value, and ccv_avg_luminance_value might not necessarily correspond to a true luminance value.

The value of ccv_min_luminance_value, when present, shall be less than or equal to ccv_avg_luminance_value, when present. The value of ccv_avg_luminance_value, when present, shall be less than or equal to ccv_max_luminance_value, when present. The value of ccv_min_luminance_value, when present, shall be less than or equal to ccv_max_luminance_value, when present.

When the visually relevant region does not correspond to the entire cropped decoded picture, such as for "letterbox" encoding of video content with a wide picture aspect ratio within a taller cropped decoded picture, the indicated ccv_min_luminance_value, ccv_max_luminance_value, and ccv_avg_luminance_value should correspond only to values within the visually relevant region.

D.3.41 Semantics of omnidirectional video specific SEI messages

D.3.41.1 Equirectangular projection SEI message semantics

The equirectangular projection SEI message provides information to enable remapping (through an equirectangular projection) of the colour samples of the projected pictures onto a sphere coordinate space in sphere coordinates (ϕ, θ) for use in omnidirectional video applications for which the viewing perspective is from the origin looking outward toward the inside of the sphere. The sphere coordinates are defined so that ϕ is the azimuth (longitude, increasing eastward) and θ is the elevation (latitude, increasing northward).

When an equirectangular projection SEI message is present for any picture of a CLVS of a particular layer, an equirectangular projection SEI message shall be present for the first picture of the CLVS and no SEI message indicating a different type of projection shall be present for any picture of the CLVS.

When general_non_packed_constraint_flag is equal to 1 in the active SPS for the current layer, there shall be no equirectangular projection SEI messages applicable for any picture of the CLVS of the current layer.

When aspect_ratio_idc is present and greater than 1 in the active SPS for the current layer, there should be no equirectangular projection SEI messages applicable for any picture of the CLVS of the current layer.

A frame packing arrangement SEI message for which all the following conditions are true is referred to as an effectively applicable frame packing arrangement SEI message:

— The value of frame_packing_arrangement_cancel_flag is equal to 0.

— The value of frame_packing_arrangement_type is equal to 3, 4, or 5.

— The value of quincunx_sampling_flag is equal to 0.

— The value of spatial_flipping_flag is equal to 0.

— The value of field_views_flag is equal to 0.

— The value of frame0_grid_position_x is equal to 0.

— The value of frame0_grid_position_y is equal to 0.

— The value of frame1_grid_position_x is equal to 0.

— The value of frame1_grid_position_y is equal to 0.

When a frame packing arrangement SEI message with frame_packing_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message, an equirectangular projection SEI message with erp_cancel_flag equal to 0 that applies to the picture shall not be present. Decoders shall ignore equirectangular projection SEI messages when a frame packing arrangement SEI message with frame_packing_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message.

When a segmented rectangular frame packing arrangement SEI message with segmented_rect_frame_packing_arrangement_cancel_flag equal to 0 is present that applies to the picture, an equirectangular projection SEI message with erp_cancel_flag equal to 0 shall not be present that applies to the picture. Decoders shall ignore equirectangular projection SEI messages when a segmented rectangular frame packing arrangement SEI message with segmented_rect_frame_packing_arrangement_cancel_flag equal to 0 is present that applies to the picture.

erp_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous equirectangular projection SEI message in output order. erp_cancel_flag equal to 0 indicates that equirectangular projection information follows.

erp_persistence_flag specifies the persistence of the equirectangular projection SEI message for the current layer.

erp_persistence_flag equal to 0 specifies that the equirectangular projection SEI message applies to the current decoded picture only.

Let picA be the current picture. erp_persistence_flag equal to 1 specifies that the equirectangular projection SEI message persists for the current layer in output order until one or more of the following conditions are true:

— A new CLVS of the current layer begins.

— The bitstream ends.

— A picture picB in the current layer in an access unit containing an equirectangular projection SEI message that is applicable to the current layer is output for which PicOrderCnt(picB) is greater than PicOrderCnt(picA), where PicOrderCnt(picB) and PicOrderCnt(picA) are the PicOrderCntVal values of picB and picA, respectively, immediately after the invocation of the decoding process for picture order count for picB.

erp_guard_band_flag equal to 1 indicates that the constituent picture contains guard band areas for which the sizes are specified by the syntax elements erp_left_guard_band_width and erp_right_guard_band_width. erp_guard_band_flag equal to 0 indicates that the constituent picture does not contains guard band areas for which the sizes are specified by the syntax elements erp_left_guard_band_width and erp_right_guard_band_width.

erp_reserved_zero_2bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for erp_reserved_zero_2bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of erp_reserved_zero_2bits.

erp_guard_band_type indicates the type of the guard bands as follows:

— erp_guard_band_type equal to 0 indicates that the content of the guard band in relation to the content of the constituent picture is unspecified.

— erp_guard_band_type equal to 1 indicates that the content of the guard band suffices for interpolation of sample values at sub-pel sample fractional locations within the constituent picture.

NOTE erp_guard_band_type equal to 1 could be used when the boundary samples of a constituent picture have been copied horizontally to the guard band.

— erp_guard_band_type equal to 2 indicates that the content of the guard band represents actual picture content at a quality that gradually changes from the picture quality of the constituent picture to that of the spherically adjacent region.

— erp_guard_band_type equal to 3 indicates that the content of the guard bands represents actual picture content at a similar level of quality as the constituent picture.

— erp_guard_band_type values greater than 3 are reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value of erp_guard_band_type when the value is greater than 3 as equivalent to the value 0.

erp_left_guard_band_width indicates the width of the guard band on the left side of the constituent picture in units of luma samples. When erp_guard_band_flag is equal to 0, the value of erp_left_guard_band_width is inferred to be equal to 0. When chroma_format_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), erp_left_guard_band_width shall be an even number.

erp_right_guard_band_width indicates the width of the guard band on the right side of the constituent picture in units of luma samples. When erp_guard_band_flag is equal to 0, the value of erp_right_guard_band_width is inferred to be equal to 0. When chroma_format_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), erp_right_guard_band_width shall be an even number.

D.3.41.2 Cubemap projection SEI message semantics

The cubemap projection SEI message provides information to enable remapping (through a cubemap projection) of the colour samples of the projected pictures onto a sphere coordinate space in sphere coordinates (ϕ, θ) for use in omnidirectional video applications for which the viewing perspective is from the origin looking outward toward the inside of the sphere. The sphere coordinates are defined so that ϕ is the azimuth (longitude, increasing eastward) and θ is the elevation (latitude, increasing northward).

When a cubemap projection SEI message is present for any picture of a CLVS of a particular layer, a cubemap projection SEI message shall be present for the first picture of the CLVS and no SEI message indicating a different type of projection shall be present for any picture of the CLVS.

When general_non_packed_constraint_flag is equal to 1 in the active SPS for the current layer, there shall be no cubemap projection SEI messages applicable for any picture of the CLVS of the current layer.

When aspect_ratio_idc is present and greater than 1 in the active SPS for the current layer, there should be no cubemap projection SEI messages applicable for any picture of the CLVS of the current layer.

A frame packing arrangement SEI message for which all the following conditions are true is referred to as an effectively applicable frame packing arrangement SEI message:

— The value of frame_packing_arrangement_cancel_flag is equal to 0.

— The value of frame_packing_arrangement_type is equal to 3, 4, or 5.

— The value of quincunx_sampling_flag is equal to 0.

— The value of spatial_flipping_flag is equal to 0.

— The value of field_views_flag is equal to 0.

— The value of frame0_grid_position_x is equal to 0.

— The value of frame0_grid_position_y is equal to 0.

— The value of frame1_grid_position_x is equal to 0.

— The value of frame1_grid_position_y is equal to 0.

When a frame packing arrangement SEI message with frame_packing_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message, a cubemap projection SEI message with cmp_cancel_flag equal to 0 that applies to the picture shall not be present. Decoders shall ignore cubemap projection SEI messages when a frame packing arrangement SEI message with frame_packing_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message.

When a segmented rectangular frame packing arrangement SEI message with segmented_rect_frame_packing_arrangement_cancel_flag equal to 0 is present that applies to the picture, a cubemap projection SEI message with cmp_cancel_flag equal to 0 shall not be present that applies to the picture. Decoders shall ignore cubemap projection SEI messages when a segmented rectangular frame packing arrangement SEI message with segmented_rect_frame_packing_arrangement_cancel_flag equal to 0 is present that applies to the picture.

cmp_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous cubemap projection SEI message in output order. cmp_cancel_flag equal to 0 indicates that cubemap projection information follows.

cmp_persistence_flag specifies the persistence of the cubemap projection SEI message for the current layer.

cmp_persistence_flag equal to 0 specifies that the cubemap projection SEI message applies to the current decoded picture only.

Let picA be the current picture. cmp_persistence_flag equal to 1 specifies that the cubemap projection SEI message persists for the current layer in output order until one or more of the following conditions are true:

— A new CLVS of the current layer begins.

— The bitstream ends.

— A picture picB in the current layer in an access unit containing a cubemap projection SEI message that is applicable to the current layer is output for which PicOrderCnt(picB) is greater than PicOrderCnt(picA), where PicOrderCnt(picB) and PicOrderCnt(picA) are the PicOrderCntVal values of picB and picA, respectively, immediately after the invocation of the decoding process for picture order count for picB.

D.3.41.3 Sphere rotation SEI message semantics

The sphere rotation SEI message provides information on rotation angles yaw (α), pitch (β), and roll (γ) that are used for conversion between the global coordinate axes and the local coordinate axes.

Relative to an (x, y, z) Cartesian coordinate system, yaw expresses a rotation around the z (vertical, up) axis, pitch rotates around the y (lateral, side-to-side) axis, and roll rotates around the x (back-to-front) axis. Rotations are extrinsic, i.e., around x, y, and z fixed reference axes. The angles increase clockwise when looking from the origin towards the positive end of an axis.

sphere_rotation_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous sphere rotation SEI message in output order. sphere_rotation_cancel_flag equal to 0 indicates that sphere rotation information follows.

sphere_rotation_persistence_flag specifies the persistence of the sphere rotation SEI message for the current layer.

sphere_rotation_persistence_flag equal to 0 specifies that the sphere rotation SEI message applies to the current decoded picture only.

Let picA be the current picture. sphere_rotation_persistence_flag equal to 1 specifies that the sphere rotation SEI message persists for the current layer in output order until one or more of the following conditions are true:

— A new CLVS of the current layer begins.

— The bitstream ends.

— A picture picB in the current layer in an access unit containing a sphere rotation SEI message that is applicable to the current layer is output for which PicOrderCnt(picB) is greater than PicOrderCnt(picA), where PicOrderCnt(picB) and PicOrderCnt(picA) are the PicOrderCntVal values of picB and picA, respectively, immediately after the invocation of the decoding process for picture order count for picB.

When an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a cubemap projection SEI message with cmp_cancel_flag equal to 0 is not present in the CLVS that applies to the current picture and precedes the sphere rotation SEI message in decoding order, a sphere rotation SEI message with sphere_rotation_cancel_flag equal to 0 shall not be present in the CLVS that applies to the current picture. Decoders shall ignore sphere rotation SEI messages with sphere_rotation_cancel_flag equal to 0 that do not follow, in decoding order, an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a cubemap projection SEI message with cmp_cancel_flag equal to 0 in the CLVS that applies to the current picture.

sphere_rotation_reserved_zero_6bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for sphere_rotation_reserved_zero_6bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of sphere_rotation_reserved_zero_6bits.

yaw_rotation specifies the value of the yaw rotation angle, in units of 2^{-16} degrees. The value of yaw_rotation shall be in the range of $-180 * 2^{16}$ (i.e., –11 796 480) to $180 * 2^{16} - 1$ (i.e., 11 796 479), inclusive. When not present, the value of yaw_rotation is inferred to be equal to 0.

pitch_rotation specifies the value of the pitch rotation angle, in units of 2^{-16} degrees. The value of pitch_rotation shall be in the range of $-90 * 2^{16}$ (i.e., –5 898 240) to $90 * 2^{16}$ (i.e., 5 898 240), inclusive. When not present, the value of pitch_rotation is inferred to be equal to 0.

roll_rotation specifies the value of the roll rotation angle, in units of 2^{-16} degrees. The value of roll_rotation shall be in the range of $-180 * 2^{16}$ (i.e., –11 796 480) to $180 * 2^{16} - 1$ (i.e., 11 796 479), inclusive. When not present, the value of roll_rotation is inferred to be equal to 0.

D.3.41.4 Region-wise packing SEI message semantics

The region-wise packing SEI message provides information to enable remapping of the colour samples of the cropped decoded pictures onto projected pictures as well as information on the location and size of the guard bands, if any.

rwp_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous region-wise packing SEI message in output order. rwp_cancel_flag equal to 0 indicates that region-wise packing information follows.

rwp_persistence_flag specifies the persistence of the region-wise packing SEI message for the current layer.

rwp_persistence_flag equal to 0 specifies that the region-wise packing SEI message applies to the current decoded picture only.

Let picA be the current picture. rwp_persistence_flag equal to 1 specifies that the region-wise packing SEI message persists for the current layer in output order until one or more of the following conditions are true:

— A new CLVS of the current layer begins.

— The bitstream ends.

— A picture picB in the current layer in an access unit containing a region-wise packing SEI message that is applicable to the current layer is output for which PicOrderCnt(picB) is greater than PicOrderCnt(picA), where PicOrderCnt(picB) and PicOrderCnt(picA) are the PicOrderCntVal values of picB and picA, respectively, immediately after the invocation of the decoding process for picture order count for picB.

When an equirectangular projection SEI message with erp_cancel_flag equal to 0 and erp_guard_band_flag equal to 0 or a cubemap projection SEI message with cmp_cancel_flag equal to 0 is not present in the CLVS that applies to the current picture and precedes the region-wise packing SEI message in decoding order, a region-wise packing SEI message with rwp_cancel_flag equal to 0 shall not be present in the CLVS that applies to the current picture. Decoders shall ignore region-wise packing SEI messages with rwp_cancel_flag equal to 0 that do not follow, in decoding order, an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a cubemap projection SEI message with cmp_cancel_flag equal to 0 in the CLVS that applies to the current picture.

For the frame packing arrangment scheme indicated by a frame packing arrangement SEI message that applies to the current picture, if a region-wise packing SEI message with rwp_cancel_flag equal to 0 is present that applies to the current picture, the frame packing arrangement scheme applies to the projected picture, otherwise, the frame packing arrangement scheme applies to the cropped decoded picture.

If a frame packing arrangement SEI message with frame_packing_arrangement_cancel_flag equal to 0, frame_packing_arrangement_type equal to 3, 4, or 5, and quincunx_sampling_flag equal to 0 is not present that applies to the current picture, the variables StereoFlag, TopBottomFlag, SideBySideFlag,

and TempInterleavingFlag are all set equal to 0, the variables HorDiv1 and VerDiv1 are both set equal to 1. Otherwise the following applies:

— StereoFlag is equal to 1.

— When the frame_packing_arrangement_type is equal to 3, SideBySideFlag is set equal to 1, TopBottomFlag and TempInterleavingFlag are both set equal to 0, HorDiv1 is set equal to 2 and VerDiv1 is set equal to 1.

— When the frame_packing_arrangement_type is equal to 4, TopBottomFlag is set equal to 1, SideBySideFlag and TempInterleavingFlag are both set equal to 0, HorDiv1 is set equal to 1 and VerDiv1 is set equal to 2.

— When the frame_packing_arrangement_type is equal to 5, TempInterleavingFlag is set equal to 1, TopBottomFlag and SideBySideFlag are both set equal to 0, HorDiv1 and VerDiv1 are both set equal to 1.

constituent_picture_matching_flag equal to 1 specifies that the projected region information, packed region information, and guard band region information in this SEI message apply individually to each constituent picture and that the packed picture and the projected picture have the same stereoscopic frame packing format indicated by the frame packing arrangement SEI message. constituent_picture_matching_flag equal to 0 specifies that the projected region information, packed region information, and guard band region information in this SEI message apply to the projected picture.

When StereoFlag is equal to 0, or StereoFlag is equal to 1 and frame_packing_arrangement_type is equal to 5, the value of constituent_picture_matching_flag shall be equal to 0.

rwp_reserved_zero_5bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp_reserved_zero_56bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp_reserved_zero_5bits[i].

num_packed_regions specifies the number of packed regions when constituent_picture_matching_flag is equal to 0. The value of num_packed_regions shall be greater than 0. When constituent_picture_matching_flag is equal to 1, the total number of packed regions is equal to num_packed_regions * 2, and the information in each entry of the loop of num_packed_regions entries applies to each constituent picture of the projected picture and the packed picture.

proj_picture_width and **proj_picture_height** specify the width and height, respectively, of the projected picture, in relative projected picture sample units.

The values of proj_picture_width and proj_picture_height shall both be greater than 0.

packed_picture_width and **packed_picture_height** specify the width and height, respectively, of the packed picture, in relative packed picture sample units.

The values of packed_picture_width and packed_picture_height shall both be greater than 0.

It is a requirement of bitstream conformance that packed_picture_width and packed_picture_height shall have such values that packed_picture_width is an integer multiple of cropPicWidth and packed_picture_height is an integer multiple of cropPicHeight, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped decoded picture.

rwp_reserved_zero_4bits[i] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp_reserved_zero_4bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp_reserved_zero_4bits[i].

rwp_transform_type[i] specifies the rotation and mirroring to be applied to the i-th packed region to remap to the i-th projected region. When rwp_transform_type[i] specifies both rotation and mirroring, rotation applies before mirroring. The values of rwp_transform_type[i] are specified in Table D.22:

Table D.22 — rwp_transform_type[i] values

Value	Description
0	no transform
1	mirroring horizontally
2	rotation by 180 degrees (anticlockwise)
3	rotation by 180 degrees (anticlockwise) after mirroring horizontally
4	rotation by 90 degrees (anticlockwise) before mirroring horizontally
5	rotation by 90 degrees (anticlockwise)
6	rotation by 270 degrees (anticlockwise) before mirroring horizontally
7	rotation by 270 degrees (anticlockwise)

rwp_guard_band_flag[i] equal to 0 specifies that the i-th packed region does not have a guard band. rwp_guard_band_flag[i] equal to 1 specifies that the i-th packed region has a guard band.

proj_region_width[i], **proj_region_height**[i], **proj_region_top**[i], and **proj_region_left**[i] specify the width, height, top sample row, and the left-most sample column, respectively, of the i-th projected region, either within the projected picture (when constituent_picture_matching_flag is equal to 0) or within the constituent picture of the projected picture (when constituent_picture_matching_flag is equal to 1).

proj_region_width[i], proj_region_height[i], proj_region_top[i], and proj_region_left[i] are indicated in relative projected picture sample units.

NOTE 1 Two projected regions can partially or entirely overlap with each other.

packed_region_width[i], **packed_region_height**[i], **packed_region_top**[i], and **packed_region_left**[i] specify the width, height, the top luma sample row, and the left-most luma sample column, respectively, of the packed region, either within the region-wise packed picture (when constituent_picture_matching_flag is equal to 0) or within each constituent picture of the region-wise packed picture (when constituent_picture_matching_flag is equal to 1).

packed_region_width[i], packed_region_height[i], packed_region_top[i], and packed_region_left[i] are indicated in relative region-wise packed picture sample units. packed_region_width[i], packed_region_height[i], packed_region_top[i], and packed_region_left[i] shall represent integer horizontal and vertical coordinates of luma sample units within the cropped decoded pictures.

NOTE 2 Two packed regions can partially or entirely overlap with each other.

rwp_left_guard_band_width[i] specifies the width of the guard band on the left side of the i-th packed region in relative region-wise packed picture sample units. When chroma_format_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), rwp_left_guard_band_width[i] shall correspond to an even number of luma samples within the cropped decoded picture.

rwp_right_guard_band_width[i] specifies the width of the guard band on the right side of the i-th packed region in relative region-wise packed picture sample units. When chroma_format_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), rwp_right_guard_band_width[i] shall correspond to an even number of luma samples within the cropped decoded picture.

rwp_top_guard_band_height[i] specifies the height of the guard band above the i-th packed region in relative region-wise packed picture sample units. When chroma_format_idc is equal to 1 (4:2:0 chroma format), rwp_top_guard_band_height[i] shall correspond to an even number of luma samples within the cropped decoded picture.

rwp_bottom_guard_band_height[i] specifies the height of the guard band below the i-th packed region in relative region-wise packed picture sample units. When chroma_format_idc is equal to 1

(4:2:0 chroma format), rwp_bottom_guard_band_height[i] shall correspond to an even number of luma samples within the cropped decoded picture.

When rwp_guard_band_flag[i] is equal to 1, rwp_left_guard_band_width[i], rwp_right_guard_band_width[i], rwp_top_guard_band_height[i], or rwp_bottom_guard_band_height[i] shall be greater than 0.

The i-th packed region as specified by this SEI message shall not overlap with any other packed region specified by the same SEI message or any guard band specified by the same SEI message.

The guard bands associated with the i-th packed region, if any, as specified by this SEI message shall not overlap with any packed region specified by the same SEI message or any other guard bands specified by the same SEI message.

rwp_guard_band_not_used_for_pred_flag[i] equal to 0 specifies that the guard bands may or may not be used in the inter prediction process. rwp_guard_band_not_used_for_pred_flag[i] equal to 1 specifies that the sample values of the guard bands are not used in the inter prediction process.

NOTE 3 When rwp_guard_band_not_used_for_pred_flag[i] is equal to 1, the sample values within guard bands in cropped decoded pictures can be rewritten even if the cropped decoded pictures were used as references for inter prediction of subsequent pictures to be decoded. For example, the content of a packed region can be seamlessly expanded to its guard band with decoded and re-projected samples of another packed region.

rwp_guard_band_type[i][j] indicates the type of the guard bands for the i-th packed region as follows, with j equal to 0, 1, 2, or 3 indicating that the semantics below apply to the left, right, top, or bottom edge, respectively, of the packed region:

— rwp_guard_band_type[i][j] equal to 0 indicates that the content of the guard bands in relation to the content of the packed regions is unspecified. When rwp_guard_band_not_used_for_pred_flag[i] is equal to 0, rwp_guard_band_type[i][j] shall not be equal to 0.

— rwp_guard_band_type[i][j] equal to 1 indicates that the content of the guard bands suffices for interpolation of sample values at sub-pel sample fractional locations within the packed region and less than one sample outside of the boundary of the packed region.

NOTE 4 rwp_guard_band_type[i][j] equal to 1 can be used when the boundary samples of a packed region have been copied horizontally or vertically to the guard band.

— rwp_guard_band_type[i][j] equal to 2 indicates that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the packed region and is on the surface of the packed region at a quality that gradually changes from the picture quality of the packed region to that of the spherically adjacent packed region.

— rwp_guard_band_type[i][j] equal to 3 indicates that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the packed region and is on the surface of the packed region at a similar picture quality as within the packed region.

— rwp_guard_band_type[i][j] values greater than 3 are reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value of rwp_guard_band_type[i][j] when the value is greater than 3 as equivalent to the value 0.

rwp_guard_band_reserved_zero_3bits[i] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp_guard_band_reserved_zero_3bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp_guard_band_reserved_zero_3bits[i].

The variables NumPackedRegions, PackedRegionLeft[n], PackedRegionTop[n], PackedRegionWidth[n], PackedRegionHeight[n], ProjRegionLeft[n], ProjRegionTop[n], ProjRegionWidth[n], ProjRegionHeight[n], and TransformType[n] are derived as follows:

— For n in the range of 0 to num_packed_regions − 1, inclusive, the following applies:

  — PackedRegionLeft[n] is set equal to packed_region_left[n].

- PackedRegionTop[n] is set equal to packed_region_top[n].
- PackedRegionWidth[n] is set equal to packed_region_width[n].
- PackedRegionHeight[n] is set equal to packed_region_height[n].
- ProjRegionLeft[n] is set equal to proj_region_left[n].
- ProjRegionTop[n] is set equal to proj_region_top[n].
- ProjRegionWidth[n] is set equal to proj_region_width[n].
- ProjRegionHeight[n] is set equal to proj_region_height[n].
- TransformType[n] is set equal to rwp_transform_type[n].

— If constituent_picture_matching_flag is equal to 0, the following applies:
  - NumPackedRegions is set equal to num_packed_regions.

— Otherwise (constituent_picture_matching_flag is equal to 1), the following applies:
  - NumPackedRegions is set equal to 2 * num_packed_regions.
  - When TopBottomFlag is equal to 1, the following applies:
    - projLeftOffset and packedLeftOffset are both set equal to 0.
    - projTopOffset is set equal to proj_picture_height / 2 and packedTopOffset is set equal to packed_picture_height / 2.
  - When SideBySideFlag is equal to 1, the following applies:
    - projLeftOffset is set equal to proj_picture_width / 2 and packedLeftOffset is set equal to packed_picture_width / 2.
    - projTopOffset and packedTopOffset are both set equal to 0.
  - For n in the range of NumPackedRegions / 2 to NumPackedRegions – 1, inclusive, the following applies:
    - nIdx is set equal to n – NumPackedRegions / 2.
    - PackedRegionLeft[n] is set equal to packed_region_left[nIdx] + packedLeftOffset.
    - PackedRegionTop[n] is set equal to packed_region_top[nIdx] + packedTopOffset.
    - PackedRegionWidth[n] is set equal to packed_region_width[nIdx].
    - PackedRegionHeight[n] is set equal to packed_region_height[nIdx].
    - ProjRegionLeft[n] is set equal to proj_region_left[nIdx] + projLeftOffset.
    - ProjRegionTop[n] is set equal to proj_region_top[nIdx] + projTopOffset.
    - ProjRegionWidth[n] is set equal to proj_region_width[nIdx].
    - ProjRegionHeight[n] is set equal to proj_region_height[nIdx].
    - TransformType[n] is set equal to rwp_transform_type[nIdx].

For each value of n in the range of 0 to NumPackedRegions − 1, inclusive, the values of ProjRegionWidth[n], ProjRegionHeight[n], ProjRegionTop[n], and ProjRegionLeft[n] are constrained as follows:

— ProjRegionWidth[n] shall be in the range of 1 to proj_picture_width, inclusive.

— ProjRegionHeight[n] shall be in the range of 1 to proj_picture_height, inclusive.

— ProjRegionLeft[n] shall be in the range of 0 to proj_picture_width − 1, inclusive.

— ProjRegionTop[n] shall be in the range of 0 to proj_picture_height − 1, inclusive.

— If ProjRegionTop[n] is less than proj_picture_height / VerDiv1, the sum of ProjRegionTop[n] and ProjRegionHeight[n] shall be less than or equal to proj_picture_height / VerDiv1. Otherwise, the sum of ProjRegionTop[n] and ProjRegionHeight[n] shall be less than or equal to proj_picture_height / VerDiv1 * 2.

For each value of n in the range of 0 to NumPackedRegions − 1, inclusive, the values of PackedRegionWidth[n], PackedRegionHeight[n], PackedRegionTop[n], and PackedRegionLeft[n] are constrained as follows:

— PackedRegionWidth[n] shall be in the range of 1 to packed_picture_width, inclusive.

— ProjRegionHeight[n] shall be in the range of 1 to packed_picture_height, inclusive.

— PackedRegionLeft[n] shall be in the range of 0 to packed_picture_width − 1, inclusive.

— PackedRegionTop[n] shall be in the range of 0 to packed_picture_height − 1, inclusive.

— If PackedRegionLeft[n] is less than packed_picture_width / HorDiv1, the sum of PackedRegionLeft[n] and PackedRegionWidth[n] shall be less than or equal to packed_picture_width / HorDiv1. Otherwise, the sum of PackedRegionLeft[n] and PackedRegionWidth[n] shall be less than or equal to packed_picture_width / HorDiv1 * 2.

— If PackedRegionTop[n] is less than packed_picture_height / VerDiv1, the sum of PackedRegionTop[n] and PackedRegionHeight[n] shall be less than or equal to packed_picture_height / VerDiv1. Otherwise, the sum of PackedRegionTop[n] and PackedRegionHeight[n] shall be less than or equal to packed_picture_height / VerDiv1 * 2.

— When chroma_format_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), PackedRegionLeft[n] shall correspond to an even horizontal coordinate value of luma sample units, and PackedRegionWidth[n] shall correspond to an even number of luma samples, both within the decoded picture.

— When the chroma_format_idc is equal to 1 (4:2:0 chroma format) , PackedRegionTop[n] shall correspond to an even vertical coordinate value of luma sample units, and ProjRegionHeight[n] shall correspond to an even number of luma samples, both within the decoded picture.

D.3.41.5 Omnidirectional viewport SEI message semantics

The omnidirectional viewport SEI message specifies the coordinates of one or more regions of spherical-coordinate geometry, bounded by four great circles, corresponding to viewports recommended for display when the user does not have control of the viewing orientation or has released control of the viewing orientation.

When an effectively applicable frame packing arrangement SEI message, as specified in subclause D.3.41.1 or D.3.41.2, that applies to the picture is present, the information indicated by the omnidirectional viewport SEI message applies to both views.

omni_viewport_id contains an identifying number that may be used to identify the purpose of the one or more recommended viewport regions.

omni_viewport_id equal to 0 indicates that the recommended viewports are per "director's cut", i.e., a viewport suggested according to the creative intent of the content author or content provider. omni_viewport_id equal to 1 indicates that the recommended viewports are selected based on measurements of viewing statistics.

Values of omni_viewport_id from 2 to 511, inclusive, may be used as determined by the application. Values of omni_viewport_id from 512 to 1023 are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of omni_viewport_id in the range of 512 to 1023, inclusive, shall ignore it.

omni_viewport_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous omnidirectional viewport SEI message in output order. omni_viewport_cancel_flag equal to 0 indicates that omnidirectional viewport information follows.

omni_viewport_persistence_flag specifies the persistence of the omnidirectional viewport SEI message for the current layer.

omni_viewport_persistence_flag equal to 0 specifies that the omnidirectional viewport SEI message applies to the current decoded picture only.

Let picA be the current picture. omni_viewport_persistence_flag equal to 1 specifies that the omnidirectional viewport SEI message persists for the current layer in output order until one or more of the following conditions are true:

— A new CLVS of the current layer begins.

— The bitstream ends.

— A picture picB in the current layer in an access unit containing an omnidirectional viewport SEI message that is applicable to the current layer is output for which PicOrderCnt(picB) is greater than PicOrderCnt(picA), where PicOrderCnt(picB) and PicOrderCnt(picA) are the PicOrderCntVal values of picB and picA, respectively, immediately after the invocation of the decoding process for picture order count for picB.

When an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a cubemap projection SEI message with cmp_cancel_flag equal to 0 is not present in the CLVS that applies to the current picture and precedes the omnidirectional viewport SEI message in decoding order, an omnidirectional viewport SEI message with omni_viewport_cancel_flag equal to 0 shall not be present in the CLVS that applies to the current picture. Decoders shall ignore omnidirectional viewport SEI messages with omni_viewport_cancel_flag equal to 0 that do not follow, in decoding order, an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a cubemap projection SEI message with cmp_cancel_flag equal to 0 in the CLVS that applies to the current picture.

omni_viewport_cnt_minus1 plus 1 specifies the number of recommended viewport regions that are indicated by the SEI message.

When omni_viewport_cnt_minus1 is greater than 0 and there is no information provided by external means not specified in this Specification on which recommended viewport is suggested to be displayed, the following applies:

— When omni_viewport_id is equal to 0 or 1, the 0-th recommended viewport is suggested to be displayed when the user does not have control of the viewing orientation or has released control of the viewing orientation.

— When omni_viewport_id is equal to 0, between any two recommended viewports per director's cut, the i-th recommended viewport has higher priority than the j-th recommended viewport for any values of i and j when i is less than j. The 0-th recommended viewport per director's cut has the highest priority.

— When omni_viewport_id is equal to 1, between any two recommended viewports, the i-th recommended viewport has higher popularity, among some selection of candidate viewports, than the j-th recommended viewport for any values of i and j when i is less than j. The 0-th most-viewed

recommended viewport has the highest popularity. The selection of the candidate viewports is outside the scope of this Specification.

omni_viewport_azimuth_centre[i] and **omni_viewport_elevation_centre**[i] indicate the centre of the i-th recommended viewport region, in units of 2^{-16} degrees relative to the global coordinate axes. The value of omni_viewport_azimuth_centre[i] shall be in the range of $-180 * 2^{16}$ (i.e., –11 796 480) to $180 * 2^{16} - 1$ (i.e., 11 796 479), inclusive. The value of omni_viewport_elevation_centre[i] shall be in the range of $-90 * 2^{16}$ (i.e., –5 898 240) to $90 * 2^{16}$ (i.e., 5 898 240), inclusive.

omni_viewport_tilt_centre[i] indicates the tilt angle of the i-th recommended viewport region, in units of 2^{-16} degrees. The value of omni_viewport_tilt_centre[i] shall be in the range of $-180 * 2^{16}$ (i.e., –11796480) to $2^{16} - 1$ (i.e., 11 796 479), inclusive.

omni_viewport_hor_range[i] indicates the azimuth range of the i-th recommended viewport region, in units of 2^{-16} degrees. The value of omni_viewport_hor_range[i] shall be in the range of 1 to $360 * 2^{16}$ (i.e., 23 592 960), inclusive.

omni_viewport_ver_range[i] indicates the elevation range of the i-th recommended viewport region, in units of 2^{-16} degrees. The value of omni_viewport_ver_range[i] shall be in the range of 1 to $180 * 2^{16}$ (i.e., 11 796 480), inclusive.

D.3.41.6 Sample location remapping process

D.3.41.6.1 General

To remap colour sample locations of a region-wise packed picture to a unit sphere, the following ordered steps are applied:

1. A region-wise packed picture is obtained as the cropped decoded picture by decoding a coded picture. For purposes of interpretation of chroma samples, the input to the indicated remapping process is the set of decoded sample values after applying an (unspecified) upsampling conversion process to the 4:4:4 colour sampling format as necessary when chroma_format_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format). This (unspecified) upsampling process should account for the relative positioning relationship between the luma and chroma samples as indicated by chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field, when present.

2. If region-wise packing is indicated, the sample locations of the region-wise packed picture are converted to sample locations of the respective projected picture as specified in subclause D.3.41.6.4. Otherwise, the projected picture is identical to the region-wise packed picture.

3. If frame packing is indicated, the sample locations of the projected picture are converted to sample locations of the respective constituent picture of the projected picture, as specified in subclause D.3.41.6.5. Otherwise, the constituent picture of the projected picture is identical to the projected picture.

4. The sample locations of a constituent picture the projected picture are converted to sphere coordinates relative to the local coordinate axes, as specified in subclause D.3.41.6.2.

5. If rotation is indicated, the sphere coordinates relative to the local coordinate axes are converted to sphere coordinates relative to the global coordinate axes, as specified in subclause D.3.41.6.3. Otherwise, the global coordinate axes are identical to the local coordinate axes.

The overall process for mapping of luma sample locations within a region-wise packed picture to sphere coordinates relative to the global coordinate axes is normatively specified in subclause D.3.41.6.5.

For each region-wise packed picture corresponding to a decoded picture, the following applies:

— When an equirectangular projection SEI message with erp_cancel_flag equal to 0 that applies to the picture is present, ErpFlag is set equal to 1, and CmpFlag is set equal to 0.

— When a cubemap projection SEI message with cmp_cancel_flag equal to 0 that applies to the picture is present, CmpFlag is set equal to 1, and ErpFlag is set equal to 0.

— If a sphere rotation SEI message with sphere_rotation_cancel_flag equal to 0 that applies to the picture is present, RotationFlag is set equal to 1, and RotationYaw, RotationPitch, and RotationRoll are set equal to yaw_rotation ÷ 2^{16}, pitch_rotation ÷ 2^{16}, and roll_rotation ÷ 2^{16}, respectively.

— Otherwise, RotationFlag is set equal to 0.

— If a frame packing arrangement SEI message with frame_packing_arrangement_cancel_flag equal to 0 that applies to the picture is not present, StereoFlag, TopBottomFlag, and SideBySideFlag are all set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

— Otherwise, the following applies:

  — StereoFlag is set equal to 1.

  — If the value of frame_packing_arrangement_type of the frame packing arrangement SEI message is equal to 3, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 1, HorDiv1 is set equal to 2 and VerDiv1 is set equal to 1.

  — Otherwise, if the value of frame_packing_arrangement_type of the frame packing arrangement SEI message is equal to 4, TopBottomFlag is set equal to 1, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 2.

  — Otherwise, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

— If a region-wise packing SEI message with rwp_cancel_flag equal to 0 that applies to the picture is not present, RegionWisePackingFlag is set equal to 0, and ConstituentPicWidth and ConstituentPicHeight are set to be equal to cropPicWidth / HorDiv1 and cropPicHeight / VerDiv1, respectively, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped decoded picture.

— Otherwise, RegionWisePackingFlag is set equal to 1, and ConstituentPicWidth and ConstituentPicHeight are set equal to proj_picture_width / HorDiv1 and proj_picture_height / VerDiv1, respectively.

D.3.41.6.2 Projection for a sample location

Inputs to this subclause are

— pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture, in relative projected picture sample units, and

— the centre point of a sample location (hPos, vPos) along the horizontal and vertical axes, respectively, in relative projected picture sample units, where hPos and vPos may have non-integer real values.

Outputs of this subclause are

— sphere coordinates (ϕ, θ) for the sample location in degrees relative to the coordinate axes specified in subclause D.3.41.6.1.

The projection for a sample location is derived as follows:

— If ErpFlag is equal to 1, the following applies:

  — If RegionWisePackingFlag is equal to 0 and erp_guard_band_flag is equal to 1, the following applies:

$$\begin{aligned} &hPos' = hPos - erp\_left\_guard\_band\_widt \\ &pictureWidth = pictureWidth - erp\_left\_guard\_band\_width - \\ &erp\_right\_guard\_band\_width \end{aligned} \tag{D-54}$$

— Otherwise

$$hPos' = hPos \tag{D-55}$$

— The following applies:

$$\phi = 180 - hPos' * (360 \div pictureWidth)$$
$$\theta = 90 - vPos * (180 \div pictureHeight) \tag{D-56}$$

— Otherwise (CmpFlag is equal to 1), it is a requirement of bitstream conformance that pictureWidth shall be a multiple of 3 and pictureHeight shall be a multiple of 2, and that pictureWidth / 3 shall be equal to pictureHeight / 2, and the following applies:

```
lw = pictureWidth / 3
lh = pictureHeight / 2
w = Floor( hPos ÷ lw )
h = Floor( vPos ÷ lh )
tmpHorVal = hPos − w * lw
tmpVerVal = vPos − h * lh
hPos′ = −( 2 * tmpHorVal ÷ lw ) + 1
vPos′ = −( 2 * tmpVerVal ÷ lh ) + 1
if( w = = 1 && h = = 0 ) { /* positive x front face */
  x = 1.0
  y = hPos′
  z = vPos′
} else if( w = = 1 && h = = 1 ) { /* negative x back face */
  x = −1.0
  y = −vPos′
  z = −hPos′
} else if( w = = 2 && h = = 1 ) { /* positive z top face */
  x = −hPos′
  y = −vPos′
  z = 1.0
} else if( w = = 0 && h = = 1 ) { /* negative z bottom face */
  x = hPos′
  y = −vPos′
  z = −1.0
} else if( w = = 0 && h = = 0 ) { /* positive y left face */
  x = −hPos′
  y = 1.0
  z = vPos′
} else { /* ( w = = 2 && h = = 0 ), negative y right face */
  x = hPos′
  y = −1.0
  z = vPos′
}
```

(D-57)

$$\phi = Atan2(y, x) * 180 \div \pi$$
$$\theta = Asin(z \div \sqrt{x^2 + y^2 + z^2}) * 180 \div \pi$$

D.3.41.6.3 Conversion from the local coordinate axes to the global coordinate axes

Inputs to this subclause are

— rotation_yaw (α_d), rotation_pitch (β_d), rotation_roll (γ_d), all in units of degrees, and

— sphere coordinates (ϕ_d, θ_d) relative to the local coordinate axes.

Outputs of this subclause are

— sphere coordinates (ϕ', θ') relative to the global coordinate axes.

The outputs are derived as follows:

$$
\begin{aligned}
&\phi = \phi_d * \pi \div 180 \\
&\theta = \theta_d * \pi \div 180 \\
&\alpha = \alpha_d * \pi \div 180 \\
&\beta = \beta_d * \pi \div 180 \\
&\gamma = \gamma_d * \pi \div 180 \\
&x_1 = \mathrm{Cos}(\phi) * \mathrm{Cos}(\theta) \\
&y_1 = \mathrm{Sin}(\phi) * \mathrm{Cos}(\theta) \\
&z_1 = \mathrm{Sin}(\theta) \\
&x_2 = \mathrm{Cos}(\beta) * \mathrm{Cos} (\gamma) * x_1 - \mathrm{Cos}(\beta) * \mathrm{Sin}(\gamma) * y_1 + \mathrm{Sin}(\beta) * z_1 \\
&y_2 = (\mathrm{Cos}(\alpha) * \mathrm{Sin}(\gamma) + \mathrm{Sin}(\alpha) * \mathrm{Sin}(\beta) * \mathrm{Cos}(\gamma)) * x_1 + \\
&\qquad (\mathrm{Cos}(\alpha) * \mathrm{Cos}(\gamma) - \mathrm{Sin}(\alpha) * \mathrm{Sin}(\beta) * \mathrm{Sin}(\gamma)) * y_1 - \\
&\qquad \mathrm{Sin}(\alpha) * \mathrm{Cos}(\beta) * z_1 \\
&z_2 = (\mathrm{Sin}(\alpha) * \mathrm{Sin}(\gamma) - \mathrm{Cos}(\alpha) * \mathrm{Sin}(\beta) * \mathrm{Cos}(\gamma)) * x_1 + \\
&\qquad (\mathrm{Sin}(\alpha) * \mathrm{Cos}(\gamma) + \mathrm{Cos}(\alpha) * \mathrm{Sin}(\beta) * \mathrm{Sin}(\gamma)) * y_1 + \\
&\qquad \mathrm{Cos}(\alpha) * \mathrm{Cos}(\beta) * z_1 \\
&\phi' = \mathrm{Atan2}(y_2, x_2) * 180 \div \pi \\
&\theta' = \mathrm{Asin}(z_2) * 180 \div \pi
\end{aligned}
\tag{D-58}
$$

D.3.41.6.4 Conversion of sample locations for rectangular region-wise packing

Inputs to this subclause are:

— sample location (x, y) within the packed region, where x and y are in relative packed picture sample units, while the sample location is at an integer sample location within the packed picture;

— the width and the height (projRegWidth, projRegHeight) of the projected region, in relative projected picture sample units;

— the width and the height (packedRegWidth, packedRegHeight) of the packed region, in relative packed picture sample units;

— transform type (transformType);

— offset values for the sampling position (offsetX, offsetY) in the range of 0, inclusive, to 1, exclusive, in horizontal and vertical relative packed picture sample units, respectively.

NOTE offsetX and offsetY both equal to 0.5 indicate a sampling position that is in the centre point of a sample in packed picture sample units.

Outputs of this subclause are:

– the centre point of the sample location (hPos, vPos) within the projected region in relative projected picture sample units, where hPos and vPos may have non-integer real values.

The outputs are derived as follows:

```
if( transformType = = 0 | | transformType = = 1 | | transformType = = 2 | |
transformType = = 3 ) {
  horRatio = projRegWidth ÷ packedRegWidth
  verRatio = projRegHeight ÷ packedRegHeight
} else if ( transformType = = 4 | | transformType = = 5 | | transformType = = 6 | |
  transformType = = 7 ) {
  horRatio = projRegWidth ÷ packedRegHeight
  verRatio = projRegHeight ÷ packedRegWidth
}
if( transformType = = 0 ) {
  hPos = horRatio * ( x + offsetX )
  vPos = verRatio * ( y + offsetY )
} else if ( transformType = = 1 ) {
  hPos = horRatio * ( packedRegWidth − x − offsetX )
  vPos = verRatio * ( y + offsetY )
} else if ( transformType = = 2 ) {
  hPos = horRatio * ( packedRegWidth − x − offsetX )
  vPos = verRatio * ( packedRegHeight − y − offsetY )
} else if ( transformType = = 3 ) {
  hPos = horRatio * ( x + offsetX )
  vPos = verRatio * ( packedRegHeight − y − offsetY )
} else if ( transformType = = 4 ) {
  hPos = horRatio * ( y + offsetY )
  vPos = verRatio * ( x + offsetX )
} else if ( transformType = = 5 ) {
  hPos = horRatio * ( y + offsetY )
  vPos = verRatio * ( packedRegWidth − x − offsetX )
} else if ( transformType = = 6 ) {
  hPos = horRatio * ( packedRegHeight − y − offsetY )
  vPos = verRatio * ( packedRegWidth − x − offsetX )
} else if ( transformType = = 7 ) {
  hPos = horRatio * ( packedRegHeight − y − offsetY )
  vPos = verRatio * ( x+ offsetX )
}
```

(D-59)

D.3.41.6.5 Mapping of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes

This subclause specifies the semantics of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes.

offsetX is set equal to 0.5 and offsetY is set equal to 0.5.

If RegionWisePackingFlag is equal to 1, the following applies for each packed region n in the range of 0 to NumPackedRegions − 1, inclusive:

— For each sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region, the following applies:

  — The corresponding sample location (xProjPicture, yProjPicture) of the projected picture is derived as follows:

    — x is set equal to xPackedPicture − PackedRegionLeft[n].

    — y is set equal to yPackedPicture − PackedRegionTop[n].

— Subclause D.3.41.6.4 is invoked with x, y, PackedRegionWidth[n], PackedRegionHeight[n], ProjRegionWidth[n], ProjRegionHeight[n], TransformType[n], offsetX and offsetY as inputs, and the output is assigned to sample location (hPos, vPos).

— xProjPicture is set equal to ProjRegionLeft[n] + hPos.

— When StereoFlag is equal to 0 or TopBottomFlag is equal to 1, and when xProjPicture is greater than or equal to proj_picture_width, xProjPicture is set equal to xProjPicture – proj_picture_width.

— When SideBySideFlag is equal to 1, the following applies:

  — When ProjRegionLeft[n] is less than proj_picture_width / 2 and xProjPicture is greater than or equal to proj_picture_width / 2, xProjPicture is set equal to xProjPicture – proj_picture_width / 2.

  — When ProjRegionLeft[n] is greater than or equal to proj_picture_width / 2 and xProjPicture is greater than or equal to proj_picture_width, xProjPicture is set equal to xProjPicture – proj_picture_width / 2.

— yProjPicture is set equal to ProjRegionTop[n] + vPos.

— Subclause D.3.41.6.6 is invoked with xProjPicture, yProjPicture, ConstituentPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the luma sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region in the decoded picture.

Otherwise (RegionWisePackingFlag is equal 0), the following applies for each sample location (x, y) that is not an equirectangular projection guard band sample within the cropped decoded picture, where a sample location (x, y) is an equirectangular projection guard band sample when and only when ErpFlag is equal to 1, x is in the range of 0 to erp_left_guard_band_width – 1, inclusive, or ConstituentPicWidth – erp_right_guard_band_width to ConstituentPicWidth – 1, inclusive, and y is in the range of 0 to ConstituentPicHeight – 1, inclusive:

— xProjPicture is set equal to x + offsetX.

— yProjPicture is set equal to y + offsetY.

— If ErpFlag is equal to 0, projPicWidth is set equal to ConstituentPicWidth. Otherwise (ErpFlag is equal to 1), projPicWidth is set equal to ConstituentPicWidth – (erp_left_guard_band_width + erp_right_guard_band_width).

— Subclause D.3.41.6.6 is invoked with xProjPicture, yProjPicture, projPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the sample location (x, y) within the region-wise packed picture.

D.3.41.6.6 Conversion from a sample location in a projected picture to sphere coordinates relative to the global coordinate axes

Inputs to this subclause are

— the centre point of a sample location (xProjPicture, yProjPicture) within a projected picture, where xProjPicture and yProjPicture are in relative projected picture sample units and may have non-integer real values, and

— pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture, in relative projected picture sample units.