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**ISO/IEC JTC 1/SC 29/WG 1**
**(& ITU-T SG16)**

# Coding of Still Pictures

**JBIG** Joint Bi-level Image Experts Group

**JPEG** Joint Photographic Experts Group

**TITLE:** JPEG XL: Additional Information to the Final Call for Proposals

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# JPEG XL - Additional information to the Final Call for Proposals

## 1 Subjective evaluation methodology

Subjective evaluation will be performed on two sets of images: SDR images and HDR images. Each **subjective** test will be performed by at least two independent labs. The test methodology for both tests is detailed below.

### 1.1 General methodology

For evaluation of both SDR and HDR images, the Double Stimulus Impairment Scale (DSIS) Variant I [1] will be used, with a randomized presentation order as described in ITU-T P.910 [2]. Images are displayed side-by-side, with a 20-pixel mid-gray (R=G=B=128) separation. The side-by-side images are centered on the display. The reference is shown on the left or right, and can vary per subject. The reference position does not change during the session. Stimuli are randomized so that the same content is never displayed consecutively. There is no presentation or voting time limit.

Fig. 1: Example of side-by-side images as presented during the subjective test.

The viewing distance depends on the image class [3]:

- For SDR viewing, participants are able to move freely during the viewing, with no fixed distance to the screen.
- For HDR viewing, a fixed viewing distance of 3.2*H will be used (H = stimulus height). In our tests, the screen height and the height of stimuli are equal.

The following five-level scale for rating the impairment will be used:

| Score | Impairment level |
|---|---|
| 5 | imperceptible |
| 4 | perceptible but not annoying |
| 3 | slightly annoying |
| 2 | annoying |
| 1 | very annoying |

Minimum 15 consenting subjects are required for the subjective assessment (excluding outliers). Each subject needs to pass a visual acuity test. The scores will be aggregated to produce MOS values with their respective 95% confidence intervals.

## 1.2 SDR image evaluation

For subjective evaluation of SDR images, the following test monitor will be used:

- Model type: Eizo CG318-4K
- Resolution: 4096x2160 pixels.

### 1.2.1 SDR test images

In order to fit the images side-by-side on the screen, the images used for subjective testing will be *cropped* versions of the original, with the resolution after cropping shown in the table below. The cropped versions (in ppm format) will be provided to participants, along with the original images. Only the cropped versions are used for *subjective* evaluations. Both the original and cropped versions will be used for *objective* evaluations.

| | **Original resolution** | **Cropped resolution** | **Bit depth** | **Rate points [bpp]** |
|---|---|---|---|---|
| APPLE_BasketBallScreen_2560x1440p_60_8b_sRGB_444_000_cropped.ppm | 2560x1440 | 2038x1440 | 8-bit | 0.06, 0.12, 0.25, 0.50 |
| ARRI_PublicUniversity_2880x1620p_24_8b_bt709_444_0000_cropped.ppm | 2880x1620 | 2038x1620 | 8-bit | 0.06, 0.12, 0.25, 0.50 |
| BIKE_2048x2560_8b_RGB_cropped.ppm | 2048x2560 | 2038x2160 | 8-bit | 0.06, 0.12, 0.25, 0.50 |
| BLENDER_Sintel2_4096x1744p_24_10b_sRGB_444_00004606_cropped.ppm | 4096x1744 | 2038x1744 | 10-bit | 0.06, 0.12, 0.25, 0.50 |
| CAFE_2048x2560_8b_RGB_cropped.ppm | 1280x1600 | 1280x1600 | 8-bit | 0.06, 0.12, 1.00, 2.00 |
| FemaleStripedHorseFly_1920x1080_8b_cropped.ppm | 1920x1080 | 960x1080 | 8-bit | 0.06, 0.12, 0.25, 0.50 |
| p06_cropped.ppm | 4064x2704 | 2038x2160 | 8-bit | 0.06, 0.12, 0.25, 0.50 |
| WOMAN_2048x2560_8b_RGB_cropped.ppm | 2048x2560 | 2038x2160 | 8-bit | 0.06, 0.12, 0.25, 0.50 |

## 1.3 HDR image evaluation

For subjective evaluation of HDR images, the following test monitor will be used:

- Model type: Sim2 HDR47ES4MB
- Resolution: 1920x1080 pixels

### 1.3.1 HDR test images

The subjective tests will be performed side-by-side on eight HDR test images. Given the display resolution, the maximum image width is 950 pixels, and the maximum image height is 1080 pixels.

| | Original resolution | Cropped resolution | Bit depth | Rate points [bpp] |
|---|---|---|---|---|
| 507_cropped.ppm | 944x1080 | 944x1080 | 12-bit | 0.06, 0.12, 0.50, 1.00 |
| HancockKitchenInside_cropped.ppm | 944x1080 | 944x1080 | 12-bit | 0.06, 0.12, 0.25, 0.75 |
| Hurdles_cropped.ppm | 1920x1080 | 950x1080 | 12-bit | 0.50, 0.75, 1.00, 2.00 |
| LabTypewriter_cropped.ppm | 944x1080 | 944x1080 | 12-bit | 0.75, 1.00, 1.50, 2.00 |
| Market3_cropped.ppm | 1920x1080 | 950x1080 | 12-bit | 0.75, 1.00, 1.50, 2.00 |
| showgirl_cropped.ppm | 944x1080 | 944x1080 | 12-bit | 0.75, 1.00, 1.50, 2.00 |
| sintel_2_cropped.pfm | 944x1080 | 944x1080 | 12-bit | 0.75, 1.00, 1.50, 2.00 |
| Sunrise_cropped.ppm | 1920x1080 | 950x1080 | 12-bit | 0.50, 0.75, 1.00, 2.00 |

### 1.3.2 HDR Image characteristics

12-bit 4:4:4 ppm images are provided as input to all codecs and proposals. These images use ITU-T Rec. BT.2020 color space (full range) and SMPTE ST 2084 (PQ) transfer function [4].

*Note that the test images were converted from their original pfm (32-bit floating point) or 16-bit EXR formats. HDRTools* [5] *was used to perform conversion to 12-bit RGB (ppm).*

# 2 Objective evaluation methodology

## 2.1 Images used for objective evaluation

| **Class A: Natural images (color)** | |
|---|---|
| 8-bit, RGB 4:4:4, BT.709, full range | ● ARRI_Lake2_2880x1620p_24_8b_bt709_444_0000.ppm<br>● ARRI_PublicUniversity_2880x1620p_24_8b_bt709_444_0000.ppm<br>● BIKE_2048x2560_8b_RGB.ppm<br>● bike3.ppm<br>● bird_of_paradise.ppm<br>● CAFE_2048x2560_8b_RGB.ppm<br>● FemaleStripedHorseFly_1920x1080_8b.ppm<br>● HintergrundMusik_1920x1080_8b.ppm<br>● honolulu_zoo.ppm<br>● oahu_northcoast.ppm<br>● p01.ppm<br>● p04.ppm<br>● p06.ppm<br>● p08.ppm<br>● p10.ppm<br>● p14.ppm<br>● p26.ppm<br>● TOOLS_1520x1200_8b_RGB.ppm |

| | |
|---|---|
| | • VQEG_CrowdRun_3840x2160p_50_8b_bt709_444_07111.ppm<br>• VQEG_ParkJoy_3840x2160p_50_8b_bt709_444_15523.ppm<br>• WALTHAM1_3600x2600_8b_RGB.tif<br>• WALTHAM2_3800x2600_8b_RGB.tif<br>• WOMAN_2048x2560_8b_RGB.ppm |
| 10-bit, RGB 4:4:4, full range, BT. 709 | • EBU_PendulusWide_3840x2160p_50_10b_bt709_444_0001.ppm<br>• HDCA_set2_0000_0000.ppm<br>• HDCA_set6_0000_0000.ppm<br>• HDCA_set9_0000_0000.ppm<br>• HDCA_set10_0000_0000.ppm |
| 10-bit, RGB 4:4:4, narrow range, BT. 709 | • Chimera_PierSeaside.ppm<br>• Chimera_ToddlerFountain2.ppm<br>• Chimera_WindAndNature.ppm<br>• ElFuente_FoodMarket4.ppm<br>• ElFuente_TunnelFlag.ppm |
| **Class B: Grayscale** | |
| 8-bit, 4:0:0 | • AERIAL2_2048x2048_8b_Y.pgm<br>• CATS_3072x2048_8b_Y.pgm<br>• GOLD_720x576_8b_Y.pgm<br>• TEXTURE1_1024x1024_8b_Y.pgm |
| 12-bit, 4:0:0 | • XRAY_2048x1680_12b_Y.tif |
| **Class C: Computer-generated images** | |
| 8-bit, sRGB, full range, 4:4:4 | • BLENDER_Sintel1_4096x1744p_24_8b_sRGB_444_00003096.ppm |
| 10-bit, sRGB, full range, 4:4:4 | • BLENDER_Sintel2_4096x1744p_24_10b_sRGB_444_00004606.ppm |
| 12-bit, sRGB, full range, 4:4:4 | • BLENDER_TearsOfSteel_4096x1714p_24_12b_sRGB_444_01290.ppm |
| **Class D: Screen content images** | |
| 8-bit, sRGB, full range, 4:4:4 | • APPLE_BasketBallScreen_2560x1440p_60_8b_sRGB_444_000.ppm<br>• HUAWEI_ScMap_1280x720p_60_8b_sRGB_444_000.ppm<br>• RICHTER_ScreenContent_4096x2160p_15_8b_sRGB_444_0001.ppm |
| **Class E: HDR/WCG images** | |
| 12-bit, BT.2020, 4:4:4, PQ, full range | • 507.ppm<br>• BloomingGorse2.ppm<br>• CanadianFalls.ppm<br>• DevilsBathtub.ppm<br>• Dragon_3.ppm<br>• HancockKitchenInside.ppm |

| | |
|---|---|
| | • Hurdles.ppm<br>• LabTypewriter.ppm<br>• LasVegasStore.ppm<br>• Market3.ppm<br>• McKeesPub.ppm<br>• MtRushmore2.ppm<br>• set18.ppm<br>• set22.ppm<br>• set23.ppm<br>• set24.ppm<br>• set31.ppm<br>• set33.ppm<br>• set70.ppm<br>• showgirl.ppm<br>• Sintel_2.ppm<br>• Starting.ppm<br>• Sunrise.ppm<br>• WillyDesk.ppm |

## 2.2 Objective metric calculation

The following metrics shall be calculated for the encoded images at all rate points. A spreadsheet will be provided as part of the Docker container (Section 5) to collect the metric values for all test images.

### 2.2.1 SDR metric calculation

| | 8-bit | | | 10/12-bit | | |
|---|---|---|---|---|---|---|
| | Y | Cb | Cr | Y | Cb | Cr |
| PSNR | Yes | Yes | Yes | Yes | Yes | Yes |
| Weighted PSNR | Weighted | | | Weighted | | |
| SSIM | Yes | No | No | Yes | No | No |
| MS-SSIM | Yes | No | No | Yes | No | No |
| VIF | Yes | No | No | No | No | No |
| VMAF | Yes | No | No | No | No | No |

#### 2.2.1.1 PSNR, SSIM, MS-SSIM

PSNR is calculated in the YCbCr color space, for each of the three color planes. Additionally, a weighted PSNR is calculated which uses the following weights for the YCbCr color planes: (6/8, 1/8, 1/8). SSIM [6] and MS-SSIM [7] are calculated on the luminance (Y) component only. Default ($K_1$, $K_2$) SSIM parameters are used, along with a block size of 8x8, and block distance of 1 pixel.

The HDRMetrics tool is used to produce SSIM and MS-SSIM calculations for all images and bit depths, as follows [5]:

HDRMetrics -f HDRMetrics.cfg -p Input0File=[REFERENCE_IMAGE] -p Input1File=[PROCESSED_IMAGE] -p LogFile=[LOG_FILE] -p NumberOfFrames=1 -p Input0Width=[WIDTH] -p Input0Height=[HEIGHT] -p Input1Width=[WIDTH] -p Input1Height=[HEIGHT] -p TFPSNRDistortion=0 -p EnablePSNR=1 -p EnableSSIM=1 -p EnableMSSSIM=1

#### 2.2.1.2 VIF and VMAF

VIF [8] and VMAF [9] calculations are limited to 8-bit images. The VMAF FFmpeg plugin is used to calculate the VIF and VMAF values [10].

Command line:

ffmpeg -s:v [width],[height] -i [dist_image] -s:v [width],[height] -i [ref_image] -lavfi libvmaf=log_fmt=json:log_path=[log_path] -f null -

### 2.2.2 HDR metric calculation

#### 2.2.2.1 Preprocessing

Objective quality metrics for HDR images are calculated on the Y component, based on the following steps [4]:

- Apply inverse PQ transfer function, leading to 12-bit PQ-RGB 4:4:4 images to obtain linear RGB images.
- Apply color space conversion from linear RGB to XYZ, CIE 1931.
- Apply transfer function (PQ) to Y component
- Compute metric on Y component.

These conversion steps are implemented in the scripts included in the Docker container (Section 5).

| | **12-bit** | | |
|---|---|---|---|
| | X | Y | Z |
| PQ-PSNR-Y | No | Yes | No |
| PQ-MS-SSIM-Y | No | Yes | No |
| HDR-VDP2 | No | Yes | No |

#### 2.2.2.2 PQ-PSNR-Y and PQ-MS-SSIM-Y

HDRMetrics is used to calculate the HDR versions of PSNR and MS-SSIM.

Command line:

HDRMetrics -f HDRMetrics.cfg -p Input0File=[REFERENCE_IMAGE] -p Input1File=[PROCESSED_IMAGE] -p LogFile=[LOG_FILE] -p NumberOfFrames=1 -p Input0Width=[WIDTH] -p Input0Height=[HEIGHT] -p Input1Width=[WIDTH] -p Input1Height=[HEIGHT] -p TFPSNRDistortion=1 -p EnableTFPSNR=1 -p EnableTFMSSSIM=1

#### 2.2.2.3 HDR-VDP2

The HDR-VDP2 [11] (v2.2.1) metric needs to be calculated outside the Docker container. A Matlab implementation is available, and we ask proponents to use this Matlab script to calculate the HDR-VDP2 metric values.

The Matlab scripts are available at https://sourceforge.net/projects/hdrvdp/files/hdrvdp/.

The following Matlab command line can be used to calculate the HDR-VDP2 metric:

hdrvdp([RECONSTRUCTED_PPM], [REFERENCE_PPM ppm], 'XYZ', [PIXELS_PER_DEGREE]);

Based on the characteristics of the Sim2 display, the PIXELS_PER_DEGREE value was determined to be equal to **66.4149**.

*Note that this value can be obtained based on the following information:*

- *screen size of the Sim2: 1021x572mm;*
- *viewing distance: 3.2 * H = 3.2 * 0.572m = 1.8304m;*
- *diagonal size: 42";*

*and by calling the Matlab function*

*hdrvdp_pix_per_deg(42, [1920 1080], 1.8304).*

## 3 Anchor generation

Proposals will be compared using the above mentioned assessment methodologies against the following anchor formats/encoders:

| Format/standard | Specification | Encoder software |
|---|---|---|
| JPEG XT | ISO/IEC 18477 | JPEG XT v1.53 |
| JPEG 2000 | ISO/IEC 15444-1 \| ITU-T Rec. T.800 | Kakadu v7.10.2 |
| HEVC | ISO/IEC 23008-2 \| ITU-T Rec. H.265 | HM16.18+SCM-8.7 |
| WebP | https://developers.google.com/speed/webp/ | cwebp 1.0.0 |

Target rate points for the objective evaluations are 0.06, 0.12, 0.25, 0.50, 0.75, 1.00, 1.50, and 2.00 bits per pixel (bpp). Proponents are asked to produce encodes at each of these bitrates. If the encoder is unable to reach a specified rate point, this shall be explicitly mentioned in the submission document.

Anchors are encoded using RGB 4:4:4 as well as YCbCr 4:2:0 color sampling for objective evaluations (excluding the monochrome images). The RGB 4:4:4 input files are converted to YCbCr 4:2:0 using the HDRConvert tool [5], as follows:

HDRConvert -f HDRConvertBT709PPMToYCbCr420fr.cfg -p SourceFile=[RGB444] -p SourceWidth=[WIDTH] -p SourceHeight=[HEIGHT] -p OutputFile=[YCbCr420] -p OutputWidth=[WIDTH]

-p OutputHeight=[HEIGHT] –p SourceBitDepthCmp0=[BIT_DEPTH] -p SourceBitDepthCmp1=[BIT_DEPTH] -p SourceBitDepthCmp2=[BIT_DEPTH] -p OutputBitDepthCmp0=[BIT_DEPTH] -p OutputBitDepthCmp1==[BIT_DEPTH] -p OutputBitDepthCmp2=[BIT_DEPTH] -p OutputChromaFormat=1

JPEG XT accepts only 4:4:4 chroma format and the subsampling to 4:2:0 is executed internally. For JPEG XT, the parameter OutputChromaFormat is set to 3 instead of 1.

Information on available software and configurations to be used for these anchors is given below.

## 3.1 Anchor software

### 3.1.1 JPEG XT

Configuration:

- Software: JPEG XT reference software, v1.53
- Available at http://jpeg.org/jpegxt/software.html.
- License: GPLv3

**The following command lines were used to generate the JPEG XT anchors:**

**RGB 4:4:4 8-bit**

jpeg -qt 3 -h -v -oz -q [QUALITY_PARAMETER] -s 1x1,1x1,1x1 [INPUTFILE] [OUTPUTFILE]

**RGB 4:4:4 10-bit**

jpeg -qt 3 -g 1 -h -v -oz -q [QUALITY_PARAMETER] -R 2 -s 1x1,1x1,1x1 [INPUTFILE] [OUTPUTFILE]

**RGB 4:4:4 12-bit**

jpeg -qt 3 -g 1 -h -v -oz -q [QUALITY_PARAMETER] -R 4 -s 1x1,1x1,1x1 [INPUTFILE] [OUTPUTFILE]

For YCbCr 4:2:0, the INPUTFILE must be YCbCr 4:4:4. The subsampling is executed internally in JPEG XT software (Section 3).

**YCbCr 4:2:0 8-bit**

jpeg -qt 3 -h -v -c -oz -q [QUALITY_PARAMETER] -s 1x1,2x2,2x2 [INPUTFILE] [OUTPUTFILE]

**YCbCr 4:2:0 10-bit**

jpeg -qt 3 -g 1 -h -v -c -oz -q [QUALITY_PARAMETER] -R 2 -s 1x1,2x2,2x2 [INPUTFILE] [OUTPUTFILE]

**YCbCr 4:2:0 12-bit**

jpeg -qt 3 -g 1 -h -v -c -oz -q [QUALITY_PARAMETER] -R 4 -s 1x1,2x2,2x2 [INPUTFILE] [OUTPUTFILE]

### 3.1.2 JPEG 2000

Configuration:

- Software: Kakadu, v7.10.2
- Available at http://www.kakadusoftware.com.
- License: demo binaries freely available for non-commercial use

**The following command lines were used to generate the JPEG 2000 anchors:**

**RGB 4:4:4 (8/10/12-bit)**

kdu_compress -i [INPUTFILE] -o [OUTPUTFILE] –rate [BPP]

**YCbCr 4:2:0 (8/10/12-bit)**

kdu_v_compress -i [INPUTFILE] -o [OUTPUTFILE] –rate [BPP] -precise -tolerance 0

### 3.1.3 HEVC

Configuration:

- An external rate-control loop is provided in the Docker image scripts to achieve the targeted bitrate.
- Software: HEVC Test Model (HM 16.18+SCM-8.7)
- Available at https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/tags/HM-16.18+SCM-8.7/
- License: BSD

The configuration files to produce the HEVC anchors are available in the HM software package:

- For 8-bit and 10-bit images: encoder_intra_main_scc.cfg.
- For 12-bit images: encoder_intra_main_rext.cfg.

**The following command lines were used to generate the HEVC anchors:**

**RGB 4:4:4 12-bit, YCbCr 4:2:0 12-bit (HDR)**

TAppEncoderStatic -c encoder_intra_main_rext.cfg -f 1 -fr 1 -q [QUALITY_PARAMETER] -wdt [IMAGE_WIDTH] -hgt [IMAGE_HEIGHT] --InputChromaFormat=[CHROMA_FORMAT] --InternalBitDepth=12 --InputBitDepth=12 --OutputBitDepth=12 --ConformanceWindowMode=1 --InputColourSpaceConvert=RGBtoGBR -i [INPUT_IMAGE] -b [OUTPUT_IMAGE] -o /dev/null

**RGB 4:4:4 8-bit, RGB 4:4:4 10-bit, YCbCr 4:2:0 8-bit and YCbCr 4:2:0 10-bit (SDR)**

TAppEncoderStatic -c encoder_intra_main_scc.cfg -f 1 -fr 1 -q [QUALITY_PARAMETER] -wdt [IMAGE_WIDTH] -hgt [IMAGE_HEIGHT] --InputChromaFormat=[CHROMA_FORMAT] --InternalBitDepth=[BIT_DEPTH] --InputBitDepth=[BIT_DEPTH] --OutputBitDepth=[BIT_DEPTH] --ConformanceWindowMode=1 -i [INPUT_IMAGE] -b [OUTPUT_IMAGE] -o /dev/null

**RGB 4:4:4 12-bit and YCbCr 4:2:0 12-bit (SDR)**

TAppEncoderStatic -c encoder_intra_main_rext.cfg -f 1 -fr 1 -q [QUALITY_PARAMETER] -wdt [IMAGE_WIDTH] -hgt [IMAGE_HEIGHT] --InputChromaFormat=[CHROMA_FORMAT] --InternalBitDepth=12 --InputBitDepth=12 --OutputBitDepth=12 --ConformanceWindowMode=1 -i [INPUT_IMAGE] -b [OUTPUT_IMAGE] -o /dev/null

### 3.1.4 WebP

WebP only supports 4:2:0 encoding with 8-bit input. WebP anchors will not be created for images with bit depth higher than 8-bit. Before encoding, the RGB 4:4:4 input files are converted to YCbCr 4:2:0 using the HDRConvert tool, as follows:

HDRConvert -f HDRConvertBT709PPMToYCbCr420fr.cfg -p SourceFile=[RGB444] -p SourceWidth=[WIDTH] -p SourceHeight=[HEIGHT] -p OutputFile=[YCbCr420] -p OutputWidth=[WIDTH] -p OutputHeight=[HEIGHT] -p SourceBitDepthCmp0=8 -p SourceBitDepthCmp1=8 -p SourceBitDepthCmp2=8 -p OutputBitDepthCmp0=8 -p OutputBitDepthCmp1=8 -p OutputBitDepthCmp2=8

Configuration:

- An external rate-control loop is provided in the Docker image to achieve the targeted bitrate.
- HDRConvert is used to convert the RGB 4:4:4 input files to YCbCr 4:2:0.
- Available software: WebP (v1.0.0-rc2)
- Available at https://developers.google.com/speed/webp/download
- License: Apache License, Version 2.0

**The following command lines were used to generate the WebP anchors:**

**YCbCr 4:2:0 8-bit:**

cwebp -m 6 -q [QUALITY_PARAMETER] -s [IMAGE_WIDTH] [IMAGE_HEIGHT] [INPUT_IMAGE] -o [OUTPUT_IMAGE]

# 4 Scripts and Docker container

To ease the objective assessment of the different proposals, a Docker [16] container and set of Python scripts have been provided to automatically perform the objective assessment of a given set of codecs. Its features include:

- Automatic installation of software: the Docker container automatically downloads and configures all anchor codecs, metrics and dependencies.
- Easy addition of new (proprietary) codecs by placing binaries and Python encoder/decoder scripts in the designated folder.
- Supported input format: ppm for RGB content and YUV planar for YCbCr content.
- Easy addition of new test images.
- Scripts for running conversions, encoding, decoding, and objective evaluation.
- Objective metrics:
    - For SDR images: PSNR, SSIM, MS-SSIM, VIF (8-bit only), and VMAF (8-bit only).
    - For HDR/WCG images: PQ-PSNR-Y, PQ-MS-SSIM-Y, and HDR-VDP2 (outside Docker).
- Automatic generation of graphs using Python libraries.
- Spreadsheet to collect metric values for all test images.

The Docker container can run on different platforms, including Windows, Ubuntu and macOS. The source code and installation instructions are available at https://github.com/pinarakyazi/codec_compare/. The code was made available under Apache License 2.0.

# 5 Location of test images

The location, login and password to obtain the test images will be made available to parties that have expressed interest to participate in the Call for Proposals (deadline: August 15, 2018). A document specifying the conditions to use the shared content will be also included. The users are expected to take notice of this document and not violate the aforementioned conditions.

# 6 CfP material submission

Instructions on how to submit the requested material (cf. “Annex A – Submission Requirements” of the final Call for Proposals) will be shared with the proponents upon registration. Proponents shall enter the results of the objective quality measurements in a spreadsheet that will be made available to proponents upon registration.

# 7 References


[1] ITU-R Recommendation BT.500-13, "Methodology for the subjective assessment of the quality of television pictures", January 2012.

[2] ITU-T Recommendation P.910, "Subjective video quality assessment methods for multimedia applications", April 2008.

[3] ITU-R Recommendation BT.2022, "General viewing conditions for subjective assessment of quality of SDTV and HDTV television pictures on flat panel displays", August 2012.

[4] ITU-T Recommendation BT.2100-1, "Image parameter values for high dynamic range television for use in production and international programme exchange" (v1), June 2017.

[5] HDRTools package, https://gitlab.com/standards/HDRTools .

[6] Z. Wang, A. C. Bovik, H. R. Sheikh, E. P. Simoncelli, "Image quality assessment: from error visibility to structural similarity", IEEE Transactions on Image Processing, 13(4), pp.600-612, 2004.

[7] Z. Wang, E. P. Simoncelli, AC Bovik, "Multiscale structural similarity for image quality assessment", 37th Asilomar Conference on Signals, Systems and Computers, 2003.

[8] H. Sheikh and A. Bovik, "Image Information and Visual Quality", IEEE Transactions on Image Processing, vol. 15 (2), pp. 430–444.

[9] VMAF – Video Multi-Method Assessment Fusion. https://github.com/Netflix/vmaf

[10] FFmpeg, http://ffmpeg.org .

[11] R. Mantiuk, K. J. Kim, A. G. Rempel, W. Heidrich, "HDR-VDP-2: A calibrated visual metric for visibility and quality predictions in all luminance conditions", ACM Transactions on Graphics, 30(4), article no. 40, 2011.

[12] ITU-T Recommendation BT.709, "Parameter values for the HDTV standards for production and international programme exchange" (v6), June 2015.

[13] ISO/IEC 10918-1 | ITU-T Recommendation T.81, "Information technology - Digital compression and coding of continuous-tone still images - Requirements and guidelines", September 1992.

[14] ISO/IEC 15444 | ITU-T Recommendation T.800, "Information technology - JPEG 2000 image coding system: Core coding system", November 2015.

[15] ISO/IEC 23008–2 | ITU-T Recommendation H.265, "High efficiency video coding", February 2018.

[16] Docker installation instructions, https://docs.docker.com/install/.