



HDR10+ System Whitepaper

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HDR10+ Technologies, LLC

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Introduction

Display devices are acquiring the ability to show an increased range of brights, darks, and color leading to an increased realism. New standards for distribution of high-dynamic range (HDR) video have also been developed to try and take advantage of new display capabilities with the most common encoding being HDR10.

This rapid expansion has created disparate approaches to content creation, distribution and display that has created market confusion about HDR technology. HDR reproduction varies widely from device to device because of differences in display capabilities and due to inherent shortcomings in the original definition and implementation of HDR10 that encodes absolute luminance beyond the range of current display capabilities.

HDR10+ is an enhancement to HDR10 that allows flexibility and improved image appearance on a wide range of displays. This whitepaper gives a background on HDR video, describes motivation for the HDR10+ technology along with its use throughout this new video ecosystem, and illustrates how HDR10+ improves the HDR10 system.

Background on High-Dynamic Range Video

Artists have struggled for years to reproduce real world images within the limits of ink on paper, paint on canvas, projection on white screens and tracing electrons on glowing CRT picture tubes. They have been challenged to show detail and vibrant colors within a limited range of grey to white and for centuries have worked on increasing the palette of available colors.

Even the inventions of the 20th century, film and television, were unable to display the full range of scenes you can see in the real world. Directors of Photography have had to carefully manage mid-luminance levels so that faces appear proper to an audience while leaving room for highlights and capturing just the right amount of shadow detail. With careful exposure of either film negatives or digital cameras, the recorded image has still exceeded the range of print film and monitors.

An explosion of new digital technologies is allowing brighter and more colorful images: liquid crystal displays (LCD) with global backlight screens, organic light-emitting diodes (OLEDs), quantum dot (QD) enhancement layers and direct-view LED technology. All of these increase capabilities for brightness, wide color reproduction, and fine control of black details. Further developments in displays, like micro-LEDs, are in sight that will only increase HDR reproduction opportunities.

High-Dynamic Range Video Standards

In 2018, the International Telecommunications Union (ITU) defined a new worldwide standard for high-dynamic range video signals in a wide-gamut color space (BT.2100) that brings a new palette to visual displays.

In ITU Recommendation BT.2100, HDR Video is delivered using the Perceptual Quantizer (“PQ”) transfer function defined in SMPTE ST 2084 rather than the traditional gamma function defined in Rec BT.709. The signal is delivered in a video-range of 10-bits and can be passed through various video encoders for transmission. The PQ transfer function allows a luminance range of 0 to 10,000 cd/m² greater than any display capability: as part of the design, each value is supposed to create the exact luminance of each code value on a display.

Among the first adopters of the PQ transfer function, the Blu-ray Disc Association added the 10-bit video range signal to their standard and called it HDR10.

Along with the PQ video essence, metadata is delivered to define the limits of the image luminance that was encoded in PQ.

Unchanging metadata that applies to an entire title, static metadata is defined in SMPTE ST 2086 for the minimum and maximum mastering luminance and the chromaticities of the mastering display. Other metadata is defined in the CTA-861 and Blu-ray standards for Maximum Content Light Level (MaxCLL) and Maximum Frame Average Light Level (MaxFall). This metadata is delivered with the video content but applies a single set of data for an entire title.

High-Dynamic Range Content Workflows

Content has been mastered in HDR to provide creators the colorful and subtle image tones seen in today’s HDR displays.

Digital workflows from camera to mastered content employ a professional colorist to creatively adjust dynamic range of the recorded imagery to produce the best appearance on different devices. Ultimately, “tone mapping” is utilized as part of this creative process. Colorists can compress highlights, can increase or decrease shadow details, and can adjust for proper mid-tones and color contrast.

Creators may carefully manage the appearance of their HDR masters separately than their choices for Standard Dynamic Range masters (SDR). Image choices are driven by looking at a “Mastering Display” in a darkened room which typically has greater capabilities than available to consumers and is in an ideal viewing environment.

Once finished these new HDR masters may be 10-bit to 16-bit integer values or 16-bit floating point values in a variety of file formats all capable of storing final, mastered HDR content. Typical digital post-production workflows maintain 12-bits or higher with 32-bit processing.

The tremendous capability of high dynamic range source content is challenged when it comes to reproduction on diverse displays. Given the assortment of brightness capabilities and levels of black reproduction in displays and the fixed luminance design of the BT.2100 standard, the ability to get the best image out of televisions is compromised because the typical consumer device is not showing the full palette the content creator designed in post-production.

Limitations of Static Metadata

The version that creators see is in an ‘ideal’ world where the mastering monitor has at least as much range as the master, if not more, and is in an ideal dark environment. Static metadata alone does not provide enough information for a display to apply an appropriate tone map for each possible scene within a given video clip. The shape of the tone mapping is static and not optimized. For example the dynamic range of each scene is not considered with static tone mapping which results in global compensations being applied during playback of scenes which otherwise would not need any adjustment.

In many displays, there is only one fixed conversion from a bright image to the display’s dynamic range (see Figure 1). Yet, the scenes being reproduced consist of many different luminance levels (e.g. bright outdoor scenes, dark night scenes, explosions, etc.) and no single approach can perform an ideal tone map every time for all content types.

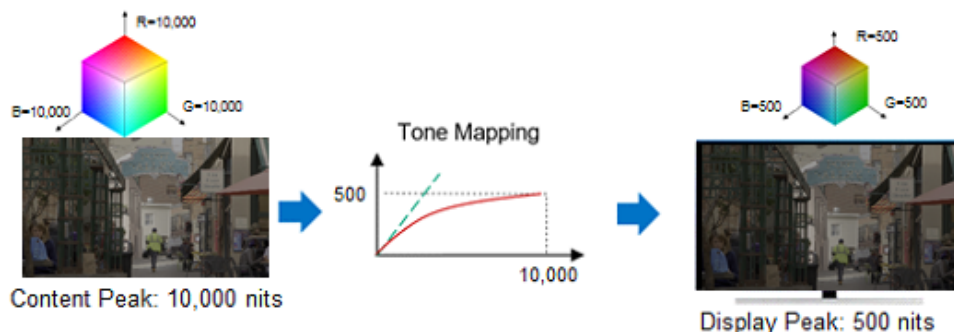


Figure 1 - Tone Mapping

(Image courtesy Amazon Prime Video)

Necessity of Dynamic Metadata

Dynamic tone mapping applies a different tone curve from scene-to-scene in order to limit the dimming and desaturation of the display that happens from static tone mapping. As seen on the left side of Figure 2, static tone mapping applies the same adaptation across an entire piece of content – bright and dark scenes alike. With dynamic tone mapping,

shown on the right side of Figure 2, an individualized tone map is applied adaptively for each scene allowing vibrant visuals and achieving unprecedented picture quality that better matches the filmmaker’s intent.

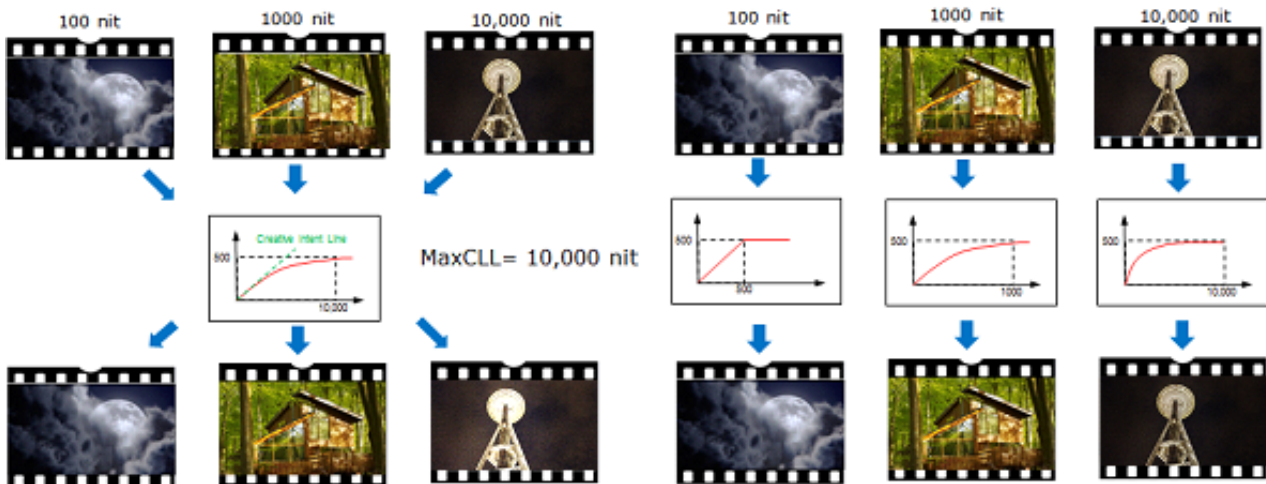


Figure 2 - Static vs. Dynamic Tone Mapping

(Image courtesy Amazon Prime Video)

The dynamic metadata in HDR10+ is necessary to provide the display with enough information to accurately reproduce and faithfully retain the intent of the original master. Such metadata will signal, as needed per scene or per frame, the scene characteristics – the binned statistics of all pixel values. This ‘fingerprint’ of a scene can show how bright or dark the important scene details should be. Any display can apply a guided tone mapping curve based on the extra information contained in the now dynamic metadata.

HDR10+ System Advantage

HDR10+ is the latest and most advanced HDR technology, building upon HDR10 to further enhance the viewing experience. HDR10+ signals not just the dynamic range (the ratio of light to dark) of video content on a scene-by-scene (or even frame-by-frame) basis, it also provides, in a small amount of metadata, the scene characteristics between bright and dark so that important detail can be kept. This enables displays to reproduce images more realistically, adhering to the creator’s intent.

Whereas static HDR, such as HDR10, utilizes static tone mapping uniformly across the duration of the content, HDR10+ employs dynamic tone mapping to optimize each scene individually increasing brightness and adding contrast to fit within a display’s capabilities.

HDR10+ is a royalty-free technology easily accessible to adopters – from movie studios and filmmakers to display and device manufacturers. HDR10+ is a technology that provides descriptive dynamic metadata and defines an ecosystem for optimized scene-by-scene dynamic tone mapping.

HDR10+ Workflows and Ecosystem

HDR10+ is designed to utilize an HDR10 master file and fits within existing HDR post-production and distribution workflows.

The HDR10+ ecosystem is used within current systems by

- storing HDR10+ metadata in JSON files
- embedding HDR10+ metadata into HDR10 content
- distributing through any digital stream (e.g. streaming/OTT is HDR10+ SEI)
- displaying the HDR10+ content on a capable display (e.g. HDMI interfaces is through HDR10+ VSIF)
- also displaying on mobile devices.

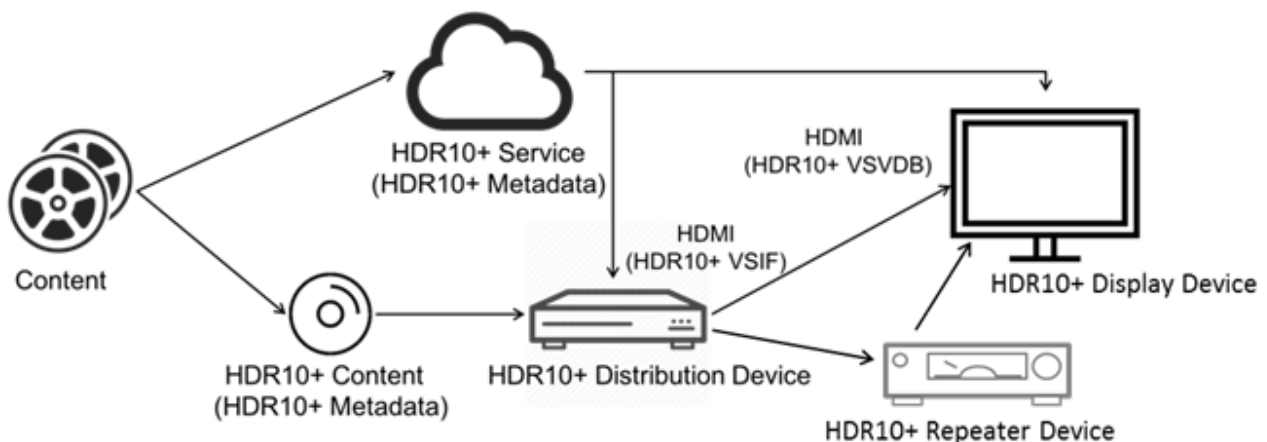


Figure 3 - Distribution Ecosystem

HDR10+ Metadata Generation

For offline and VOD (e.g. UHD Blu-ray, OTT, MVPD), HDR10+ Metadata may be created during the post-production, mastering process or during transcoding/encoding for distribution back-ends by HDR10+ content generation tools in two steps,

- 1) Identifying scene cuts, and
- 2) Performing an image analysis on each scene or frame to derive statistics similar to a histogram, and optionally providing a reference tone curve unique to each scene.

HDR10+ metadata is easily interchanged through a low complexity JSON-structured text file, which can be easily parsed and injected into video files every frame (duplicated per frame across scenes).

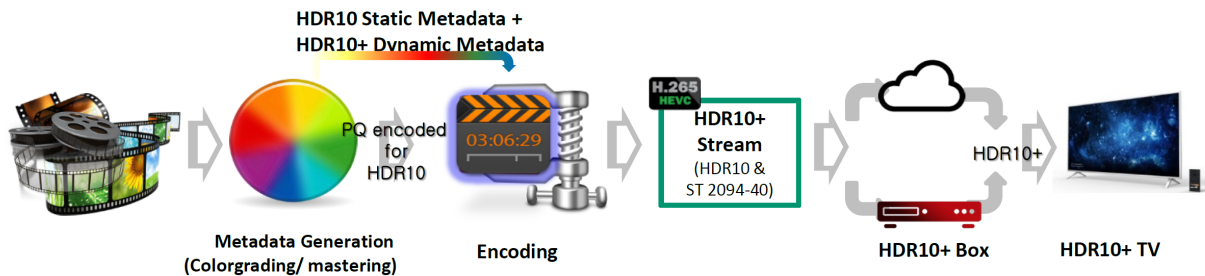


Figure 4 - HDR10+ Metadata Workflow

HDR10+ Live Encoding

As HDR10+ is delivered in every frame “live” use cases are thus enabled. Already HEVC encoders are available which generate metadata on live content as well as mobile phones which record video and generate HDR10+ metadata during the recording.

Live encoding is easily supported in encoders with the following workflow (see Figure 5). With a live encoder, real time broadcast operations are supported at the point of transmission enabling a metadata-less broadcast operation if desired.

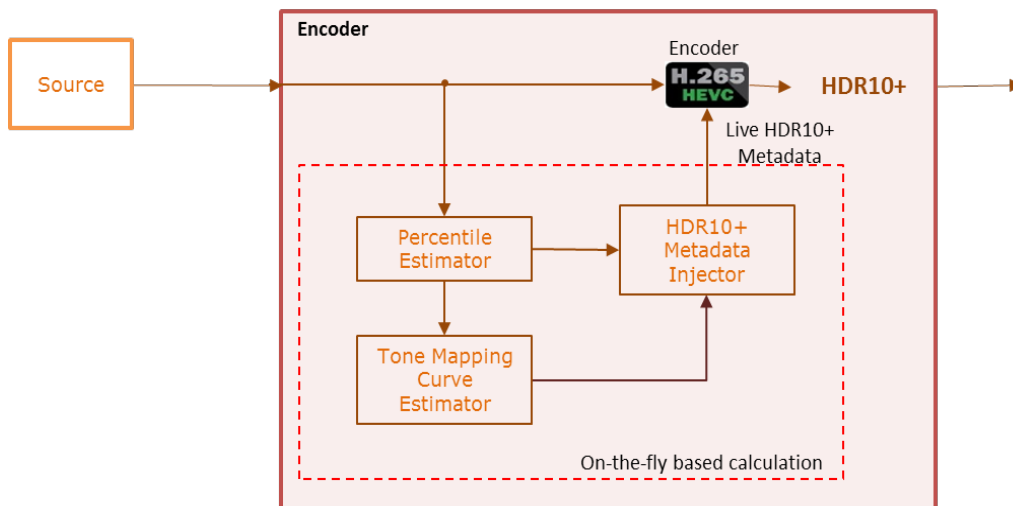


Figure 5 - Live Encoder Workflow

HDR10+ Backward Compatibility

HDR10+ metadata follows ITU-T T.35 and can co-exist with other HDR metadata such as HDR10 static metadata that makes HDR10+ content backward compatible with non-HDR10+ TVs as shown in Figure 6.



Figure 6 - HDR10+ Backward Compatibility

(Image courtesy Amazon Studios)

HDR10+ Applicable Content Profile

- EOTF: SMPTE ST 2084 (PQ)
- Chroma Sub-sampling: 4:2:0 (for compressed video sources)
- Resolution: Agnostic (2K/4K/8K, etc.)
- Bit Depth: 10-bit or more (up to 16-bit)
- Color Primaries: ITU-R BT.2020
- Maximum linearized pixel value: 10,000 cd/m² for each color R/G/B (content)
- Metadata (Required): Mastering Display Color Volume Metadata
- Metadata (Optional): MaxCLL, MaxFALL

No matter the workflow used, HDR10+ technology can support the full range of HDR standards to 10,000 cd/m², 8K and BT.2020 color gamut. Being resolution agnostic, metadata needs to be created only once and can be applied to any target resolution.

HDR10+ is applicable for HEVC and VP9 compatibility via WebM as well as any codec that supports ITU-T T.35 metadata.

Device Tone Mapping

HDR10+ displays will process the video, frame by frame, with HDR10+ metadata to apply the best tone mapping for the content on the device. An example diagram is shown in Figure 7.

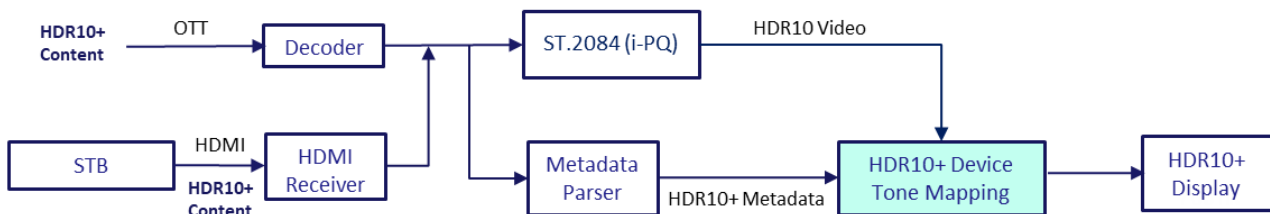


Figure 7 – HDR10+ Device Tone Mapping

Tone mapping happens when the source content peak luminance is higher than the display device peak luminance. Once HDR10+ content is delivered to a display device, the decoder will parse the HDR10+ metadata and video essence and process through the video pipeline. If a display doesn't support the HDR10+ metadata, it will be simply ignored as any other optional ITU-T T.35 metadata and the display reverts to show the strict version of HDR10.

The existing HDR technology, HDR10, leads to inconsistent reproduction of HDR content from one display device to another as only limited static metadata for content can be provided.

HDR10+ provides articulated scene based statistical data and optional guided tone mapping information to the display. This data enables a consistent reproduction of the source master content across displays of varying capability. Additionally, when a knee-point is included with HDR10+ metadata, displays maintain the content's original look in shadow detail as no tone mapping happens below the knee-point.

The Quality of HDR10+ tone mapping

As mentioned previously, HDR10+ processes images dynamically, which equates to scene-by-scene or frame-by-frame picture enhancement. HDR10+ allows displays to be fully capable of portraying optimized visuals with consistent color saturation and detail - no matter the display capabilities.

This dynamic approach to image optimization results in rich and accurate colors, increased scene highlights and more visible shadow details. It means that when watching a show or film, characters' expressions and the details of a scene appear crisp and nuanced, making the scene appear more lifelike. The following is a subset of image reproduction enhancements due to HDR10+ as contrasted to traditional HDR technology.

Shadow Details Remain (Figure 8)

Left-side Image - HDR10+ enables displays to show optimal curves with more control points than simple gamma or s-curves and does not require multiple versions to be created. For example low light details set in mastering are often crushed with a less sophisticated tone curve (like an s-curve) that then requires creatives to make additional versions to address curve limitations.

Right-side Image - HDR10+ follows the original artistic intent, up to the capabilities of the display (knee-point), before applying a tone curve. Dark details set in mastering are not tone mapped, preserving the creative look and feel in low-light areas.



Figure 8 - Shadow Detail

(Image courtesy Amazon Prime Video, fig. 8-11)

Preserves Color Hue (Figure 9)

Left-side Image - Changes in luminance can shift color hues causing color distortion if not properly applied in the correct proportions.

Right-side Image - HDR10+ tone mapping holds the color ratios constant when applying the luminance tone curve, preserving original color hue and only adjusting luminance.



Figure 9 - Hue Preserved

Banding Artifacts are Avoided (Figure 10)

Left-side Image - Banding is a common artifact introduced by discontinuities in a poorly constructed tone curve. Kinks or bends in a tone curve can result in visual artifacts.

Right-side Image - HDR10+ utilizes a smooth, nuanced and continuous tone curve based on scene pixel distributions and is free of banding artifacts.



Figure 10 – Banding*

* Artifact detail may not be visible in printed document.

Provides Details in Highlights (Figure 11)

Left-side Image - Details in highlights are easily washed out or clipped when tone mapped. Overly aggressive tone curve eliminates specular highlight details and clips the brightest pixels.

Right-side Image - HDR10+ metadata is generated on scene statistics so the highest color values are taken into account when creating the tone curve, gradients in highlights are retained and the brightest pixels in the source content are appropriately mapped to the display limits.

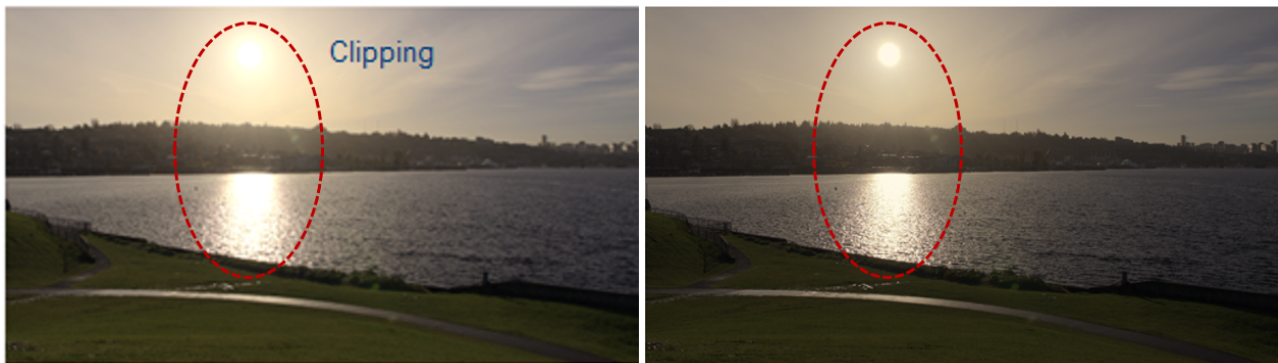


Figure 11 - Clipping

HDR10+ Adoption

HDR10+ is a royalty-free technology easily accessible to adopters – from movie studios and filmmakers to display and device manufacturers.

HDR10+ is available to support common post-production tools.

HDR10+ is a system that provides descriptive dynamic metadata and defines its ecosystem for optimized scene-by-scene dynamic tone mapping.

HDR10+ specifications for the logo are defined by the [HDR10+ Technologies, LLC](#) and adoption is encouraged for all --

- Ultra-High Definition displays,
- Ultra HD Blu-ray disc players,
 - Systems-on-chip (SoC)
 - Set-top boxes
 - A/V Receivers
 - Streaming applications
 - Mobile Displays

All players in the HDR ecosystem can adopt the technology to ensure the most robust dynamic metadata is broadly available.

Overview of HDR10+ Technologies, LLC

HDR10+ Technologies, LLC administers the license and certification program that ensures a premium HDR viewing experience for the HDR10+ ecosystem. HDR10+ Technologies, LLC provides the technical specifications, test specifications, and certified logo. Certification is provided through third-party Authorized Test Centers.

HDR industry stakeholders such as content providers, content distributors, display and distribution device manufacturers, systems on chip (SoC) manufacturers, tool makers and others can join the HDR10+ License program.

A current list of HDR10+ adopters can be found on the HDR10+ website, <https://hdr10plus.org/adopters/>.

For more information about becoming an adopter of HDR10+ or information about this white paper, please contact

email: info@hdr10plus.org or

submit a registration form to HDR10+ Technologies, LLC,
<https://hdr10plus.org/registration/>.

This document or its latest version is available at <http://www.hdr10plus.org>

