



Nucoda

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Film and Video Restoration

Working in High Dynamic Range  
2018.3 R2



# Working in High Dynamic Range 2018.3

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## Grading HDR material

- ST 2084 PQ - This includes deliveries for the HDR10 specification - we do not calculate the MaxFall and MaxCLL values.
- ST 2100 Hybrid Log Gamma - (BBC/NHK HDR BT.2100)
- **Dolby Vision** - based on ST2084 PQ it is a system that utilises 12 bit monitoring and dynamic metadata to map to different monitor brightness levels. Setup and working in Dolby Vision is covered in a 'HDR Mastering with Dolby Vision - 2018.3'

### Things to remember about mastering material for HDR

- Although formats like HDR10 and HLG specify delivery in 10 bit, working with material that was captured on a camera with as much dynamic range as possible will dramatically increase your options while grading. Even moving to 12 bit will make a difference in what you can achieve. Using material
- Mastering in HDR currently requires a monitor that is capable of applying the HLG or PQ EOTF (Electro Optical Transfer Function) in the monitor, the specification also requires the mastering monitor to be a rated to display a minimum of 1000 nits, and be able to display P3 and 2020 colour gamuts. Currently the only monitor capable of this is the Sony X300, it is able to display most of the P3 gamut but not all of the BT.2020 colour gamut.
- It is your choice whether to master the Rec.709 or HDR versions first and to derive the other master afterwards, but you should ensure that there is time allocated to do a trim pass or regrade for the second version as conversions do not always provide the best results.
- You should be aware, and bear in mind the requirement to convert between colour spaces for deliveries. While going between Rec.709 and P3 is a common conversion, the size of the 2020 gamut can cause issues if materials were graded and there are colours that fall outside the Rec709 or P3 gamut. This is where ACES could be a benefit.
- Online for final delivery should be done on a system capable of working with EXR files, such as Smoke or Flame
- Make sure that titles and supers are not at peak white - bear this in mind for GFX design.
- HDR standards are still changing and you should ensure that you double check the requirements for deliverables and ask questions if the requirements don't make sense or is confusing.
- It is advisable to have technical monitoring with CIE charts to help guide the process.

**PQ-2084 is not a color space, it is a Transfer Function, it is more often referred to as PQ space.**

## Technical requirements for mastering at HDR

### HDR Monitoring

The recommendation for HDR mastering is a monitor that can come close to displaying P3 and Rec.2020, and is capable of peak brightness level of at least 1000 Nits.

Currently this is the Sony BVM X300 and some non-commercially available displays from Dolby.

- Choose a monitor that is suitable for working in HDR and connect it to the Kona 4.
- Make sure the monitor is correctly set up - check your delivery specifications.
- For delivery in HLG the Sony X300 monitor should be set to HLG SG Variable in the menu.

The monitor must be set up in **full range** for working in ACES and in HDR in general, to set the monitor to full range the output must be 10 Bit 444 RGB or 12 bit 444 RGB - full range is not available in YUV 422.

### Technical Monitoring

In Nucoda and Phoenix you can use the Luma\_PQ and RGB\_PQ scopes to measure the signal it is possible to use non HDR scopes to work in HDR.

The signal will still fit within the 10 bit full range scale (4 to 1019 if you are being absolutely faithful to the SDI specification) - for the rest of us 0 - 1023 will work. If you are grading HDR the values will map to the waveform roughly as follows:

- 1023 = 10,000 nits - Theoretical peak luminance
- 920 = 4000 nits - peak luma on Dolby Pulsar (not commercially available)
- 844 = 2000 nits - peak luma on Dolby PRM 32FHD (not commercially available)
- 767 = 1000 nits - peak luma on a Sony BVM X300
- 711 = 600 nits - peak luma on a PRM 4220
- 528 = 108 nits - Dolby Cinema projector peak luminance
- 519 = 100 nits typical maximum for Rec.709 SDR monitor
- 447 = 48 nits - peak luma on a standard cinema projector
- 0 = 0 nits - black, corresponds to less than 0.05 nits on LCD, 0.0005 nits on OLED display

Working within these ranges when grading the HDR version should ensure that the SDR version has no clipping issues if you are going to try and conversion between PQ and rec.709

### Mastering and File delivery

Once the grade is complete you will require additional software to allow mastering of your content if a format such as IMF or HEVC is required. Proper mastering is essential.

For HDR10 deliveries masters must be delivered with MaxFALL and MaxCLL static metadata values (SMPTE ST 2086:2014) -this calculation can be done using Dolby Vision analysis and using the calculate HDR10 option - this will calculate the values for all selected clips.

Mastering and file delivery systems include:

[Colorfront TransKoder](#) - [DVS - Clipster](#) - [Marquise Technologies](#) - [MIST](#) - [MTI Cortex Enterprise](#)

## Choosing a Workflow and Project setup

Working in HDR in is very similar to grading any other project. There will most certainly be a requirement for both and HDR and SDR delivery. A decision will have to made on which version should be created first. Whatever the outcome, time will be needed to do a trim pass or a re-grade on the other version.

This post from Alexis van Hurkman is has some insights into creative grading in HDR and is well worth the read. [HDR, Resolve and Creative Grading](#) (permission provided)

### HDR grading using ACES

ACES provides standardised transforms to ensure that all material is presented in a unified colour space, and also provides a standardised way of creating multiple colour space and display deliveries from a single master.

Using the ACES workflow it is possible to more easily create different masters based on ACES output transforms.

Material can also then be exported and archived as linear scene referred images, making it easy to create other masters as required.

#### [ACES documentation](#)

The project will store files in half float, as EXR files. These files are larger than DPX 10 bit files normally used and may require a more powerful workstation and fast storage, especially for UHD work.

### Project setup

Add a project name in the dialog box  
Select a resolution and frame rate for the project.

Create additional output formats set to the same resolution and frame rate as the main output format.

In the colour space menu, select *ACES* and select *V1.1*  
Select *ACEScct* as the working colour space

In the CMS/ACES menu select ACES output transform and then set the output transform that matches your mastering monitor, use the ST2084 transforms for the HDR grade. For SDR versions, select the matching output transform.

Likely transforms would be:

- Rec.2020\_1000nits\_15nits\_ST2084\_P3\_Limited (HDR10 Amazon)
- P3D65-1000 nits-15 nits-ST2084 (HDR10 - Dolby Vision)
- Rec.2020-1000 nits-15 nits-HLG (BBC/NHK Hybrid Log Gamma)
- Rec709 or Rec.709 Clip

Each output format will have its own output transform set. Make sure to enable the "Apply CMS" button to ensure that the rendered image contains the required transform as part of the output.

The first, or main output format, cannot render the transform as part of the image, it is purely for monitoring and creating scene linear exports in the ST 2065-1 colour space.

### Creating other masters from the HDR master

After completing the PQ grade - make a copy of the composition and switch the output format to the Rec.709 version. Trim the SDR version to create the Rec.709 master.

Follow the same procedure for the HLG master, remember that the HLG master is used for both HLG and SDR, so during grading it may be prudent to regularly compare the HLG and SDR version to make sure the best look is achieved for both versions.

#### Using Dolby Vision Content Mapping to create your SDR master

It is also possible to use the Dolby Vision analysis and combined with the Integrated Content Mapping to create the 100 Nit Rec.709 version. **Note:** You are not creating a Dolby Vision Master, just using the Dolby Vision content mapping to create a good starting point.

Please be sure to check the "HDR Mastering in Dolby Vision 2018.3" guide for help.

If you worked in ACES you don't have to create a SDR output transform since Dolby Vision will do the mapping to SDR. Make sure you use a secondary output with "Apply CMS" enabled

Unless you have a Dolby license you will not be able to use the Dolby Trim controls, however, using the analysis and mapping could possibly put you in a good starting place for the SDR version.

Turn on Dolby Vision 2.9 or 4.0 (4.0 could possibly provide improved analysis and mapping results to 2.9)

You can always use the master layer to trim the grade slightly, as this will affect the content mapped version. Once you are happy with the result you can export the content mapped version as a Rec709 100 nit master. Make sure Dolby CM is turned on in export options.

## HDR grading in Full Range - RGB 444

If you do not want to grade in ACES, then work in a full range project, with the project bit depth set Half. Ensure that the material is correctly prepared to allow grading in PQ. It is recommended that material is all set to Half in the material properties.

The workflow is display referred, that is, the material is graded to look correct on the mastering monitor, this means that if the image on the monitor is correct, the output files will be correct for the connected display.

Ensure that the display is set up correctly.

For HDR10 it will be Rec.2020 D65 ST2084 or P3 D65 1000 Nits - see your project specifications.  
For HLG set to Rec.2020 D65 HLG SG Variable (on Sony X300)

If the material is in Log-C or S-Log3 it is possible to grade the content directly to the monitor without any transforms required.

If you are using 2018.2 or later, use the Colour Convert tool to convert your material by changing colour space and curve and apply the PQ EOTF.

If the material is P3 or Rec.709 it should be converted using the Colour Convert tool.

Using this type of material is not ideal as dynamic range could have been lost during the original mastering process. But it is conceivable that clients may want to repurpose material for HDR, when the original masters no longer exist.

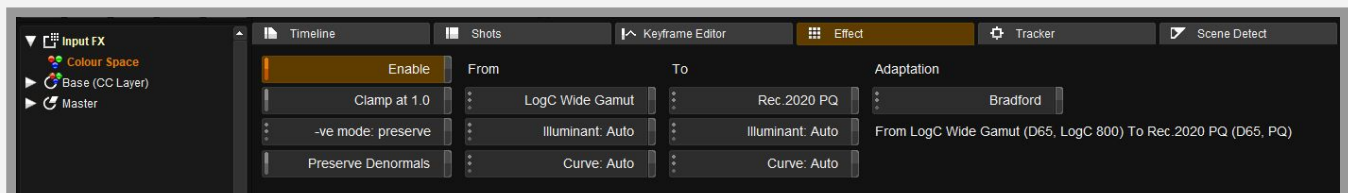
### Preparing RAW or Log material

It is preferred that the source material is either RAW or in a Log space, such as Arri LogC, Slog2 or Slog3 or REDLog. This ensures that there is as much dynamic range available for the grade as possible.

RAW material can be decoded to PQ if the option is available in the RAW converter, else, decode to a preferred colour space like Alexa Wide Gamut and use the Colour Space convert tool to convert to Rec.2020 PQ or P3 PQ. Material with PQ applied will look Log like when viewed on a monitor without PQ enabled.

### Colour Space Convert

- The Colorspace tool has been added to allow for simple accurate conversion between colour spaces. It can be applied as an input effect or user effect. It allows the user to select the input and output from a preset list that can be updated by the user.
- The tool covers all the major colour spaces, illuminants and curves and also has settings for chromatic adaptation. Custom Gamma can also be entered by selecting Gamma in the curve dropdown.



## Creating other masters from the HDR master

After completing the PQ grade - make a copy of the composition and switch the output format to the Rec.709 version. Trim the SDR version to create the Rec.709 master.

Follow the same procedure for the HLG master, remember that the HLG master is used for both HLG and 709 , so during grading it may be prudent to regularly compare the HLG and 709 version To make sure the best look is achieved for both versions.

### Using Dolby Vision Content Mapping to create your SDR master

It is also possible to use the Dolby Vision analysis and combined with the Integrated Content Mapping to create the 100 Nit Rec.709 version. **Note:** You are not creating a Dolby Vision Master, just using the Dolby Vision content mapping to create a good starting point.

Please be sure to check the "HDR Mastering in Dolby Vision 2018.3" guide for help.

If you worked in ACES you don't have to create a SDR output transform since Dolby Vision will do the mapping to SDR. Make sure you use a secondary output with "Apply CMS" enabled

Unless you have a Dolby license you will not be able to use the Dolby Trim controls, however, using the analysis and mapping could possibly put you in a good starting place for the SDR version.

Turn on Dolby Vision 2.9 or 4.0 (4.0 could possibly provide improved analysis and mapping results to 2.9)

You can always use the master layer to trim the grade slightly, as this will affect the content mapped version. Once you are happy with the result you can export the content mapped version as a Rec709 100 nit master. Make sure Dolby CM is turned on in export options.

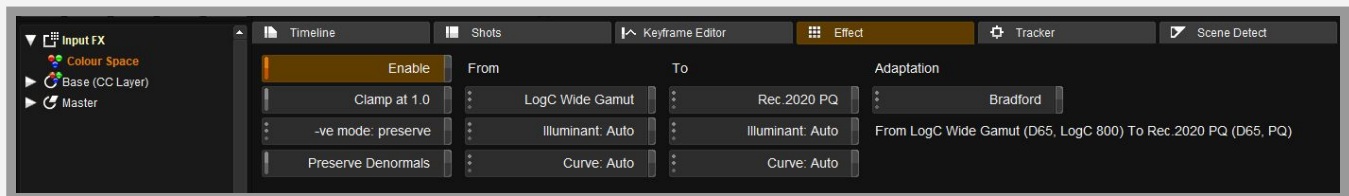


## Tools and options to make HDR easier

**Note: Full colour correction layers only in Nucoda and Phoenix Finish**

### Colour Space Convert - new in 2018.2

- The Colorspace tool has been added to allow for simple accurate conversion between colour spaces. It can be applied as an input effect or user effect. It allows the user to select the input and output from a preset list that can be updated by the user.
- The tool uses GPU acceleration and covers all the major colour spaces, illuminants and curves and also has settings for chromatic adaptation.
- Custom Gamma can also be entered by selecting Gamma in the curve dropdown.
- Remember that chromatic adaptation will only be valid when there is a change in the illuminant.



### PQ Matrix and Gamma Matrix tools

The Gamma Matrix is used to linearize image gamma and the PQ Matrix is used apply or remove the PQ Transfer function to linear images. Both tools need to be applied to Rec.709 and P3 material in order to grade in PQ. Using this type of material is not ideal as dynamic range could have been lost during the original mastering process. But it is conceivable that clients may want to repurpose material for HDR, when the original masters no longer exist.

A typical scenario might be that you are working in a project with a PQ monitor as an output. If the monitor is set to apply the PQ EOTF, your material must have the PQ Curve applied. At this point you will need to apply a Gamma Matrix to make the images linear, then use the PQ Matrix

So the PQ Matrix and Gamma Matrix would be added to the process tree.

Gamma Matrix:

- Pre Transform would be set: From PQ
- Apply Matrix (if required)
- Post Transform would be set: From PQ

The PQ Matrix could also provide an alternative workflow option to use SMPTE 2084 without having the project setup for HDR-ACES. For this you will need to have the project bit depth set to Half.

You can also use the tool to pre-convert material to PQ before delivering to VFX.

This transform is not needed if you are working in an ACES project or if you are using Log material you are grading directly to the PQ display, this is because PQ is display referred.

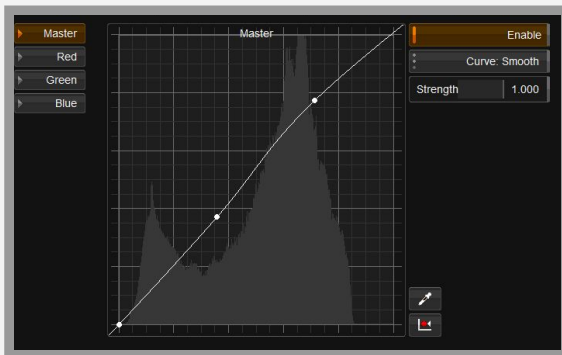
## Colour tools for working in HDR

Certain colour tools have been updated to better support both HDR, PQ and ACES grading.

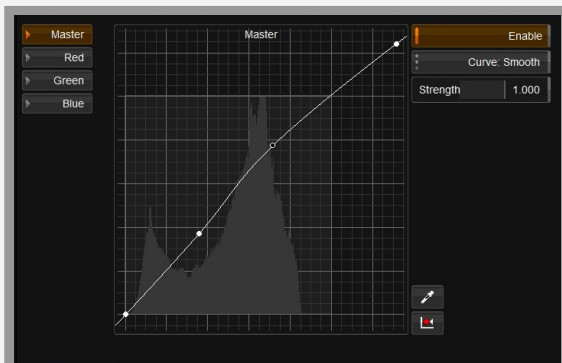
### RGB Curves

The RGB Curves tool has been updated so that the graphs can be manually scaled and points can then be easily added beyond the normal 1.0 range.

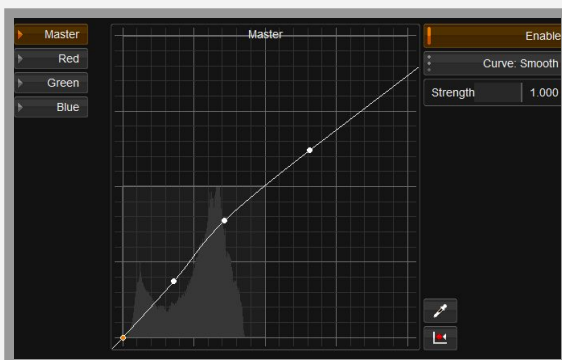
NOTE: Due to the changes that have been made to this tool it should be understood that if a project that utilised RGB Curves from an earlier version of software is attached in there could be a difference in the render result.



Shown here is the graph scaled to fit using the F hotkey.  
Fits to the default range which was set at 0-1



In this image the new Ctrl F hotkey is used to scale to Max value of the curve



This image shows the same graph as above but scaled to the 0-4 range

## Soft Clip

The Soft Clip tool has been enhanced so that when the HDR Max value is adjusted the Clip value automatically scales to the same value. HDR Max allows setting the soft clip level at point higher than 1000 nits.

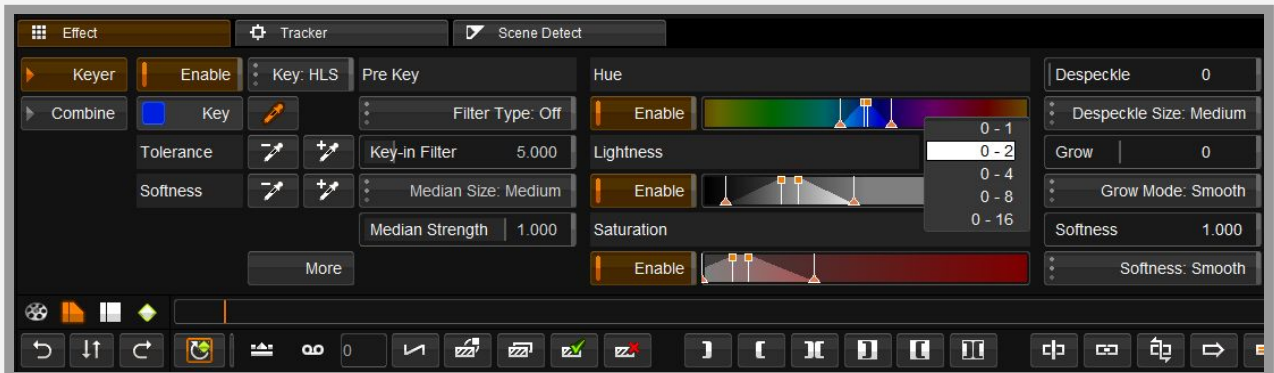


## Isolation Tools

Isolation tools have been updated to better support both HDR, PQ and ACES grading.

### HLS Keyer - With Lightness Range control

This new control allows the user to scale the Lightness control in the HLS keyer to be able to have better control when working with HDR imagery

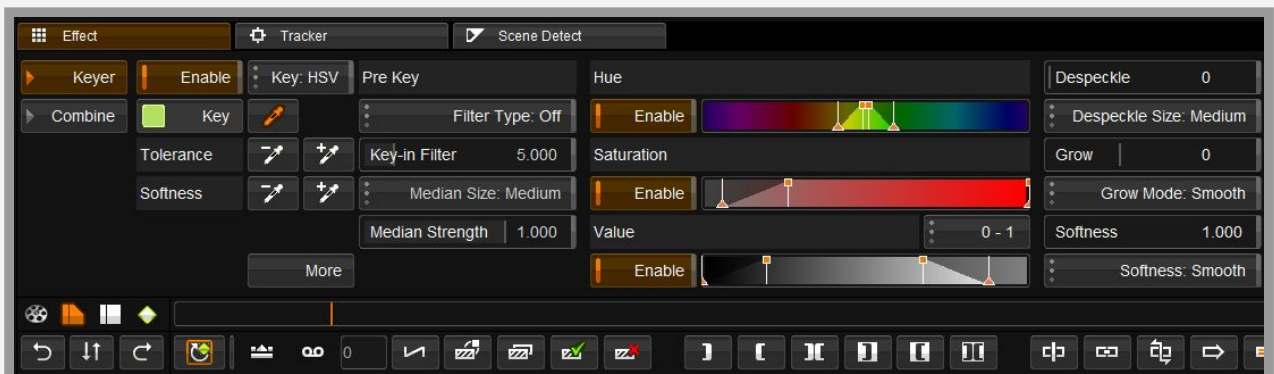


## HSV Keyer

A new keyer has been added - Hue, Saturation, Value.

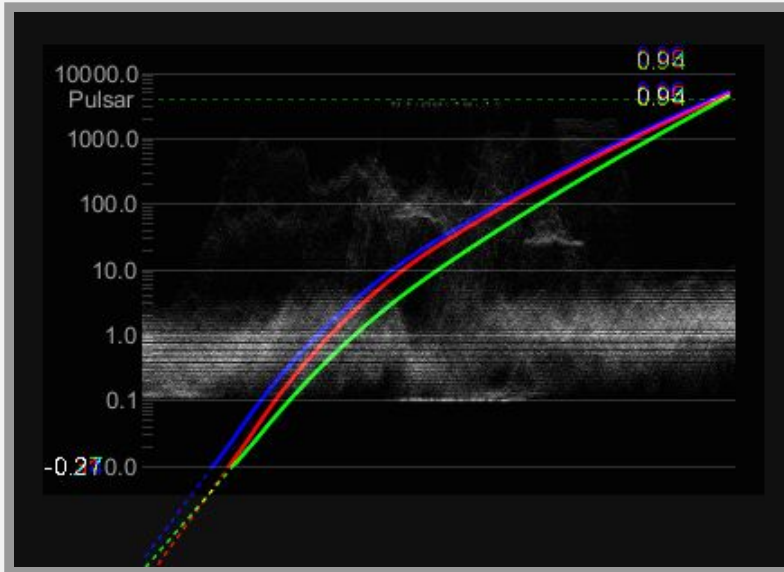
This is a much better tool for working with HDR images than the traditional HLS keyer.

It also has a Value range control.



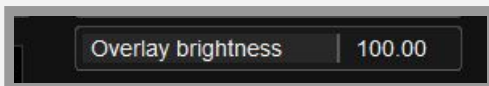
## New PQ Waveforms Waveforms

Dedicated P3 PQ and 2020 PQ Waveform have been added. Scaling is in Nits. Pixel selection allows the user to get values on selected pixels



## Application Preferences Overlay Brightness

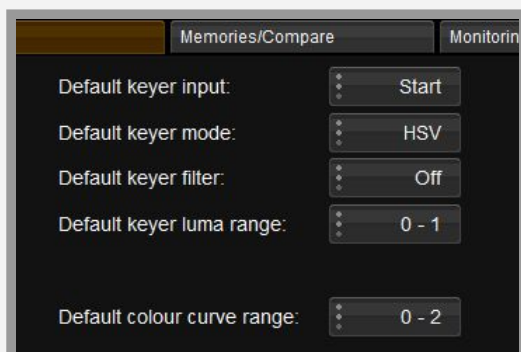
When working with HDR monitors the overlays used in the product (i.e. Grids, Borders, Keys, Mattes etc.) would all be at maximum brightness and could disturb the user.



Preference in Monitoring/Video IO tab (select next for second page) This enables you to set the brightness of the overlays.



Preference to select default keyer and the default luma range.



Preference to select the default colour curve range.

## Appendix

### Why is ACES particularly well suited for working in HDR?

**Excerpt from the SMPTE document : Study Group On High-Dynamic-Range-HDR-Ecosystem**

#### **Appendix B: HDR Tone Mapping Technologies**

##### **B.1: Academy Color Encoding System (ACES) for HDR and WCG Mastering:**

ACES is a color management and image interchange framework for production, mastering, and long-term archiving of digital content. It is designed to bring images from multiple sources into a common color space and provide a standard approach for viewing the images across a wide variety of output devices, including high-dynamic range and wide-color gamut displays. ACES images are used as a 'digital negative' allowing high fidelity manipulation while output tone curves that limit the dynamic range are deferred to a set of 'virtual prints' for different output display capabilities. ACES serves the purpose of a Digital Source Master feeding distribution of mastered content into digital cinema, film exhibition, broadcast, and home entertainment.

The ACES system preserves all of the information captured by cameras through use of 16 bit half-floating point values that cover 33 stops of dynamic range, more than double any existing camera encoding.

The ACES color space (ST 2065-1) covers the entire visible color gamut, and the primaries can be described as wide RGB primaries (not XYZ).

Images are converted into the linear-light ACES space with an input transform (IT: Input Transform) that converts colors from the native camera response to a colorimetric encoding (ACES: also the name of the color space).

Photographic exposures are referenced to a system design point -- a mid-grey value of 0.18 in ACES -- loosely representing the scene-referred color value of a properly-lit 18% grey card. ACES code values are equal to each other at the white point D60, a default which is considered more pleasing in theatrical presentations, but grading can change scene white balance to any value.

ACES images are viewed using an ACES Viewing Transform which provides an adjusted 'rendered' image appropriate for viewing in a dark-surround environment whether in the theater or at home. Production users may often select from a list of ACES Viewing Transforms that include other output devices (OT: Output Transforms) which can also be software customized for different signal encodings, transfer functions, color spaces, white points, viewing surrounds, and dynamic ranges devices at 100 cd/m<sup>2</sup>, 600 cd/m<sup>2</sup>, and 1000 cd/m<sup>2</sup>.

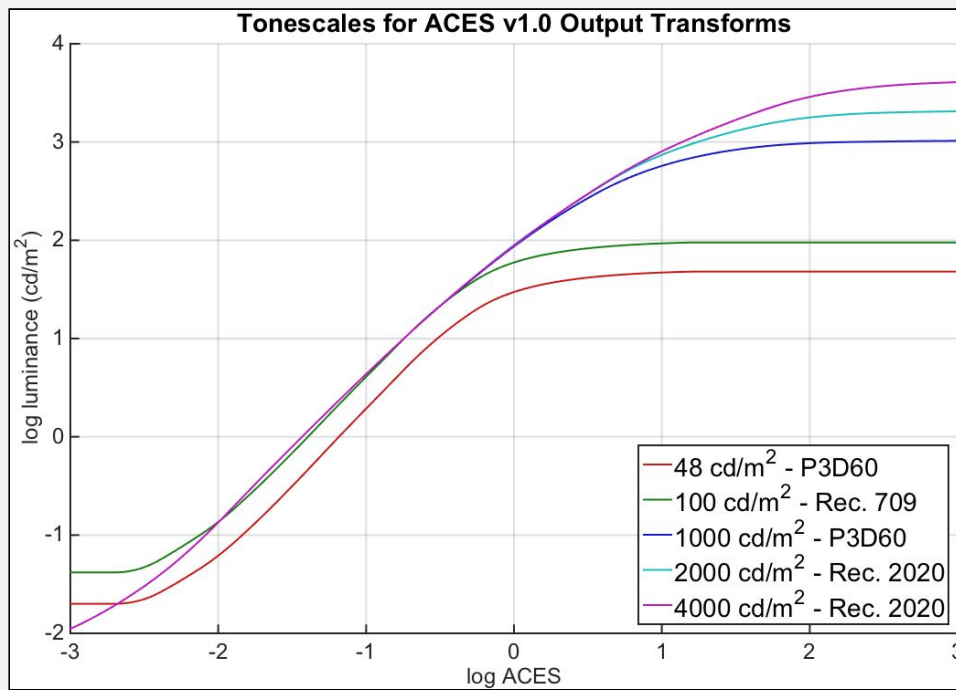


Figure B-1: ACES system tone curve

For HDR production, ACES has a consistent set of viewing transforms based on S-shaped tone curves as seen in Figure B-1:

HDR masters can be quickly created for different dynamic range displays using a colorist graded ACES master. OTs for different dynamic ranges have similar shapes, but the center of the curves are common to each other (though different for cinema than video), and content that is in the mid-tone region should look similar on different devices regardless of the extended highlight range or extended shadow range. Color space conversion from Rec.2020 to Rec.709 is handled in the OT where ACES uses fairly simple techniques using tone curve compression and saturation adjustments. Corrections for dim surround, chromatic adaptation to D65, and corrections for shadow colors and the Hunt effect are included in the transforms.

ACES ODTs for HDR at 1000 cd/m<sup>2</sup> 2000 cd/m<sup>2</sup> and 4000 cd/m<sup>2</sup> are present in the ACES v1.0 release distribution although tagged as 'for evaluation'. ACES preserves a lot of flexibility for HDR and WCG production since the original image can be manipulated without compromising the dynamic range or color space coverage.

ACES 1.03 is described in SMPTE standards:

- ST 2065-1:2012 Academy Color Encoding Specification
- ST 2065-2:2012/ST2065-3:2012 Academy Printing Density & Academy Density Exchange -ADX
- ST 2065-4:2012 ACES Image Container File Layout and features described [oscars.org/aces](https://oscars.org/aces)

## Links and documents for additional reading

### HDR TV Standards

The following standards have so far been created by various organisations such as The Society of Motion Picture and Television Engineers (SMPTE), the Consumer Electronics Association (CEA), Motion Picture Experts Group (MPEG), The International Telecommunications Union (ITU), and the Blu-ray Disc Association (BDA)

#### **SMPTE ST2084:2014 (and CEA-861-3)**

Standard for an Electro-Optical Transfer Function (EOTF) for HDR that was developed by Dolby Laboratories. Used in HDR10, Dolby Vision and Technicolor/Philips

#### **SMPTE ST2086:2014**

Defines static metadata; metadata that does not change during playback of the video content.

#### **SMPTE ST2094**

Which is under consideration, along with CEA-861-G/HDMI 2.x, will define (dynamic) metadata.

#### **ITU-R Rec BT.2020**

Defines a wide gamut color space, among other aspects of a UHD TV system.

#### **ITU-R Report BT.2381-0 (07/2015)**

Requirements for High Dynamic Range Television (HDR TV) Systems, is a summary of performance criteria that should be met by a newly implemented HDR TV delivery system that includes the criterion of backward compatibility of HDR content with SDR displays.

#### **ITU-R -Report-BT.2390-2016**

High dynamic range television for production and international programme exchange

#### **ITU-R-REC-BT.2100-0-201607**

Image parameter values for high dynamic range television for use in production and international programme exchange - Recommendation for adopting PQ and HLG

#### [Study Group On High-Dynamic-Range-HDR-Ecosystem](#)

This is a comprehensive document from the SMPTE Study Group and has a lot of information on HDR.

[www.smpte.org](http://www.smpte.org)

#### [HDR Demystified](#)

Created and maintained by the folks at [www.spectralcal.com](http://www.spectralcal.com) - please sign up for updates

#### [HDR\\_X300 Explained](#)

Document from Sony with information about the Sony X300

#### [Ultra High Definition Video Formats and Standardisation - BT Media](#)

BT Report on UHD and UHD formats <http://www.btplc.com/innovation>

#### [Understanding UHDTV Displays with HDR, HLG, and WCG](#)

Very informative technically accessible explanations

#### [HDR, Resolve and Creative Grading](#)

This post from Alexis van Hurkman has some insights into creative grading in HDR and is well worth reading

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