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Standards, HDR, and Colorspace

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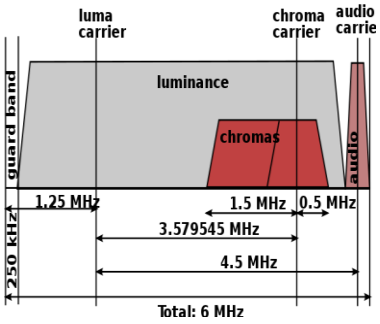
Introduction

- **Lets begin with a true/false question: Are high dynamic range (HDR) and wide color gamut (WCG) the next big things in displays?**
- If you answered "true", then you get a gold star!
- The concept of HDR has been around for years, but this technology (combined with advances in content) is now available at the reseller of your choice.
- Halfway through 2017, all major display manufacturers started bringing out both midrange and high-end displays that have high dynamic range capabilities.
- Just as importantly, HDR content is becoming more common, with UHD Blu-Ray and streaming services like Netflix.
- Are these technologies worth the market hype?
- Lets spend the next hour or so and find out.

Broadcast Standards

Evolution of Broadcast - NTSC

- **The first NTSC (National Television Standards Committee) broadcast standard was developed in 1941, and had no provision for color.**
- In 1953, a second NTSC standard was adopted, which allowed for color television broadcasting. This was designed to be compatible with existing black-and-white receivers.
- NTSC was the first widely adopted broadcast color system and remained dominant until the early 2000s, when it started to be replaced with different digital standards such as ATSC.



Evolution of Broadcast - ATSC 1.0

- **Advanced Television Systems Committee (ATSC) standards are a set of broadcast standards for digital television transmission over the air (OTA), replacing the analog NTSC standard.**
- The ATSC standards were developed in the early 1990s by the Grand Alliance, a consortium of electronics and telecommunications companies assembled to develop a specification for what is now known as HDTV.
- The standard includes a number of patented elements, and licensing is required for devices that use these parts of the standard.
- ATSC1.0 includes two primary high definition video formats, 1080i and 720p. It also includes standard-definition formats, although initially only HDTV services were launched in the digital format.

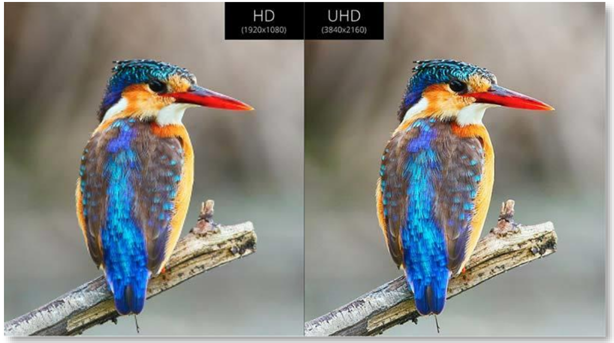
ATSC

How About ATSC 2.0?

- **ATSC 1.0 is still the standard in use today. Since the digital transition, just about everything about video and audio delivery has changed.**
- Radio spectrum is at a premium having been scooped up by wireless operators, and video and audio streaming efficiency has improved dramatically.
- Mobile devices (like tablets and smartphones) and over-the-top (OTT) streaming services (like Netflix and Hulu) have proliferated.
- Most importantly, consumers have come to demand internet-like interactivity and beautiful HD picture quality.
- **This is why a planned update to ATSC 2.0 has been eclipsed and replaced by ATSC 3.0.**

Evolution of Broadcast - ATSC 3.0

- **ATSC 3.0 is the newest version of the ATSC standards and as noted before, eclipses ATSC 2.0.**
- ATSC 3.0 will support mobile television, 3D television, 4K UHD, high dynamic range (HDR), high frame rate (HFR), and wide color gamut (WCG).
- ATSC 3.0 will provide more services to the viewer, increased bandwidth efficiency, and better compression performance – all of which requires breaking backwards compatibility with the original ATSC system.



Evolution of Broadcast - ATSC 3.0

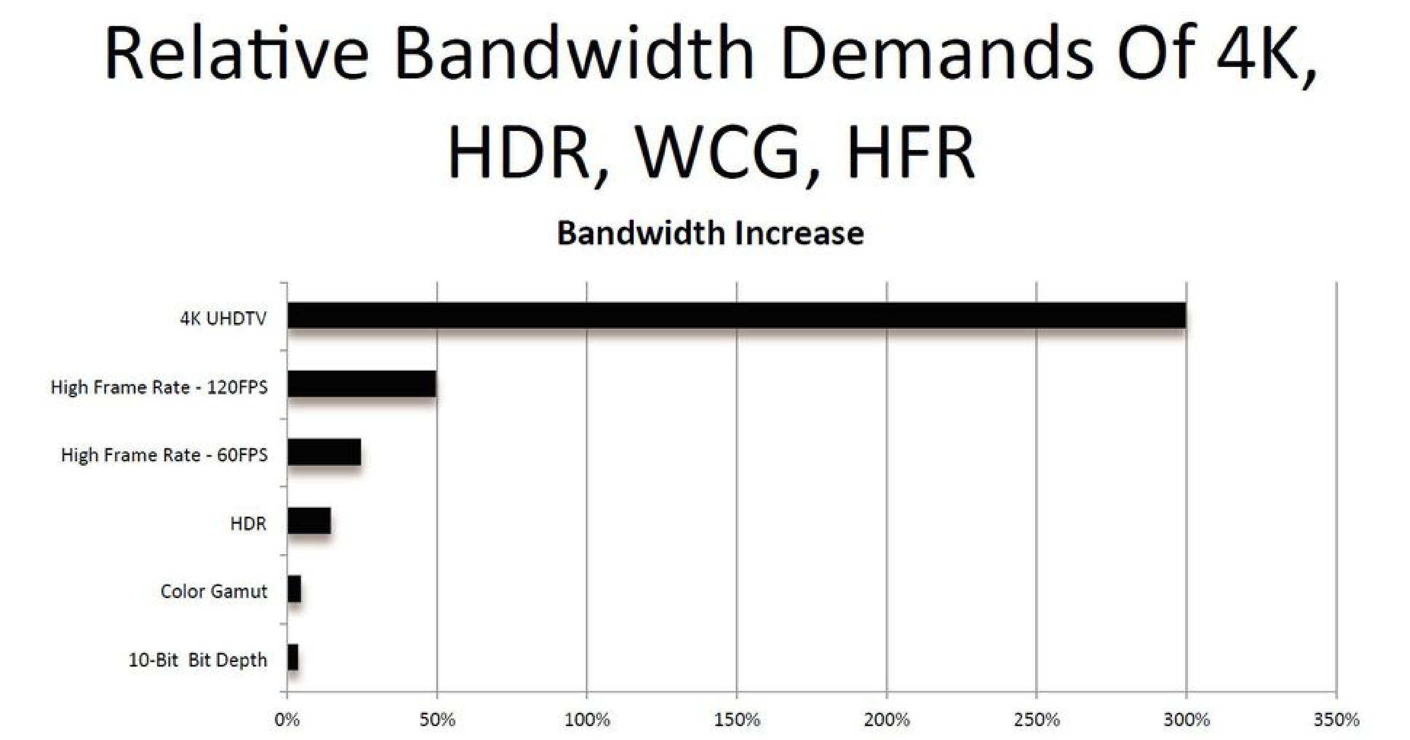
- **Promising to deliver ultra-high definition (UHD) TV anywhere, anytime, ATSC 3.0 is an Internet Protocol (IP)-based Over-the-Air (OTA) TV broadcast system that combines broadcasting and broadband internet.**
- It's not expected to come to early-adopters in the US until 2019 at the earliest, so you'll be able to enjoy your current OTA TV technology until then… and beyond.
- In a nutshell, ATSC 3.0 will be a hybrid television delivery system. The audio and video content will be broadcast OTA, and other content - like targeted ads - will be sent over your internet connection and integrated into the program.
- This will require a different kind of OTA tuner, which will essentially be an ATSC 3.0 home gateway that connects to your home Wi-Fi router.

ATSC 3.0

ATSC 3.0 Benefits

- **The best news is that OTA signals will be stronger with ATSC 3.0 than today's digital broadcast TV and will propagate over greater distances and deeper into buildings.**
- Benefits:
  - Ultra high definition
  - Better reception
  - IP transport
  - Mobility
  - Better audio
  - Advanced emergency alerts
  - In-car TV

ATSC 3.0 Bandwidth Increases



UHD Differences – An Overview

Courtesy of the UHD Alliance™

UHD Alliance™ Premium Certification

- **The UHD Alliance's ULTRA HD PREMIUM logo identifies products and services that meet or exceed strict performance levels for resolution:**
  - 4K resolution (4 times sharper than HD)
  - high dynamic range (HDR – brilliant brights, deepest darks)
  - wide color gamut (more lifelike colors),
  - immersive audio (multi-dimensional sound).
- These performance advances enable certified displays, content and other devices to fully replicate the richness of life's sights and sounds, and allow viewers to more accurately experience the content creator's vision.

UHD ALLIANCE ULTRA HD™ PREMIUM

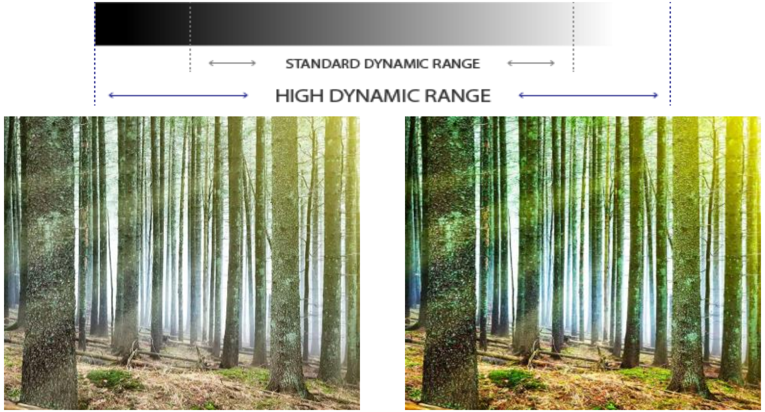
UHD Alliance Specifications

- **Resolution**: 3,840x2,160 pixels
- **Color depth**: 10-bit
- **Color gamut**: Wide, including the ability to show at least 90 percent of the P3 color gamut. Rec. 2020 on the CIE chart.
- **High dynamic range**: Specifically the ability to use SMPTE ST2084's electro-optical transfer function, which Dolby helped create.
- **Minimum brightness and contrast ratios**: There are two possible minimum specs. A minimum brightness of 1,000 nits, along with a black level of a maximum of 0.05 nits (20,000:1 contrast ratio), *or* a minimum brightness of 540 nits, along with a black level of a maximum of 0.0005 (1,080,000:1).

UHD ALLIANCE ULTRA HD PREMIUM™

UHD Premium: HDR

- **High Dynamic Range (HDR): Brilliant Brights, Deepest Darks**
  - Dynamic range creates contrast in the images—the difference between the brightest whites and the darkest blacks. Images with high contrast can be shown with much greater clarity and detail. It's designed to deliver an image that has greater details in the shadows and highlights.



UHD Premium: Wide Color Spectrum

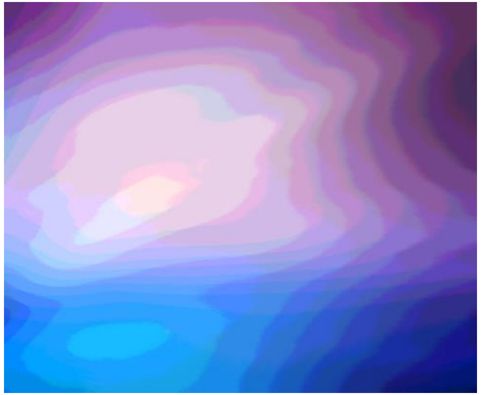
- **Wide Color Spectrum: More Lifelike Colors**
  - Wide Color Spectrum (sometimes called Wide Color Gamut) allows for many more colors. See colors never before visible on televisions, such as the true red of a London Bus. In the current home viewing environment, only a portion of the colors visible to the eye can be displayed. Ultra High Definition with Wide Color Spectrum can more than double the range of colors that can be displayed, making the picture much more lifelike and much more akin to what is experienced in digital cinema.

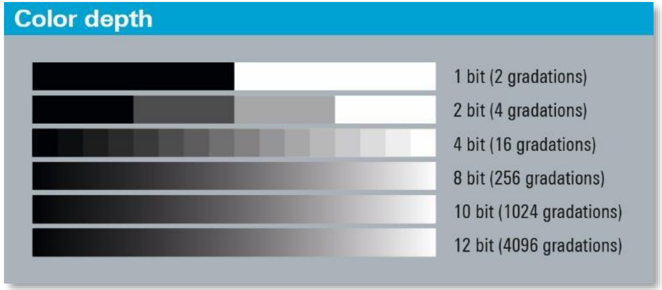
UHD Premium: 4K Resolution

- **4K Resolution: Four Times Sharper Than HD**
  - 4K supports resolutions of up to 3840 x 2160 pixels. That’s four times as many pixels as Full HD televisions (1920 x 1080). This increase in density adds striking detail, smoother curves and more realism to an image and allows larger screens to be viewed from closer distances without individual pixels becoming visible.

UHD Premium: Color Bit Depth

- **Color Bit Depth: Natural Color Transition**
  - The amount of detail used to describe colors. The higher the bit depth, the more natural the transition between colors.





UHD Premium: Higher Frame Rate

- **Frame Rate: Smoother Motion**
  - The number of images shown for video every second. The higher the number, the smoother the motion and the more real-life moving images appear.

Understanding HDR

High Dynamic Range

- HDR is a set of techniques used in imaging, to reproduce a greater dynamic range of luminosity than possible using standard digital imaging techniques.
- The aim is to present the human eye with a similar range of luminance as that which, through the visual system, is familiar in everyday life.
- The human eye, through adaptation of the iris and other methods, adjusts constantly to the broad dynamic changes ubiquitous in our environment. The brain continuously interprets this information so that a viewer can see in a wide range of light conditions.

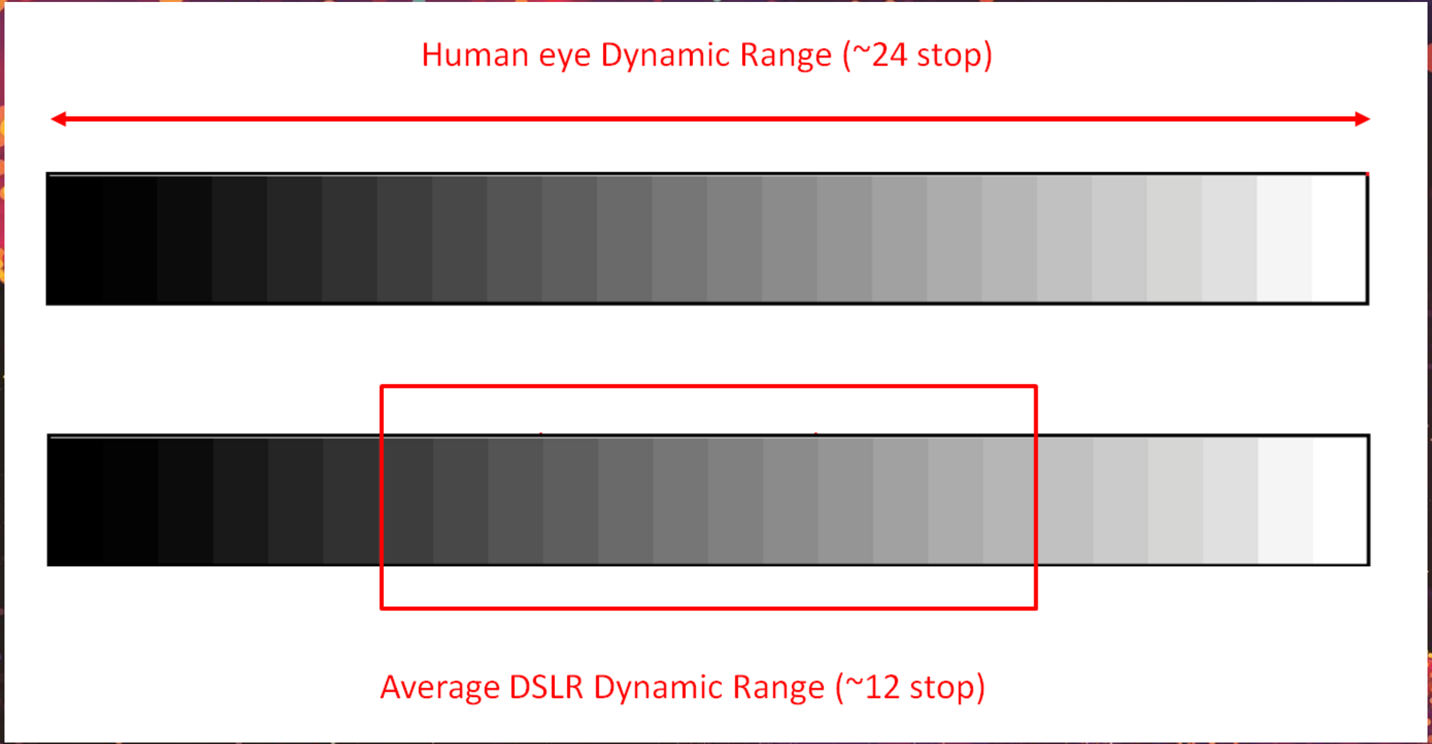
Confusion in HDR

- As you research the topic of HDR, you will encounter a lot of confusing information, as there are two different types of HDR – photographic, and display.
- **Photographic HDR** involves combining multiple images with different exposures to create a single image with greater dynamic range. This can appear unnatural, and is a stylistic choice.
- **Display HDR** expands the display's contrast ratio and color gamut to offer a realistic, natural image, greater than what's possible with HDTV.

What is Dynamic Range?

- Display **contrast** is the difference between how dark and bright it can get.
- **Dynamic range** describes the extremes in that difference, and how much detail can be shown in between. Think of grey scale segments.
- Just expanding the range between bright and dark in a display is insufficient to improve a picture's detail. It can ultimately only show so much information based on the signal it's receiving.
- Current popular video formats, including broadcast television and Blu-Ray discs, are limited by standards built around the physical boundaries presented by older technologies.
- Black is set to only be so black, and white could only get so bright within the limitations of display technology.
- While display technologies are improving, current video formats can't take advantage of it. Only so much information is presented in the signal, and a display capable of reaching beyond those limits still has to stretch and work with the information present.

What is Dynamic Range?



What is HDR?

- **HDR (High Dynamic Range)** removes the limitations presented by older video signals and provides information about brightness and color across a much wider gamut range.
- Besides the wider range, HDR video contains more data to describe more steps in between the extremes.
- This means that very bright objects and very dark objects on the same screen can be shown (if the display supports it), with all of the necessary steps in between described in the signal and not synthesized by the image processor. In other words, more shades of grey.
- HDR produces deeper and more vivid reds, greens, and blues, and can show more shades in between.
- Deep shadows show more detail and aren't simply black voids.
- Bright shots shows fine details and aren't simply sunny, vivid pictures

What is HDR?

Standard Dynamic Range High Dynamic Range

What Makes Up HDR?

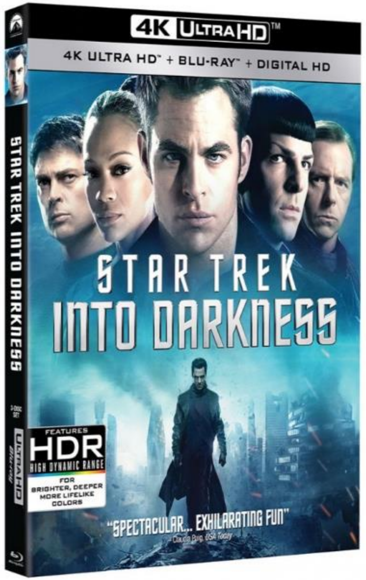
- The two most important factors in viewing a display are contrast and color accuracy, in terms of how closely colors on the screen replicate real life (or the color palette the videographer and editor intends).
- If you put two displays side by side, one with simply more pixels (i.e. standard 4K) and the other one being 1920 x 1080 but with better contrast and more accurate color, the latter will be chosen by the majority of viewers.

It IS All About Contrast and Color

- **HDR expands the range of both contrast and color significantly.**
- In terms of contrast, bright parts of the image can get much brighter and dark parts much darker, resulting in and image that seems to have more "depth of field."
- Colors get expanded with Wide Color Gamut (WCG) to show more (and brighter) reds, greens, and blues, as well as the secondary colors in between. Colors in WCG have been heretofore impossible to reproduce on any display.

HDR Media

- **HDR requires much more data, and like UHD video, current optical media can't handle it.**
- Standard Blu-ray discs cannot hold UHD and HDR information. That is changing, as the UHD Alliance pushes the Ultra HD Blu-ray standard.
- It's a disc type that can hold more data, and is built to contain 4K video, HDR video, and even object-based surround sound like Dolby Atmos.
- It could solve all of the distribution problems of 4K and HDR without requiring a very fast Internet connection.
- Online streaming can also offer 4K and HDR video, but Ultra HD Blu-ray provides a physical and broadly accessible way to get it.



Displaying HDR Content

- **To enjoy an HDR experience, you need content that has been mastered with HDR, a source device capable of decoding it, a signal path that supports the appropriate bandwidth, and finally a display that can reproduce it.**
- Most of the HDR-enabled content right now comes from streaming services such as Amazon and Netflix, as well as from new Ultra HD Blu-ray players and discs.
- For streaming 4K videos with HDR, you need a relatively fast broadband connection, of at least 25Mbps.
- Ultra HD Blu-ray discs, using HEVC/H.265 compression at a 100Mbps data rate, provide the best 4K picture quality currently available.

HDR Standards

- There are four competing standards emerging in the world of HDR:
  - **HDR10 and HDR10+**
  - **Dolby Vision**
  - **HLG**
  - **Advanced HDR**
- This does not have to be as complex as it sounds. Looking at specific requirements for each standard shows that display manufacturers can support multiple standards.
- Let's break down what the different formats are, who supports them, and why the differences may not be so scary after all.

HDR Standards

- Currently HDR content is split into two dominant standards: **HDR10** and **Dolby Vision**.
- **HDR10** and **HDR10+** is the standard of the UHD Alliance. It's a technical standard with specific, defined ranges and specifications that must be met for content and displays to qualify as using it. HDR content available on Ultra HD Blu-ray discs are generally HDR10. Televisions that support HDR10 are allowed to display the UHD Alliance's Ultra HD Premium logo.
- **Dolby Vision** is Dolby's own HDR format. While Dolby requires certification for media and screens to say they're Dolby Vision compatible, it's less of a true standard than HDR10.
- Both formats contain much more information about light and color for each pixel. However, Dolby Vision media is calibrated to fit the profiles of individual Dolby Vision displays to produce the best picture based on each panel or projector's limitations and range.
- **The end result is still a picture that has wider, more varied colors than standard dynamic range video.**

HDR10 and HDR10+

- **HDR10** is the more open standard for HDR developed by device manufacturers (including Samsung and Sony) to avoid having to submit to Dolby's own standard and fees.
- It's the default standard for 4K Ultra-HD Blu-ray disks, and has been embraced by both Sony and Microsoft for the PlayStation 4 and Xbox One S.
- The downside is that while HDR10 is more open, it holds to a lower standard of video quality than Dolby Vision, mastering content at 1,000 nits of brightness compared to Dolby Vision's theoretical 10,000-nit limit.
- The former also supports 10-bit color to Dolby Vision's 12-bit, which translates to a smaller color range.
- **HDR10+**, was announced by Samsung and Amazon Video. HDR10+ updates HDR10 by adding dynamic metadata. The metadata is additional data that can be used to more accurately adjust brightness levels on a scene-by-scene or frame-by-frame basis.
- HDR10+ is an open standard and is royalty-free.

Dolby Vision

- **Dolby Vision** is the other primary competing standard for HDR content. Unlike HDR10, Dolby’s format requires displays and media devices that have been specifically designed with a Dolby Vision hardware chip — from which the company receives licensing fees.
- It's also the more future-proof of the two formats, with content being mastered for a higher level of brightness and color gamut than what today's top displays can provide.
- Of the four formats Dolby Vision has the highest barrier to entry since it requires specific hardware to support.
- But it also offers the best HDR experience of any of the four standards since it can calibrate the picture for the specific TV hardware, in addition to the high mastering requirements.

DOLBY VISION

HLG

- **HLG**, or **Hybrid-Log Gamma**, is a one of the newer standards on the market, but it's entirely different from Dolby Vision and HDR.
- HLG was developed by the BBC and NHK broadcasting networks to serve as an HDR format for live video.
- Unlike other HDR methods, which pre-encode the content with metadata to properly display the HDR effect, the HLG system is designed to work similar to regular broadcast television.
- It simply includes additional information regarding the HDR effect that compatible sets can implement. The broadcast is also backwards compatible with older standard dynamic range images should the set not offer HLG compatibility.
- While HLG is still years away from any mainstream rollout, there's nothing about the spec that would prevent any HDR set from offering a firmware update to support it later on.

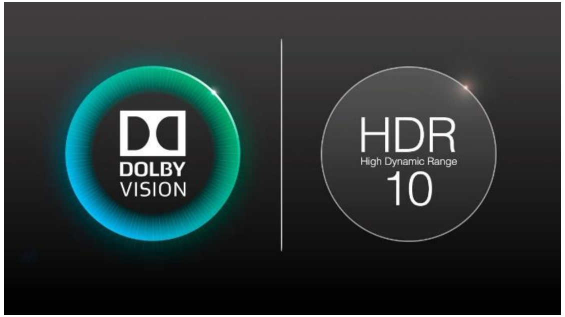
Advanced HDR

- **Advanced HDR** is perhaps the least established of the four major formats.
- Advanced HDR has the smallest amount of information about it available, being the newest, but it's also primarily built for broadcast media and upscaling SDR video to HDR.
- It is designed to be cross compatible across different HDR hardware, making it likely that display manufacturers will be able to support it.

technicolor

Dolby Vision vs. HDR10

- The first of the two major differences between Dolby Vision and HDR10 is that Dolby Vision uses 12 bits per color (red, green, and blue), where HDR10 uses 10 bits per color. That’s where the name HDR10 comes from.
- While those 2 bits per color won’t mean much with a lot of material, they allow more subtle detailing and completely eliminate artifacts such as contour banding that can still crop up under some circumstances with 10-bit color. The effect is subtle, but discernible.

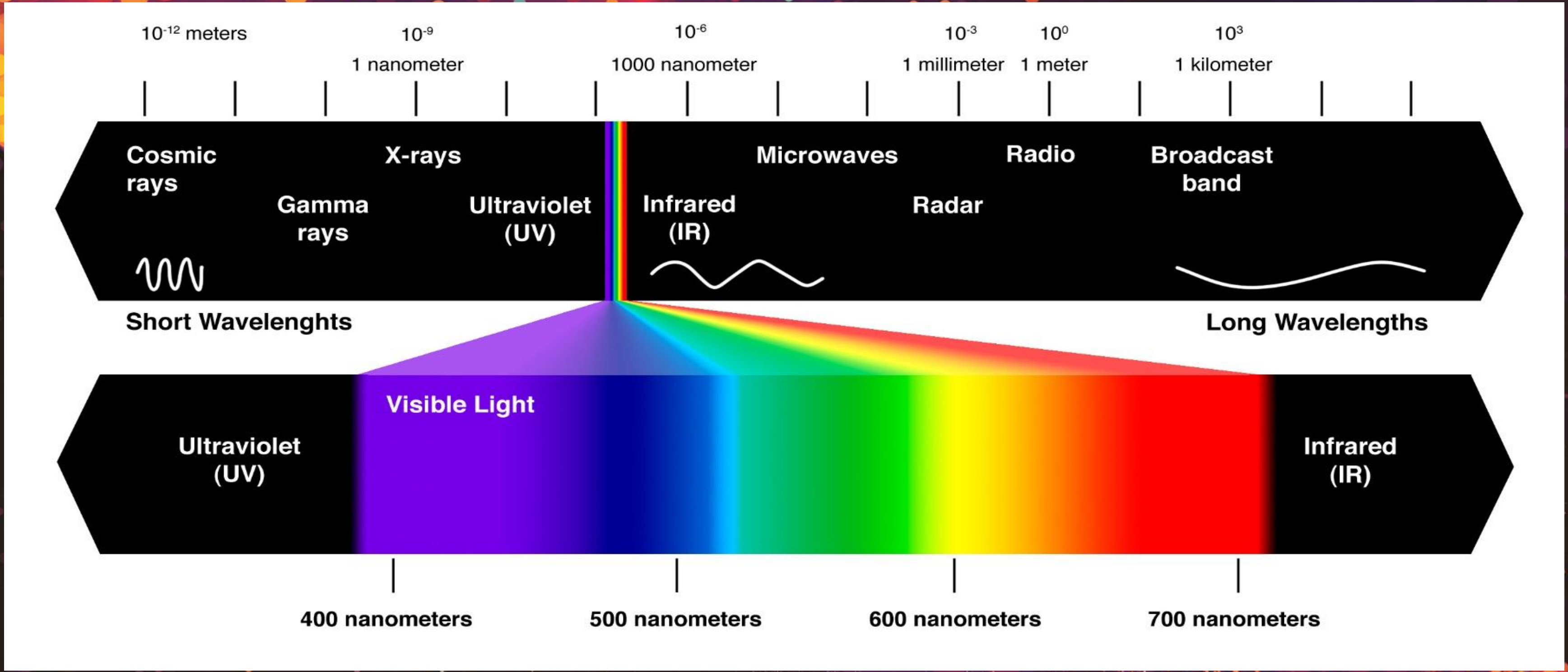


Dolby Vision vs. HDR10

- The second and more significant difference to content creators is in the metadata—the extra data that tells a display how to display the HDR content.
- Dolby Vision uses *dynamic*, or continuous metadata so that color and brightness levels can be adjusted on a per scene, or even frame-by-frame basis. HDR10 uses *static* metadata that is sent only once at the beginning of the video.
- In real life, that means that Dolby Vision can optimize night scenes, daylight scenes, and everything in between individually, while HDR10 forces a compromise based on the overall characteristics of the content.

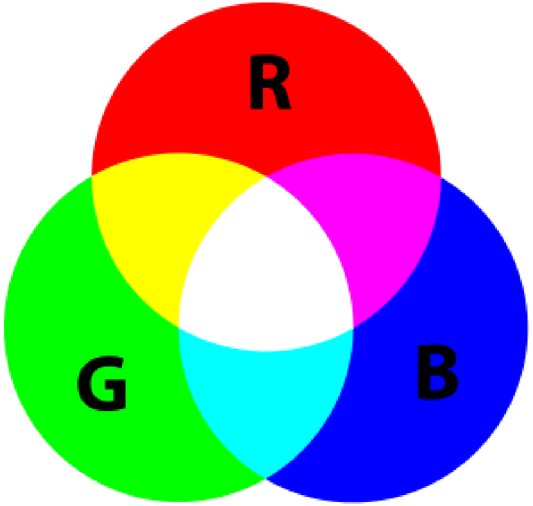
Understanding Wide Color Gamut

The Electromagnetic Spectrum and Visible Light



Additive Color

- **Additive color** is the process of overlapping (mixing) wavelengths of light, combining them to create multiple colors, used in display technologies of all types
- The base **primary colors** are **Red**, **Green**, and **Blue**
- Combining primary colors, creates **secondary colors**; **Cyan**, **Magenta**, and **Yellow**
- Combining primaries and secondaries can create various additional colors. Combining all primaries and secondaries will create white.

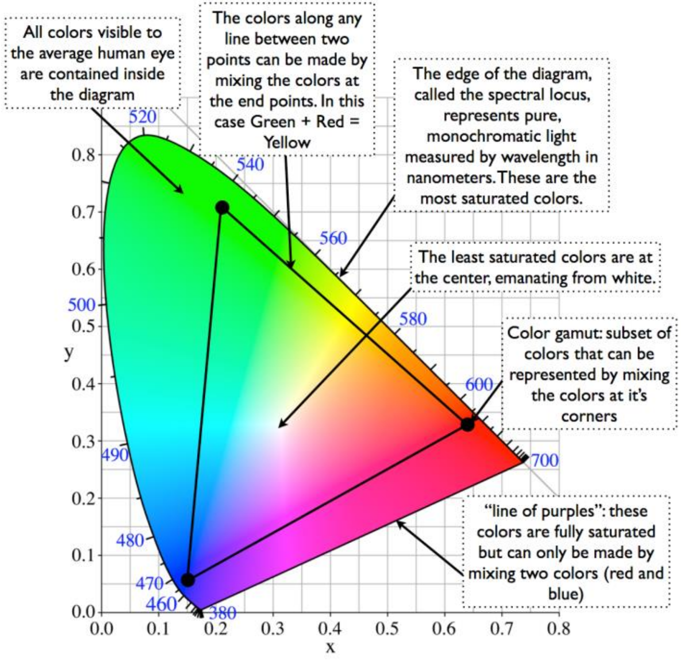


Colorspace and Gamut

A **colorspace** is a standard that defines a specific range of colors that a particular technology is able to display, with maximum red, green and blue points, mapped to sit inside the full CIE XYZ space.

The space within the full CIE XYZ space that a particular colorspace covers is called its **gamut**.

No three points on the chart can cover 100% of what the human eye can see



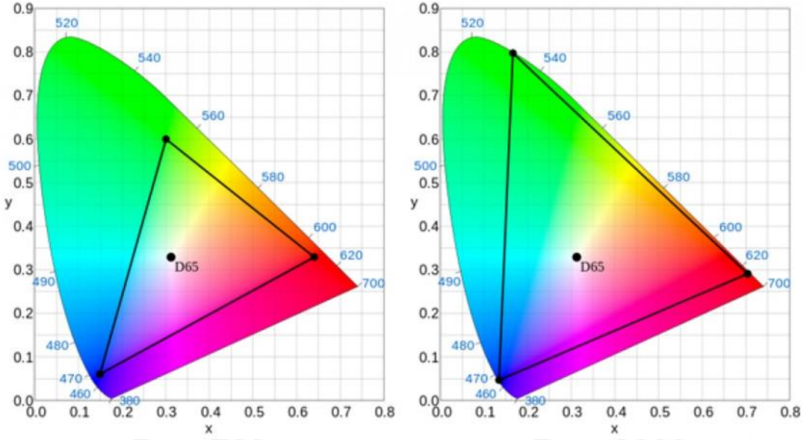
Anatomy of a CIE Chromaticity Diagram

Standard "Color" of White

The standard color of white for almost all current color gamut standards is called D65, which is the color of outdoor natural daylight at noon, with a color temperature close to 6500K.

To deliver accurate image colors, a display must match the same color gamut and also the same color of white that was used to create the content.

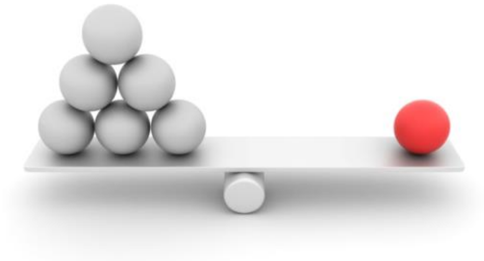
Dr. Ray Soneira of DisplayMate admonishes that *"Unfortunately, many displays accurately reproduce the Color Gamut, but then use an inaccurate (typically too blue) White Point, which then introduces color accuracy errors throughout the entire inner regions of the Color Gamut."*



Rec. 709 Rec. 2020

Color Gamut Explained

- **All imaging based applications need a specific, well-defined color gamut in order to accurately reproduce the colors in the image content.**
- Over the years this has given rise to many different standard color gamuts for the current image content, and they have generally been based on what the currently existing displays at the time could produce.
- So both the displays and content have evolved together over time, and many different color gamuts have been defined, but they are not all created equal…



Color Gamut Standard

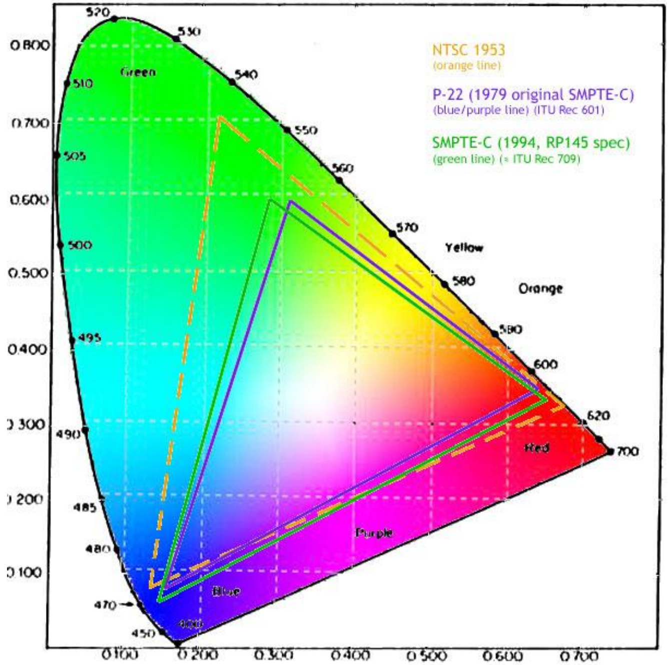
- **What makes a color gamut an industry standard is the existence of a significant amount of content created specifically for that gamut. This necessitates manufacturers to include that standard in their products.**
- Content creators and the content they produce defines a true color gamut standard. It is then up to the display to deliver it as accurately as possible on-screen.
- Viewers tend to think of color gamuts in terms of their most saturated colors, but according to Dr. Soneira, the greatest percentage of content is found in the *"interior regions of the gamut, so it is particularly important that all of the interior less saturated colors within the gamut be accurately reproduced"*.
- As in all things related to content and their interaction with displays, keep in mind that ambient light diminishes the saturation of color gamuts as it reduces the overall contrast of a displayed image.

NTSC and SMPTE-C Gamut

In 1953 the NTSC color gamut was part of the introduction of US color television broadcasting. But as Dr. Soneira points out in his white paper, *“the NTSC primary colors were too saturated and couldn’t be made bright enough for use in the consumer (CRT) TVs of that era, so the NTSC color gamut was never actually used for volume commercial production of color TVs”*.

The SMPTE-C color gamut standards became the first standard in actual use. The genesis of this was the color phosphors that Conrac™ used in their production monitors for the broadcast industry.

The SMPTE-C gamut is 13% smaller than today’s sRGB / Rec.709 gamut. Many later gamut standards were based on SMPTE-C, including up to Rec.601 for Digital Standard Definition TV.



sRGB / Rec.709 Color Gamut

- **Since the introduction of HDTV and the expansion of internet content, the sRGB / Rec. 709 color gamut standard has been used for producing virtually all content for television, the internet, and digital photography.**
- Since the source material is created based on these standards, if you want to see accurate colors as they were created and intended, then the display needs to match the sRGB / Rec.709 standard color gamut .
- If the display inaccurately replicates the gamut used as the standard, either larger and or smaller, the colors will then appear either over or under-saturated.
- Today a display will be evaluated in terms of color reproduction as a percentage of the amount of sRGB/Rec.709 or in the future, Rec. 2020 that they produce.

sRGB Colorspace

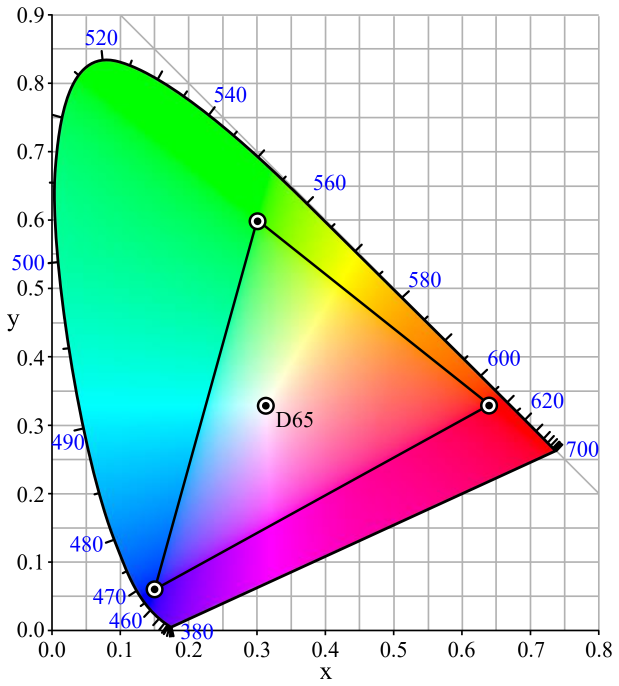
sRGB is a colorspace, proposed in 1996, to approximate the color gamut of the most common computer display devices.

It was originally created for CRT computer monitors, graphics and print.

It is based on the same primaries and has basically the same gamut as Rec. 709.

It has become the standard colorspace for displaying images on the Internet.

sRGB is still the standard for computer imaging and most consumer to mid level displays, cameras and home printers.



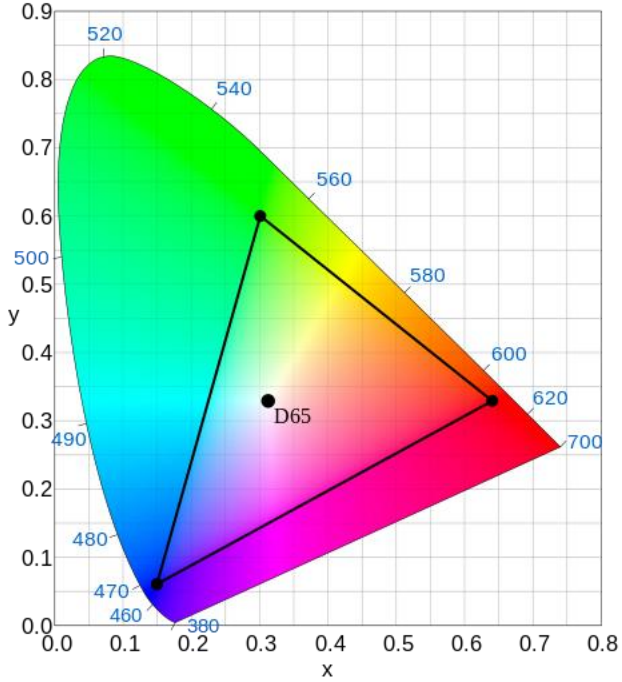
Rec. 709 Color Space

Rec. 709 is the international recognized standard video color space for HDTV with a gamut almost identical to sRGB.

For broadcast it is defined in 8-bit depth, where black is level 16, and white is level 235.

10-bit systems are common in post-production, as typically the source from camera is of a much wider gamut and bit depth than Rec. 709.

In this case levels are between 0 and 1023 in post, but the final result is mapped to broadcast standard 8-bit 16-235 when creating deliverables.

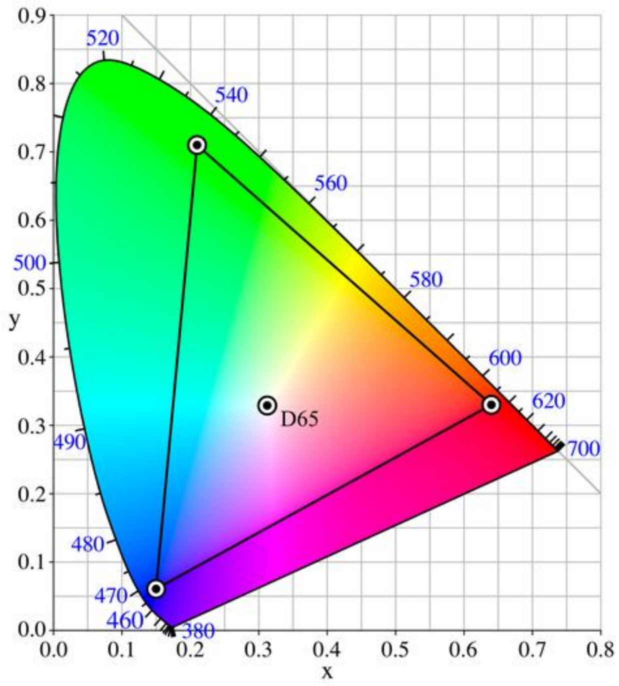


Adobe RGB Colorspace

The **Adobe RGB** color space is an RGB color space developed by Adobe Systems, Inc. in 1998.

It was designed to encompass most of the colors achievable on CMYK color printers, but by using RGB primary colors on a device such as a computer display.

The Adobe RGB (1998) color space encompasses roughly 50% of the visible colors specified by the CIELAB color space – improving upon the gamut of the sRGB color space, primarily in cyan-green hues.



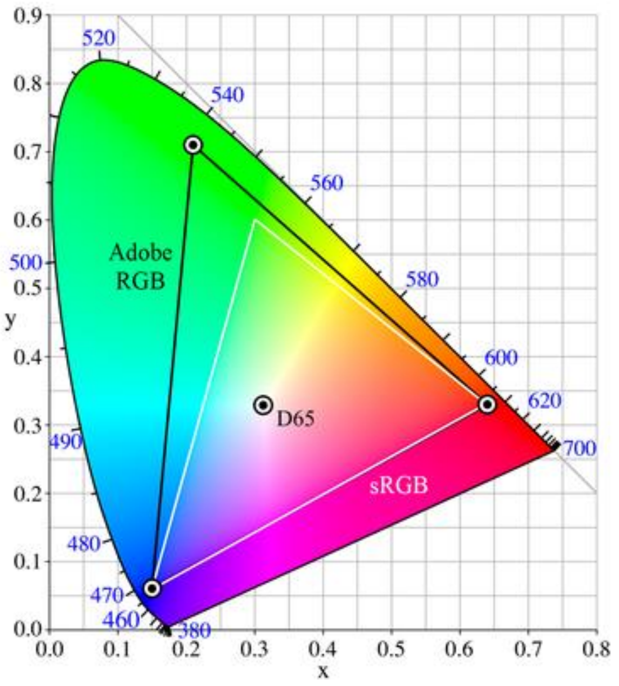
sRGB vs Adobe RGB

sRGB's color gamut covers 35% of the visible colors specified by CIE, whereas Adobe RGB encompasses slightly more than 50% of all visible colors.

Adobe RGB extends into richer cyan and green than does sRGB – for all levels.

The two gamuts are often compared in mid-tone values (~50% luminance), but clear differences are evident in shadows and highlights as well.

In fact, Adobe RGB (1998) expands its advantages to areas of secondary colors as well.

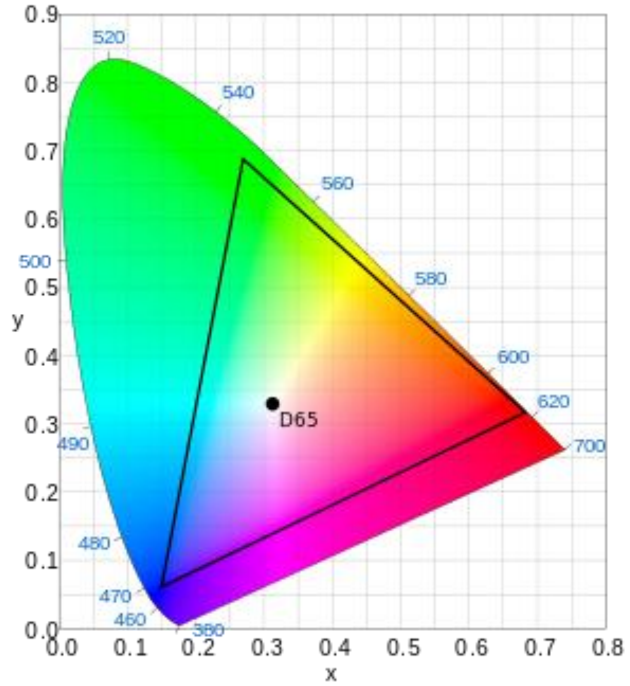


DCI-P3 Color Space

DCI-P3 is a wide gamut video color space introduced by SMPTE (Society of Motion Picture and Television Engineers) for digital cinema projection.

It is designed to closely match the full gamut of color motion picture film. **It is not a consumer standard and is only used for content destined for digital theatrical projection.**

Few monitors are able to display the full DCI gamut but DCI spec projectors can.



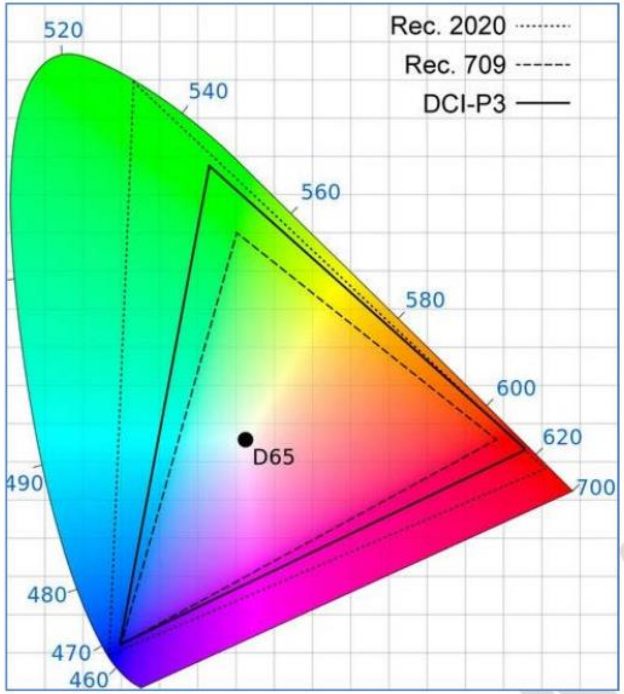
Rec. 2020 Color Gamut

The newest generation standard color gamut is the impressively large **Rec. 2020 standard**.

It is a significant 72% larger than sRGB / Rec. 709 and 37% larger than DCI-P3.

The color gamut is extremely wide and the color saturation extremely high.

There is little existing content for Rec.2020 and few displays (yet) that will show it but that is increasing exponentially.



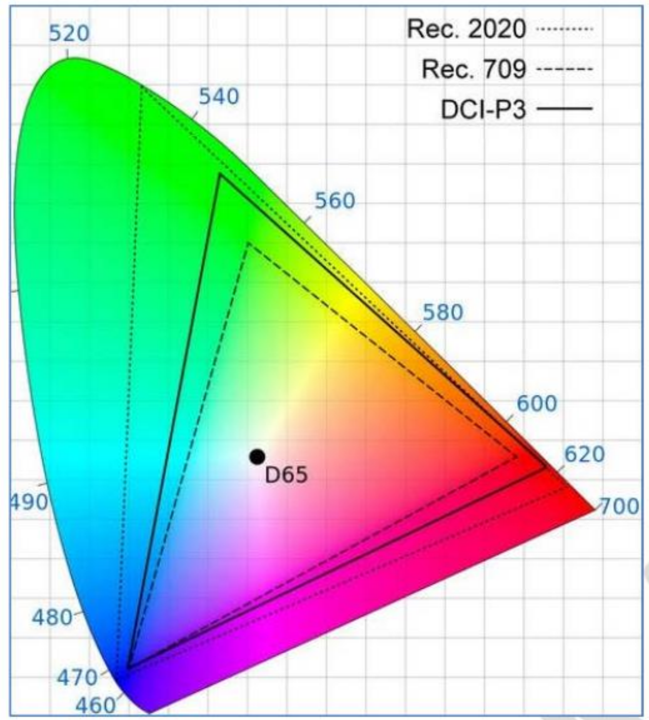
Handling Multiple Gamuts

- When a display needs to support one or more additional color gamuts like sRGB / Rec. 709 that are smaller than its native color gamut, that can be accomplished with digital color management performed by the firmware, CPU or GPU for the display.
- The digital R,G,B values for each pixel in an image being displayed are first mathematically transformed so they colorimetrically move to the appropriate lower saturation colors closer to the white point.
- The available color gamuts can either be selected manually by the user, or automatically switched if the content being displayed has an internal tag that specifies its native color gamut, and that tag is recognized by the display's firmware.

UHDTV vs. HDTV

Words to the wise!

You should be working in a wide gamut color space that encompasses all the expected output standards and have your displays calibrated to match.



Q&A

For More Information

- If you would like more information, please contact Brawn Consulting:

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