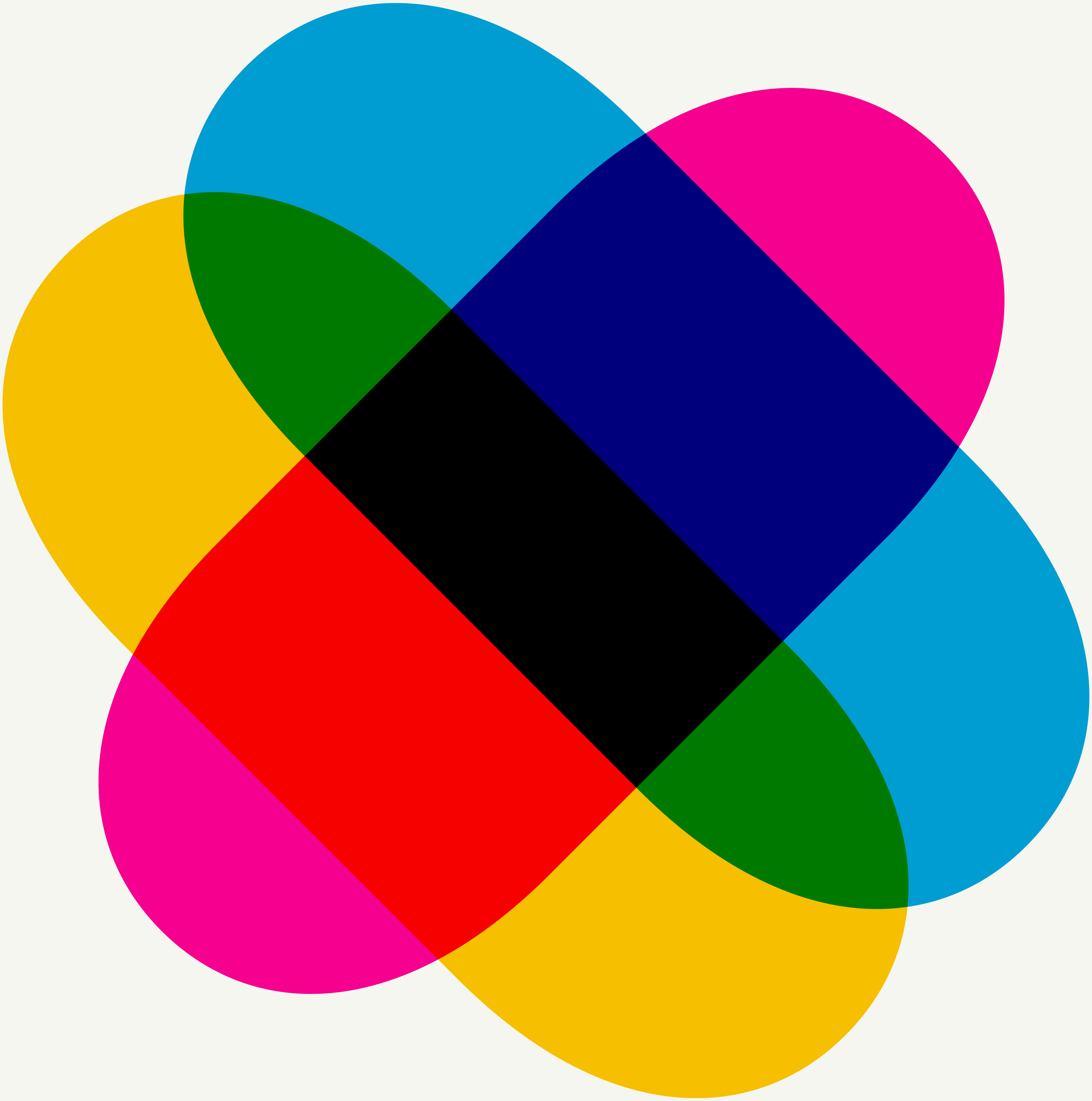

megapixel

Color in Film Production

2024-03-28

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About Megapixel

Megapixel is the unrivaled authority in cutting-edge professional display technology and video processing for top-tier brands, creatives and design-led homes. Led by Jeremy Hochman and Keith Harrison, our unrivaled team of engineers and designers consistently delivers the most unique and breakthrough LED solutions to market, helping our visionary clients bring their ideas to life in ways that inspire a sense of wonder and make the seemingly impossible possible. With over 200 patents and award wins from Live Design, the Emmys, and the Oscars, we endeavor to always be at the forefront of digital displays and technology for which we set the bar as the industry standard.

We are the unrivaled authority in cutting-edge professional visual technology and video processing for top-tier brands, creatives and design-led homes.

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Introduction

Color in film production is an extremely important part of the creative workflow. The use of color palettes help to enhance things like ambience and emotion. This is vital to telling the story and must be executed accurately.

The introduction of LED usage for In Camera Visual Effects (ICVFX for short) has created new technical challenges between the camera and LED on-set. One of the main challenges is the consistency of color through the production's signal pipeline. Creating a consistent and reproducible pipeline from content to the LED wall is critical to the creative process so there is not a change to artistic intent.

The use of color palettes help to enhance things like ambience and emotion.

We will talk about the following topics:

- How human perception differs from a camera
- Color Space versus Color Gamut
- Color Spaces and why we often deviate from them
- Color Temperature
- Color-accurate reference equipment and tools

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Human vs. Camera Perception

What the human eye perceives as color and what the camera sees are often very different. This is due to the differences between the human's rods and cones compared to the camera's sensor. Even past that, two people could look at two LED panels side by side, and one says they match while the other perceives different colors. This disparity is due to observer metamerism.

For ICVFX it is important to adjust color based upon what the camera is seeing and not what the eyeball sees. This is why it is important to make sure all devices inline are working in the same container. Once all devices are working in the same container, color management becomes predictable and repeatable. This predictability allows the creative process to have a defined pipeline for pre- and post-production. This is the primary objective.

Cinematic filming
In-Camera VFX 3

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Color Space Standards

From an academic point of view, color space encompasses the color gamut, transfer function, and additional details of the video signal. Let's look at a couple of common Color Spaces.

- ITU-R Recommendation BT.709 (or Rec. 709 for short) is a color space developed by the ITU Radio-communication Sector (ITU-R) that acts as a standard used by many high-definition displays. It is used to ensure that all the devices on the market adopt it as their standard is the same in terms of color reproduction.

- DCI P3 is a color space that was developed by the Digital Cinema Initiative and covers 45.5% of the CIE color space diagram; this is the closest to photopic vision (human vision) under well-lit conditions. This is usually paired with a D65 white point (Display P3 for example) which represents average midday light.

- ITU-R Recommendation BT.2020 (or Rec. 2020 for short) is a color space that was developed for Ultra High Definition content. Rec. 2020 utilizes the Rec. 2020 color primaries but now uses SDR (Standard Dynamic Range). The standard recommends using Rec. 709 transfer function with improved bit depth.

- ITU-R Recommendation BT.2100 (or Rec. 2100 for short) is a color space that was developed for Ultra High Definition content. Rec. 2100 utilizes the Rec. 2020 color primaries but now uses HDR (High Dynamic Range). The standard recommends using PQ or HLG as the HDR functions.

While it is important to understand these standards, in the real world most people tend to separate each of the components. Most software and hardware devices allow the user to set each of these independently allowing the user the flexibility to achieve the look and feel they are striving for. For example, in a mastering software tool, we typically would separately choose Rec. 2020, PQ, and mastered Min/Max Nits rather than an encompassing standard selection of “ITU-R BT2100.”

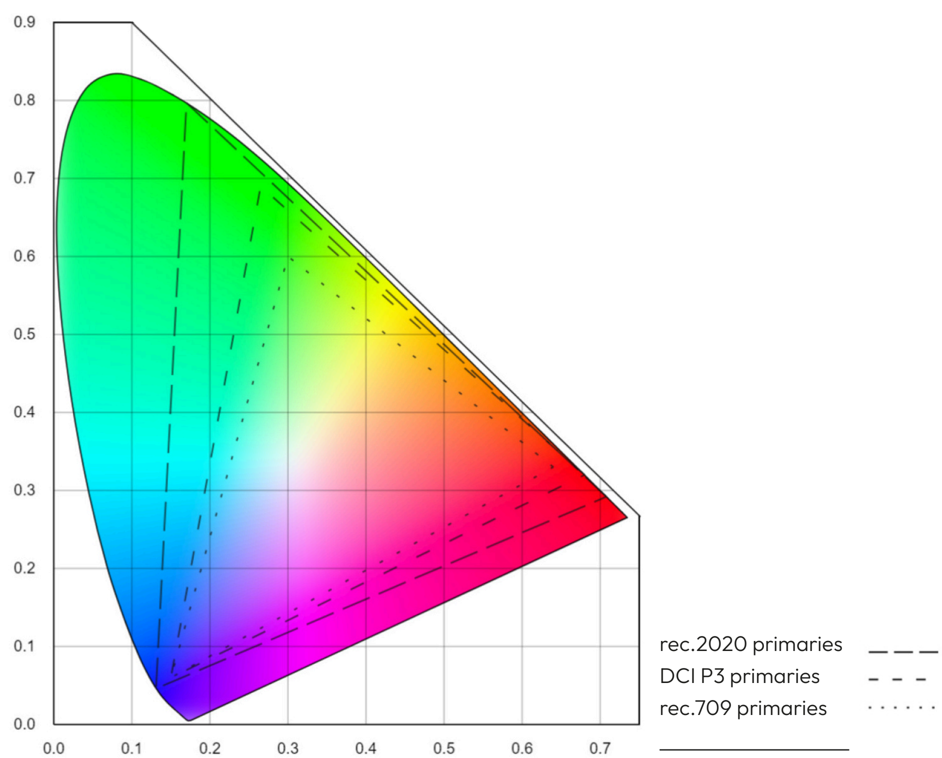
Most software and hardware devices allow the user to set each of these independently allowing the user the flexibility to achieve the look and feel they are striving for.

Considering this, the majority of workflows revolve around High Dynamic Range (HDR) with a PQ or HLG transfer function. By integrating content with a Rec. 2020 color gamut, the objective is to maximize the LED’s color capabilities and exploit its full spectrum of color profiles, resulting in an expanded color range. This heightened color reproduction contributes to the display’s ability to render more vivid and precise colors. For reference, some LED panels are capable of achieving 75-85% of the Rec. 2020 gamut while only a few LED panels are capable of nearly the entire gamut. LED displays with lower coverage may encounter a reduction in color performance when attempting to reproduce the Rec. 2020 gamut.

Some LED products are capable of Rec. 2020 (for example) but are not actually able to reproduce the gamut. To know the actual gamut of the LED tile it is important to reference the data sheet or check with the manufacturer. The HELIOS® LED Processing Platform will report back the achievable tile gamut in real-time if this is needed by the user. This report is important to understand the LED product's capabilities in color reproduction, as this factor can dictate the structure of your color pipeline and workflows.

The HELIOS® LED Processing Platform will report back the achievable tile gamut in real-time if this is needed by the user.

CIE xy Chromaticity Diagram
Displaying the primaries of each mentioned color space



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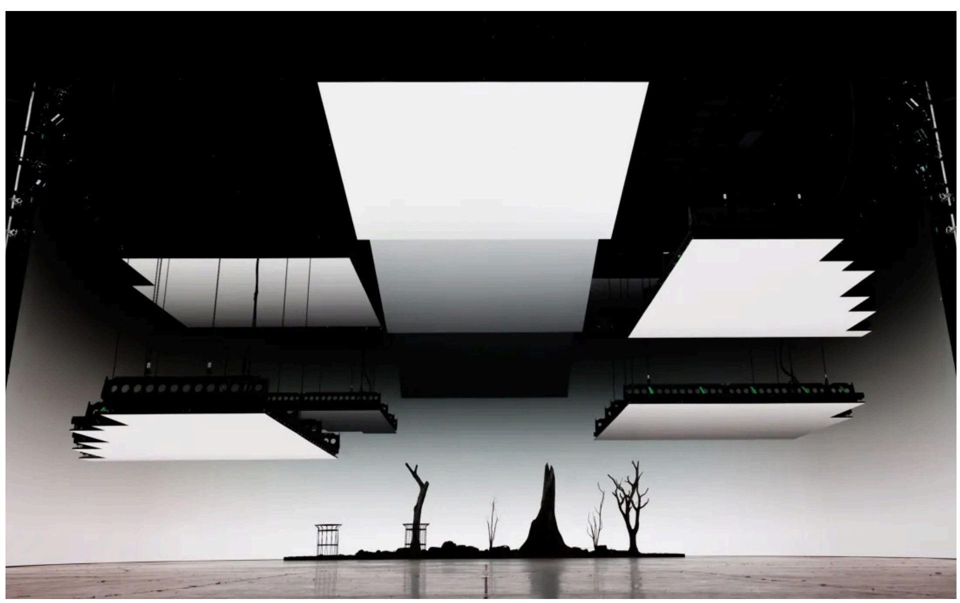
Color Gamut

For the purposes of this section, we will treat color primaries (Rec. 709, Rec. 2020, etc) separately from the transfer function (PQ, HLG, SDR gamma etc).

Color space and color gamut are related but sometimes when used interchangeably can cause confusion when working with color. One of the components that color space defines is a set of color primaries that specify all of the usable colors on a CIE xy chromaticity diagram. This set of colors allows for known and repeatable color transformations between different displays. Alternatively, color gamut represents the range of colors supported by the display product. Where the confusion comes in is when we use the term color gamut to describe the range in a color space.

Most LED processing can support multiple color spaces but this does not necessarily mean that the LED panels can support 100% of the color space's primaries. In the below example, HELIOS supports Rec. 2020 but the panel itself can not reproduce all the colors in Rec. 2020. This color

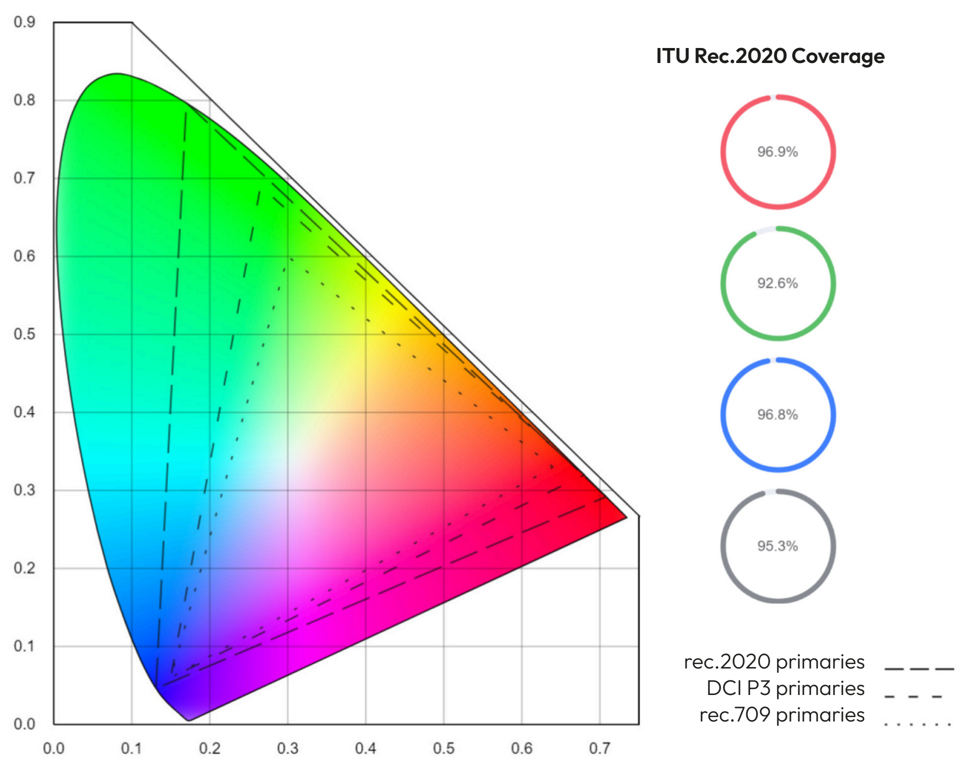
Image credit
Prysm Stages



coverage is determined by LED component capabilities. Color coverage better expresses a screen's capability because it is representative of the percentage of overlap between the device's color gamut and the Rec. 2020 standard. The below example is from a device with a coverage of 95% of Rec. 2020 is guaranteed to be able to reproduce 95% of the Rec. 2020 color gamut accurately. If you look closely at the green area, you can see that this is the area that the panel is having the hardest time with coverage.

...guaranteed to be able to reproduce 95% of the Rec. 2020 color gamut accurately

CIE xy Chromaticity Diagram
Megapixel proprietary LED package gamut shown



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Color Temperature

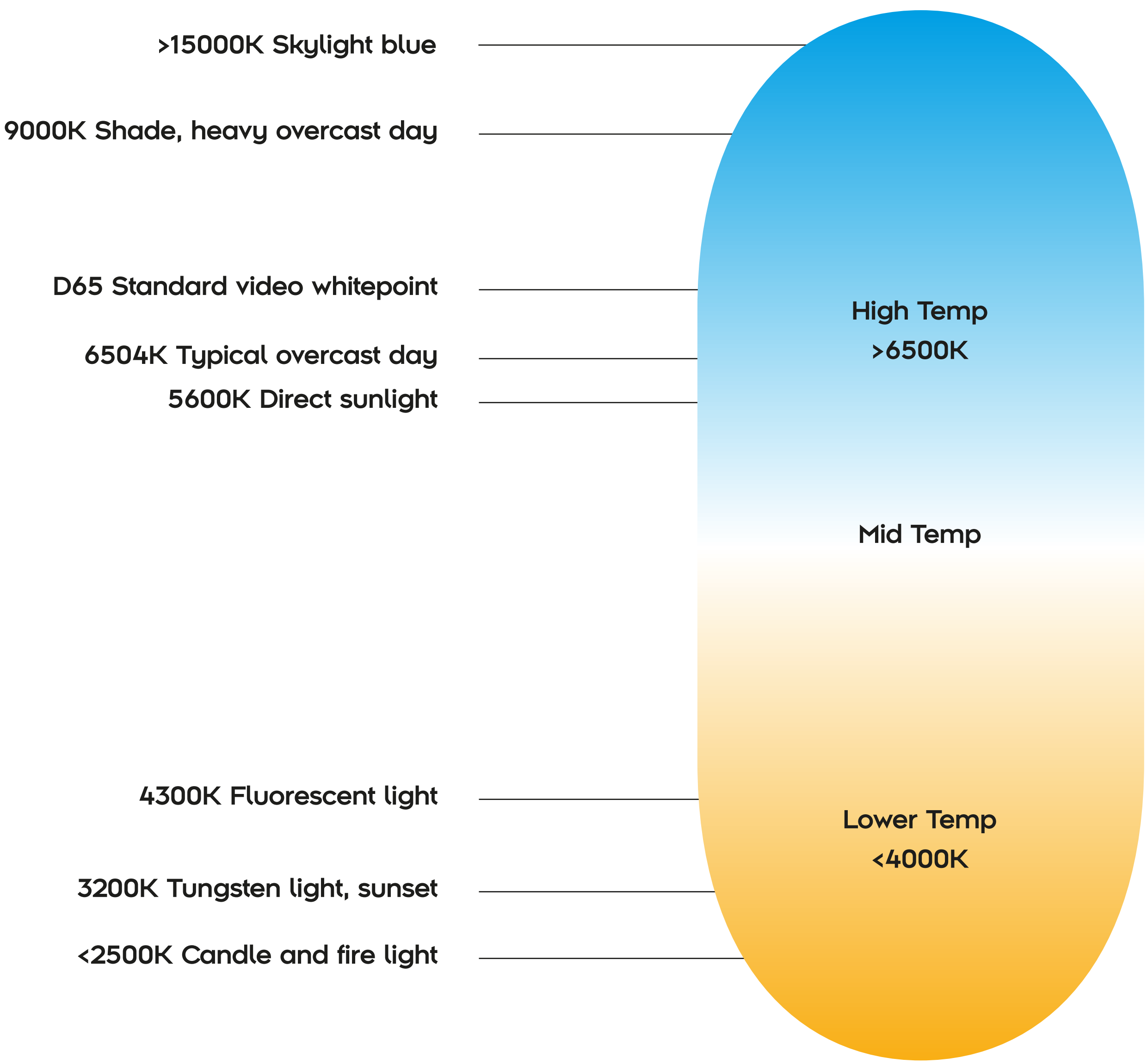
Most displays, including LED Volumes, have a white balance that is set to either 6504 Kelvin (denoted as D65) or 5000 Kelvin (D50). Most LED processing allows the user to set the white point to a wide range of different temperatures. For example, HELIOS allows the user to adjust between 1667 K - 10,000 K. Higher values result in a colder (more blue) look while lower values result in a warmer (more red) look.

It's also important to set the white point of your display when shooting in a volume since your camera will be recording the projected image. If your white point is off, the background will never match the light falling on your subject. While all of this is the color temperature in a technical sense, the color temp scale can also be used creatively.

Color temperature is typically predefined by the director or the cinematographer/DoP, with the intent of using color temperature as part of the creative workflow. This is something that should be discussed before shooting on a volume begins as this will impact the content workflow.

In ICVFX we specify a calibration reference white point, normally 6504K, that all other colors in the scene are based from. This ensures that colors are represented correctly and all creative choices can be made from that solid foundation.

Did you know that Color temperature is non-linear in perceptibility? Just as we perceive brightness changes more intensely at lower light levels, we also perceive shifts in color more at lower color temperatures.



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Production Monitors

Making sure that the color pipeline is fully calibrated would be the initial main focus of the production. It is very common for productions to use TVs that are not production quality and out of the box these TVs are not able to accurately reproduce colors. When using these monitors, it is important to either consider using a LUT box to correct the colors, or simply use a TV that allows for LUTs to be uploaded. Like all the devices talked about in this document, any monitor being used as a production monitor must be calibrated to the correct color space in order to accurately reproduce the correct colors.

Image credit
Alex Forge/Netflix

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Measuring Color

There are a variety of different means to measure and validate color. It will be important to understand the differences between the types of devices you will see in the field for measuring color.

Spectroradiometers are devices that measure light by means of wavelength. This is likely the most accurate device that you will likely see on a production. Spectroradiometers excel at accuracy and repeatability but are much slower to measure light than Colorimeters. It's also important to note that while people will often call Spectroradiometers "Spectrometers" or "Spectrophotometers" interchangeably, these types of cameras are entirely different and should not be used for this purpose.

Colorimeters on the other hand are tristimulus light measuring devices where the light passes through 3 color filters. This approach to measuring light is useful because it is much more representative of the human eye's response to light. Colorimeters are also significantly faster at measuring light than a Spectroradiometer. An important note for Colorimeters is that they need to be calibrated to a Spectroradiometer for each new light source measured due to a variety of different characteristics. For example, if I have a Virtual Production stage with a ceiling and main wall that are two different types of LED, the Colorimeter must be calibrated separately for each display using a Spectroradiometer (or better).

Light Measuring Instruments

- **Colorimetry Research Inc (spectroradiometer)**
  https://www.colorimetryresearch.com/products/cr-300
- **Colorimetry Research Inc (colorimeter)**
  https://www.colorimetryresearch.com/products/cr-100

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Pipeline Checklist

Color Matching

Pick a known color space, this allows reproducible results across the entire pipeline. Most displays and content playback solutions will work alongside color space standards, for example; Rec. 709, Rec. 2020 and DCI-P3 Follow the below checklist to validate that your system is all using the correct standards.

Checklist

Establish a single color space for all devices to work within.

- Color space
- Brightness range
- Color temperature
- EOTF

Make sure all of the below devices are set correctly.

- Content rendered at established color space
- Source/playback device
- Input routers
- Input converters
- HELIOS (Output page -> Display Gamut)
- Cameras
- Reference Monitors

Check in the HELIOS UI (input page) to validate the signal is arriving as the correct format. If the UI is reporting something else, this means that one of the above devices is not set up correctly.

Validate that all items are calibrated correctly and showing correct colors.

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Glossary of Terms

Bit Depth — Bit depth refers to the count of bits that each pixel is capable of displaying. As the bit depth increases, the number of tones the display can represent also increases which in turn causes quality and sharpness of images to also improve. An image with 8 bits can present 256 color values for red, green, and blue, resulting in approximately 16.7 million colors. Increasing to a 16-bit image expands this count to around 281 trillion colors. Within cinematography, prevalent bit depths comprise 10 and 12 bits.

Chromaticity Diagram — The chromaticity diagram illustrates the depiction of human color perception using two CIE color parameters, x and y. Spectral wavelengths are positioned along the periphery of the "color space". Then everything within those bounds represent all perceived hues. This chart establishes a human readable representation for plotting colors.

Color Gamut — The color gamut defines a collection of colors within the spectrum or color space that can be replicated on an output device.

Image credit
Alex Forge/Netflix

Color Palette — A chosen set of colors that is meant to achieve a creative look and feel. Being able to accurately reproduce these colors will be very important to any production.

Color Space — Color Space defines the coordinates of color range on a CIE xy chromaticity diagram, a transfer function, and other details about the signal. These intent is to support colors that are easily reproducible regardless of the device. The spectrum of colors within an image are derived from elements like color channels e.g., Red, Green, Blue, spectrum, hue, saturation and lightness.

Color Standards — Formulated by the ITU, color standards are designed to uphold the consistency of wireless telecommunications distribution.

Genlock — Genlock is a common method in which the video output of one source, or a distinct reference signal from a signal generator, is employed to synchronize other picture sources. This allows displayed content to be in synchronization with the camera capture.

HDR — HDR stands for High Dynamic Range, and it pertains to the contrast or distinction between the brightest and darkest portions within an image. The concept behind HDR is that it enables your eyes to perceive whites that are more brilliant and blacks that are deeper than what conventional SDR displays were capable of presenting. HDR content retains intricate details in both the darkest and brightest regions of an image, details that were frequently compromised using previous imaging standards like Rec.709.

In Camera Visual Effects (ICVFX) — A modern filming technique that is used capture visual effects while filming rather than adding in post-production. Oftentimes this is accomplished by using projection or LED video walls.

Pixel Pitch — The measurement between the centers of adjacent LEDs on the panel is typically specified in millimeters (mm).

Refresh Rate — The refresh rate of an LED display indicates how many times an image is rendered on the screen each second. For top-tier LED displays, a refresh rate of 7680 or higher is necessary to ensure stable broadcasting and minimize flickering. This is a crucial criterion for LED screen displays in Virtual Production (VP) or Extended Reality (XR) studios. A lower refresh rate can result in increased scanning lines and noticeable flickering.

Scan Ratio — Scan Ratio, also known as Multiplexing or Scan type, signifies the number of LED pixels that a single Driver IC can link to. Each LED pixel establishes a connection with a distinct pin on the driver

Image credit
Alex Forge/Netflix

Image credit
Alex Forge/Netflix

IC situated on the PCB board. A higher number of driver ICs on a PCB leads to a reduced scan type. Most suppliers offer a range of scan types, such as 1/2, 1/4, 1/8, 1/16, and 1/32, 1/48. The lower the ratio the better the scan rate.

Signal Pipeline — The devices that carry the video data from source to destination. This includes devices such as playback, video distribution, converters, and video processors.

Further Reading

Bit Depth
https://en.wikipedia.org/wiki/Color_depth

Color Space
https://en.wikipedia.org/wiki/Color_space

Color Gamut
https://en.wikipedia.org/wiki/Gamut

International Telecommunications Union