6P COLOR

TECH FOCUS **ENTHUSIAST**

There's an old expression that goes like this: "You don't know what you're missing!" And it's an apt description of the current crop of televisions, monitors, and projectors. Despite the substantial improvements to image quality over the past decade (higher resolution and luminance, wider contrast ratios, and improved viewing angles), today's displays still can't render many of the colors you see in real life.

Here's why. For decades, electronic displays have relied on a three-color (tristimulus) system to generate a wide spectrum of color shades. Building on advances in color photography and motion picture film from the early part of the 20th century, the first attempts at full-color displays used sequential color wheels containing red, green, and blue filters, positioned in front of a monochrome cathode-ray tube (CRT) and synchronized to a television's vertical (picture) refresh rate.

Later on, the first color TV system implemented in the United States, NTSC, employed red, green, and blue phosphors in CRTs. The brightness limitations of phosphor compounds led to a greatly reduced gamut of colors when compared to the CIE 1931 visible color gamut, as seen with the SMPTE-C standard gamut. As color television became popular in the 1970s, phosphor technology improved, leading to more consistency from television to television. But the gamut of colors that could be reproduced accurately remained small.

New Display Systems, Same Color System

With the advent of digital television in the 1990s, a new color gamut – ITU Recommendation BT.709 – replaced the SMPTE-C gamut. Concurrently, the first flatscreen displays began coming to market, with liquid crystal displays (LCDs) using color filters and plasma display panels (PDPs) relying on phosphors, similar to CRT displays. New video projectors using solid-state imaging devices with color filters also made their debut. And while each of these next-generation Displays were able to boost average image luminance levels far beyond that of CRTs, they still relied on a tristimulus process to create colors.

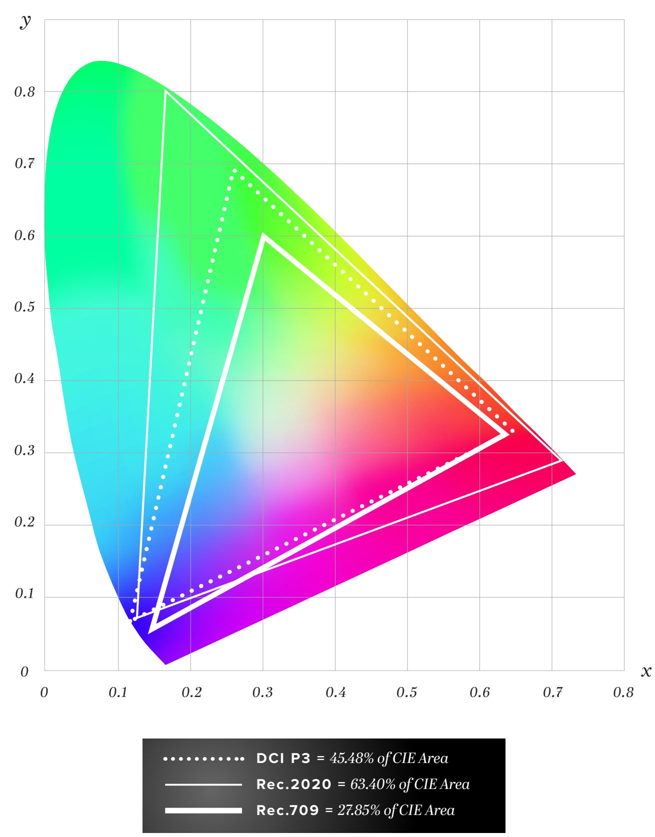

ILLUSTRATION 1: SAMPLE OF EXISTING COLOR GAMUTS

In fact, improvements to projection and direct-view display technologies have until recently focused almost exclusively on achieving higher levels of picture luminance along with higher pixel resolution. The introduction of high dynamic range (HDR) imaging in recent years continued along that same path, all the while staying within the limitations of tristimulus color systems. The resulting triangular-shaped color display gamuts (DCI P3 and ITU Recommendation BT.2020) have increased in size primarily in blue-green, green, and yellow-green regions due to higher luminance for these colors.

New high-intensity imaging systems exhibit narrow spectral bandwidths for each primary color, with examples being laser and LED emissive displays and add-on enhancements such as quantum dots (QDs). These next-generation displays and enhancements have all boosted luminous energy, required for high dynamic range imaging, and hold up well in environments with high ambient light levels. But they still can't reproduce shades of color that fall outside their RGB triangles.

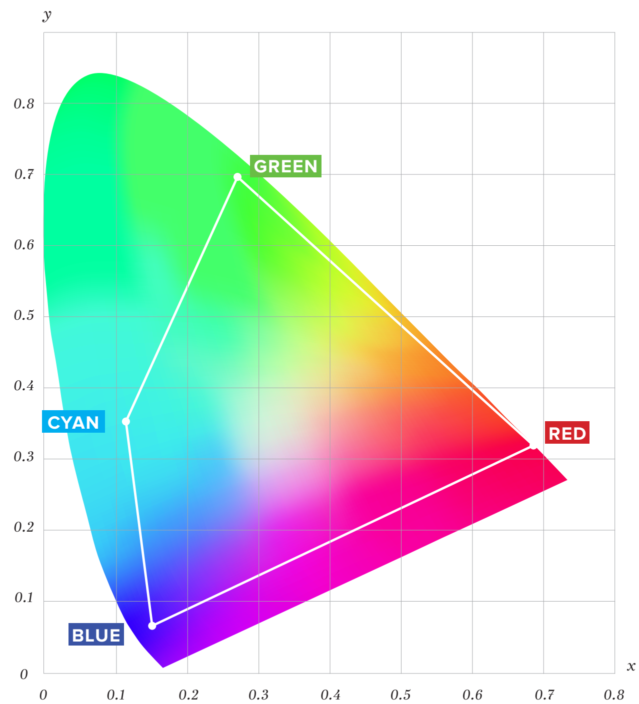

ILLUSTRATION 2A: POSSIBLE RGBC SYSTEM

Breaking Out Of The Triangle

We've reached a point where display brightness is no longer an issue. Numerous televisions and professional displays are now capable of peak luminance levels of 1000 cd/m2 to 1300 cd/m2, over ten times brighter than CRTs of the past. It's long past time to stop obsessing over display brightness and break out of the triangle, focusing instead on expanding color gamuts by using additional color primaries to achieve a more accurate representation of real-world colors.

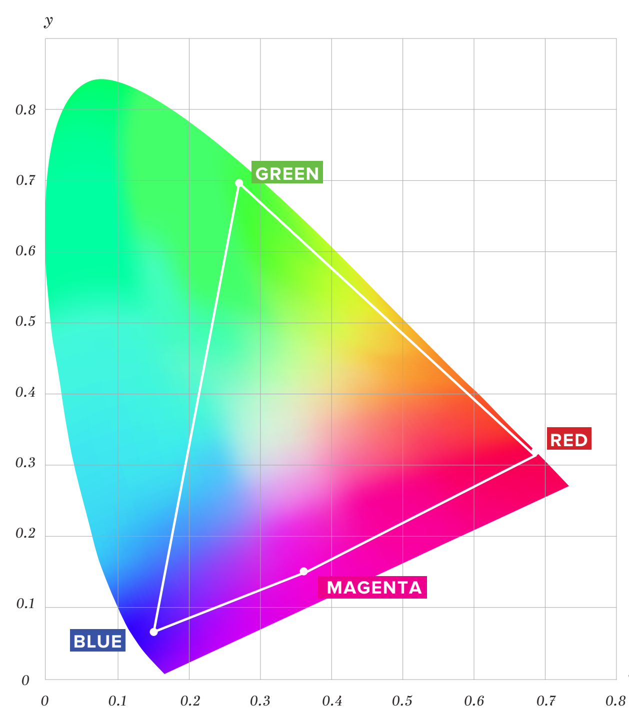

ILLUSTRATION 2B: POSSIBLE RGBM SYSTEM

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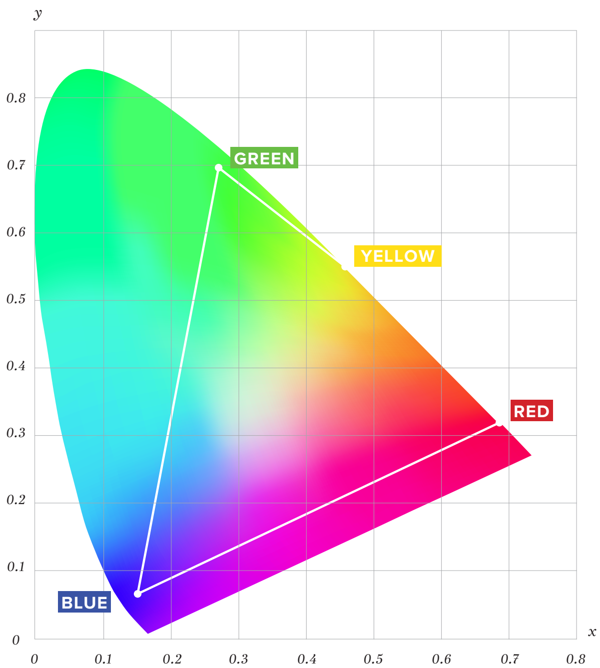

ILLUSTRATION 2C: POSSIBLE RGBY SYSTEM

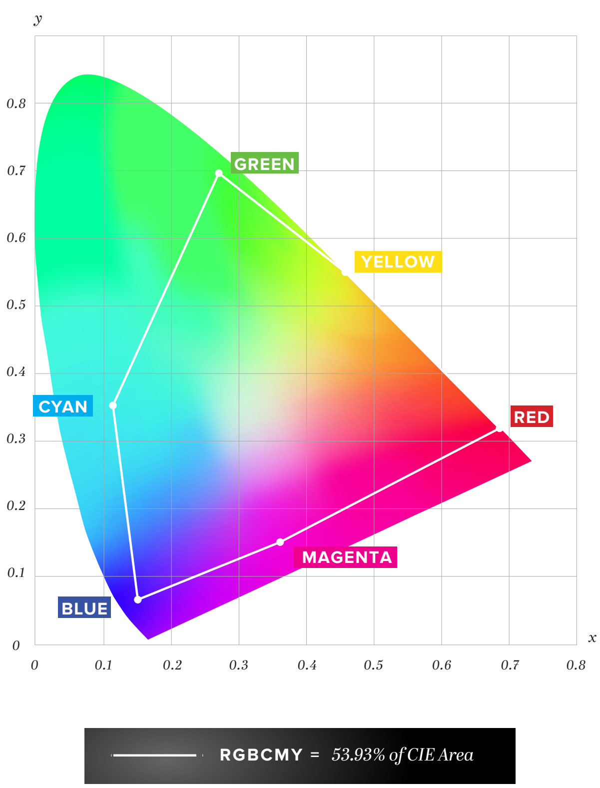

ILLUSTRATION 2D: POSSIBLE RGBCMY SYSTEM

But which additional primaries should we use? Looking at the ITU Recommendation BT.2020 and DCI P3 color gamuts overlaid on the 1931 CIE color perception diagram, you can see that adding a yellow primary (RGBY) would increase the number of colors by a minimal amount. Okay, how about adding a magenta primary (RGBM)? This would produce an increase in gamut size over adding a yellow primary, but still not by a substantial amount.

We'll get the most bang for the buck by adding a cyan primary (RGBC). By doing so, the display's color gamut will be increased by about 20% just along the blue-green axis, finally revealing many color shades we've never seen before on any display. Additionally, we can shift the locus of the green primary to expand the color gamut by an additional 10% and enable the rendering of more shades of yellow that haven't been seen before on electronic displays.

By adding a fourth primary color and shifting the coordinates of the green primary slightly towards yellow, we've increased the display's color gamut by a total of 30%. Selecting a cyan primary with additional green mixed in while shifting the green locus even further along the red-green axis would essentially capture all visible shades of yellow and further increase coverage of the 1931 CIE color space. And we finally have a display that is rendering a more lifelike representation of colors without sacrificing luminance, preserving high dynamic range.

Adding a cyan primary has an additional benefit for graphic artists, designers, and printers. The gamut of surface colors – commonly known as Pointer's Gamut – takes in many shades of cyan, magenta, and yellow that cannot be displayed accurately on computer monitors. Adding cyan also enhances colors with subtle red tints, such as flesh tones. All of these color shades usually fall outside of the RGB triangle, but would be visible with a four-color imaging system.

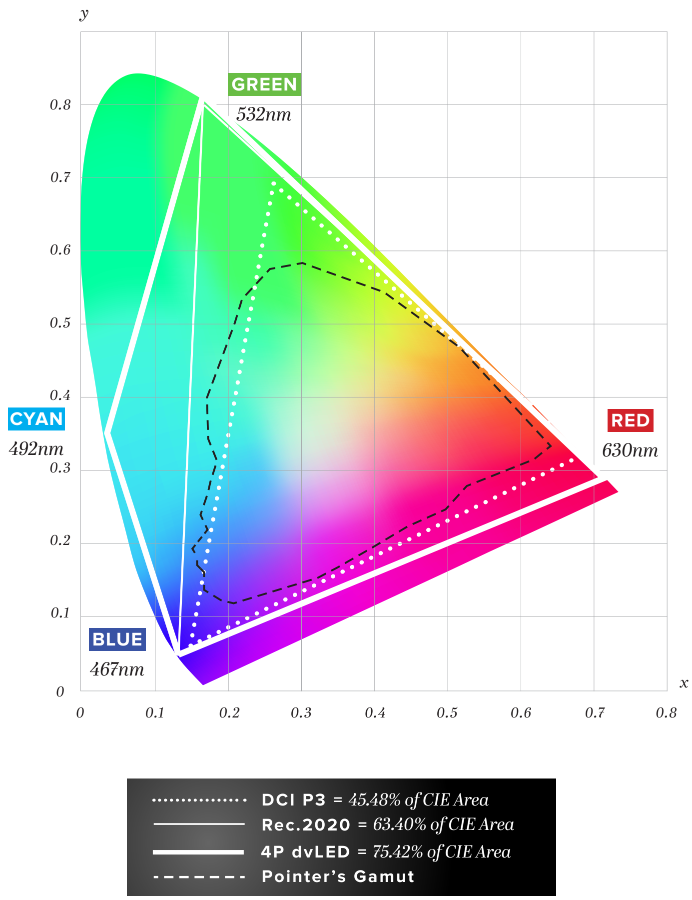

ILLUSTRATION 3: 4 PRIMARIES
RGB + CYAN & POINTER'S GAMUT

These color space conversion problems can be minimized by using the expression Yxy. "Y" in this expression represents an absolute luminance value independent of any color shade, while "xy" specifies data coordinates on the CIE 1931 chart for that color shade. It's a simple system, and it works. As we add more color primaries to our displays, it's far easier to specify color shades and luminance values with this system, obviating the need for any specific display standards going forward.

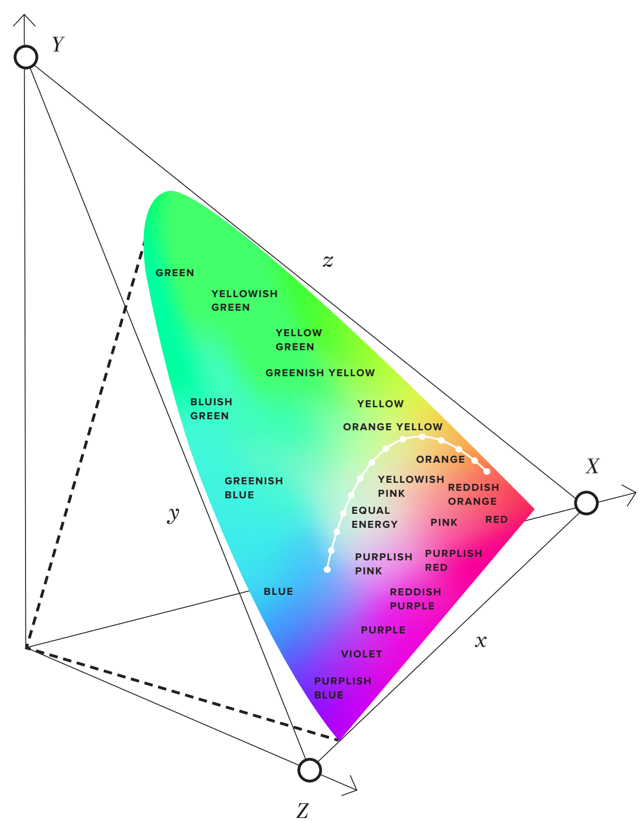

ILLUSTRATION 4: Yxy AS A PROJECTION OF XYZ

But Wait, There's More

Expanding the color reproduction capabilities of displays is only half of the solution. We're also changing our thinking about specifying color shades. Until recently, it's been done by specifying the coordinates of a given color tied to a specified white luminance value, such as RGB for computer displays, YPbPr for television, and the X'Y'Z' system employed for digital cinema. These different expressions create color space conversion problems when distributing media content across different platforms (cinema, television, and streaming video).

And because we've kept the two data sets separate, it becomes a much easier task to translate those values into legacy formats. Adopting the Yxy system will also simplify the conversion process between standard dynamic range (SDR) and high dynamic range

(HDR) images. In such a conversion, the color locus remains unchanged – only the luminous intensity of the images change. When receiving Yxy data, a given display will reproduce all colors as close as possible to the specified values, limited only by its peak luminance and color gamut.

The Yxy system is also more data efficient than other, older ways of encoding color information. A new way to transport color and luminance information from camera to screen goes by the name Data Range Reduction (DRR). DRR is based on data efficiency and not any particular display type or camera gamma (tone) curve. With DRR, displays can process the luminance of the image to match their particular capabilities. Different DRR values are set by bit levels and not by display brightness. DRR also uses the full bit range for luminance and color data values and eliminates any uncertainty about working with full or limited luminance and color data.

Time For A Change

There you have it – a color imaging system for the future - one that expands the gamut of displayed colors to more closely match what we see every day, and one that simplifies the expression and definition of color and luminance values across any content distribution platform. It's clear that we need to break out of the RGB triangle that has limited display systems for over 70 years and instead take full advantage of recent breakthroughs in electronic imaging to get more lifelike colors on screens.

And we can go a long way toward achieving that goal by simply adding a fourth primary color while shifting the values of an existing primary color. The results can be clearly seen as a larger, more life-like palette of colors on RGBC-equipped televisions, monitors, and with projectors. And the addition ofacyan primary color increases the number of colors that can be accurately reproduced, a boon to anyonewho needs to evaluate inks, paints, pigments, dyes, and dispersions on electronic displays.

