BY MIKE WOOD

Making the same color twice— A proposed PLASA standard for color communication

The need for standardization in color communication

WITH INCANDESCENT LIGHTS AND GEL it was easy. Put the same gel in front of any luminaire from any manufacturer and you got, more or less, the same color on stage. Now we have LEDs instead of incandescent lamps; and with every manufacturer of LED luminaires using their own version of RGB, how is it possible to get the same color out of two different lights? A new standard in development, PLASA ANSI E1.54, seeks to provide a standardized color space and color language for control desks to be able to communicate color to luminaires in an unambiguous, and manufacturer agnostic, manner. The goal? Simple. Make the same color twice. Please.

Today just about every manufacturer of entertainment luminaires uses their own RGB color gamut. That gamut is usually defined, in the case of LED-based fixtures, by the wavelengths of the specific red, green, and blue emitters being used. The choice of precise emitter color is a subjective one and varies from manufacturer to manufacturer. Some like a more saturated red, others a more saturated blue, and so on. With every manufacturer using different wavelength emitters there is no commonality of RGB control settings between manufacturers, or even between products from the same manufacturer. Send a single set of RGB or HSI values to 20 different luminaires and you'll get 20 different colors. **Figure 1** shows three hypothetical different RGB gamuts from just three luminaires. Sending a control command to "Go to Full Red" to those three luminaires will result in three completely different reds on stage, likely not what the lighting designer wanted.

This situation was probably an inevitable waypoint in the development of LED luminaires as, in most cases, control of the individual colored emitters has been direct with little or no attempt at calibration or reference to any color standards. (*By direct control, I mean that fading up the red channel on the desk causes the luminaire to illuminate just its red LED, not a mix of LEDs to make a standard red.*) However, things are improving, and, as luminaire and LED technologies have advanced, many manufacturers are now calibrating their luminaires to an absolute reference and would be capable of referring the mixed colors produced by their luminaires back to a standardized color definition. There is no particular commercial benefit to a single manufacturer in using one color definition over another, however there is considerable benefit to the entire industry if all manufacturers were to use the same one! Control desks would be able to send the same information to all lights and get the same color from each one. The situation is analogous to the early days of digital communication before DMX512 became the standard. The benefit that DMX512 brought was not that it was absolutely the best method to communicate, but that everyone spoke it. We need the same again, but for a color space, color language, and an unambiguous way to communicate precisely which color we want.

> **"How is it possible to get the same color out of two different lights?"**

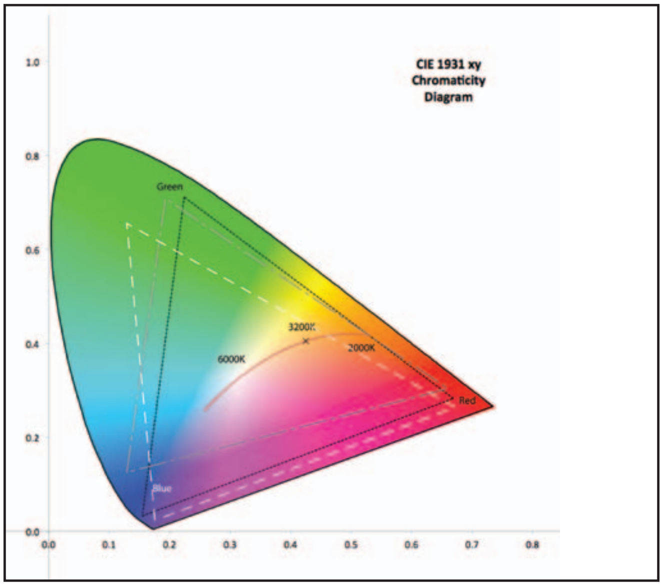

Figure 1 – Arbitrary RGB color gamuts defined by Specific LED emitters

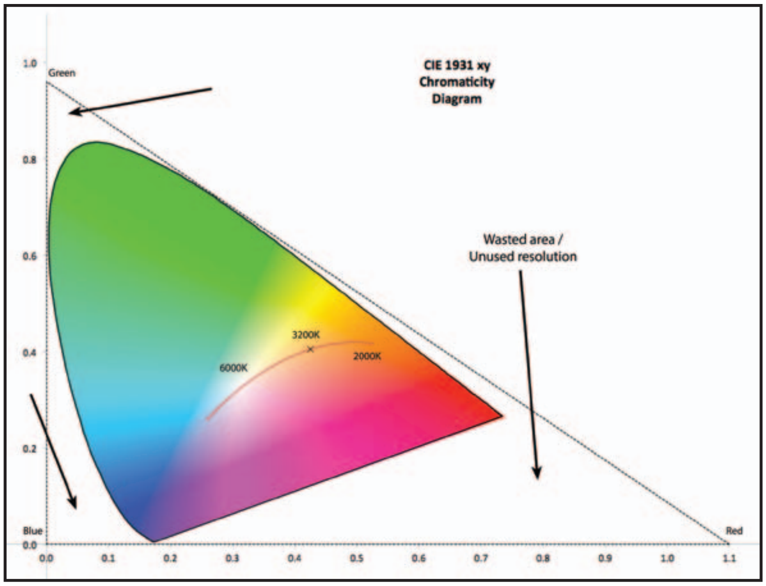

Figure 2 – Large RGB color gamut with dead-space outside the legal colors

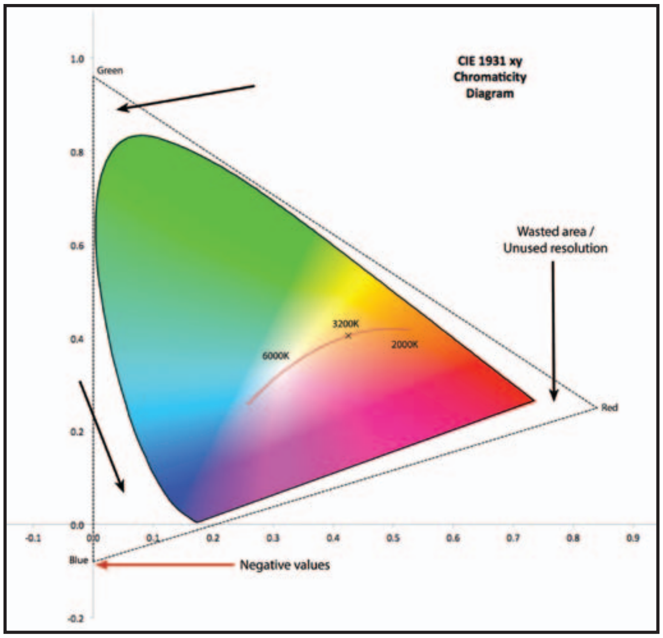

Figure 3 – RGB color space with negative parameters

PLASA color space

There are a number of ways to communicate color information in an unambiguous manner from a control console to a luminaire. Perhaps the simplest thing to standardize would be to agree a color space such as the familiar CIE 1931 x,y space used as the background plot in **Figure 1**. Although the CIE 1931 space has been superseded by newer spaces such as L*u*v* or L*a*b* which have better uniformity, it is still the most familiar color space to most people. *Any of these color spaces would work for us as a standard, they all cover the same underlying range of colors and they are all linear transformations of each other.*

Proposal 1
PLASA color communication should use the CIE 1931 x,y color space.

Although using the x,y space is comprehensive and unambiguous, and it is an excellent way to communicate final color targets, it's not a great color space to crossfade in, nor is it very intuitive to program with. Do you know what color x,y coordinates of 0.5, 0.2 represent? On the other hand, we know that users are much more familiar with dealing with selecting colors using RGB (Red, Green, Blue) or HSI (Hue, Saturation, Intensity) parameters. They are offered by many control consoles and are much more intuitive. They also provide better spaces in which to crossfade between colors. Therefore, it seems sensible that the proposed PLASA standard should provide standards for RGB and HSI as well.

Considerations for the selection of a PLASA RGB color gamut

There are two main, potentially conflicting, requirements in selecting an RGB space for entertainment lighting use. Firstly, the gamut of the defined RGB space should be large enough to encompass all the colors we are likely to want to produce. This suggests we should pick a very large triangle, such as that illustrated in **Figure 2**. However, this has a large amount of its area outside of the allowable color space, and thus would end up with a lot of dead space on faders, a subsequent loss in resolution, and strange crossfading with a lot of crossfades happening in areas of undefined colors.

Secondly, we want the color space to be understandable, and the math to be simple. It is possible to suggest smaller RGB triangles that still include the entire legal color space, but only by allowing one or more of our parameters to go negative, which can cause issues with the underlying math and, at the very least, is confusing! There's still a lot of dead space too. **Figure 3** shows one such possible RGB triangle that includes a negative value for the blue y coordinate.

However, if we step back a little, the problem can be simplified. If we consider which areas we actually use of the 1931 color space then we find that, (a) all that green isn't that useful and, (b) real world colors don't completely fill the space. What we need for our use is a triangle with as little wasted space as possible, that gives us good resolution (particularly in pastels where we are very sensitive to small changes in hue), and, most importantly, provides good crossfading.

We also don't want to reinvent the wheel. Kodak has already been through this exercise and developed the ProPhoto color space as a suggested color space for imaging and photographic use.

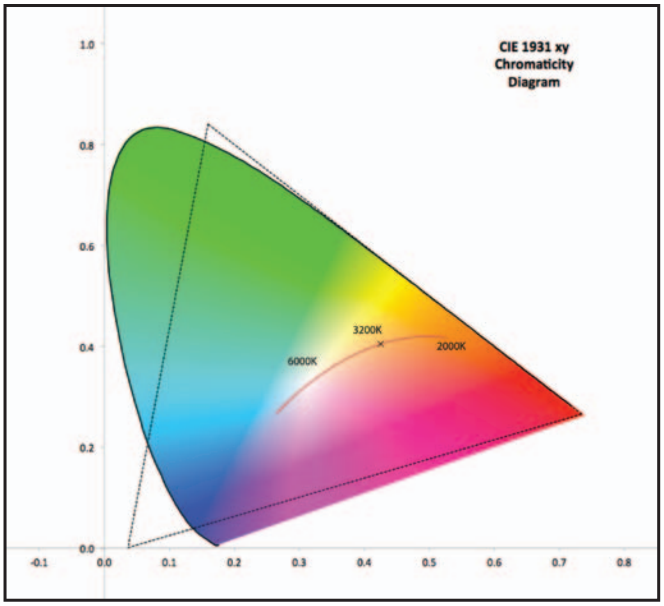

Figure 4 – Kodak ProPhoto Color Space – ROMM RGB

It has the following attributes:

- It is a larger space than any imaging device can achieve
- There is very little dead or unused space. Best use of available resolution
- No negative values of x or y
- It encompasses 90% of all possible colors and 100% of all real world colors

> "The benefit that DMX512 brought was not that it was absolutely the best method to communicate, but that everyone spoke it."

The ProPhoto space has been adopted as part of both ANSI/I3A IT10.7666:2003 and ISO 22028-2:2013 and is now commonly referred to as "ROMM RGB" (Reference Output Medium Metric RGB). ISO 22028-2:2013 contains the following introduction which explains the usage of the ROMM RGB space in the imaging and photographic communities.

"This part of ISO 22028 has been developed in order to meet the industry need for a complete, fully-documented, publicly-available definition of a wide-primary output-referred extended gamut red-green-blue (RGB) colour image encoding. This colour image encoding provides a way to represent output-referred images that does not limit the colour gamut to those colours capable of being displayed on typical monitors, as is the case with the sRGB colour encoding, or require the use of negative RGB colourimetry coordinates, as is the case with extended sRGB colour encodings like bg-sRGB.

"An extended colour-gamut colour encoding is particularly desirable for professional photography applications. For example, colours used for company logos can be outside a monitor gamut and would therefore need to be clipped or compressed to a less saturated colour. Similarly, photographic prints can contain colours outside a monitor RGB colour gamut. By using a standard output-referred extended gamut colour image encoding, images containing such colours can be stored, interchanged, manipulated, and later printed, without limiting or distorting the colours of the final output."

That final sentence applies equally importantly to our industry, and, with a small amount of editing expresses the goal we have for this project. "By using a standard reference gamut for color communication, lighting scenes containing such colors can be stored, interchanged, manipulated, and later output, without limiting or distorting the colors of the final illumination."

If we adopt the same RGB color gamut for the PLASA standard then it can be defined as follows:

Proposal 2
CIE 1931 chromaticity coordinates of PLASA RGB primaries:

Red: x=0.7347, y=0.2653
Green: x=0.1596, y=0.8404
Blue: x=0.0366, y=0.0001

PLASA white point

The remainder of the ANSI and ISO standards are less relevant to us, in particular they utilize the D50 white point which is not an appropriate white point for our use. Instead, it is proposed that we adopt as the standard white point for entertainment luminaires the white light of a 3,200 K black body emitter. (*3,200 K is commonly used as a standard white point for theatrical luminaires, gel swatch books, and lighting control consoles and is a well understood reference.*)

It is important to understand that the choice of the white point does not in any way limit the color choice. For full reference to a color using an RGB or HSI reference, we need to not only define the corners of the triangle, but also the white point achieved when R, G, and B values are all at full, or saturation is zero. Either the console or the luminaire could still work internally with a different white point, such as 5,600 K or D50, and perform the simple math to convert from one white point to another. The intent for a PLASA standard would be to provide the default RGB gamut and white point that can be used for communicating the desired color point unambiguously from controller to luminaire. Using a 3,200 K white point achieves that goal. Accordingly, the white point is defined as follows as a 2° Planckian source at 3,200 K:

Proposal 3
CIE 1931 chromaticity coordinates of PLASA white point:

White: x=0.4254, y=0.4044

Now we have a defined RGB triangle and a white point, it is possible to derive the equations to convert to and from x,y color coordinates and either RGB or HSI control inputs (or any other color space the manufacturer may choose to use). As I've mentioned before, the idea behind this standard is not in any way to limit the creative freedom or choice of both users and manufacturers to do what they want to with color within their luminaires or desks. All the standard would do is to provide a means to communicate that color from one device to another without any ambiguity or confusion. The standard should be invisible to the user in the same way that DMX512 is invisible when used to communicate dimmer levels or the position of a moving light.

What if the luminaire can't make the color it's asked for?

Using a standard color space and color language will inevitably lead to a luminaire being requested to produce a color that is outside of its color gamut. In that case, we should define what happens so that the failure is graceful, and as unobjectionable as possible. The best way to achieve that seems to be to require that, in those circumstances, the luminaire should produce a color of the same hue, but reduce the saturation until it falls within its gamut. **Figure 5** shows an example. A luminaire is capable of the color gamut shown by the Red, Green, Blue triangle. It can make any color within that triangle, but none of the colors outside of it. If it is asked to make the saturated Cyan shown as point 1, it should reduce the saturation (which is equivalent to moving along a line back towards the white point) until the color falls within its capabilities. In this case, it will instead produce the color at point 2. It's a cyan of the same hue, but of lower saturation. This kind of saturation change error is generally unobjectionable, and often not apparent.

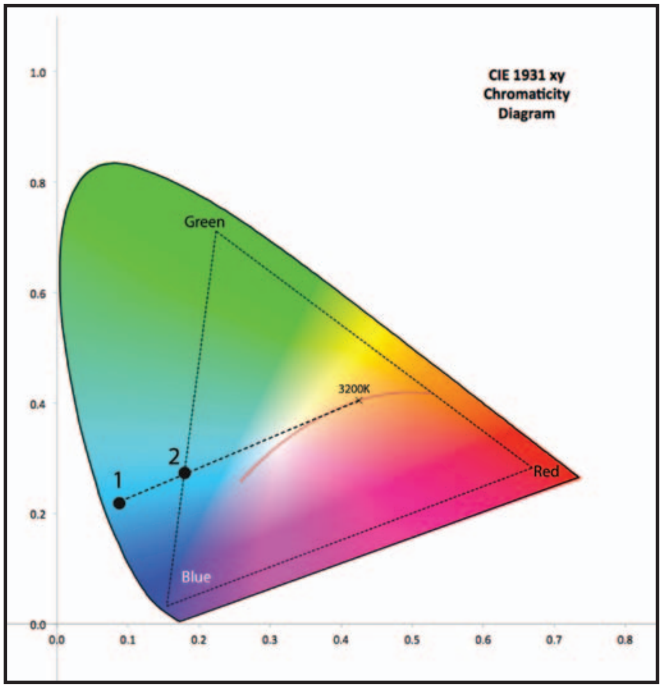

Figure 5 – Out of gamut colors

Conclusion

Agreement between console and luminaire manufacturers on a standard means of communication for color information would significantly improve the ease of use of modern lighting systems, particularly those using multiple colors of LEDs arranged to provide additive color mixing. Much as was the case with DMX512, the benefit to the industry is indirect and comes from being able to connect any console to any light and be confident of the outcome.

So, why am I writing about it in this column? Again, as with DMX512, for a standard like this to be successful it must be adopted by a critical mass of manufacturers. A communication standard is useless unless everyone uses it. It's not a life safety standard, and cannot be legislated for, however, I'm confident that the more progressive manufacturers would drag the rest into compliance once the benefits become apparent. Even if every manufacturer's calibration was not exact (and I don't expect them to be—this isn't easy to achieve), even systems with no calibration at all would still be easier to use with a common color language. There would still be variations, but the colors produced would be much closer than they are today. In my opinion, it's a step we must take as an industry before we can move forward with system-wide color control.

This proposal is a work in progress, with the goal, if everyone agrees, of becoming a PLASA ANSI standard as soon as possible. If you have comments or thoughts on it, please let me know immediately. We'd love some feedback. ■

Mike Wood runs Mike Wood Consulting LLC, which provides consulting support to companies within the entertainment industry on product design, technology strategy, R&D, standards, and Intellectual Property. A 35-year veteran of the entertainment technology industry, Mike is the Immediate Past Chair of the PLASA Governing Body and Co-Chair of the Technical Standards Council. Mike can be reached at mike@mikewoodconsulting.com.