Evolution In UHD

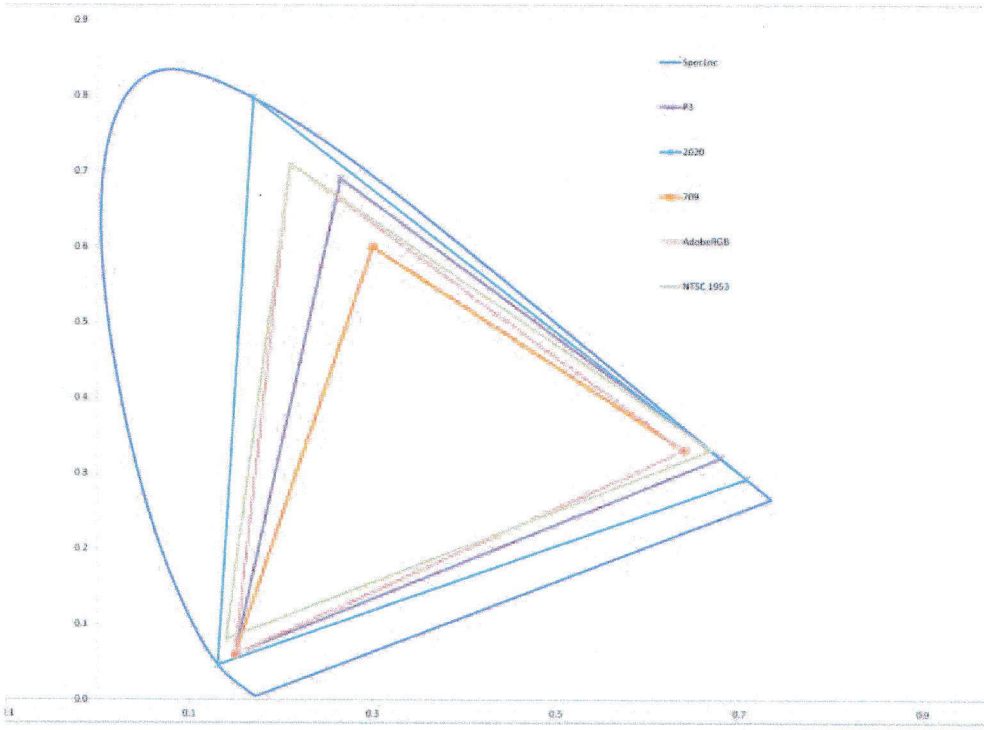
Joe Kane

Ultra High Definition (UHD) came about in 2012 as part of the ongoing progression in image quality. It's part of the path forward from High Definition. It is often advertised as 4K and was originally going to be 4096 by 2160 in resolution. It got scaled back to 3840 by 2160 so a 10-bit version of it would fit in the HDMI signal path of the time. The name 4K stuck, even though few, if any, UHD sets lived up to the name. On the supply side, true 4K has been available from some over-the-top (OTT) program providers. None of the ITU or SMPTE standards documents I've found mention 4K being a part of UHD, but it is there anyway, almost as if "someone" believes UHD is 4096 by 2160. Of course, this begs the question, what happens when 4096 is delivered to a 3840 set? One might hope any set with a 4K label would do something intelligent with it. This is part of the evolution in UHD, an ability to deal with what comes into the consumer's home in the name of UHD.

UHD first appeared on the market as an increase in resolution over HDTV. Since then there has been an industry-wide call for "more, better, and faster pixels." The ITU-R BT.2020 document suggested a higher bit depth of 10 or 12 bits, instead of the 8 bits used for HDTV, and a larger color pallet, 2020 instead of 709. While there are problems with the proposed color space of 2020, a compromise was reached, using the P3 primary colors of digital cinema. It offers a noticeably better color capability than is being used for HDTV. Since P3 hadn't been specified for use in UHD, I am putting it inside the 2020 container that is defined in the document.

With the use of P3 not yet being formally defined, there may be some misunderstanding about how it is supposed to work. Then there is the issue that if we can put P3 in a 2020 container, why not put 709 or some other color space in it as well? I've illustrated just a few options and suggest that when a document is created defining this, it should include an ability to deal with more than just P3 and 709 inside the 2020 container.

Implementing HDR hasn't been easy, if for no other reason than several approaches describe a lot of light output, much more than current sets can produce. For the time being, HDR-10 seems to be the dominant system, with Dolby Vision on its heels. Broadcasters are looking at HLG, and the Technicolor-Philips system approach to HDR gets mentioned now and again.



Color spaces inside ITU 2020.

As if there isn't enough going on, the evolution of HDR has introduced the possibility of new versions of Standard Dynamic Range (SDR). SDR is what we've been watching all along in HD. The first content available for UHD followed the HD 8-bit SDR format, except at a higher resolution. Moving forward, we could present SDR as 10-bit 709 color mastered at 100 nits, the light level established way back in the CRT days. We could also live up to current display capability of consumer displays and create an SDR format at 10 bits, P3, mastering it at 300 nits. The transition to UHD—and we are in a transition—might be the time to abandon the 100 nit mastering system for new materials.

As much as all of this might sound complicated, UHD signals come into your home with identifiers telling your TV set what to do with each type of signal. With this capability, we could someday find UHD being defined by the way a signal is conveyed and identified, not by the display capability. The signal would tell the display what to do—I've made the point in past articles. If a universal delivery system can be defined, then TV set manufacturers are free to invent new capabilities without a worry for source material to drive it. Finding source material to drive UHD was a problem when it first hit the market. There wasn't much content at the resolution or bit depth. At least, in part, this has driven Hollywood studios to master content in such a way as to never get caught short again. On the consumer side, HDMI connections have had a difficult time keeping up ever since. You likely know the numbers—HDMI 2.0, 2.0a, 2.0b, 2.1, 2.2? I

am being incremented to death by this approach. At some point, I need to set a long term goal for conveying UHD content and build the infrastructure to deal with it. Again, I believe UHD should be defined as a communication system with metadata capability to allow for continued innovation on both the production and display sides of the system. Creative types on both ends of the system should be free to be innovative and not be bound by a communication system that is always shy of what is needed.

Ideas like these are examples of UHD happening in all sorts of directions, sometimes faster than can be formally documented. In past articles, I've mentioned wanting to include at least 1080p, if not 720p in UHD. These two pixel counts would be better for OTT video while otherwise being capable of most of the innovations UHD has to offer. Including 1080p and 720p would provide a path forward for UHD to encompass HD and fully replace it. Digital TV has essentially replaced analog TV. It is now time for the ultimate digital system.

All of this creates interesting challenges for me in trying to come up with a new *UHD Test & Demonstration Materials Ultra HD Blu-ray Disc* and or a USB stick with new materials. There is always a need for content to challenge whatever is happening today. In my case, I've always tried to include something I see coming in the future. I mastered my first analog composite LaserDisc, *A Video Standard*, in digital component. I mastered my standard-definition *Digital Video Essentials* DVD in HD. Where possible, I am now mastering the current product in nearly 8K, with a 14- to 16-bit picture at a wider color capability than can be conveyed in P3. I am shooting a lot of my motion material at 60 Hz progressive.

I've decided it is too early in the game to provide everything I see coming in the future, if for no other reason than the communication system is yet in place to convey what I am creating. That said, the second generation of my UHD content will have some innovations in it, and I expect to illustrate the point of a UHD system being all about the connectivity, not what might be done on the production or display side of the system.

For those of you who don't remember, I made my first pass at UHD on a USB stick that became available in October 2014. It has 8-bit SDR content for the consumer and up to 16-bit, half-float content for the professional world of content creation. The content was all still images, and all of the material was presented in the RGB domain. I didn't deal with the new equations for Y Cr Cb in UHD. There was no definition for color, 709, P3, or 2020, and there was no metadata telling the set what to do with the signal. Enough has happened since then where I feel it is time to go for it again, this time providing H.265-encoded material for SDR and HDR. In addition to stills, I'm going for motion content; for a number of reasons, and up to 60 Hz. I'm leaving things like 120-Hz motion and 8K resolution for a future program.

Sony management introduces their new Z Series sets at Video & Audio in Woodland Hills, California.

When I discuss how fast things are moving and what a new UHD program would have to contain to keep up, I have found some challenges in the latest sets to come to market. On Thursday, August 11, Sony officially introduced their new Z Series sets at the Video & Audio Center in Woodland Hills, California, a suburb of Los Angeles. The LCD-based series of sets is LED backlit with a full panel dense lighting array. It is designed to have the contrast of an OLED display, with far better black levels than most LCD displays, with a far higher brightness in the HDR mode than is currently available from OLED technology. It is said to have 14-bit processing, moving in a direction I've long advocated. (I'm still hoping for 16-bit half float.)

This says the test disc I am currently creating should have an ability to help differentiate an OLED set from an LCD set. I have to give consideration to an LCD set designed to meet some of the OLED capabilities. There are a lot of possibilities to explore, including checkerboard patterns for contrast ratio, performance just above black, light output versus average picture area, color saturation versus light output... Sony is making claims for a large color volume in their sets, something I see as possible, but I need to be able to plot it to see the reality of what it is doing versus other sets. Color volume may become a new parameter to report in reviews of UHD sets. I need to be able to look at performance based on average picture level (APL). Right now, as APL goes up beyond 10 percent, the light output goes down. Ironically, in many sets, as the average picture level goes much below 10 percent the light output also goes down.

Talking about what I am putting into the *UHD Test & Demonstration Materials Disc* is a view of what I see happening in UHD. The disc is a production of JKP and Florian Friedrich Consulting in Munich, Germany. It will have both SDR and HDR content. The SDR portion of the program will be split into two parts, HDR and SDR. The SDR section will be subdivided into two formats, SDR as 10 bit, 709 color mastered at 100 nits; and SDR as 10 bit, P3 color, mastered at 300 nits. For the time being, I'm only supporting HDR-10 in HDR. I'll be supporting other HDR formats in future programs. The first edition of the disc is scheduled to be on the

market this fall. When you purchase the disc, you'll be asked to register it so I can offer you discounted prices on subsequent versions. There will be subsequent discs, as it is the only way we see being able to support the ongoing changes in UHD. It's also part of the reason I'm not doing a tutorial on UHD in the first disc. It's not the right time. Subscribers will be notified of tutorials I post online. I see this as the better way to document things I think you'll want to see.

The easiest way to show what's on the disc is to illustrate the disc's menu system.

If you pick the first option, you go into the HDR menu page. Again, I'm currently only supporting one HDR system, the HDR-10 used by the UHD Alliance. It follows the PQ curve specified in the SMPTE ST 2084 document. I'm using P3 color inside a 2020 color carrier at 10 bits mastered at 1,000 or 10,000 nits, as specified in the options. When you select the HDR option in the main menu, it will lead you to a sub menu detailing the option available in HDR.

I firmly believe 1080p should have a place in UHD and HDR, so here it is in HDR, both in test and demonstration materials. While a lot of HDR-10 material is mastered at around 1,000 nits, some of it is mastered at a much higher level. Rather than try to pinpoint specific levels that are higher, I decided to provide test patterns that go to the 10,000 nit maximum level and provide an opportunity for the observer to determine what an individual set is doing. I'll provide an ability to visually inspect the set for its light output capability at a 10 percent average picture level, the APL where most HDR sets seem to hit their maximum light output capability.

For those with light measurement capability, I'll be providing a 50 percent signal level as part of the tests. When displayed, it should provide a 100-nit level from the set.

While the HDR test patterns may look a bit like the SDR test patterns I've presented in the past, they have been modified to fit the requirements of HDR. The PLUGE with Log Gray scale is an example.

In the SDR version of this test pattern, the steps are 4 percent below black, black background, and 4 and 2 percent above black. In the HDR version, the steps above black should provide specific light output levels. The gray scale range and peak white will step up to about the 75 percent level or 1,000 nits in the 1,000-nit master. It will step up to the 100 percent level in the 10,000-nit master, but, of course, be cut off before that level in all of the current sets I know about. The 10,000-nit version of the signal could be interesting on the video walls I talked about in an earlier *Widescreen Review* article.

UHD Test & Demonstration Materials - Options

HDR Test & Demonstration Materials

SDR Test & Demonstration Materials

Audio Test Signals

HDR Test & Demonstration Materials Options in P3 Color

HDR 2160p/24 (3840 x 2160) Test Patterns - 1,000 nit master

HDR 1080p/24 (1920 x 1080) Test Patterns - 1,000 nit master

HDR 2160p/24 (3840 x 2160) Test Patterns - 10,000 nit master

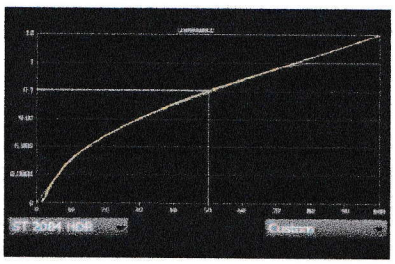
HDR 2160p P3 Demonstration Materials - 1,000 nit master

HDR 1080p P3 Demonstration Materials - 1,000 nit master

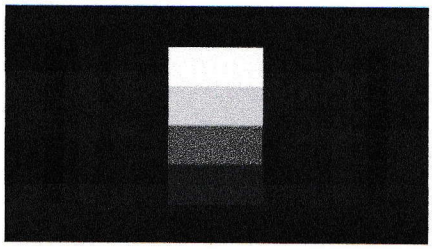
HDR 2160p P3 Alternate Demo Materials - 1,000 nit master

The HDR test patterns are no longer the static test patterns you are used to seeing from my prior products. I am concerned for having static patterns in HDR on TV sets, therefore, motion has been added to the majority of the patterns. This is necessary for an additional reason, beyond trying to help avoid possible burn patterns in the display. HDR TV set and Ultra HD Blu-ray Disc player manufacturers will often turn the HDR mode off if they don't see motion in the image. I am aware of this and know I need to put motion in the menu system background of the HDR menus as well as in the patterns themselves.

You'll notice an alternate set of HDR demonstration materials. I've noticed there is more than one approach to interpreting how P3 should go inside the 2020 color container. I suspect the possibility of a different interpretation, and I think a possible difference in approach to P3 in a 2020 container might account for some HDR content being judged as being oversaturated.

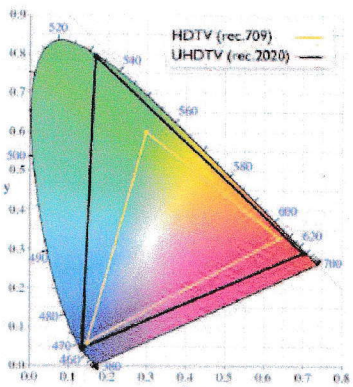


ST 2084 PQ curve out to 10,000 nits, 50 percent signal level at 100 nits.



SDR PLUGE w/ Log Gray Scale.

Look at the CIE drawing where I've shown the 709 and 2020 color triangles in the same space, as if 709 were contained within 2020. If you pick a white point in the center and draw a line to the green of each color triangle, you'll notice they go off in different directions. Now consider what would happen if the TV set took the color from gray to 2020 green, when the signal was encoded using the 2020 Y Cr Cb equation, instead of taking it in the direction of the 709 green. Most of the colors would be oversaturated. The main HDR example tells the set to follow the direction of P3, while the alternate version tells the set to follow the 2020 direction. What I am trying to see is if the set will follow directions correctly. This is an example of where I'll need a tutorial, but it can't be put together until I get the test materials out there and see what is happening.



Different vector directions between color spaces.

Demonstration materials in HDR are at three different frame rates: 23.976 Hz, 30 Hz, and 60 Hz. It's too early in the evolution of UHD to be pushing 120 Hz, but it will likely be included in some future version of my program. When I brought out the USB

stick, I labeled it Version 0.9. I can only justify calling the latest version 1.0 if there is an understanding there is more to come.

The 23.976 frame rate material comes from the motion picture film Allen Daviau shot for me in January 2001. It's my look at what can be done with film shot long before anyone considered HDR to be a possibility. The 30 Hz and 60 Hz material has all been shot electronically.

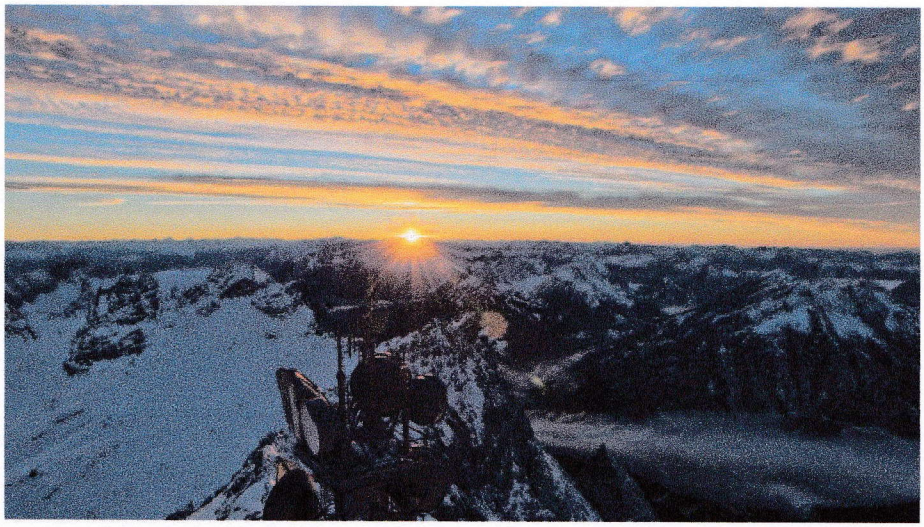
I shot a number of images on a stage in Ludwigsberg, Germany where I was able to tightly control exposures and include fine gradation of gray to illustrate the advantage 10-bit depth has to offer.

I'm introducing a new SDR format in this program, one that takes advantage of UHD—HDR sets, providing a 10-bit capability at P3 color and a much brighter level than the conventional 100-nit level of SDR images of the past. As much as I've said not everything is written about UHD and it is an ongoing format, this is my example of doing something that is perfectly logical. It has long been accepted that a 100-nit level is only good in a well-controlled viewing environment. While many people concerned with properly reproducing an SDR image as it was intended will have a calibrated 100-nit 709 color position on their set, any display device set up for HDR-10 should be able to deliver an SDR, 2.4 gamma, P3, 10-bit image. This is my addition to UHD, which has yet to be defined or even considered for use in UHD. What I think you'll see is a far better SDR image and something far easier to derive from existing HDR-10 content, should an SDR version be desirable. I believe once you've set up a memory in your HDR set for this version of SDR, you'll find the quality far more compelling than the 709 100-nit version, which is also part of the program. In part, this example is being included to push the idea that UHD has to be all about an ability to communicate, leaving the what and by how much to the creative community, which includes the TV set manufacturers.

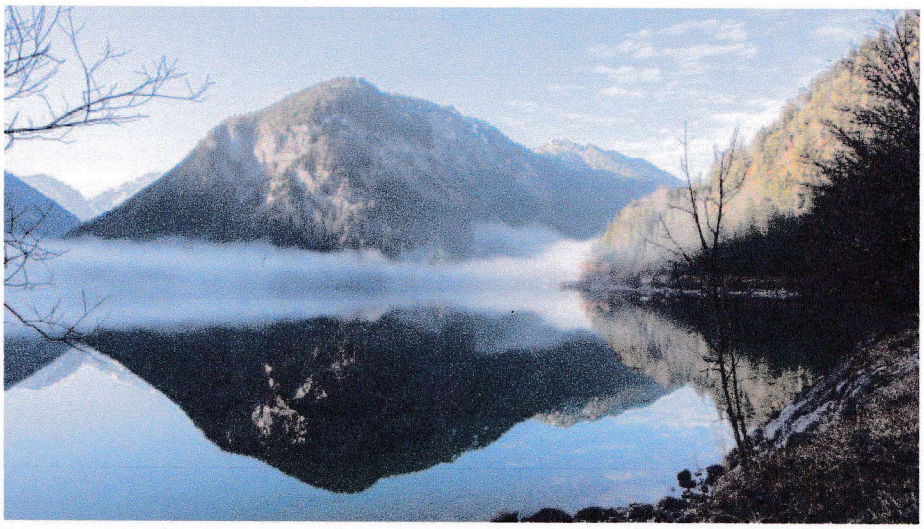
A look at one of the two SDR menus in the program will give you an idea of the options. You'll see an option in 1080p as well as a true 4K. The test patterns are in a true 24 Hz instead of the fractional 2.3976 Hz of the film material. The menu system allows you to go back and forth between the 709 100-nit SDR options and the P3 300-nit options.

I've been talking about more light output for both SDR and HDR and room environment. It seems way out of date to look at the pictures in the tutorial I created for *DVE* back in 2001 with the CRT set in the room. The lesson about needing a backlight is important. I believe backlighting is going to

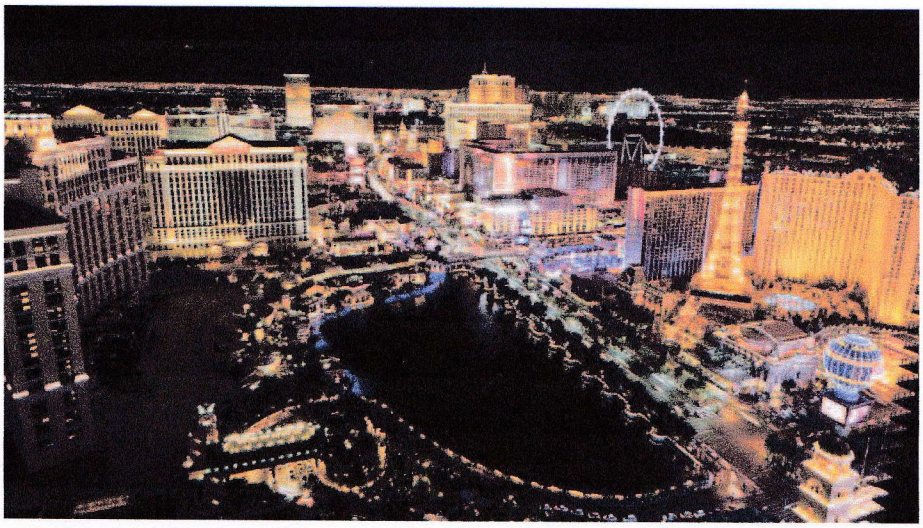
Film content in the HDR sequence.



Sample 1 of images from my demonstration content.



Sample 2 of images from my demonstration materials.



Sample 3 of images from my demonstration materials.

Sample 4 of images from my demonstration materials.

be necessary, more so for HDR than it was for SDR, so I'm working with Medialight™ to come up with high-color-rendering index D65 lighting that is dimmable. I'm using strip LED lighting so it can be attached to the back of flat panel displays. This way, even sets mounted to the wall can be easily lit from the back.

There is a new standards document that addresses the need for backlighting, but I'm not going to quote from it prior to doing my own research. What's important to me is that the source of D65 light at a high-color-rendering index is available for us as a starting point. The idea of it being dimmable essentially means it can be set to the level it needs to be. When I was working with this in the days of CRT sets, I established the maximum light output should be no more than 10 percent of the peak white coming from the set. While you might be tempted to just extend the peak light output capability to the 1,000-nit mastering level, I'm not confident that's the way to go. First of all, I know peak light output capability is dependent on APL and I also know the peak light output will only happen when it is a small area of the picture. I also know HDR is designed to give us a bit more detail in the dark areas of the picture, meaning we might not want the backlighting to be too high. I'll have more of this in a future article.

SDR Test & Demonstration Materials Options in P3 Color

SDR 2160p/24 (3840 x 2160) Test Patterns

SDR 4K/24 (4096 x 2160) Test Patterns

SDR 2160p Demonstration Materials

SDR 1080p Demonstration Materials

Go to SDR Materials in 709 color space

I'm finding reviewers of UHD sets just catching up to issues of putting P3 in a 2020 carrier or the need for a larger bit depth for HDR than SDR—even at a time when SDR is getting more bits.

One retailer of HDR TV sets asked me if I was done with modifications to UHD. The best short answer I could provide is, I'm just getting started with more, better, faster pixels.

I believe we can put connectivity issues out of the way if we agree upon a communications system defining UHD, and from that point on we'll be free to innovate as technology allows us to move forward. I'll keep participating in and reporting on such innovations. WSR

Room environment and backlighting a TV set from *DVE HD-Basics*.