**Color Management and Computer Monitors:**
**What you see is NOT what you get…**

The photograph that you see on your computer monitor (its video display) may not accurately portray the colors recorded by your digital camera. There are three reasons for this discrepancy.

First, because they are not color-calibrated, most computer displays do not precisely display the colors that they obtain from the image file of a digital camera or flatbed scanner. As a result, the reds, greens and blues that are produced by the monitor may not be the same hue (color) as those in the actual image.

Second, the monitor's screen may be set either too dark or too bright (this brightness is correctly called luminance we perceive the luminance as brightness). An improperly calibrated monitor's brightness gives the viewer a false impression of the brightness of the actual photograph.

Finally, most computer monitors use only the sRGB color space, which displays a more limited range of colors than the additional colors produced by more sophisticated color spaces. This color space was developed in 1996 to match CRT monitors (those using cathode ray tubes).

**Color Spaces**

Multiple color spaces were created to define the boundaries of differing ranges of colors. They were created so that color professionals would have a common language when referring to color output in the form of internet images, printed publications, and printed photographs.

Each color space is a set of red, green and blue colors, within its own specified range. Graphics professionals use the names of the various color spaces to identify their color range.

All color spaces are "device dependent." Without the particular device which uses them, color spaces have no meaning. Printers can produce oddly colored prints if the printer's driver (the hardware's software) is unable to interpret color spaces larger than sRGB or Adobe RGB.

Professionals like those at Henley's can print using any color space you specify, although some adjustments may be necessary. However, some commercial printing shops do not fully understand color spaces. In such stores, their printers sometimes can use only the sRGB color space. If a commercial printer gives you a blank stare when you say, "Please print this in the Adobe RGB color space," you must either find another source to process your prints or change the color profile of your image files to match the capabilities of the printer that is available.

Many large commercial printers can convert RGB image files to CMYK (four color press) image files. To do this, they use Photoshop or specialized RIP (raster image processing) software. This process, called color separation, is best left to experts.

(By the way, a raster image is a digital image that is made up of pixels. A vector image is made of lines and fills, defined by mathematical formulas. Adobe Illustrator (CAD) images are vector images. Vector images can be rasterized, brought into Photoshop, adjusted and printed.)

Converting from a smaller color space to a larger color space cannot increase the colors in an existing .jpeg file. However, it can provide “elbow room” to adjust or correct the existing colors.

Photoshop can easily convert a file that has one defined color space into a different color space. If a file has no color space assigned at all, you can assign one using Photoshop. First, assign the color space you want to use (Edit > Assign Profile) and then convert the file to the color space you wish to use (Edit > Convert to Profile).

*Note*: Once you assign the color space in Photoshop, you must also convert the file. Assigning a color space without converting it just changes the file’s metadata (the information file attached to a computer file) but does not actually change the color content of the file (remap the colors to the chosen space).

Remember that, regardless of which color space you originally choose in Photoshop, you can always change the color space to match your particular device. This means, for example, that a photo that was processed in Photoshop within the ProPhoto RGB color space at 16 bits can be converted later to an 8-bit sRGB image (for the internet or email) or converted to a 16-bit Adobe RGB image (if necessary to match a particular printer’s specifications).

**sRGB** – The sRGB color space was developed in 1996. It was designed for widespread “consumer use” with the assumption that most people do not need color-calibrated monitors, are not too finicky about color accuracy, and just want to easily view, email, and print their digital photographs on inexpensive inkjet printers.

The sRGB color space meets the need for mass-produced equipment by providing a basic color space for easily reproduced values of red, green and blue. The sRGB color space is compatible with most monitors, scanners, cameras and printers – right out of the box, without any color adjustments, making it the easiest color space option.

The basic sRGB color space is the worldwide standard adopted for use on the internet (see: www.w3.org/Graphics/Color/sRGB.html). It is so widely accepted as the default color space for consumer products that most internet images are .jpeg files saved “within” the sRGB color space.

Because of its limited color range, the sRGB color space is best suited to images containing natural colors. If the sRGB color space is used for an image which has a larger range of colors, some loss of color (called “clipping”) will occur, particularly in greens and reds/oranges. Artificially manufactured colors (fluorescent dyes or neon lights, for example) often push the boundaries of Mother Nature's color palette.

Although the sRGB color space is not small, it is too confining to produce professional-quality images. Additional color spaces are better suited for more demanding uses.

**Adobe RGB (Adobe RGB 1998)**– The Adobe RGB color space, developed in 1998, offers many more colors (a wider "color gamut") than the sRGB color space. It was created for commercial printing presses that use quality inkjet printers and four (or more) colored inks.

Although most computer monitors cannot display the Adobe RGB color space, the computer monitors that are intended for use by design professionals for graphic art and fine art photography may be able to display 98% of the Adobe RGB color space.

Sophisticated digital cameras can record digital color information in either the sRGB or the Adobe RGB color spaces. Using Adobe RGB to capture jpeg images with your digital computer works well. Just make sure that you use a printer that is capable of interpreting the Adobe RGB color space. However, your digital camera records many more colors than those within the Adobe RGB color space, so it is not your optimal color space choice when shooting photos in RAW.

**ProPhoto RGB** – When you shoot RAW images, your camera records many more colors than are within the Adobe RGB color space. The ProPhoto RGB color space, significantly larger than the Adobe RGB color space, can hold nearly all of the colors that can be captured by a digital camera.

In fact, the ProPhoto RGB color space is so big that it includes deep greens and blues that are beyond the range of human vision. This can create a problem when adjusting the colors with ProPhoto RGB for images that you intend to print.

If you add too much saturation in Photoshop, dark greens and blues may look just fine on your computer monitor but actually be beyond the range of "real" colors. When this occurs, the colors seen in the prints can be surprisingly different from those on your screen.

When used wisely and cautiously, ProPhoto RGB is an excellent color space for use by both professionals and amateurs who wish to get the best results from their investment in technology.

## Color Space RAW Photos

The best color space for RAW shooters is the ProPhoto RGB color space. It is available in Adobe Lightroom, Adobe Photoshop and in Photoshop's Camera RAW plug-in. To accommodate the full color potential of RAW data, be sure to set the RAW plug-in to receive RAW data in ProPhoto RGB at 16 bits.

The ProPhoto RGB color space is considerably larger than the Adobe RGB color space and includes colors beyond the range of human vision. To use this color space, be sure to change color settings in Photoshop (Edit > Color Settings) to ProPhoto RGB and select the 16-bit color mode (Image > Mode).

The 16-bit mode allows for far more than the 8-bit 256 colors per red, green and blue color channel. In fact, 16-bit color depth provides 65,536 colors (or 256 squared) per color channel. No computer monitor now manufactured can display all the colors that are included in the huge ProPhoto RGB color space. However, that does not mean that the colors are not in the RAW photograph's file. They are certainly there, although no monitor has the capability to show all of them. Yet.

So why doesn't everyone use the ProPhoto RGB color space? It requires a modern computer with at least 4 gigabytes of RAM (computer memory) to manage large, 16-bit image files. Also, some printers are not equipped to deal with either 16-bit image files or anything more than the sRGB color space. And, of course, not all consumers can or will invest the time and energy to learn how to use Camera RAW, employ 16-bit processing, or experiment with a color gamut larger than sRGB.

Remember: only a computer with a 64-bit operating system, using an operating system such as Windows 7, can use more than 3.6 gigabytes of RAM. Squeezing the most color out of camera RAW images requires modestly sophisticated software and sophisticated printers. Even pricey, fine art printers have their own idiosyncrasies that must be overcome (paper jams and alignment, clogged nozzles, etc.) to achieve satisfactory results.

**Computer Monitors**

If color were money, computer monitors would be rich, compared to most printers. Monitors have a vast array of colors to project onto their screen in what is known as an additive color process. Red, green and blue (RGB) are added in various luminosities to produce many millions of colors. To maintain color accuracy from a camera to a computer monitor to a printer is challenging

What's the "ultimate" computer monitor?  Probably this one:

> The 30" NEC MultiSync PA301W is the ultimate LCD display for professional graphics and photography applications and can tackle the most demanding color-critical projects. This 10-bit widescreen LCD, which features four digital inputs, a 2560 x 1600 resolution with a wide color gamut, a 14-bit 3D LUT, high brightness and an integrated USB hub with DisplaySync Pro, sets the standard for accurate, consistent and repeatable color performance.
>
> - 98.2% coverage of Adobe RGB color space
> - Superior screen performance (1000:1 contrast ratio, 2560 x 1600 native resolution, 350cd/m$^2$ brightness)

However, at $2,300, it is more than a bit pricy. Nevertheless, this is a highly desirable list of characteristics for any similar device where color accuracy is demanded.

What is a somewhat adequate but modestly priced alternative? Perhaps this one:

Dell™ UltraSharp™ U2410 Monitor (about $500). Key features include:

- **Exceptional Screen Performance:** Enjoy 1920 x 1200 maximum resolution, 16:10 widescreen aspect ratio and 80,000:1 dynamic contrast ratio
- **Vibrant, Accurate Color:** PremierColor technology delivers color depth of 1.07 billion and 110% color gamut (typical)[1]
- **Superb User Experience:** Advanced digital connectivity, intuitive controls and ergonomic design for enhanced viewing comfort.

An assortment of models can be found between the examples above.

The best way to choose a monitor is to see it in person. But it is always wise to check online reviews to see what others think about the product before you buy it.

### Color Calibration

Quality-minded publishers, professional photographers and graphic artists are very conscious of color quality and wish to maintain color accuracy from camera to print. Color management (also called “color managed workflow”) is extremely critical to publishers, garment manufacturers, advertising companies, web designers, cereal box manufacturers, etc. It also can prevent embarrassing color casts or improper colors in our prints when we “go professional” with our photographs.

To insure a more accurate color display of your photographs on your computer screen, you can calibrate your monitor’s display using a device such as Datacolor’s Spyder4Pro. When using Spyder4Pro, you load a Datacolor’s software into your computer and connect a receiver to it with a USB plug. The receiver hangs over the front of the computer screen (like a spider on a web). Then specialized software generates color samples in the monitor, which are transmitted to the receiver. The received colors are analyzed by the software and then an ICC file (International Color Consortium, refer to www.color.org) is saved to the Windows\System32\spool\drivers\color directory for use by the computer.

When you turn on your computer, a modern video card will search for the ICC information in the Windows color directory and load it, producing a display that has accurate colors and proper luminance or color temperature (Kelvin scale).

Spyder4Pro list lists for about $170. It is available at http://spyder.datacolor.com.

The i1Display Pro is another excellent monitor calibration device. It is sells for about $250 (see: http://www.xrite.com/home.aspx).

Luminance or brightness is an important setting on your computer monitor. A display that is too bright can produce prints that are too dark. A display that is too dark may produce prints that are too bright.

### Previewing Photos in Photoshop before Printing

Photoshop's View > Proof Colors can be a valuable tool for previewing a print. However, ICC color values for the specific paper that will be used in the printer must be entered into the computer before Photoshop can approximate how an image will look when it is printed.

### Printing Photos

Printers use subtractive colors to produce images. Subtractive colors are printed as small dots. Dots of certain colors, when printed close to other colors, fool the eye into seeing a wide range of colors, depending upon the pattern and proximity of the dots.

Computer printers often are rated by how many dots per inch (DPI) they produce. Digital printers transform pixels per inch (PPI) into DPI for printing.

The colors cyan, magenta, yellow and black are often used produce images in a four-color (CMYK) printing process. (The letter K represents black because if a B were used, it might be confused with blue).

Printer manufacturers offer a staggering variety of papers for fine art printing. Some common varieties are glossy, semi-gloss, matte and velvet.

Each kind of paper has its own "dot gain," which is how much a tiny drop of printer ink will spread out before being absorbed by the paper. Consequently, if you choose an Epson printer, I recommend that you use Epson paper and an Epson ICC for the specific paper you are using. Epson will gladly give you the free ICC color profile software for its papers [where/how?].

When loaded, these ICC color files will be used by Photoshop and the printer driver software that came with the printer. Check periodically to see if your printer's manufacturer has updated your printer driver; if so, you should be able to download it from the manufacturer's website.

Printer problems can baffle novices (or even experts) who rush the printing process. For example, if the computer's printer driver is set to matte paper and glossy paper is used instead, the resulting print will look muddy. Matte paper absorbs more ink than glossy paper, so the printer dispenses more ink onto the paper when this matte paper is selected. The resulting excess ink will accumulates on the surface of the harder, glossy paper, producing a fuzzy print.

### Printing Photos

A printer's output can only be as good as its input. Remember the old proverb: garbage in, garbage out. To get optimal results, we must send the printer a file of adequate size.

Digital images are made of pixels. The resolution (quality) of digital images can be described by the number of pixels that are found within a linear inch of the image (pixels per inch, or PPI).

For Epson printers, the optimal input is 360 PPI. For Canon printers, it is 300 PPI (some say 600). For the best possible print, I therefore send my Epson printer a computer image at 360 PPI and cropped to the planned dimensions of the print (8 x 10 inches,11 x 14 inches, etc.).

I do this in Photoshop, using Image > Image Size, using the Bicubic setting, before I send the photo to my printer. I also select options within the printer driver's output software, to make certain that Photoshop manages the color. I never allow printer settings to control the color process. Conveniently enough, this is usually shown in the printer driver as "Photoshop Manages Colors."

To identify a problem before the print is made, I also select "Print Preview" before actually printing it. (Many printers will let you know if you are about to make a bad decision by showing you just how awful things will be if the print process is allowed to proceed without tweaking the settings.)

Inkjet printers have a stated "native resolution." Its native resolution is the number of dots per inch (DPI) that result in the highest quality output for that printer. A printer that has, for example, a native resolution of 4800 x 2400 DPI must make internal calculations about the color of every dot of ink. It does this according to the PPI information that is sent to it from Photoshop (or Adobe Lightroom).

The ideal PPI input for the above printer would probably be 300 PPI, a good working number for most high-quality inkjet printers. Some inkjet printers can use 360 PPI and some very sophisticated digital printers may be able to take advantage of 600 PPI, but more than that amount is unlikely to be of benefit.

Why use a round number such as 300 PPI? When the printer is given an input PPI that is a multiple of its native resolution, it is easy for the printer to obtain results without having to interpolate. Interpolation is the art of making a mathematical guess. No guessing results in better printing. The printer does not have to do any fancy math to "fit" a file into its way of thinking.

Dividing the above native resolution by 4800 DPI by 300 PPI gives the number 16. The Canon PIXMA PRO-1 boasts 4800 x 2400 DPI. If the image were sent to the printer at 300 PPI, that's a potential of 16 dots per pixel of information. Although it sounds impossible, the printer is capable of printing *up to* that amount of detail.

Although a computer monitor has only 72-120 pixels per inch, a printer can easily utilize 360 PPI. Once again, the monitor does not tell us the full story. This is why, when we use Unsharp Mask in Photoshop to sharpen our images for printing, we often over-sharpen them. (Typically, portraits are not sharpened very much, as no one wants those age-revealing wrinkles to stand out).

Practice with your printer to determine the range of sharpening it can best use. Smaller files require less sharpening than larger files and files intended for the internet should be very carefully sharpened. Viewing images at 100% in Photoshop can help you determine the best values for sharpening.

Like monitors, printers have limitations. Many digital printers cannot reproduce all the colors that can be displayed on a computer monitor that is capable of accurately presenting the Adobe RGB color space. Although printers have a limited variety of inks, a professional quality computer video display has a vast number of possible colors to project onto the rare earth elements of your computer monitor.

Even relatively sophisticated printers such as the Canon PIXMA PRO-1 (about $1,000) have “only” twelve inks: Cyan, Light Cyan, Magenta, Photo Magenta (bright magenta), Yellow, Red, Photo Black, Matte Black, Gray, Dark Gray, Light Gray and Chroma Optimizer. Some of these inks are well able to print many of the colors within the ProPhoto RGB color space.

With my own photos, I am willing to spend the time and effort to draw every last bit of performance from my equipment, to get the results that satisfy me. However, that may not be a profitable objective where efficient production is required. Many photographers simply shoot and print in sRGB because the workflow is simple. Because the sRGB color space is small, their photos tend to have saturated reds, greens and blues that are well received by their friends and admirers.

Even if you don’t print or publish in ProPhoto RGB, when making adjustments such as contrast, saturation and brightness, a digital image will be less likely to degrade if you use 16-bit ProPhoto RGB than, for example, 8-bit sRGB. You can always adjust the final output to meet the specifications or limitations of your particular printer.

For guidance in building a suitable computer for use with modern digital cameras, refer to *Building Your Own High-Performance Computer* by Ed Ruth. This ebook is available for download at Amazon.com for Kindle and at BarnesandNoble.com for Nook.