

# A Basic Guide to Color Management

By Shelly Smith  
shelly.smith@nyu.edu

**C**olor management is a technology that helps ensure visually equivalent colors between devices, such as scanners, monitors, and printers, making it possible, for example, for an RGB scan viewed on an RGB monitor to happily match a CMYK print of the same image. The goal of color management is to establish reliability, predictability, and consistency of color when transferring or reproducing any image—a process that can often present many challenges.

The following information has been collected and organized as a beginners' guide to basic color management concepts. Adobe Photoshop is used in examples throughout this guide because of its value and range of capabilities as an image processing and color management package.

## GLOSSARY OF GENERAL COLOR MANAGEMENT TERMS

### > Calibration

The process of adjusting specific devices to ensure that they produce the most accurate color possible. Can involve monitor adjustments and/or the use of external hardware to precisely measure the output of a monitor's phosphors

and the density of ink on a page. Calibration is intended to make a device produce colors that are as close as possible to an objective standard.

### > CIE

The International Commission on Illumination (<http://www.cie.co.at>). Founded in 1920, CIE is an authority on lighting and is recognized by ISO, the International Standards Organization. The International Standardization body developed a way to assign numbers to every color visible to the human eye: CIE L\*a\*b.

### > Color Management Module (CMM)

Software that translates color information from one profile to another. Adobe Color Engine (ACE) is an example of a CMM.

### > Color Management System (CMS)

A collection of color engines, ICC profiles, color settings, and other bits and pieces to manage color. A set CMS applies Apple's ColorSync or chosen custom profiles specific to the devices used (e.g., monitors, printers, scanners). Apple's ColorSync or Microsoft ICM for Windows are system-level color management systems. Kodak CMS is a program-level CMS.

### > CMYK Profile (In Photoshop's Color Settings)

A profile which identifies to the color management engine the capabilities of a specific output, press, or print device. Profiles for inkjet printers that require RGB images are also loaded as CMYK profiles. The CMYK profile determines the CMYK working space.

### > Color Management Engine (Color Engine)

Software that serves as a translator between devices, mapping color from one device profile to another. The color engine reads color data in a file and color profile for any monitor, and converts the colors to the color space of another device, for example:

- Monitor > Color Engine (mapping translation) > Printer
- Foreign Computer File > Color Engine (mapping translation) > Printer

### > Color Management Policies (In Photoshop's Color Settings)

These options determine what Photoshop does when you open a file with an embedded profile that doesn't match your working space. The embedded profile can be retained, which may result in an inaccurate appearance on screen. Otherwise, you can convert to a

working profile or simply ignore the profiles altogether.

#### > **Color Mapping**

Translating color information from one profile to another. A color engine looks at an image's color data, takes into account the source profile embedded in the file, and then maps color information to the destination profile.

#### > **Color Model**

A system of notation used to numerically describe the specific colors within a gamut. RGB, CMYK, Grayscale, L\*a\*b and HSB are examples of color models.

#### > **Color Settings**

A term that refers to both the options you've selected for color management and the Photoshop dialog box.

#### > **Color Space**

The collection of possible colors that can be created by a specific technique or device. In Photoshop, L\*a\*b space has the widest theoretical color space, encompassing all the colors that the human eye can see. RGB space is produced by mixing red, green, and blue light. CMYK color space includes only those colors created by using the four process color inks (Cyan, Magenta, Yellow, and Black). Color space is restricted by the capabilities of the specific devices being used.

#### > **Embedded Profile**

A profile that is created when a file contains information about the devices with which or for which the file was prepared. RGB or CMYK profiles are embedded into the file itself—the document is tagged. When the file is opened or output, a color management engine reads the embedded profile(s) and applies the color management policies, either converting the image's colors to the working space or not. ICC-aware

file formats (PSD, TIFF, EPS) give the option of embedding a profile in the "Save As" window. Profiles can be changed in Photoshop as follows:

Image > Mode > Assign Profile or Convert Profile

#### > **Gamut**

The collection of colors that can be reproduced by a monitor or printer for a particular color model (e.g., RGB, CMYK, L\*a\*b).

#### > **International Color Consortium (ICC)**

The ICC (<http://www.color.org>) was founded in 1993 by eight companies: Apple, Microsoft, Agfa, Adobe, Kodak, and others. Their intent was to establish a system to standardize color from computer to computer, program to program, or printer to printer. The ICC file format was developed as a way to store and provide access to information about a specific device's capabilities.

#### > **ICC Profile**

A type of file (.icc for Macintosh and .icm for Windows) that records device-specific information for a monitor, printer, or scanner profile. ICC profiles are loaded into Photoshop's Color Settings dialog box as Working Spaces.

#### > **L\*a\*b**

The CIE L\*a\*b color model.

#### > **Profiling**

After a device is calibrated, it is then profiled. Also called characterizing, this process records how close a device comes to matching an objective standard for color reproduction. This record becomes the device's ICC profile. Calibration, as the first step, adjusts a device to as close a match as possible, then profiling measures any shortfalls in the calibration. Adobe Gamma control panel adjusts and profiles a monitor instead of calibrating it. Third party hardware/software

products often calibrate using the same procedure.

#### > **RGB Profile (In Photoshop's Color Settings)**

The gamut that a monitor is capable of reproducing, along with vagaries in performance, is recorded as the RGB profile. This profile is used by the color engine.

#### > **Working Space**

The gamut of an image's color model, which is restricted by the device profile. CMYK images have a working space defined by a CMYK profile. RGB images are defined by an RGB profile.

### **COLOR MANAGEMENT PROCESS**

Color management can be considered a system of compensating for the individual characteristics of devices so as to produce uniform color. This often entails making corrections based on best guesses or trial and error—aiming for a target and eventually hitting it.

In terms of process, color management revolves around a color management system (CMS). The CMS is based on the color engine, software that actually translates one set of color values to another. The engine uses color profiles embedded in an image file that describe how a particular piece of hardware reproduces color. When a profile is applied to the image, color values are skewed for the particular characteristics of the specific device. When color values need to be prepared for output to different devices, the engine translates the colors so that they appear as consistent as possible in the final product.

#### **Example of a Problem:**

Monitor with a blue cast that negatively affects the colors on the screen (due to settings or the general age of the hardware).

### Possible Solutions:

- Calibrate or adjust monitor to show most accurate color onscreen.
- “Characterize” the monitor by creating a profile with RGB settings. Added color is assured to be the same hue and tint as onscreen output.
- In preparation for commercial printing, the color in question should be considered as to whether it can be reproduced by print service’s inks and paper. An appropriate CMYK setting or profile may be needed for the print job. RGB can display colors on the monitor that are out of gamut, meaning that they cannot be output on press. Color engines will handle the translation to colors within the gamut range. Colors are then translated to the CMYK color space.
- Clip colors to remove suspect colors from an image, avoiding out of gamut range completely.
- Alternately, suspect colors can be brought into a printable color space by two systems: Perceptual or Relative. In a Perceptual system, color is shifted from RGB to match as closely as possible the CMYK equivalent. In a Relative system, color is compressed into the single nearest printable color.

### WORK ENVIRONMENT

The most important detail or step in any color management system is to ensure that the onscreen color is as exact a match as possible to the colors recorded in an image file.

1. Control ambient lighting when doing color correction. Too little ambient light isn’t ergonomically practical and too much competes with the monitor. Shield the monitor from ambient light with a hood device. Shield the

top and sides of the monitor to a distance of 12”. The inside of the hood should be matte black; this can be a commercial hood or homemade device.

2. Computer desktop should be as neutral as possible; gray or black are best.
3. In Photoshop, press the F key to toggle through the available Screen Modes for viewing an image file.
4. Remove other objects from on or around the monitor (e.g. files on the desktop, post-it notes on the monitor).
5. The visible walls around the monitor should be as neutral as possible; gray is recommended.

### SYSTEM LEVEL COLOR MANAGEMENT

#### > Macintosh

The System Preferences for Mac OS X ColorSync can specify ICC profiles. Photoshop defaults to these profiles when launched. Profiles can later be changed within Photoshop on a document-by-document basis, if desired. ColorSync can also specify a Color Management Module or CMM to handle all color conversion. Document profiles will tell ColorSync (and programs that use a CMS) how to handle images without embedded profiles.

#### > Windows

The Windows CMS is called Image Color Management (ICM). This is a component of Windows designed to work with ICM-aware programs and devices to standardize color not used directly from Photoshop. Other ICM-aware programs can be set to use ICM by selecting: File > Color Management

### CALIBRATING THE MONITOR

Third party calibration hardware is recommended for prepress professionals, artists, photographers,

or general Photoshop users that need to rely on color accuracy. If you generally output to a home or office printer or a monitor for web publishing, however, third party hardware is probably not necessary.

Monitors can be adjusted by making a profile and saving it in a known location, named in a meaningful manner with the monitor’s name and date (Macintosh profiles should be named with a .icc extension and Windows profiles should be named with a .icm extension).

#### > Adobe Gamma Profiling

Photoshop automatically installs an Adobe Gamma control panel that allows you to create a custom monitor profile. The panel is accessible in Windows by selecting:

Start > Settings > Control Panel  
In Mac OS 9, select:

Apple Menu > Control Panels > Adobe Gamma

Adobe Gamma is not compatible with Mac OS X, so a display calibration program is used instead:

System Preferences > Displays > Color Tab > Calibration Button

The Calibration Button activates the “Display Calibrator Assistant”, which is a wizard program that walks you through the process of creating monitor profiles. Expert Mode turns on all of the available options.

### PHOTOSHOP’S COLOR SETTINGS

The first time you launch an image file in Photoshop, a window opens that gives you the option of customizing the color settings. If you choose “yes”, the Color Settings window will open. If you choose “no”, Photoshop will load colors appropriate for a web-safe palette.

To access the Color Settings at any time in Windows or Mac OS 9, select: Edit > Color Settings

In Mac OS X select:

Photoshop > Color Settings

In Adobe Photoshop 7.0, color settings are stored in the Settings Folder. Deleting a profile restores the file to the default settings. The Settings Folder is accessed through the Color Settings window by clicking the “Load...” or “Save...” buttons.

#### > The Settings Menu

The Settings pop-up menu at the top of the window is a list of preset packages of color settings. Choosing a package automatically configures the remaining options in the window. You can also create a custom package through the Settings menu.

#### > RGB Working Space

The selections made in the RGB working space area completely define the RGB working space, and color profiles embedded in an RGB image space include the settings defined here. For a well-calibrated production environment, Adobe RGB is the recommended official RGB profile. Radius Pressview Monitors should use ColorMatch RGB. Wide-gamut dye sublimation printers or photo-quality printer operations should use ProPhoto RGB. Keep in mind that service bureaus may prefer one specific gamut over another.

Photoshop users outputting to inkjet printers and web designers are best served by using custom monitor profiles created with Adobe Gamma or another such calibration/profiling procedure. The profile is then geared for monitor display with resulting accurate onscreen color. Monitors profiled with Adobe Gamma have a custom profile available in the RGB menu.

#### > CMYK Working Space

Proper CMYK profiles are necessary even for basic inkjet printing. Printers handle RGB color

data from images, but are CMYK devices at their foundation. Many inkjet printers with accompanying software install ICC profiles for combinations of resolution and paper quality. Service bureaus can also help you customize a profile for a specific printing process. To load a custom CMYK profile, in the Working Spaces section of the Color Setting window, select:

CMYK > Custom CMYK > Desired Profile

If you are not working with a custom profile, choose the stock profile that best fits your needs. If you are unsure of which profile to choose, you may want to start with “Generic CMYK”.

#### > Gray Working Space

Gray working space settings only affect the onscreen appearance

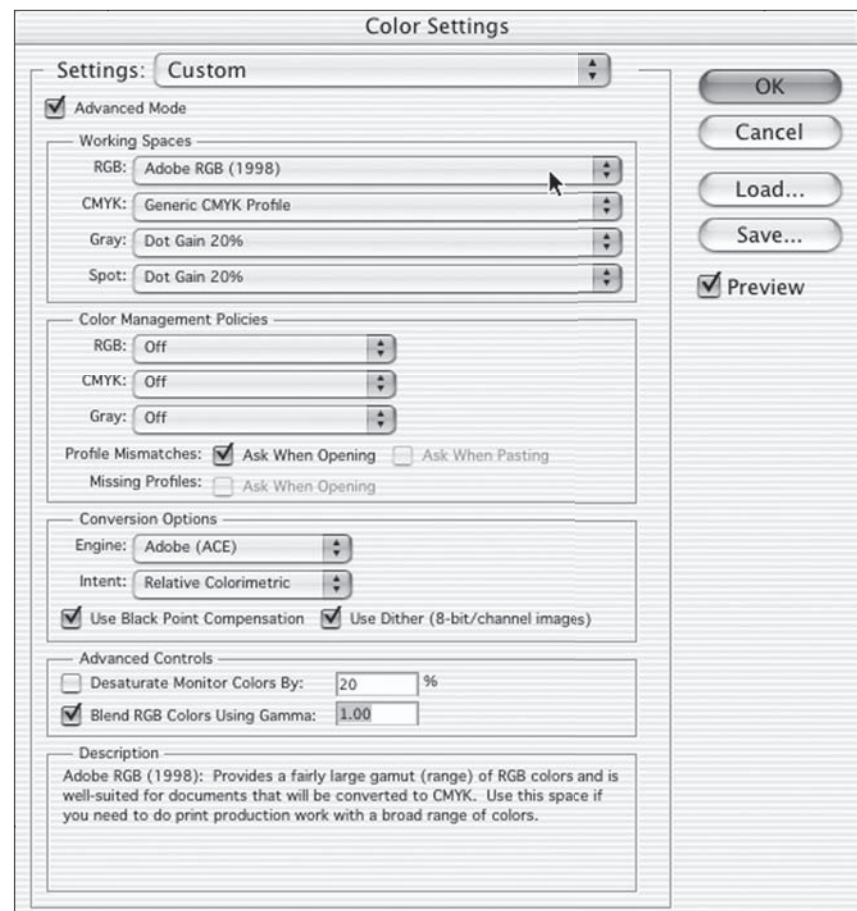
of grayscale images. The Gray working space enables you to see the dot gain or gamma on an image. Print prepress traditionally uses a dot gain of 20%, while web professionals are best served by a gamma of 2.2.

#### > Spot

The default dot gain setting for Spot channels is also 20%. Dot gain refers to the amount of spread for the “dot” or drop of ink on a given paper stock. Coated papers (gloss) produce little dot gain. Uncoated papers absorb more ink and consequently produce more spreading or dot gain. Dot gain settings compensate for the amount of spread by reducing the size of each ink dot.

#### > Mismatch Notification

When opening a file, this important



*An example of a custom Photoshop Color Settings profile on Macintosh OS X.*

tool lists the profiles involved in a given file and gives you the opportunity to evaluate the situation and choose whether to save the embedded profile, convert the working space, or discard the profile. Activate this tool by checking the Profile Mismatches > Ask When Opening option in the Color Management Policies section of the Color Settings window. You should uncheck this option when batch processing large numbers of images that must be handled in the same manner.

#### > Color Engine

Under Conversion Options, choose your preferred color engine. All of the available engines do a good job of converting color from one profile to another, but Adobe ACE is the usual choice. Mac users also have the option of using ColorSync or Apple CMM, and Windows offers Windows ICM engine.

#### > Intent

Also under Conversion Options, this setting determines how the color engine deals with colors that fall outside the destination gamut. Intent settings come into play primarily when converting from a larger to a smaller gamut. For example, converting from sRGB (small) to Adobe RGB (large) won't result in a visual shift since the range of color is increased, but converting from Adobe RGB to a CMYK gamut will result in shifting. The color engine uses the Intent setting to determine how it handles these translations:

- **Perceptual:** Results of color conversion are as close as possible to the original according to the human eye. If the source gamut is larger than the destination gamut, all colors are shifted. Use Perceptual when you want to maintain the image's overall appearance and

don't need to retain any specific colors within image.

- **Saturation:** Colors out of destination gamut retain saturation values and are brought into gamut by adjusting lightness and hue. This works best for highly saturated work, such as clipart, graphics, or logos.
- **Relative Colorimetric:** Colors reproducible in the destination gamut are unchanged. Colors falling outside the new gamut are brought into gamut by adjusting hue and saturation. Only colors on the fringe of the gamut are affected, and they maintain their lightness values. This preserves the image's overall tonality, and because the human eye is far more sensitive to tonal changes than changes in hue, this option is the best choice for most images.
- **Absolute Colorimetric:** The absolute L\*a\*b coordinates of source colors are mapped to a destination gamut without regard for white point mapping and can result in unusual color shifts. You can use Absolute Colorimetric for one- or two-color graphics, but it isn't appropriate for continuous tone photographic images.

#### > Black Point Compensation

When selected, this setting maps the darkest neutral pixels in the source gamut to the same in the target gamut. When unchecked, neutral shadows are mapped to black. When converting from RGB to CMYK, this setting should be selected.

#### > Monitor Dithering

Dithering during conversion can increase file size but can also reduce visible banding in continuous tone images where too many colors are mapped to too few in the destination gamut.

#### > Desaturating Monitor Colors

If activated, this setting enables you to see more detail in the highlighted areas in large RGB spaces like Adobe RGB. This option should only be selected when working with strong highlight images or if part of the gamut is not portrayed onscreen.

#### > Blend RGB Colors Using a Different Gamma

This setting can be used to reduce artifacts along distinct edges of an image. By default, Photoshop uses the assigned monitor gamma to blend RGB values onscreen. Increasing or decreasing this option can help to smooth artifacts.

#### > Loading and Saving Color Settings

After configuring the appropriate Color Settings, click Save... You will be able to use the Load... button to access these settings at a later date, as needed.

#### > Changing Embedded Profiles

Embedded profiles can be changed in a variety of ways. They can be converted upon the opening of a file; modified with the color mode of a document; and stripped from the image by selecting "Discard the Embedded Profile" when you are notified of a mismatch.

To do any of the following, select Image > Mode > Assign Profile:

- Strip the embedded profile from the document.
- Tag document with working profile (RGB, CMYK and Grayscale).
- Choose another profile of the appropriate color mode.

Assigning a new working space does not change the color values in the image; rather, it embeds a new profile in the document and shows you onscreen what the image will look like in that gamut.

The preview option enables you to view the result before assigning the changes to the file.

To convert the embedded profile, select:

Image > Convert > Profile

This option does change the color values; the image's colors are mapped from an embedded profile to a selected profile. Options selected in this window override those in Color Settings. The Convert command attempts to maintain the appearance as closely as possible when remapping.

## SOFT PROOFING IN PHOTOSHOP

Select View > Proof Setup to make a proof selection for onscreen viewing from a selection of profiles, including CMYK, individual color channels, or RGB gamuts. Use the "Custom" option from the View > Proof Setup menu to view how the image would look with any available profile. Two additional options for Simulate Paper White and Simulate Ink Black are available. These options attempt to display onscreen the physical characteristics of paper and black information recorded in the profile.

Select View > Proof Colors to preview images on screen but not as a substitute for the actual printed proof. Hard proofs are the best way to color correct. Proof Colors is best used to view how RGB images will convert to the selected CMYK working space.

For a side-by-side comparison of the effects of different profiles on the image, select Window > Documents > New Window. Choosing an individual CMYK working plate for proofing is comparable to converting a document to CMYK and viewing a single channel in the Channels palette.

## SPECIAL NOTES

The filename in the Image window indicates whether a profile is embedded in the image or if there is a profile mismatch between image and working space. If an asterisk (\*) appears after the color mode in the title bar, there is a profile mismatch. When a pound (#) sign appears, the image is not color managed and no profile is embedded.

Any color management system's responsibility is the accurate reproduction of color. If an image contains color casts or other color issues, proper color management won't correct the problems. Color management is not a substitute for color corrections or adjustment functions.

## COLOR MANAGEMENT LINKS

Consult these helpful online color management resources for additional information:

### > Apple

Apple Main Website: <http://www.apple.com>

Apple ColorSync: <http://www.apple.com/macosx/features/colorsync/>

Apple Seminars: <http://seminars.apple.com/seminaronline/colormgmt/apple/index.html?s=203>

### > CMS

Aurelon: <http://www.aurelon.com>

CHROMiX ColorThink: <http://www.chromix.com/colorthink/?PID=1>

ColorBlind: <http://www.color.com>

ColorVision: <http://www.colorvision.com>

ColorWizzard: <http://www.colorwizzard.com>

Datacolor Spectrophotometer Products: [http://www.datacolor.com/products\\_instruments\\_list.jsp](http://www.datacolor.com/products_instruments_list.jsp)

FUGIFILM ColourKit: <http://www.colorprofiling.com>

GretagMacbeth: <http://www.gretagmacbeth.com>

Praxisoft: <http://www.praxisoft.com>

Rods and Cones: <http://www.rodsandcones.com>

X-Rite: <http://www.xrite.com>

## > General Concepts & Resources

Adobe Systems Incorporated: <http://www.adobe.com>

CIE: <http://www.cie.co.at>

Color Remedies: <http://www.colorremedies.com>

Kodak: <http://www.kodak.com>

Macworld: Sony Artisan Color Reference System: <http://www.macworld.com/2003/01/reviews/sonyartisan/>

Microsoft Color Management Concepts: [http://msdn.microsoft.com/library/en-us/icm/icm\\_6ulv.asp](http://msdn.microsoft.com/library/en-us/icm/icm_6ulv.asp)

"Out of Gamut: Color-Correct Vocabulary":

<http://www.creativepro.com/story/feature/11132.html>

"Out of Gamut: Setting Up Color Management in Photoshop 6": <http://www.creativepro.com/story/feature/14331.html>

Raph's Color Management Page: <http://www.levien.com/gimp/gcmm.html>

Real World Color Management: <http://www.amazon.com/exec/obidos/ASIN/0201773406/digitaloutbackph/104-1320756-2803947>

## > International Color Consortium (ICC)

ICC Main Website: <http://www.color.org>

ICC Profile Information: <http://www.color.org/wpaper2.html>

---

Shelly J. Smith is a Senior Arts Technologist with the Arts Technology Group in ITS Academic Computing Services.