

Color Management in Adobe Photoshop CS4



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Email me (andrew@digitaldog.net) if you need this presentation in PDF form.

Most of the definitions found throughout this presentation are taken from my book “Color Management for Photographers, Hands on Techniques for Photoshop Users” published by Focal Press. A table of content and sample chapter can be downloaded from the web site above. Or go to:http://www.amazon.com/exec/obidos/ASIN/0240806492/digitaldog-20/104-1213564-0901541?creative=327641&camp=14573&link_code=as1

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What is Color Management?

The ability to accurately and predictably control the reproduction of images from beginning to end of the imaging pipeline.

There are many kinds of “color management” such as altering your display to match a print. This is ineffective and dangerous! For the following presentation ICC Color Management will be covered.

What it's not:

Fix bad color, especially bad originals

Color management will ensure that ugly color is faithfully reproduced. Color management ensures that you know that what you're viewing is ugly or not.

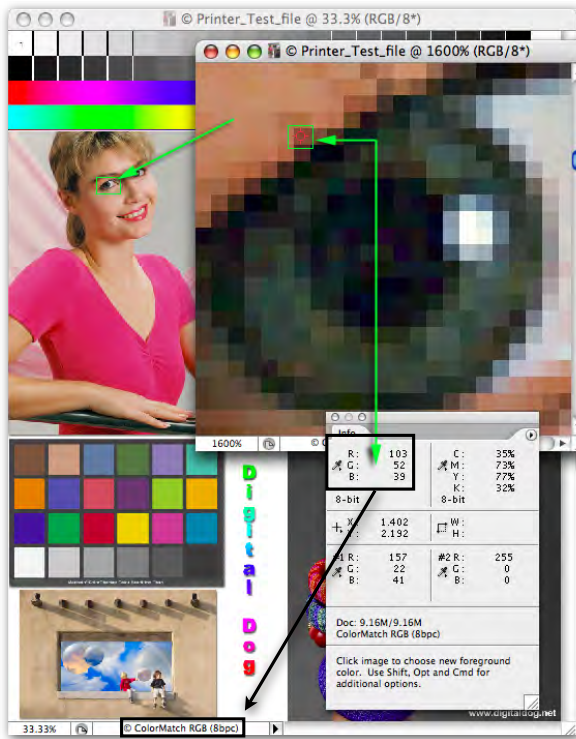
GIGO - Garbage In - Garbage Out.

ICC color management is cross platform and common in many desktop applications like Photoshop, InDesign, Illustrator, Lightroom, and many scanner and capture applications. Applications that do not support ICC color management will not produce accurate on-screen previews (soft proof.) An example is most web browsers which simply send the numbers in a document directly to the screen. This is why many users find images on a web site don't match the image previews seen in Photoshop.

Digital Images are a mosaic of square pixels of solid colors, each having a specific numeric value.

Numbers alone do not provide enough information to reproduce color. The solution to this is color management!

Color management gives all the numbers a definition. The result is color we expect on any output device!



Why Color Management ?

Device Dependent Color

If we define a color numerically such as 233R/45G/89B, what does it look like? This is only a partial recipe for color; we need the scale these numbers represent. That's a color space!

Since each device treats the same color numbers differently, how can we ensure the desired color appearance reproduces on all devices?

The answer is the use of ICC device profiles to define the right numbers to send to a printer to produce the expected color! ICC profiles give the numbers a definition. Profiles also create new numbers from existing files, allowing us to reproduce the color appearance on differing devices.

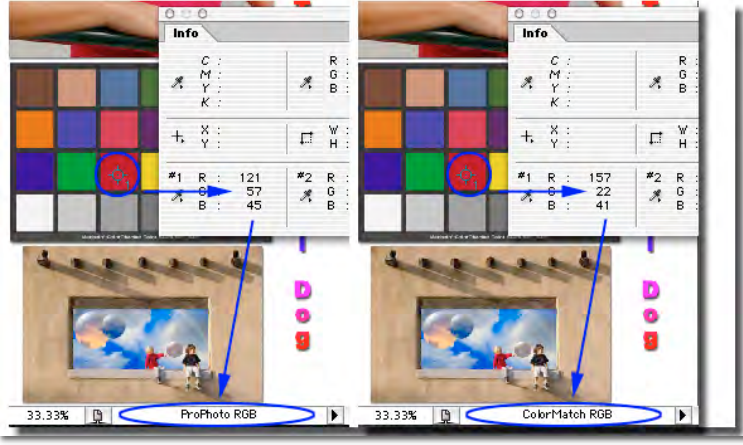
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Device Dependent: Used to define a color space that is tied to a specific device behavior such as a specific printer, scanner, camera or display. Each device produces its own unique behavior and the color space that describes this behavior is device dependent. The device itself influences the color produced.

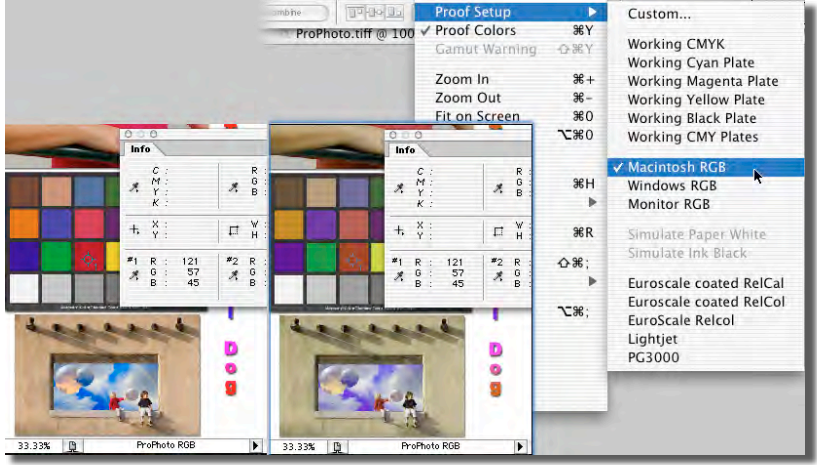
Color Model: Color Model - A method of mapping color using a set of defined dimensions. Some scientific color models such as x,y,Y or L*a*b* encompass all of human vision and have a defined scale such that a particular color will always have the same set of values. Other color models such as RGB or CMYK have no standard defined reference or scale. In order to understand a color in these models you must have a color space definition that provides a scale and reference.

Color Space: A color space is a scientifically defined portion of human vision. A color space may be defined with any color model. The RGB values R10,G100,B10 have no meaning by themselves other than the color is mostly some kind of green. By using a color space definition the same set of values can be translated into one of the scientific color models, giving the values exact meaning. Having a set of RGB values associated with a color space allow for the exact reproduction of the color.

Numbers and color:
 Color appearance is the same but numbers are NOT
 NOT
 The colors are in different color spaces!



Numbers and color:
 Color appearance is different but numbers are the same! Identical numbers without color management will preview incorrectly!



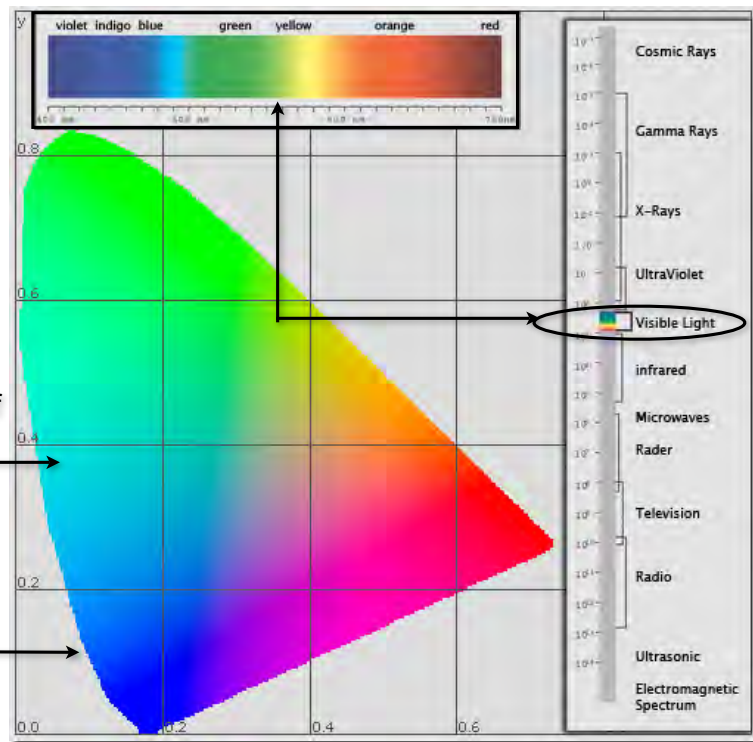
You can demo this effect yourself in Photoshop. Open a tagged file in a color working space such as ColorMatch RGB as seen above. Use the Convert to Profile command and convert to a different working space. Using the Info palette, examine the same area in both documents to see that indeed, while both preview the same color appearance, they both have different color numbers.

Color spaces and color numbers.

The gamut (range of visible colors) of human vision Plotted 2 dimensionally produces this horseshoe shaped plot.

This is a color space.
It is the color space of Human vision!

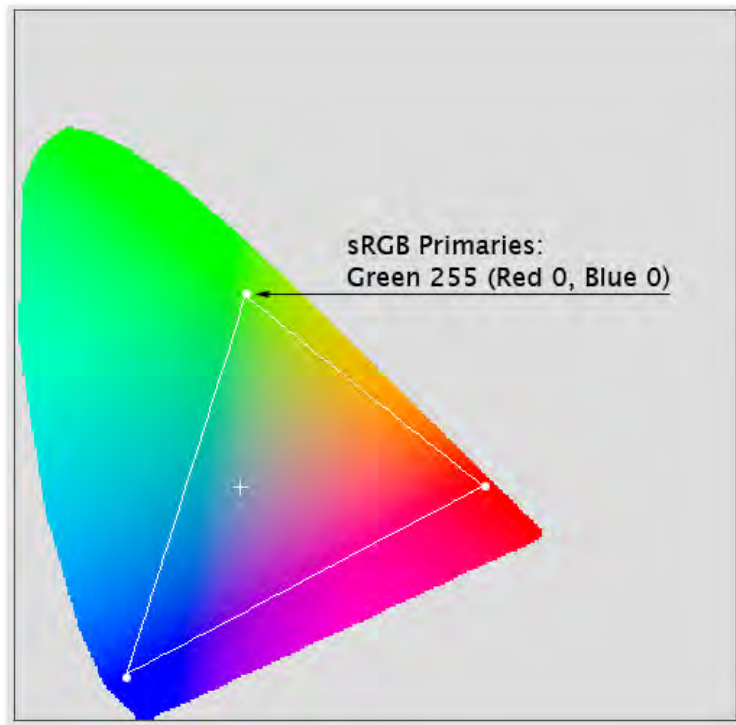
Everything outside the space is not visible. It is out of gamut!



Here's a metaphor for a color space: suppose I supply a recipe for chocolate chip cookies but do not provide the unit for each ingredient in the recipe. The recipe provides each ingredient followed by a number. Without units you can't make the cookies. The numbers alone are not enough information to describe how the cookies will be produced. Likewise, R78/G103/B23 or C23/M98/M123/K6 is not enough information to reproduce that color. Using a chocolate chip cookie recipe analogy, suppose a color model is a cookie recipe with only three ingredients. I give you this recipe, which simply calls for 1-flour, 8-butter and 2-chocolate chips. You don't have enough information to make the cookies. However if I provide you the recipe with a specific scale—1 cup of flour, 8 tablespoons of butter, and 2 cups of chocolate chips—I've provided the necessary information, the scale, to make a dozen chocolate chip cookies. I can give you the cookie recipe in the metric scale such as liters and grams and you can still make the same cookies even though the numbers are different. A color space is a color model that has a known reference and scale, in this case primaries (the ingredients, in this case R, G and B) and scale (specific quantities of these ingredients).

By plotting 255 green within the color space of human vision, we define that color based on how we would see it!

The sRGB color space plotted on top of the color space of human vision. Anything outside this triangle is "out of gamut."

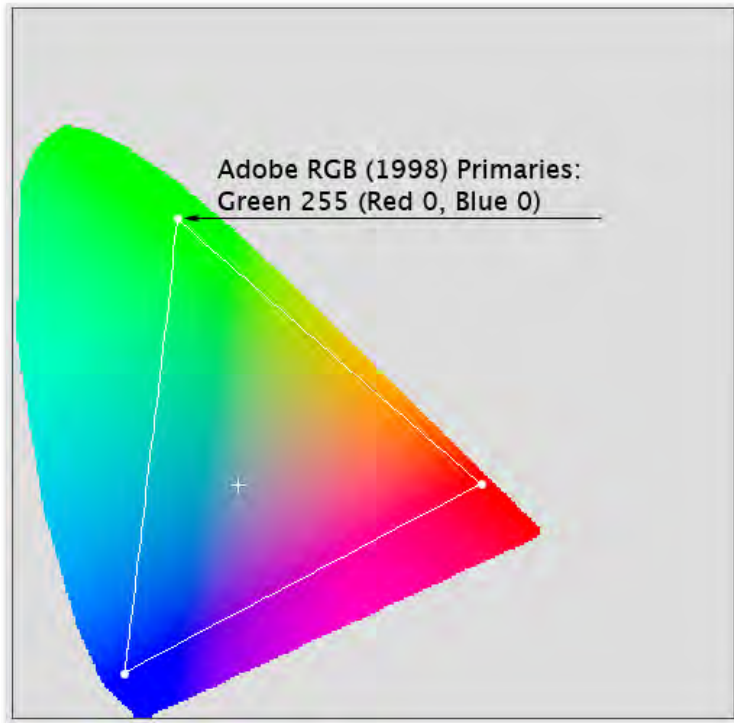


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Suppose I specify a color as R10/G130/B50 and specify a color reference by saying the color space is Adobe RGB (1998), which defines the scale of the RGB primaries; the color coordinates of this color space. The R10/G130/B50 set of numbers can now reproduce a color by anyone with the proper tools since the reference and scale have been defined. Different RGB color spaces use a different scale of red, green, and blue primaries. Adobe RGB (1998) and sRGB are different color spaces, however both are based on the RGB color model using RGB primaries. Although each color space uses the same three primary ingredients (R, G, and B), the specific colorimetric scale of each color space is different. The maximum of red, green, and blue are more saturated in the Adobe RGB (1998) color space than the sRGB color space. Even though R0/G255/B0 is the greenest green ingredient in both Adobe RGB (1998) and sRGB, knowing that the scale is different in both color spaces explains why this green value is more saturated in Adobe RGB (1998). This also illustrates how R0/G255/B0 alone can't tell us what green.

255 Green has a different scale in Adobe RGB (1998)
than sRGB but share the same numeric value!

The Adobe RGB
(1998) color space
plotted on top of the
color space of human
vision.



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An ICC profile simply defines this scale and gives the numbers a meaning allowing us to reproduce the color using something far more concrete than using the English word "Green" or a set of numbers, which alone is far too ambiguous to produce a specific color appearance. So R255 in Adobe RGB (1998) and R255 in sRGB share the same numbers but have a different scale. When you assign a color space to either number, you're telling Photoshop the scale, it's updating it's preview and showing you this (correct or not, you've defined the scale so Photoshop believes you). The number hasn't changed the color appearance has. Now you know why.

Problems can arise due to gamut mismatch

- We can define 16.7 million color (24-bit color).
- We can see approximately 12 million colors.
- Typical 4 color press can produce 70,000 colors.
- ICC Color Management has powerful options for gamut compression and gamut clipping:

ICC profiles have 4 Rendering Intents:

Perceptual

Relative Colorimetric

Absolute Colorimetric (proofing)

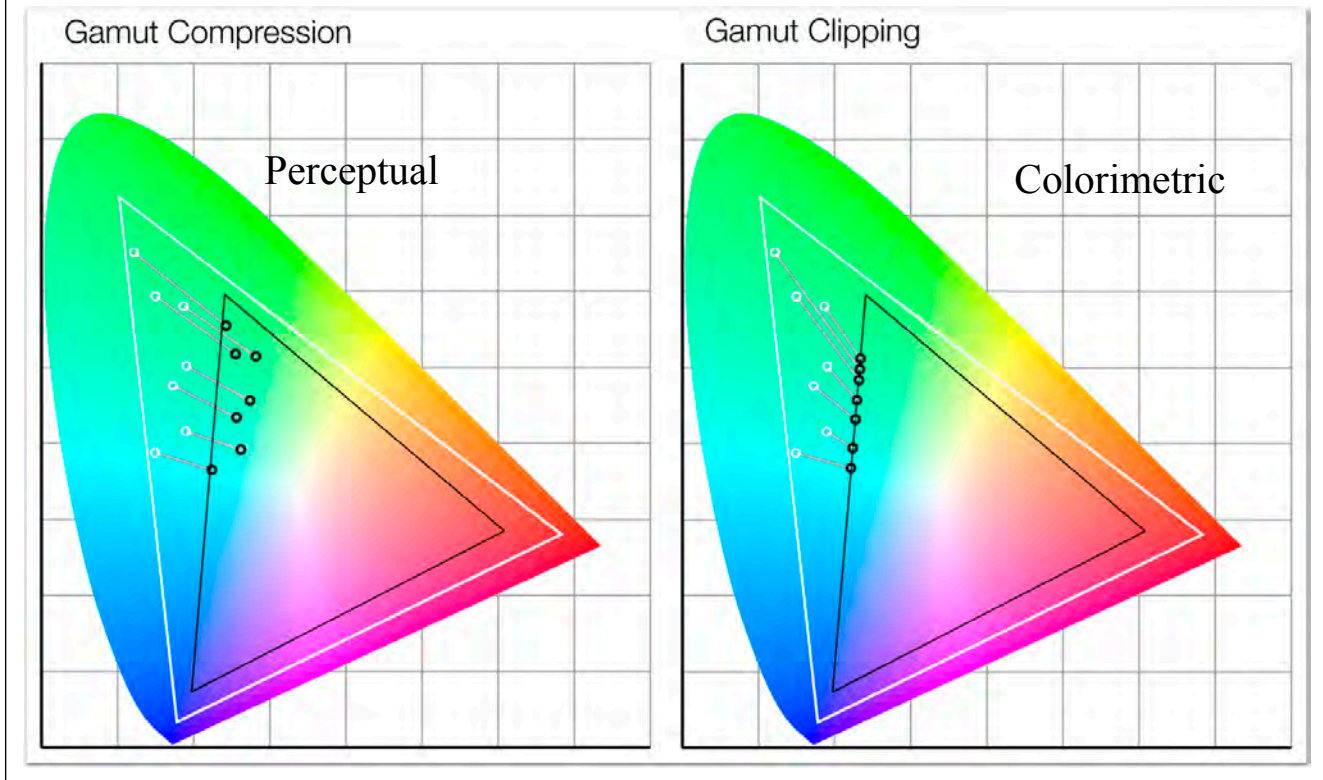
Saturation

Geek Alert

16.7 million due to 3 to the 8th power (three color channels in 8-bit) or $3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3$.

Rendering Intent: The ICC specifies three rendering intents for mapping out of gamut colors of a source color space into the gamut of a destination color space; Perceptual, Saturation, and Colorimetric (Absolute/ Relative) . Two basic techniques are utilized; gamut compression where all colors are compressed and affected and gamut clipping, where only out of gamut colors are affected. Perceptual uses gamut compression while Colorimetric rendering intents use gamut clipping.

Rendering out of gamut colors



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Colors in the original (source) color space need to be mapped to colors that exist within the gamut of the new (destination) color space. There are two basic techniques for mapping out-of-gamut colors. One technique is to take all the colors that are out-of-gamut and map them to the closest colors that are within color gamut of the destination. We call this technique gamut clipping. The second technique is to compress the range of color into the gamut of the destination. It is important to note that when using this method, some colors that were perfectly matched between the two devices will actually change. We call this method gamut compression. The ICC system provides different methods of gamut mapping and calls these rendering intents. When you perform ICC color transformations within an application, you will need to choose a rendering intent. The rendering intents were created for different situations. The names of the renderings are colorimetric, saturation, and perceptual. The colorimetric method is a form of gamut clipping. The saturation intent is also a form of gamut clipping, but attempts to preserve the saturation of colors over lightness. The perceptual method is a form of gamut compression. When using the perceptual method, visual detail and luminance are preserved over hue and saturation. Note that the Colorimetric rendering intent seen above right is shared by both Relative and Absolute rendering intents. Both are Colorimetric however the differences are how paper white is mapped from source to destination (colorimetric meaning no alteration of the white values, or Relative to the paper).

Calibration vs. Profiling

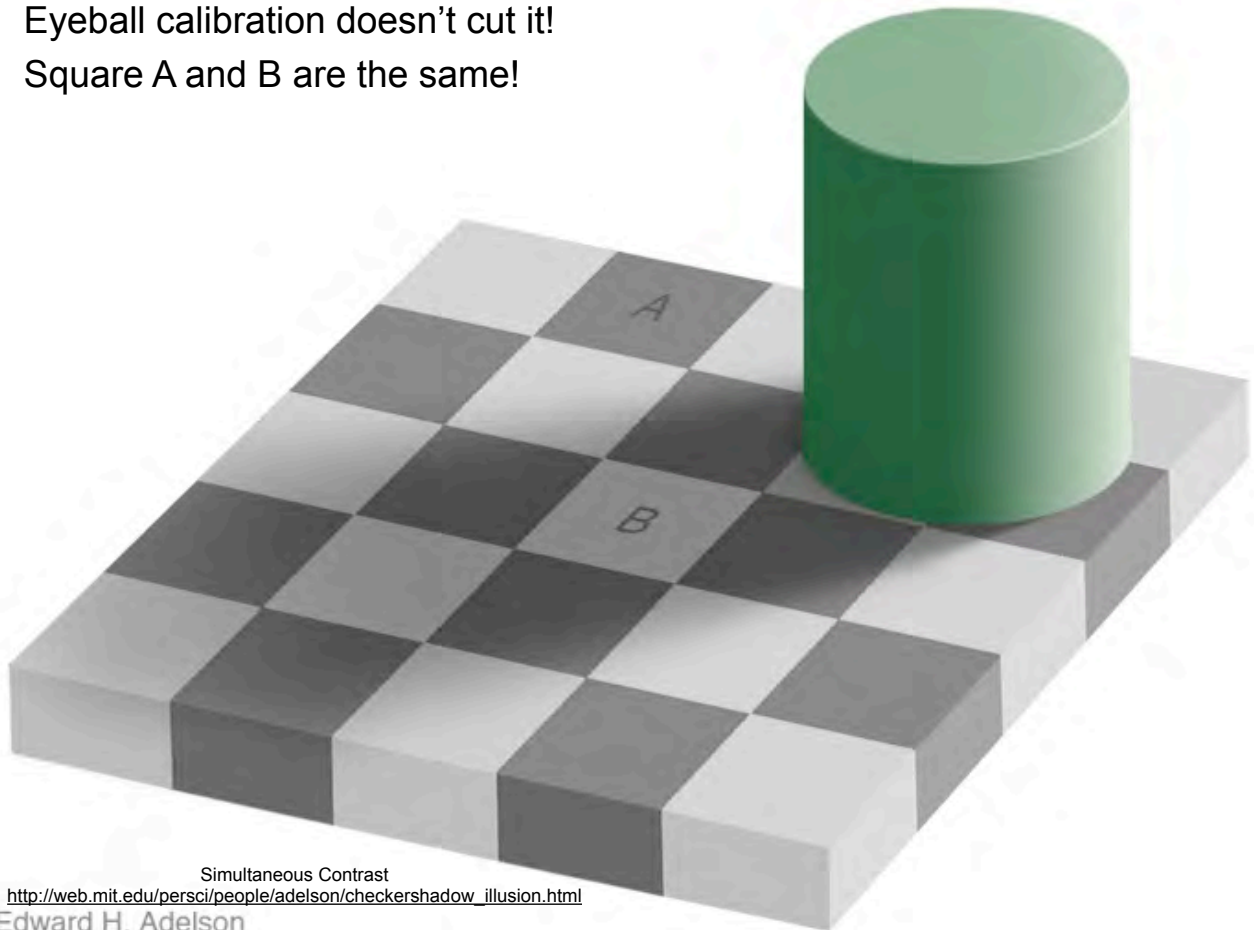
- Calibration places devices into a known and repeatable state.
- Profiling “fingerprints” the behavior of the device.
- ALL devices should be calibrated or at least consistent! We can't work with un-calibrated devices either with, or without ICC Color Management! Some devices are consistent in their behavior that calibration isn't necessary or even possible however we may be profiling a behavior that isn't ideal.

Calibration is like running replenishment or control strips on a processor. Process control is critical in all aspects of imaging both conventional and digital. The Epson driver in it's “No color adjustment” mode is very non-linear meaning it's ink delivery is less than ideal. It is not possible to calibrate (or linearize) this behavior although we can profile this behavior. The good news is that the driver and printer behavior are consistent so while we can't improve upon the ink delivery, at least we can profile the behavior and it will remain consistent .

Profile Overview

- Profile camera/scanner
- Calibrate and profile monitor
- Profile proofing device
- Profile output device
- Use profiles in production: Photoshop CS4 or other ICC aware applications such as Lightroom, InDesign, Acrobat, print drivers and RIPs...

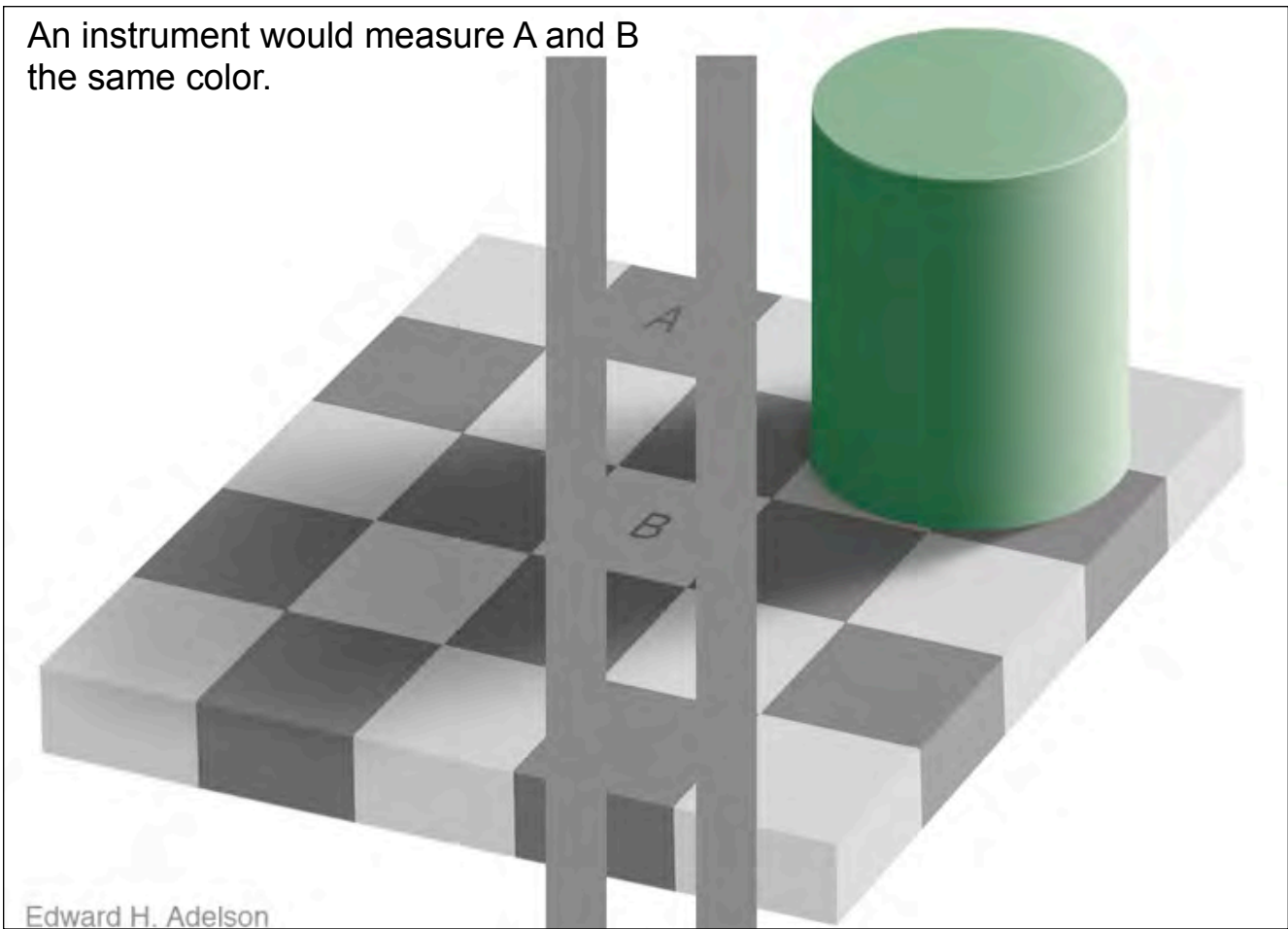
Eyeball calibration doesn't cut it!
Square A and B are the same!



Simultaneous Contrast
http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html
Edward H. Adelson

Square A and B are the same color! They don't look the same but an instrument would correctly read the values as the same. Don't believe me?

An instrument would measure A and B
the same color.



Edward H. Adelson

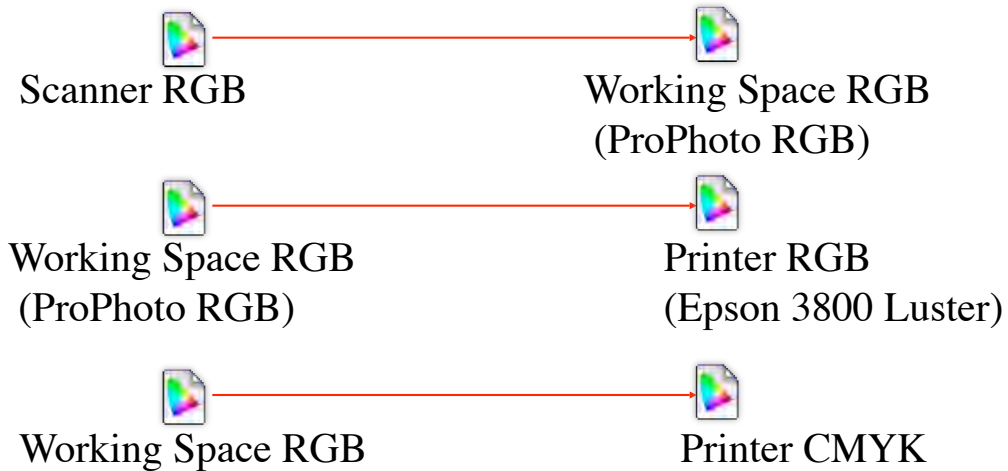
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When the lines are drawn as seen here, the optical illusion is broken. So much for eyeball calibration.

Edward H Adelson: Why does the illusion work? The visual system needs to determine the color of objects in the world. In this case the problem is to determine the gray shade of the checks on the floor. Just measuring the light coming from a surface (the luminance) is not enough: a cast shadow will dim a surface, so that a white surface in shadow may be reflecting less light than a black surface in full light. The visual system uses several tricks to determine where the shadows are and how to compensate for them, in order to determine the shade of gray "paint" that belongs to the surface. The first trick is based on local contrast. In shadow or not, a check that is lighter than its neighboring checks is probably lighter than average, and vice versa. In the figure, the light check in shadow is surrounded by darker checks. Thus, even though the check is physically dark, it is light when compared to its neighbors. The dark checks outside the shadow, conversely, are surrounded by lighter checks, so they look dark by comparison. A second trick is based on the fact that shadows often have soft edges, while paint boundaries (like the checks) often have sharp edges. The visual system tends to ignore gradual changes in light level, so that it can determine the color of the surfaces without being misled by shadows. In this figure, the shadow looks like a shadow, both because it is fuzzy and because the shadow casting object is visible. The "paintness" of the checks is aided by the form of the "X-junctions" formed by 4 abutting checks. This type of junction is usually a signal that all the edges should be interpreted as changes in surface color rather than in terms of shadows or lighting. As with many so-called illusions, this effect really demonstrates the success rather than the failure of the visual system. The visual system is not very good at being a physical light meter, but that is not its purpose. The important task is to break the image information down into meaningful components, and thereby perceive the nature of the objects in view.

ICC profile transforms require we specify a Source and Destination profile.

Each device “speaks” it’s own language. Profiles are translators for describing each color space



In an ICC workflow, there has to be a Source and Destination profile!

Where profiles live on your system:

Windows98: C:\Windows\System\Color

Windows XP: C:\Windows\System32\Spool\Drivers\Color

Windows 2000, XP:C:\WinNT\System32\Spool\Drivers\Color

OSX: System->Library->ColorSync->Profiles

Photoshop 5.0 to CS4 uncouples the Display from the editing process

- Editing is NOT based on the idiosyncrasies of your monitor.
- All images preview perceptually the same thanks to RGB Working Spaces & display profile.



Monitor RGB (Device Dependent)



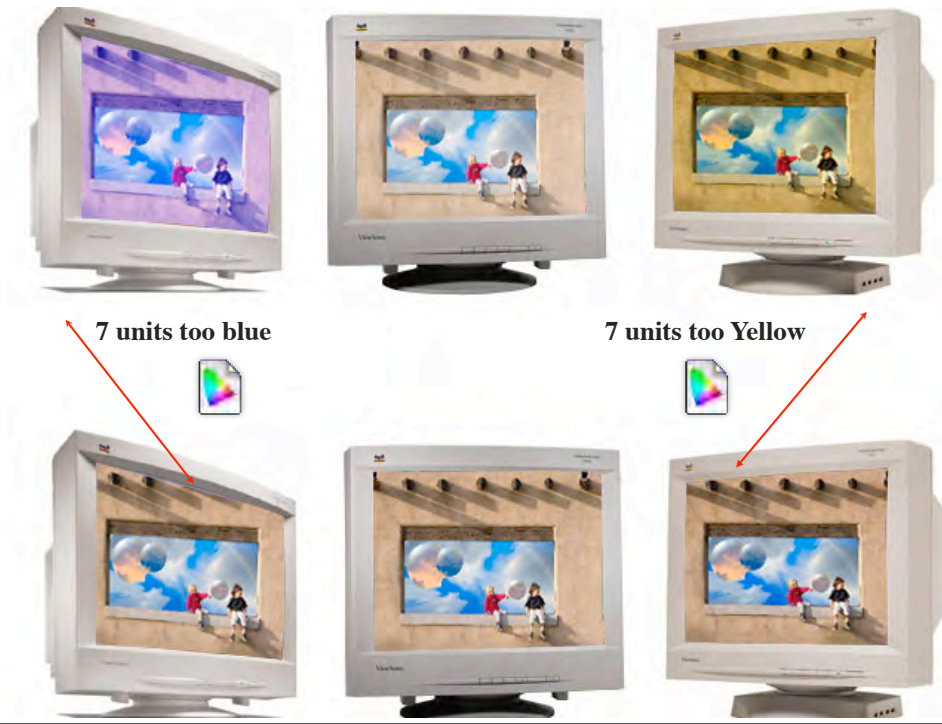
RGB Working Space (Adobe 1998)
Quasi-Device Independent

Device Independent: A color space that is not influenced by a device nor behaves like any specific real world device. Device independent color spaces are based on synthetic color models or constructions since all real world devices being device dependent have their own unique ways of producing color. These imagery color spaces are mathematically based upon how humans perceive color not based on any physical device like a printer or scanner. LAB is a device independent color space. Since technically RGB is a color model that isn't device independent, the term Quasi-device independent is used here.

Display Using Monitor Compensation

- Since the Working Spaces are identical among all users, what about the display?
- The ICC profile that describes your display produces a unique compensation that ensures proper color previews. All users see the same numbers the same way despite differences in display conditions.
- Photoshop does an on-the-fly conversion from Working Space to monitor color space for all previews.
- Display Using Monitor Compensation is always on in Photoshop 6 through CS4. Color Management cannot be turned off!

Display Using Monitor Compensation



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Goldielocks and the three displays. One is too blue, one is too yellow but one is just right. Thanks to ICC profiles that describe the bias, Photoshop can compensate on the fly as seen on the lower displays.

RGB Working Spaces

Used in Photoshop, Lightroom and Camera Raw...
But which one?

Ideally the working space can contain all captured colors and colors you wish to output. The “big 3” are:

sRGB: Smallest Gamut. Good for the web. Gamut of most displays.

Adobe RGB (1998): Useful gamut for many output needs but larger than the gamut of most displays. New display technology matches and exceeds.

ProPhoto RGB: Excellent in RAW workflow's. Not appropriate for 8-bit editing. Many possible colors outside display gamut!

While two of these working spaces can contain colors you may not see on your display*, you *will* be working with many devices that **can** reproduce these colors.

*Newer, Adobe RGB wide gamut displays reduce this to issue.

ProPhoto RGB is supported in Adobe Camera RAW and I've been using more and more as often I find I have images that exceed the gamut of Adobe RGB (1998). I encode the data into ProPhoto RGB in 16-bit.

Photoshop's Color Settings

Forget the default settings. Instead, use *North America Prepress (US Prepress Defaults)* then set RGB working space to *ProPhoto RGB*.

The image shows the Photoshop Color Settings dialog box with several annotations and a menu overlay. The dialog box is titled "Color Settings" and has a warning at the top: "Unsynchronized: Your Creative Suite applications are not synchronized for consistent color...".

Annotations with arrows point to the following elements:

- Presets toggle entire dialog**: Points to the "Settings:" dropdown menu, which is currently set to "North America Prepress 2".
- Select preferred working space**: Points to the "Working Spaces" section, where "RGB" is set to "Adobe RGB (1998)".
- Polices and Warning check boxes**: Points to the "Color Management Policies" section, where "Profile Mismatches" and "Missing Profiles" are both checked with "Ask When Opening".
- Conversions**: Points to the "Conversion Options" section, where the "Engine" is "Adobe (ACE)" and "Intent" is "Relative Colorimetric".
- Advanced Controls (stay away)**: Points to the "Advanced Controls" section, where "Desaturate Monitor Colors By:" is set to 20% and "Blend RGB Colors Using Gamma:" is set to 1.00.

A menu overlay is shown on the right side of the dialog box, with a dashed red border. It is titled "Conversions only used when you select Mode:" and lists various color modes. The "CMYK Color" option is highlighted.

The menu items are: Bitmap..., Grayscale, Duotone..., Indexed Color, RGB Color, CMYK Color (highlighted), Lab Color, Multichannel, 8 Bits/Channel, 16 Bits/Channel, 32 Bits/Channel, Color Table..., Image Size..., Canvas Size..., Pixel Aspect Ratio, Rotate Canvas, Crop, Trim..., Reveal All..., Variables, Apply Data Sets..., and Trap...

Color Policies

- Controls the default behavior for documents that do not match the “Preferred” (current) RGB/CMYK/Gray Working Spaces set in *Color Settings*.
- *Preserve* Policy provides the **most flexibility** for users working with many color spaces. If documents don’t match, you can open in existing color space then decide what to do next (convert or preserve).
- *Convert* Policy attempts to “force” the Working Space upon files that don’t match current settings. OK if you always want documents in the color space set in color settings.
- *Off* Policy is not recommended!!!

Convert and Preserve are the same when warnings are on. When warnings are off, there is a much bigger difference due to automatic conversions with Convert policy!
Preserve colors changes the data to keep colors looking “correct.”

Photoshop's Color Settings

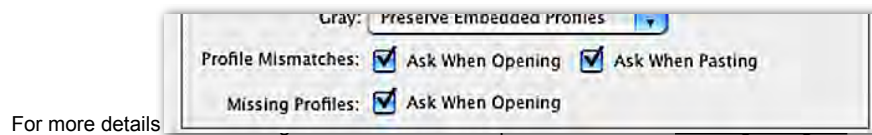
Photoshop Color Settings:
Warning check boxes

Have the *Ask When...* checkboxes on to warn about: *Missing Profiles*

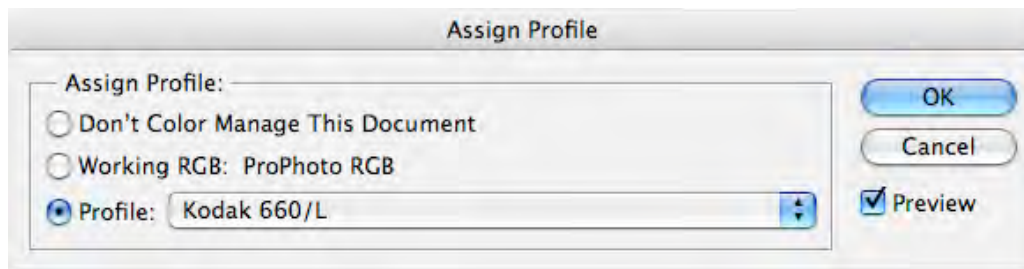
Profile Mismatches

Paste Mismatches

This is your safety net! However, turning off warnings can speed up automated production. This will allow automatic conversions depending on policy settings.



See the tutorials available on my web site, which walk users through the policies and their exact behavior on different documents.



- Photoshop **always** uses the currently selected working space as an assumption for documents without a profile. This may be incorrect and hence, the *Assign Profile* command.
- *Assign Profile* doesn't change the numbers of a document, it provides a new definition for the numbers.
- Note that the *Convert to Profile* command **does** change the numbers in documents. Both *Assign Profile* and *Convert to Profile* embed this profile into our documents so they provide the correct definition of these numbers.

Soft Proof your images

Lets see a soft proof before we print!

- Use Photoshop's Customize Proof setup and load your output profile.
- Edit in your RGB Working Space **WHILE** viewing the output simulation(s).
- Once you edit for a specific output device, edit on a copy or Layer! The original file in the RGB working space is your “master” which you will go back to each time you wish to print it.
- Always show client images on-screen with the soft proof! If you show them the RGB preview, that's what they will expect you to provide and that's not possible!

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Soft Proof: A term that describes the process of using ICC color management to produce a preview of an image on screen that simulates (proofs) how that image will output to a specific printer.

For those working with untagged files or files that are in a print/output space (CMYK specifically), it is useful to see what the document would look like if the current set of numbers were simply sent to the printer “as is.” For example, I'm provided a document in U.S. Web Uncoated (SWOP) v2 but the document will be output to a device where Eurocoated v2 is the behavior of the device. By unchecking Preserve Color(CMYK in CS2) Numbers, a soft proof is produced showing what the output would look like if those numbers from SWOP were sent directly to the output device that prints Eurocoated. I can then decide if it's appropriate to send the U.S. Web Coated (SWOP) v2 document to the Eurocoated printer or if some conversion or editing is necessary, based upon what I see displayed.

NEVER allow the client to see the image without a soft proof or they will expect this on output (which is impossible).

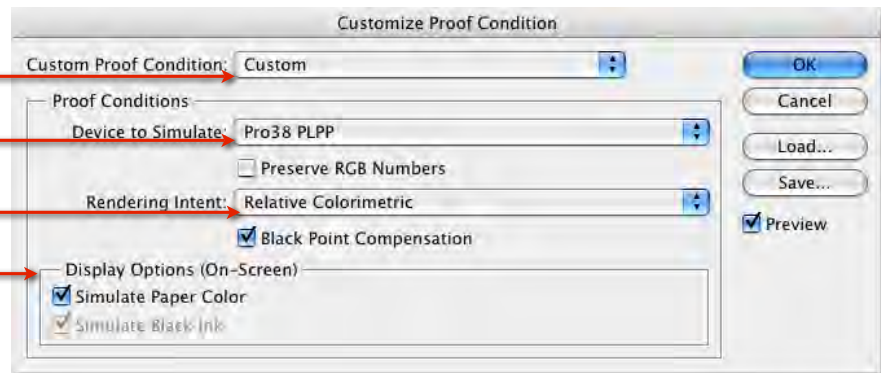
Custom Proof Setup

Saved Presets

Output device to Soft Proof

Conversion Options

Control Dynamic Range



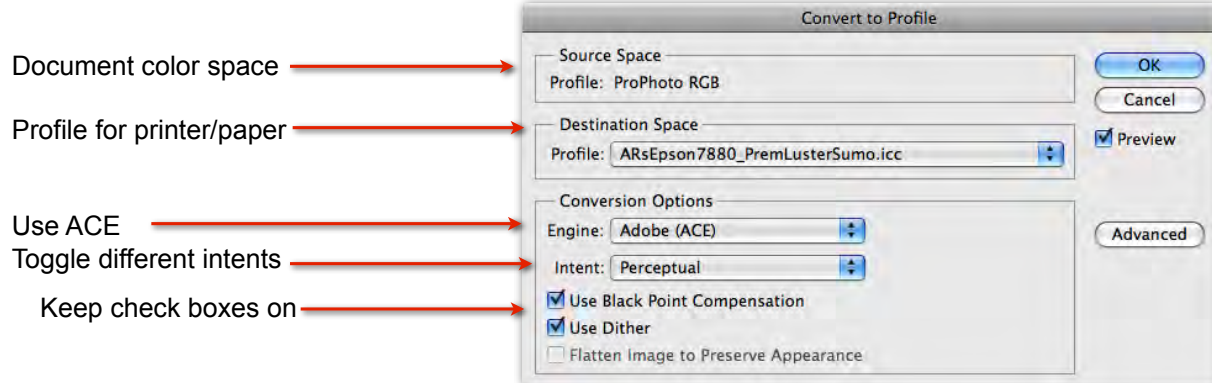
- Presets can be selected after you configure and save them to disk. Quick way to toggle different settings and view soft proof. Notice that Rendering Intent was saved in name.
- Device to Simulate: Pick your printer here.
- Preserve RGB Numbers: What does output look like **without** the use of a profile?
- Rendering Intent: Select the best based on soft proof.
- Simulate check box affect dynamic range of soft proof by taking paper and ink into account. Use in Full screen mode only!

*See the "Soft Proof" tutorial on www.digitaldog.net

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When you use the Simulate check boxes, only the black and white within your image undergo the simulation. Problem is, the user interface (menus, palettes) do not change their appearance and your eye always adapts to the whitest white in a scene. For this reason, you should be in Full Screen Mode with NO palettes showing when using this simulation. Setup the soft proof as you wish. Type the F key twice, then the Tab key once and you will have the image in Full Screen Mode.

Printing and color space conversions: Convert to Profile



Once you select the proper printer profile that defines the printer and paper, toggle the rendering intent popup from Relative Colorimetric to Perceptual. Select the intent based on the soft proof you see and prefer visually.

The same functionality is seen in *Print*.

Do NOT apply a profile in **both** *Convert to Profile* and *Print* command. This results in double profiling. Pick one or the other method to apply the profile.

The Print Command in CS4

Now it exports 16-bit data!

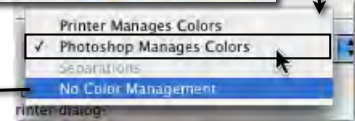
Document is in ProPhoto RGB and will be converted to an Epson 3800 for Exhibition Fiber paper because the color handling is set to *Photoshop Manages Colors*.

The functionality is the same as *Convert to Profile* command.

Do not allow print driver to apply color management!



Use the *No Color Management* setting if you previously used *Convert to Profile*. Check Document Radio button above!



Print to Display matching

Both need to be accounted for!!!
Calibration of luminance ("Backlight" intensity) based on viewing conditions!

Older, CRT at current max luminance @95cd/m2
(Must lower viewing booth to match)

Booth dimmed 50% to match LCD

Solux task light

Wide gamut LCD with proper luminance calibration 150cd/m2 (to match booth)



Position booth and display to avoid any light spill on display

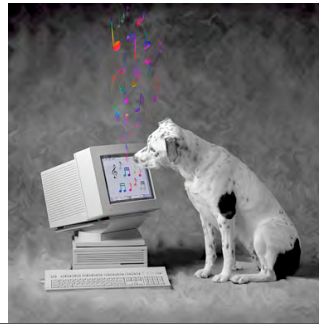
Setting up a CMS:

- You don't have to deal with all items at once. Start by calibrating and profiling the monitor using an instrument (not eye-ball calibration!)
- Get your service provider to profile their devices and give you the profiles! This allows you to control conversions based upon the output soft proof
- Demand that scans are provided with an input (scanner) profile in more than 8-bits pre color! You can't convert into a Working Space without one. This provides the widest gamut data from the capture device and ensures suppliers are profiling their devices

Try to use instrument based display calibration. Products now start at under \$100. If you run into a service provider that asks you to match your display to a reference print they supply using on display controls, run away from them as fast as you can! This is an exercise in failure using ICC aware applications like Photoshop.

Question & Answers

Thank you for coming. If you were provided with evaluation forms, please fill them out.



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Thank you for coming. If you were provided with evaluation forms, please fill them out.

Web sites you might want to investigate:

http://www.adobe.com/digitalimag/pdfs/phscs2ip_colSPACE.pdf

Holm and Rodney: <http://www.color.org/>

[ICC white paper 20 Digital photography color management basics.pdf](#)

Reichmann's "Expose to the Right": <http://www.luminous-landscape.com/tutorials/expose-right.shtml>

http://labs.adobe.com/wiki/index.php/DNG_Profiles:Editor

Bruce Lindbloom's synthetic Color checker: <http://www.brucelindbloom.com/>