ABOUT THIS WHITE PAPER

This white paper introduces the key concepts and terms for discussing and understanding color and color management. After reading this white paper, you will understand how digital presses allow end users to control, produce, and repeat consistent, high quality color output.

Designed to be accessible for the layperson, this white paper is an ideal refresher for any color management professional on many of the key concepts of digital color management. The capabilities of the digital press have evolved rapidly over the past few years, and professionals need to keep pace with the changes in technology that will benefit end users.

FREQUENTLY ASKED QUESTIONS

- When should I calibrate?
- What is color management?
- Are rendering intents important?
- What is an ICC profile?
- Should I convert all of my spot colors, or leave them as is?
INTRODUCTION

In the simplest terms, color management is a set of standards, rules, and procedures that when followed control the variables involved in color workflow. When properly implemented, color management can help obtain consistent color results across various devices, from digital camera to display to proof to press. We generally refer to a mature set of color management standards, rules, and procedures as a Color Management System (CMS).

How does a Color Management System communicate color between various devices? With ICC profiles. The International Color Consortium (ICC) has established standards defining the data set that characterizes a device’s unique color space, called an ICC profile. The profile describes the attributes of the device, defining a mapping between source and target color spaces via a profile connection space (PCS). A PCS serves as a standard color space connecting all the devices in your color managed workflow, and is usually based on the CIE L*a*b color space, which includes all colors visible to the human eye, and is also device independent.

ICC PROFILES

ICC profiles are digital characterizations of the color capabilities of a digital device. As such, this is a standard for the device. Think of the ICC profile as a digital fingerprint for a device.

What to profile?

Scanners, Cameras, Projectors, Monitors, Color Spaces, Named Colors (Pantone, TRUMATCH, DIC etc.), Output Devices/Paper Combinations

Manufacturers ship standard profiles representing the average color capabilities of a statistical sampling of their products. Usually this is more than sufficient. When you want more accuracy, each device can be individually profiled (the process differs by device and the software you choose). Be aware, if your device cannot be calibrated, it cannot be profiled, and you cannot change the defaults supplied by the manufacturer.

In printing, if you want to improve the results of your CMS, you may choose to profile your specific printer with different combinations of the paper stocks you print. By doing so, you will help optimize your CMS by detecting and adjusting for any variation in your printer’s color capabilities with a particular paper stock, and by allowing your CMS to transform your color data to match the capabilities of your output media.

Never forget, the canvas makes the color!
Difference Between ICC Profiles and Device Link Profiles

ICC Profiles:
In color management, an ICC profile is a set of data that characterizes a color input or output device, or a color space, according to standards promulgated by the International Color Consortium (ICC). Profiles describe the color attributes of a particular device, or viewing requirements, by defining a mapping between the device source and target color space and a profile connection space (PCS). This PCS is either CIELAB (L*a*b*) or CIEXYZ. Mappings may be specified using tables, to which interpolation is applied, or through a series of parameters for transformations.

Every device that captures or displays color can be profiled. Some manufacturers provide profiles of their products. Several products allow end users to generate color profiles, typically with a tri-stimulus colorimeter or preferably a spectrophotometer. The ICC defines the format precisely but does not define algorithms or processing details. This means there is room for variation between different applications and systems that work with ICC profiles.

Device Link Profiles:
This is a special variant of ICC profile that maps a color conversion directly from the source to the target in one profile. Each color of the source color space directly maps to a specific color of the target color space. Unlike in ICC profiles that can be combined freely as source target profiles, a special Device Link Profile, or DLP, is calculated for each specific task.

Since a Device Link contains the results of the algorithms and processing details, any two Device Links created using the same method that are put on two different manufacturers of a Digital Front End (DFE) will produce the same results. Two ICC profiles created using the same method but put on two different DFEs may produce different results. An ICC profile relies on the DFE to do the math that on a Device Link is inherently embedded. Device Link profiles specifications are defined by the International Color Consortium (ICC).

What does all that amount to?
ICC profiles describe the color gamut of devices, and carry color information from one device to the next in a color workflow. ICC profiles are stand-alone profiles, and can be combined freely together. Device Link profiles are specialized ICC profiles that link two specific devices together, translating the color information from the first device to the second specifically. They cannot be combined freely together.

ICC profiles offer portability between workflows (e.g. when you send your files to another location to be printed, ICC profiles are ideal), while Device Link profiles offer greater specificity (e.g. when you are running the same job side by side in one location, DLPs work great). There are advantages and disadvantages to both, so unfortunately there is no single answer to the question, “Which one should I use, ICC or DLP?” The answer depends on your situation.
Creating a color management system that all key people in the lifecycle of a document can understand, implement, and follow is the key to creating a color workflow that is consistent, repeatable, and produces the best possible output. This means more than just educating the key operator of your press. Color management begins as early as the idea stage of a document, and is dependent on the tools they will use to create it.

- Which software package will they use?
- What file format will they create?
- Will they want to use spot colors?
- Will the document be for print only, or exist in a cross media environment and potentially be viewed in a variety of situations using different technologies (Internet, email, iPad, iPhone, Android, PC, Mac)?
- Will they leave RGB color alone, or convert everything to CMYK? What color spaces will they select?
- What about people who do not have color aware programs, and want to use Microsoft Word, Publisher, or PowerPoint to create print ready documents?

These are just some of the basic decisions that are made very early in the document creation cycle that will affect the ability of any press, offset or digital, to produce acceptable color output. By establishing a color managed workflow, all these decisions are pre-determined. A color managed workflow allows your creative people to not focus on the mechanics of creating consistent files, but instead on what they love to do: create! It also means that your print people will not be spending time fixing files from your creative team. Instead, they will be able to print the files as intended on the first try. They get to focus on what they love, producing beautiful, consistent color products that delight the customer.

WORKFLOW IS THE SOLUTION!
Unmanaged versus Color Managed Workflow

The diagram on the bottom left illustrates an unmanaged color workflow. Each digital device is not characterized with an ICC profile, and there is no consistent translation of color data when moving an image from one device to another using a device-independent color space.

The diagram on the bottom right illustrates a color managed workflow where each device is characterized by an ICC profile, and there is a Profile Connection Space (PCS) where color data from one device is translated into the appropriate color data for another device utilizing the device’s ICC Profiles.

The panel at lower left shows the result of an unmanaged color workflow: color is inconsistent throughout the process. The panel at lower right illustrates a color managed workflow: color is consistent throughout the process. The benefits are clear. By managing and defining color parameters upfront, all key players in the color workflow can produce and see consistent quality color at each step of the process. This means at every step, the correct color is passed forward, and the end product looks as intended by each contributor to the creative process.

COLOR MANAGED WORKFLOW

The photographer creates a photo with a characterized (profiled) camera, and passes the photo and his ICC profile to the designer. The designer then embeds the information in his layout, along with his artwork and other color information, and passes the layout to the prepress operator. The prepress operator prepares the layout for production, incorporating all the color information and the color information of the press that will be used, and then passes the print ready file to the press and the key operator. All the key operator must do is ensure that his press is set up for the parameters of the job, calibrate, and the job will print as intended by not only the prepress operator, but also as intended by the designer and the photographer.
Calibration is the measurement of a device’s state of operation at a certain point of time and the process of bringing it into adjustment with a known standard, which in our case is the ICC Profile. Through calibration, each key player can control the variables in their devices and achieve consistency and repeatability in the quality of your color.

What to calibrate?

The answer is you should calibrate all the devices in your workflow that you have profiled, such as output devices, paper combinations, monitors, projectors, cameras, scanners, and spectrophotometers.

When to calibrate?

The answer depends on how much you care about consistency and repeatability in your color management process. The most important point to understand is that calibration is not changing your press; it is gathering information about the current state of your press at a given point in time, and transferring that information to your Color Management System (CMS). In the case of a digital press, the RIP (raster image processor) is the color management module of the CMS that takes this information and makes adjustments to color based on the input files and the current calibration set of your printer.

Ambient Temperature and Humidity are two chief factors that affect the electrostatic process that is the basis of digital press technology. When temperature and humidity change, the state of the digital press changes: it is time to calibrate.

Temperature and humidity change constantly, most noticeably throughout the course of the day. Think about when you wake up in the morning to go to work. Now think about how the changes in weather during the day sometimes make you wish you had brought your umbrella, or worn that scarf. These atmospheric changes affect your digital press as well as your wardrobe.

Even in a temperature and humidity controlled room, there are two additional factors to keep in mind: paper and people. Different paper stocks have different characteristics, including moisture content. Paper directly affects the electrostatic process. Whenever you change paper, you need to calibrate. The human factor covers all the other things that can happen to a digital press during the course of its working life. Perform preventative maintenance; it’s time to calibrate. Change a toner bottle; it’s time to calibrate. The list of potential factors goes on and on.

In the end, you will learn through experience how often you should calibrate to achieve an acceptable level of consistency and repeatability in your color managed workflow.

The tools are there for you to use. It’s up to you to do it!

THE KEY TO IT ALL: CALIBRATION!
THE WHITE DOT IN THE i1PRO2’S CRADLE IS FOR WHITE POINT CALIBRATION OF THE SPECTROPHOTOMETER.

Notice that every time you use the device, your software will prompt you to calibrate the spectrophotometer using this white dot. Think about that: every time you use a spectrophotometer, you calibrate it first.

Good color management software prompts you to calibrate the spectrophotometer before every measurement, for consistency and accuracy.
RENDERING INTENTS

The manner in which a color management system deals with out of gamut colors when translating color from one color space to another is known as rendering intents. Understanding how rendering intents behave is important for two reasons:

1) you need to know which one to choose and when, and
2) you need to know how each rendering intent affects the output of your color.

What does each intent do?

- **Relative Colorimetric**: compresses out of gamut color to the nearest in gamut color. In gamut colors are not touched. This is a good place to start with photographic images, to maintain the expected appearance of the image across various digital devices in a color managed workflow.

- **Absolute Colorimetric**: DROPS out of gamut colors, indicated by the grey areas, and used to simulate the color of the paper on output.

- **Perceptual**: will compress the entire gamut of an image to fit within the gamut of the destination device.

- **Saturation**: compresses out of gamut colors to the closest in gamut color, and the saturation of in gamut colors are increased, sometimes effecting hue and chroma.

Which rendering intent to use?

It depends, but a general rule of thumb is to start with Relative Colorimetric, unless you are printing photos only, in which case, use Perceptual. Saturation is best for business graphics or logos. Use Absolute Colorimetric in proofing workflows where you want to simulate the appearance of the output on a specific paper.

The RGB and CMYK gamuts represented on this page illustrate the position of five color points within the RGB image of the whale. The following page demonstrates the effect of different rendering intents on the output.

Because the RGB picture of the whale is within the RGB color space, none of the colors are altered by rendering intents when viewed on the monitor.

The image of the whale demonstrates the effect of different rendering intents on the expected output of the file on the same device (in this case US SWOP Coated).
Relative Colorimetric

The Grey indicates colors that are out of gamut and will be moved when printed, or viewed on a device with a gamut that cannot reproduce those colors.

Perceptual

All colors are shifted inward to be in gamut. This can create a perception of “color shift” when the image contains colors far out of gamut.

Saturation

Colors out of gamut are shifted in, colors in gamut are saturated. This can cause the appearance of color to seem to change from device to device.

Absolute Colorimetric

Absolute Colorimetric is the same as Relative Colorimetric above, but in addition, will simulate the color of the paper when printed. Compare the image at right with the Relative Colorimetric image at the top of the page. You can see that some information in the image is missing (note the white water at the surface where the whale is breaching).
A WORD ON SPOT COLORS AND THE DIGITAL PRESS:

A spot color is a special premixed ink that is used instead of, or in addition to, CMYK process inks. In the offset printing world, a spot color requires its own printing plate or separation.

In the digital printing world, no special plate is required for spot colors, so the use of spot colors is not limited by physical separations as in the offset world. But beware; many spot colors are not only outside the gamut of the CMYK color space, but also outside of the RGB color space (i.e., even your monitor won’t display some spot colors accurately). See the CIE 1931 Chromaticity diagram, above left. Open a Pantone Formula Guide solid coated swatch book and select a color (e.g., Pantone 200 C). The Pantone book provides the formula for a pressman to mix Pantone inks in the correct proportions to create this color (12 parts Pantone Ruby Red, 4 parts Pantone Yellow, 1/8 part Pantone Black). The Formula Guide also provides key information as to whether a particular color is achievable in the RGB and/or CMYK color gamuts. In this case, Pantone 200 C is achievable in both.

Switch to the Pantone ColorBridge Coated Guide and select Pantone 200 C. Next to this swatch is a second swatch, Pantone 200 PC. This represents the Pantone approved CMYK ink equivalent of Pantone 200C. The given recipe is 3 100 66 12. An RGB formula is also given, 183 18 52, as well as an HTML code, B71234. Many designers, following a long established best practice, use one of these numbers to create their spot colors for digital printing. The result is close, but not quite correct. The given recipes are for creating the color using ink, not toner. So when printed on a digital press, the recipe may or may not produce a desirable result.

Another old “best practice” needs to be updated in the minds of designers and printers alike. Many creative professionals and pressmen follow the old rule of thumb that dictates converting All Spots to Process when preparing documents for production. See the Ink Manager screen shot from InDesign in the diagram above. This procedure saves money on an offset press by eliminating the need for a spot color separation for the job.
Not so in the digital world. Each RIP manufacturer partners with printer manufacturers to create unique lookup tables for each spot color library, for each combination of digital press and RIP. By converting All Spots to Process, the RIPs can no longer identify your spot colors and correctly select the CMYK recipe representing your desired spot colors. The digital press prints the CMYK recipe in the file, but as we now understand, that recipe may or may not be the correct one. From practical experience, the resulting CMYK recipe is never the correct one. Why is that the case?

Go to your RIP, and open your spot color editing tool and look up the CMYK recipe for Pantone 200 C. Three results are shown at right, each representing the manufacturer’s recommended formula for achieving this color using their RIP on a particular printer. Notice the variations.

When you convert All Spots to Process, your input file lacks the correct information for the RIP to print your file correctly, and also prevents you from adjusting those spot colors to meet your particular needs (i.e. if you do not like the result of the recommended formula, you can change the color at the RIP). This is an important distinction and a very powerful capability.
When photographers or designers use color aware programs such as Adobe Creative Suite, they have the ability to define the color space the programs use for particular files. The working color space effectively defines the color gamut of the file.

How does this affect the color workflow? When designers or photographers view their creations on screen, they will see a far larger gamut than can be printed on offset or digital presses. Often, they may be disappointed with the result from the press because they do not see all the color they saw on their monitor or their printout.

Color managed workflows specify the working color space for all key players. When retouching photos or designing layouts, if the files are created using the working color space of the workflow, the photographers and designers will see the output they can expect to get off press.

Take the example below. The photo of the red rose demonstrates the effect of different CMYK working spaces on the expected output of a file. The grey areas indicate which colors in the RGB file will be out of gamut in each CMYK color space. The same rules for rendering intents apply here as well.

If a photographer retouches the photo using an RGB color space, as you can see, the output will disappoint. But, if the same photographer retouches the photo using one of the working color spaces, the output will match what was displayed on the monitor during the retouching process. The same goes for the designer and the prepress operator.

- Which printing color space reproduces the most amount of the red in gamut?
- Which printing color space reproduces the most amount of detail in gamut?
- Which printing color space will give you the best results?
- Which color space(s) are you currently using in your workflow(s)?
A FINAL WORD ON COLOR SPACES:

The color spaces below represent various RGB and CMYK color spaces that you may encounter in your digital life. SWOP is a standard space for offset presses. It is very obvious that the CMYK spaces are smaller (therefore there are RGB colors that will shift when printed in CMYK). The superimposed color spaces demonstrate something less obvious. The CMYK space contains colors that the RGB color space does not accurately represent (these colors will be shifted when displayed on your monitor, just as Pantone colors outside the RGB color space will appear different on a monitor).

Knowing your color palette before you design and testing it on your output devices is the first step towards creating documents that will sail smoothly through your color managed workflow.

The color spaces below demonstrate the achievable Pantone Coated Spot colors in RGB, SWOP and Canon imagePRESS C800 color spaces.
Today, the state of the art approach to creating and managing color profiles is through iteration. This approach brings a number of key advantages to end users that were not available with profile editing.

- Iteration eliminates the guesswork in optimizing color profiles. The color engine in the software finds the weak parts of your first color profile, and creates new measurement charts based on the data from the first pass to refine the profile of your device.

- Iteration is quick and easy with the processing power of today’s computers, software, and chart readers. Letting the software do the work for you means that you get consistent and repeatable results, every time.

Profile editing was the preferred method in the past for a number of reasons that are now obsolete through improvements in processing power and technology in the last decade.

- Limited processing power often made the creation of effective profiles excessively time-consuming for end users. As a result, end users were looking for short cuts to reduce the size for the measurement charts to a minimum. This would create gaps in the profile that end users would address by manually editing the profile to address a specific color.

- Hand-held spectrophotometers made reading large measurement charts time-consuming and error prone.

Today’s chart readers and automation tables increase chart reading productivity and reduce operator error to an absolute minimum.

- Controlling black: end users who have learned how to edit black (or any specific color) on their digital presses are sometimes reluctant to relinquish this control based on past success. Today’s software allows you to dial in specific colors (including black) with an iterative approach that means there is no guesswork in optimizing your results. This is easier, more reliable, and ultimately more accurate than the traditional editing method.

Iteration is today’s preferred method for creating effective color profiles. All the major Color Management vendors, including EFI, CGS, and X-Rite support this point of view, and it is reflected in the design of their software products; Color Profiler Suite, ORIS LYNX, and i1Publish respectively. For those who want to manage their color, iteration gives a standard, repeatable process that can be performed at a variety of levels, from beginner to advanced.

Editing can still be performed on an existing profile using a variety of tools, including the RIP controls directly. As with any tool, just because it is available does not necessarily mean it must be used to achieve the best results. You would not use a hammer to install a sparkplug in a car; you would use a socket wrench. Use the right tool for the job to get consistent repeatable results.
Iterative versus editing methods

**Iterative:** is a repetitive process used to optimize a profile programmatically. It gives consistent and repeatable results with a minimum of human intervention and error. It is the act of repeating a process with the aim of approaching a desired goal, target, or result. Each repetition of the process is also called an “iteration”, and the results of one iteration are used as the starting point for the next iteration.

**Editing:** is the traditional method of manually editing a color profile to make adjustments to the color output. Editing relies on human adjustment of the profile to achieve a desired result. The editing process can involve correction, condensation, organization, and other modifications performed with an intention of producing a correct, consistent, and accurate output.
WHAT COLOR MANAGEMENT DOES NOT DO!

Color management cannot make bad images look better. If you begin with a bad image in a color managed workflow, you end up with a perfect reproduction of that bad image on every device in your workflow.

Color management does not replace calibration and maintenance of your devices, whether they are presses, proofing devices, displays, or digital cameras. Conversely, calibration alone does not provide accurate, reliable output without color management.

Conclusions

After reading this white paper, you should have a correct understanding of the principal elements of color management as they relate to digital devices. Tying together the relationships among ICC profiles, calibration, color managed workflows, rendering intents, and working color spaces will help you design a color workflow that will produce quality color output. Understanding how spot colors work separately from process colors, and how to properly define spot colors in your files, helps ensure proper reproduction of both process and spot color with your output device.

With digital printing, it is just a matter of a few mouse clicks for operators to change that output from one standard to the next to meet the requirements of specific jobs or customers. All these settings can be automated, to make color management of your production workflow truly hands-off. Lastly, using the current best practices in creating and maintaining your color profiles helps ensure that you have a consistent, repeatable workflow that can be easily maintained without the need for color experts.

With this knowledge you can explore the strengths and weaknesses in your own color workflow, and begin to make changes to your workflow that can enhance your productivity and the quality of your color.
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Fred Lampe joined Canon Solutions America in 2011 and manages the Production Print Software portfolio within the Enterprise Services and Solutions division. Prior to joining Canon Solutions America, Fred worked for 15 years as a production print analyst for other major imaging equipment manufacturers, selling and supporting digital production printers and presses in virtually every vertical market including Commercial Print, Government, Advertising, Legal, Education, Manufacturing, and others. Fred is an evangelist for color managed workflows and educating customers on the benefits of automation and standards-based workflows.

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