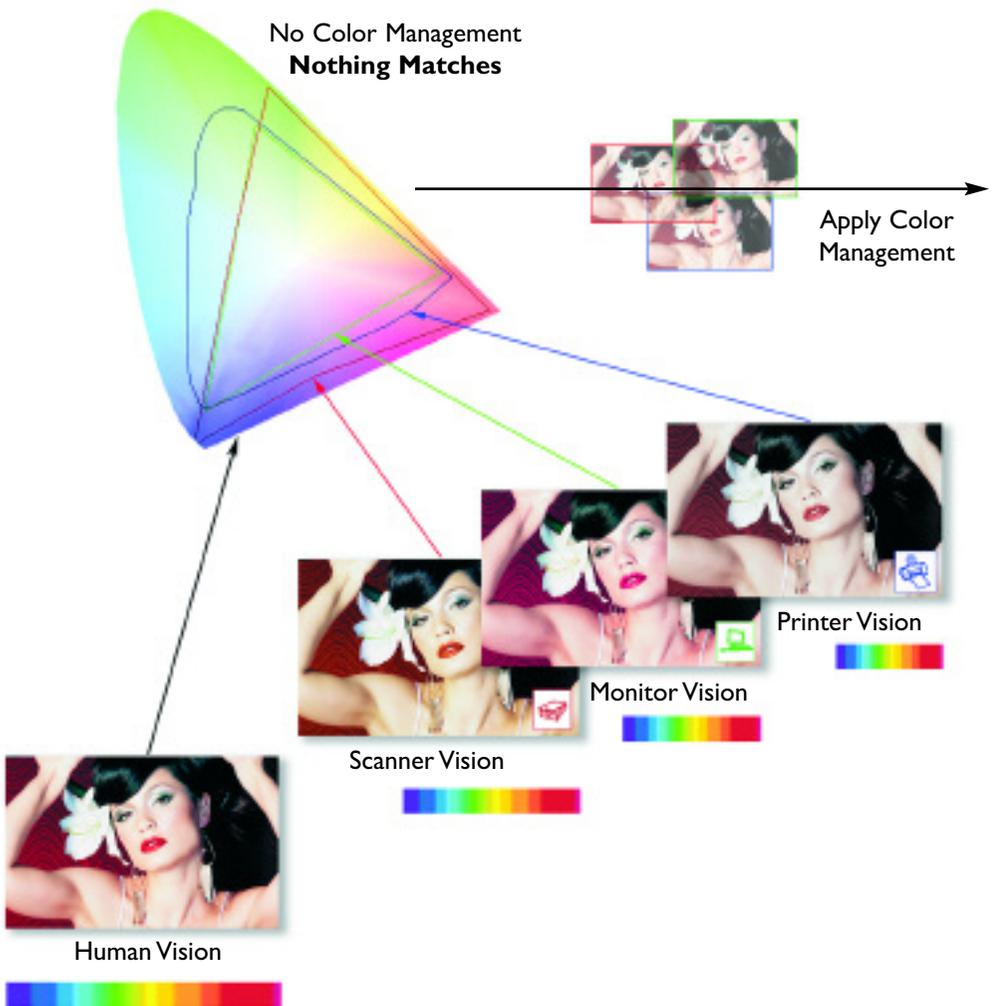**x·rite**

COMPLETE
GUIDE
TO COLOR MANAGEMENT

Tired of Prints that don't match your monitor?
The fact is all your devices – scanners, digital cameras, monitors, and printers – reproduce colors differently. There are even differences in the way individual printers of the same model manage color. Many variables affect color, including your ink and paper type. Time to take control!

Color Management – is a way to set up your environment (called a workflow) to allow all these devices to speak the same language so you can get accurate and predictable results. The ultimate goal is to match the colors of the image displayed on your monitor with the ones produced by your printer.

We use Color Management software to create profiles for all your devices. A profile provides a description of each device's color gamut – the range of reproducible color. You use these profiles in your workflow, and the result is an accurate translation from one device to the next, giving you consistent, predictable color.

This diagram (FIGURE 1) presents a simple look at Color Management. The fact is the human eye sees a very wide range of colors – wider than scanners and cameras can "see" and much wider than any monitors and printers can "show". Each of these devices reproduces color differently, both in terms of how many colors and also in terms of which colors, or the shape of their "vision" (gamut). They truly each speak a different language. Color Management acts as the translation system and finds a

No Color Management
Nothing Matches

Apply Color
Management

Printer Vision

Monitor Vision

Scanner Vision

Human Vision

common language or vision. Once we turn on Color Management software and apply the unique translation controls (profiles) the work is done – colors match! If you are expecting to get a match between your original image and your final output, without the hassle of trial and error, Color Management is for you. Get the competitive edge to creating accurate prints. Get out of the loop – save time, money, ink and paper using proven techniques to control color throughout your system.

Color Management
Got a Match!

Translate to a
Common Vision

See accurately what you Scan, and Print what your Monitor Displays
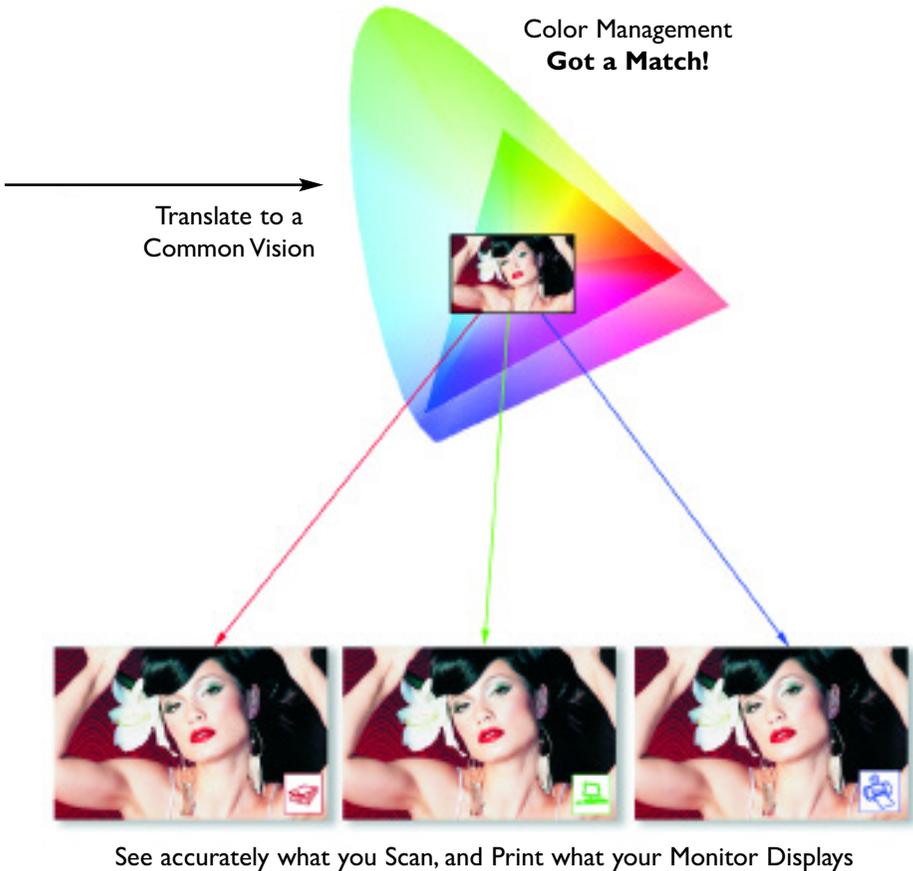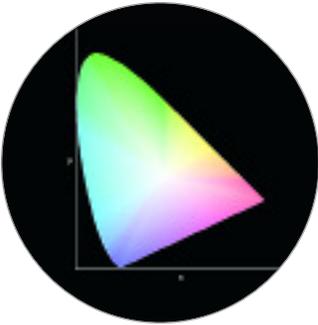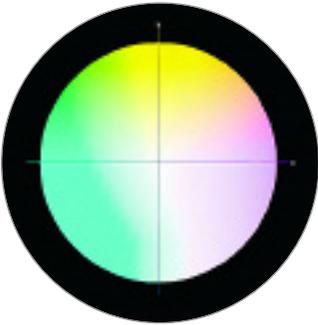
FIGURE 1

FIGURE 2

FIGURE 3

If you really want to understand how things work we need to start with some basics. When color reproduction was first becoming a science it was determined that all the colors visible to the average person could fit into a twisted horseshoe-shaped graph affectionately know as the *xyY Chromaticity Diagram*.

This diagram (FIGURE 2) represents the way we see and accurately indicates the uneven sensitivity we have to all of the colors. It's also convenient as we can count on this space to stay the same regardless of how it's viewed or imaged with any device. In fact, because of the lack of dependence on any other factors we call it *device-independent*.

As more technologies evolved it became apparent that measurement systems and computers needed a better balance of information, so the spacing between colors was shaped to become more consistent and even. We call this space L*a*b*, or simply *Lab* (FIGURE 3).

Technically a* represents the red/green axis, b* represents the yellow/blue axis, and a straight line going right through the center corresponds to L or the lightness.

Lab is a great place for scientists, but it's also the space that's hidden in all of our computers. So we're going to look at a few images the way our computers do.
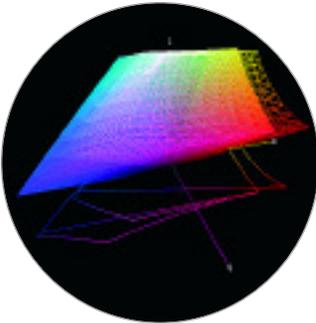
FIGURE 4

FIGURE 5

Since the computer monitor is our window into the digital world, the question is just what colors can it display. This diagram (FIGURE 4) gives you a three dimensional view of *Lab* and shows the basic boundaries of reproduction, which is called the *gamut*. Not only can we see the reproduction range on the a/b axis, but in this view the L axis clearly indicates the depth into the dark colors and height into the light colors.
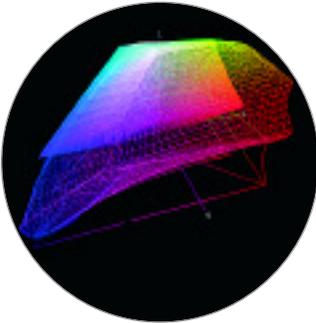
In a perfect world this would be a full sphere, but the world is far from perfect. These are real examples of the gamut of colors a professional CRT (solid shape) and professional LCD (wire shape) can reproduce on their displays. The color we see depends on each of these devices, and therefore, as opposed to color space, hardware is *device-dependent*.

Now that we know what the computer monitor can display, how does that compare to an input device like a camera or scanner? Well let's see. Here's a good example (FIGURE 5) of a professional desktop scanner (wire shape) and a professional CRT (solid shape).

Scanners and cameras can see much more than you could hope to reproduce (just like film). The actual effects of this are shown here (FIGURES 6 & 7) (recognizing limitations to the inks used on this page).

SCANNER GAMUT
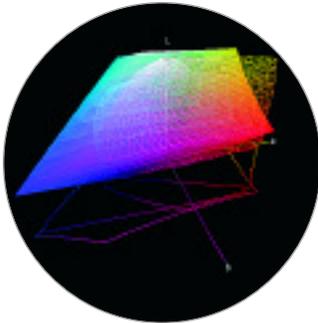
FIGURE 6

MONITOR GAMUT

FIGURE 7

FIGURE 8

Taking this to the next logical step, let's compare the monitor to a printer. Here's a good example (FIGURE 8) of the output of a professional six color inkjet (wire shape) and a professional CRT (solid shape).

The printing process has always been a limiting factor in how photographs reproduce and that hasn't changed much over the years. However, since there is a closer match between these two gamuts, the actual differences in the effects shown here are not as dramatic (FIGURES 9 & 10).

MONITOR GAMUT
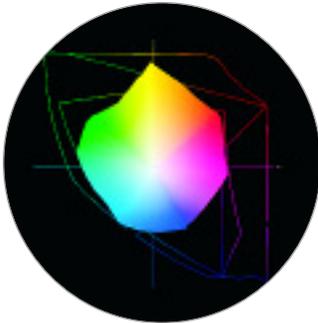
FIGURE 9

PRINTER GAMUT

FIGURE 10

FIGURE 11

Finally, let's put it all together. But this time we're going to compare the three gamuts in a two dimensional space for simplicity (FIGURE 11).

It's quite clear that the printer (solid shape) is the limiting factor. The next outlined shape represents the computer display which pretty well encompasses the gamut of the printer. And of course the outermost line shows the wider range of the scanner (similar to a camera with its extreme gamut).
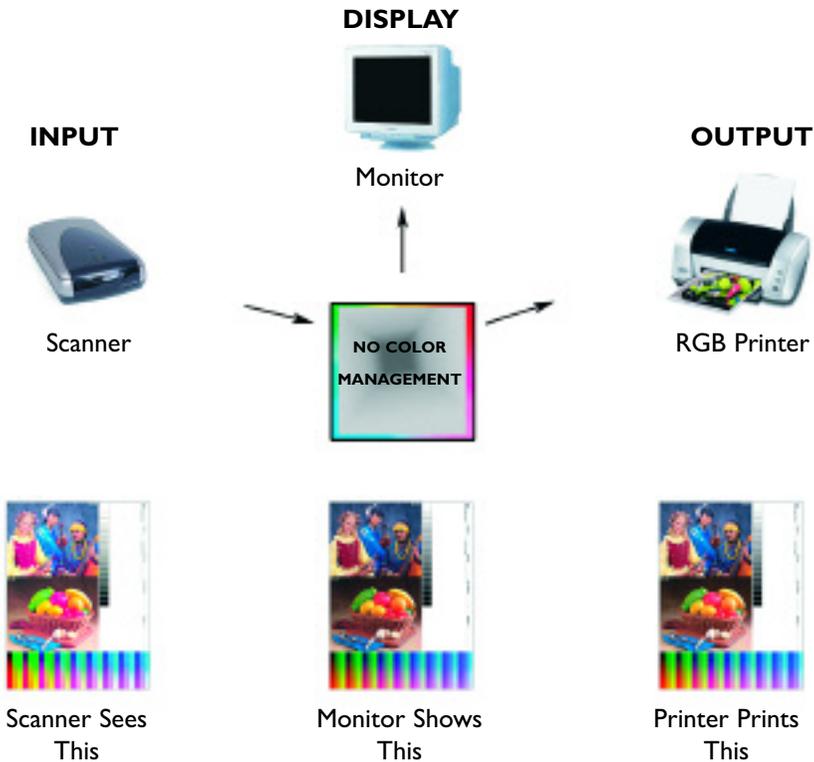
Said another way (FIGURE 12):

DISPLAY

Monitor

INPUT

Scanner

NO COLOR MANAGEMENT

OUTPUT

RGB Printer

Scanner Sees This

Monitor Shows This

Printer Prints This

FIGURE 12

It's important to recognize that because every piece of hardware has it's own gamut, we need to translate all of their rendering abilities in a common and shared way – that's Color Management.

X-Rite brings powerful color control to you. And considering X-Rite's only business is making Color Management solutions, you'd better believe we want to make the color look right!

So how does it work? The first step to Color Management is to look at your window into the digital world – your monitor. Making your monitor the reference is actually a two-part process: you need to set the display to some fixed level of performance *(calibration)* and then measure its color-rendering capability in a definable way *(profile)*.

Profiles translate the uniqueness of each device into a universal language that can be shared among devices in a *"device-independent"* Color Management System (FIGURE 13).

Note: Mac users will see profiles identified as .ICC files. Windows users have .ICM extensions, otherwise both systems essentially work the same way and are cross-platform compatible.

DISPLAY

Monitor

INPUT

Profile
(ICC/ICM)

OUTPUT

Scanner

Profile
(ICC/ICM)

COLOR
MANAGEMENT

Profile
(ICC/ICM)

RGB Printer

Scanner Color
Translates to This

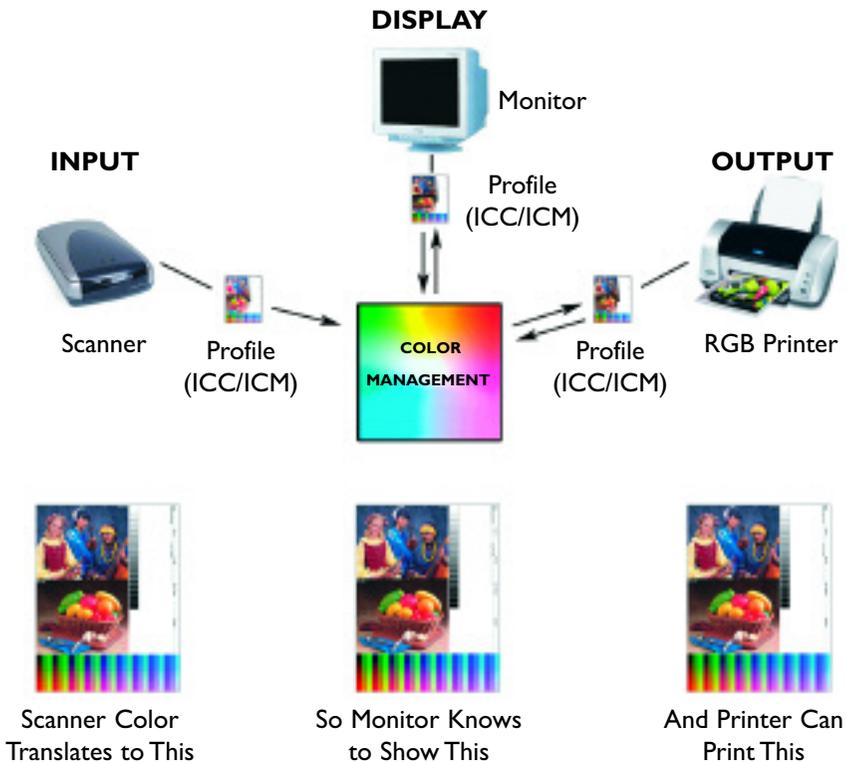So Monitor Knows
to Show This

And Printer Can
Print This

FIGURE 13

Calibration can be done by eye with simple software, but we all see color differently so that doesn't work too well. A special light meter, called a *Colorimeter* does the job. X-Rite color software automatically guides you step-by-step through the process. In just minutes your brightness and contrast are set to optimum levels, and by comparing actual output from your monitor to reference color data in the software, your computer is told everything it needs to know about how your monitor displays colors – and your *profile* is created.

Whether you make your own prints or send them out, all monitors need to be calibrated and profiled. Otherwise it's like talking on the phone and telling someone how to adjust their television set to display the same color you're seeing on yours.

If you've got all the basics on your desktop, then X-Rite color software also makes it just as simple to ensure color accuracy in the workflow between your scanner, monitor and printer. And, special test targets and profiling software can keep the color from your digital camera just as faithful.

There are two types of measuring devices: Spectrophotometers and Colorimeters. *Colorimeters* typically match human vision and measure color targets in four broad areas as we can see in the graph here (FIGURE 14) and offer an excellent price/value relationship. For printer calibration, or more professional monitor calibration you may prefer to use a *Spectrophotometer*. The range of colors that we can see, the visible spectrum (light), consists of wavelengths of radiation ranging from approximately 400 to 700 nanometers (or nm – a unit equaling one billionth of a meter). Spectrophotometers as their name implies look at the whole spectrum and give more accurate results by making up to thirty-one measurements (in 10nm increments).

FIGURE 14

400nm   500nm   600nm   700nm
WAVELENGTH
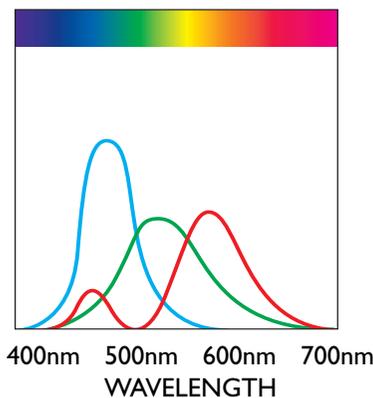
Profiling the Monitor

Here are the steps used to profile the monitor, but before you begin, turn off any color management settings that may have come with the monitor as you will apply your own later.

Adjust the Room Lighting – Before any measurements are taken or images viewed, the room lighting should be adjusted to the way you normally work. Avoid any harsh direct lighting on the face of the monitor. This will allow more accurate measurements and a better profile.

Put the Monitor in Its Optimal State – Before profiling any device, it should be set up to produce its largest, most consistently reproducible color gamut. For monitors, this is accomplished by adjusting the brightness and contrast settings.

Pick Profile Settings – Monitor profiles typically have a white point setting (how white will appear on the screen) and a gamma setting. X-Rite profiling software allows you to customize these settings based on your viewing condition and operating system (Mac or Win.).

Naming and Saving the Profile – After entering a few easy-to-choose settings, the profile is automatically saved in the correct location so ICC-compliant applications, such as Photoshop, can find it.

Profiling the Input and Output Devices

Printer profiles are built by printing a set of known color patches. A spectrophotometer then reads the color patches so the software can interpret the difference between the original file and the printed patches. This information is stored in the form of an output profile, which is applied to images to ensure they are printed correctly.

Printer profiles are applied when you are ready to print your image. The profiles compensate for any variance that the printer introduces and help the printer to match the image displayed on-screen. If you have a profile for another printer along with a profile of your own printer, the profiles can be used in conjunction to have one printer simulate another.

Depending on the level of color management and application, procedures vary. The final step to profiling and calibrating your scanner and printer essentially involve the following:

Create a profile for your scanner or digital camera using the appropriate target. Scan, crop and name the target.

Select a target patch from an extensive list, and print it using your printer. Color patches vary depending on which level of color management suits your purpose. Targets can range in size from having just a few colors to thousands of colors. And they are read and measured using a spectrophotometer.

Profiles are created by the software which gives further control with features such as ink limiting, black generation, and advanced UCR/GCR.

Step-by-step wizard driven software assures your success! Once you have profiled and calibrated the scanner, monitor and printer, what you see on the monitor is what you'll get from the printer. You'll save at least 75% of your time, 66% of your resources, and at least 33% of your cost. These numbers were verified by an independent study.

Editing Output Profile

Profiling the output, or printer files is a snap and X-Rite software creates accurate profiles right out of the box. However, sometimes profile editing is necessary. This option allows you to modify any RGB or CMYK printer profile. Printer profiles are edited to create a better monitor-to-print match, original-to-print match, or to shift color balance or tonal values towards a desired result.

With professional software packages there is even greater control over your output file editing. The editing feature is used by those who have a super eye for detail. This option gives you powerful tools for adjusting output curves, editing CIELAB (L*,a*,b*) color attributes, customizing gamut compression to affect color selectivity, and fine tuning colors and neutrals in the color space of the profile.

To edit an output profile, simply use the color tools to alter a sample image (or your own image) that has been processed using the profile. Once color edits are made, they are proofed by viewing the image on a calibrated monitor and/or by printing a hard copy of the image.

When editing is complete, your adjustments are saved in the profile and subsequently applied to all images processed using the same profile. You can optionally apply the edits to the sample image if desired.

Using ICC Profiles

You've successfully created profiles for your scanner and printer. Now what do you do?

To use the profiles, you need an ICC-compliant application, such as Adobe Photoshop, Illustrator, InDesign, and QuarkXpress.

Why not use the print drivers color management from the printer manufacturer?

Color management associated with drivers supplied by the printer manufacturer offers a good starting point to approximate the way color should be reproduced. However, variations in ink and paper manufacturing ensure that a standard print driver will not be able to offer the precise color matching required in professional imaging. Also, the standard print driver does not take into account different inks or paper stocks. These variations can show a significant difference in the printed color.

Finally, the print driver alone provides no support for matching the printer to the monitor. So if it is not possible to see what you are going to print, you cannot judge the image until after it is printed.

Color management do's and don'ts

What it does...

• Build custom ICC Profiles for color devices such as monitors, printers and scanners
• Improve color matching from device to device
• Provide accurate soft proofing and digital proofing

What it doesn't do...

• Apply ICC profiles within the graphic application. Applying the profile is done through menu selection within ICC supportive programs such as QuarkXpress and Adobe Photoshop.
• Fix poor quality images or expand the gamut of a device. Proper ICC profiles can only ensure that the reproduction matches the original.
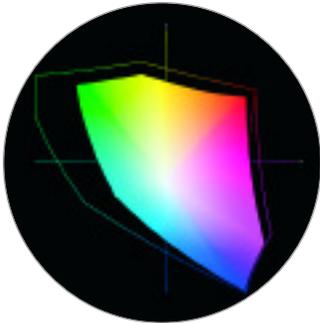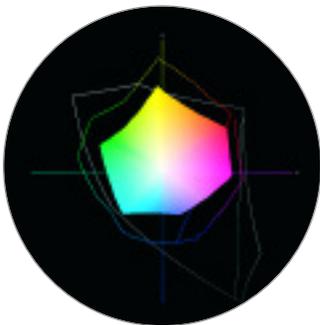• Work on devices that are out of calibration.

FIGURE 15

FIGURE 16

There are many options for the actual Color Space in which you choose to work, but the two most common are Adobe RGB (1998) and sRGB. The basic purpose of Adobe RGB is to provide a very wide range of colors that still can be managed in the viewing and final printing space. While this has been great for serious professionals, it requires more advanced techniques than most users want to learn in order to get good results with the majority of photographic imaging systems. To satisfy this application, sRGB was developed. As you can see from this two dimensional view (FIGURE15), sRGB (the solid shape) provides a smaller gamut when compared to the larger outline shape which represents Adobe RGB.

Although some users may feel the "safe space" offered by sRGB is too restrictive, if we compare it to the printer's output we see a different story. In this view (FIGURE16) the solid shape indicates the gamut of a high-quality printed page (SWOP coated – CMYK). The outermost line shows the gamut of sRGB which totally encompasses the color rendering capabilities of the printed page. The inner line represents a professional six-color inkjet output which is still mostly well within the boundaries of sRGB. The small difference that Adobe RGB can offer requires much work to compress the colors into the output space.

In order to understand how colors are compressed *(Rendering Intent)*, let's plot some actual images directly into three dimensions. First to make it simple we'll start with an image that only contains 24 discreet colors, a Macbeth ColorChecker (FIGURE17).
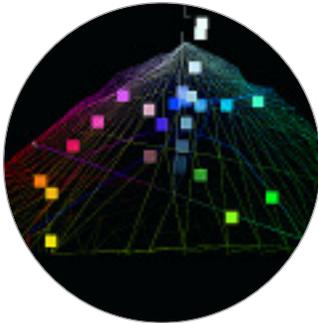

FIGURE 17

FIGURE 18

If we position these colors relative to our six-color inkjet system we can see where they fall on the gamut (FIGURE18). The gray scale tracks quite nicely on the vertical L axis, and the colors fall on the higher, more saturated levels (those of you with sharp eyes and more than 24 fingers will notice two extra gray scale steps which are actually the blackest-black of the frame of the ColorChecker, and the white letters on the frame).

Now that we get the idea of how this looks let's move on to something more complex – an IT8.7-2 Target (FIGURE 19) which is used for profiling many photographic systems (as they all work in RGB).
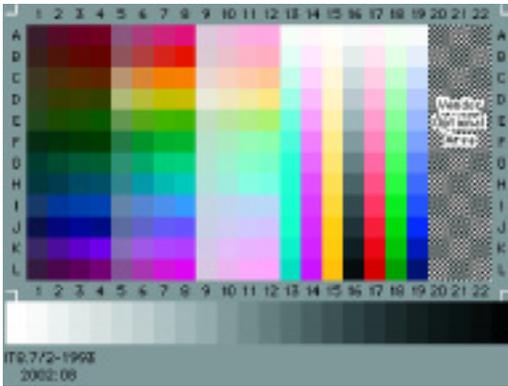

FIGURE 19

We had to back off a little on the view of the inkjet color space (FIGURE 20) to show everything, but all of the colors in the target are clearly visible and if you look carefully many, especially the brighter areas are actually floating above the surface of the space which means they're beyond the printer's capability to render – they are *out of gamut*.

Fortunately our color managed system has a number of options to make sure these colors still are represented in some way on the final print. This is called the *Rendering Intent*.
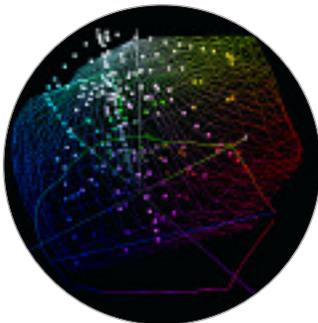
Adobe Photoshop provides four different conversions for this purpose in their software and the one you choose will vary according to the kind of work you are doing. There are many technical explanations of exactly how each of these four "Conversion Options" manages this, but a simple way of deciding what to test first is based on your business. If you're dealing with photos select "*Perceptual*; for graphics try *"Saturated;"* on logos choose *"Relative Colorimetric;"* and if you need the most strict conversion (including simulation of the color of the paper base) use *"Absolute Colorimetric."*
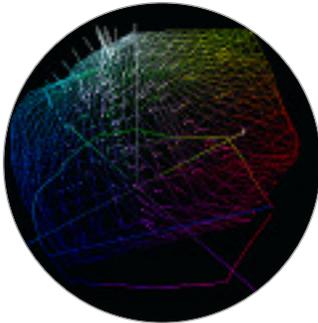

FIGURE 20

FIGURE 21

The next image (FIGURE 21) shows the application of *Perceptual* as the *Rendering Intent*. This has moved the out of gamut colors into the range where they can print safely. If you compare the two images you'll see the little streaky comet-like shapes show where the colors were, and also where they have been repositioned to print (the little square dots) as a result of the rendering.

For a more dramatic example let's see how color is shaped to fit the printed page. Our image for this application is the IT8.7-3 Target (FIGURE 22) which is used to profile most 4-color web, sheet fed and offset printers (CMYK). The printing industry has long been very color conscious and needed a different chart with a much greater range of colors to help make images fit into the small gamut of the printed page.
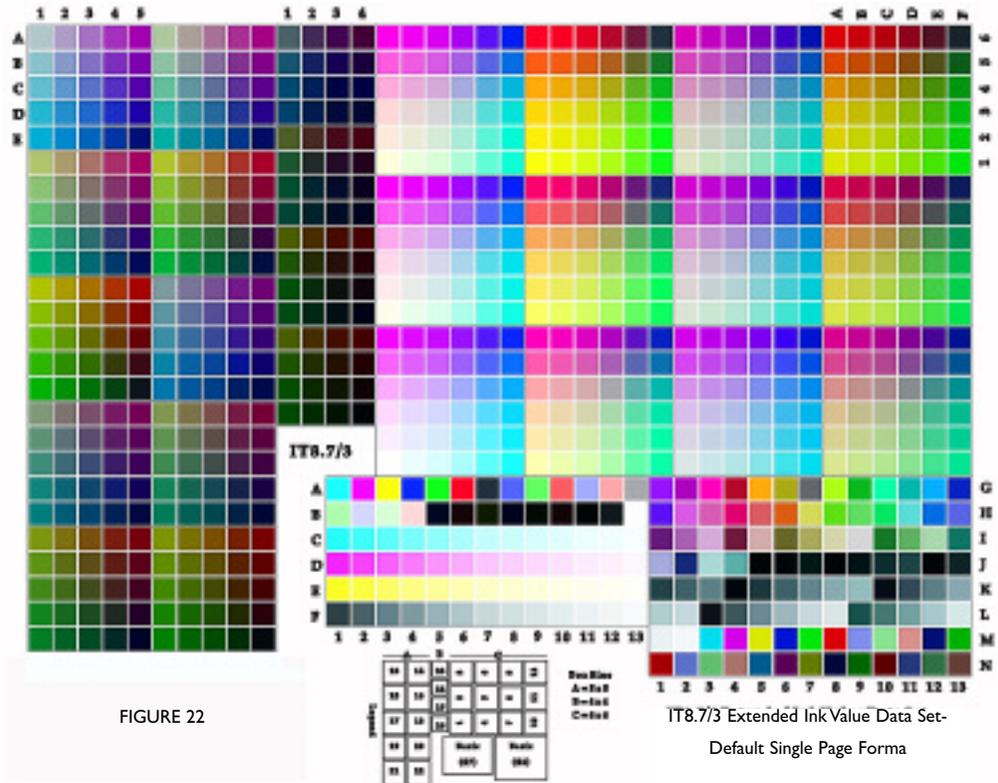

FIGURE 22

IT8.7/3 Extended Ink Value Data Set-
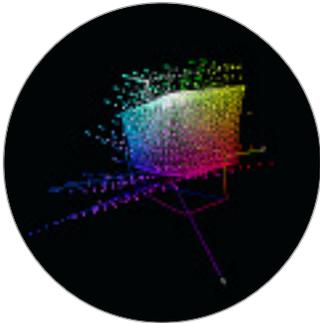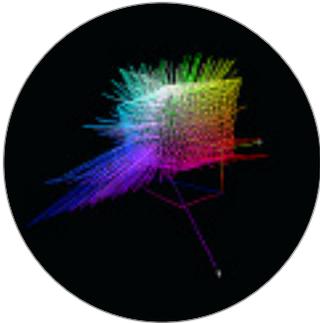Default Single Page Forma

FIGURE 23

FIGURE 24

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