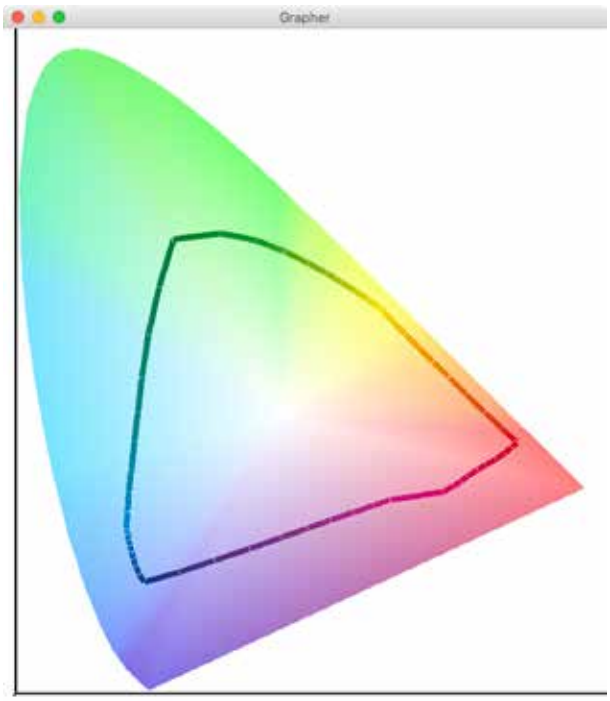
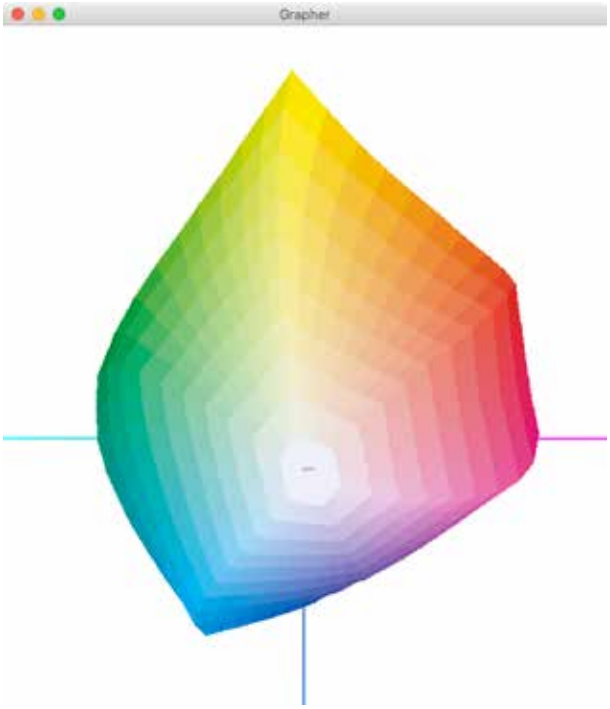




2D gamut.

Print Gamut Ins and Outs

Gamut plays a significant role in how colors in a workflow get converted and how they appear in the final product.

Print gamut is typically defined as the total colors that can be printed using a particular printing system. This is sometimes depicted as a 2D gamut blob.

Ignoring the third dimension — lightness — is a big mistake, as the brightness of the paper and the printer's ability to create dark blacks play a huge role in the range of colors one can print. Gamuts are very much a 3D phenomenon, and effective gamut evaluation and comparison should always be done in three dimensions.

Inks and the media (paper, film, etc.) to which they're applied significantly affect a printer's overall gamut. Along with the printer settings, they are the most controllable elements when trying to print vibrant, accurate images.

Print gamut is created by the interaction between your inks and substrate. Its outer limits are defined by the substrate's media-white level (almost always the brightest color), the maximum black level (the darkest ink combination), and the colored inks alone at 100% and overprinted with other inks at 200%.

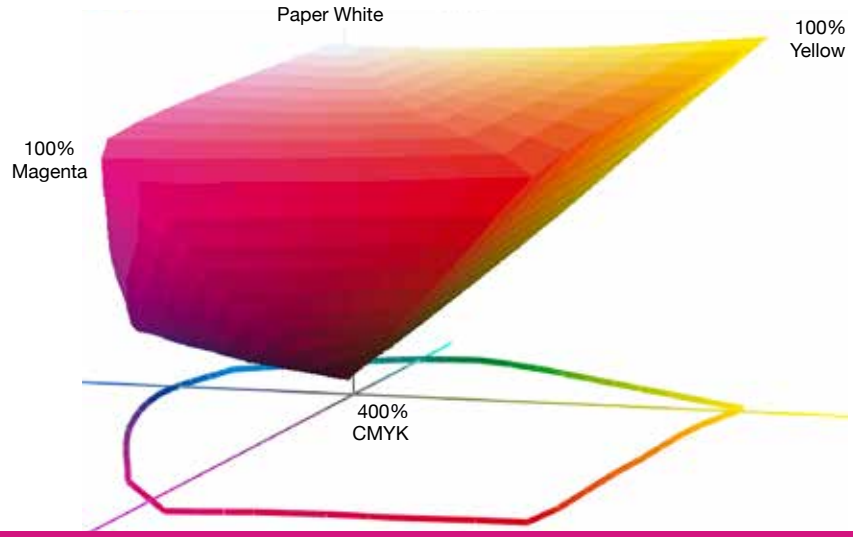
A Business Essential

Simply put, everything inside the gamut is a (theoretically) printable color, and everything outside is not. Many Pantone® colors are left outside typical printer gamuts. ICC printer profiles do a great job of finding in-gamut colors to print instead, but if too many of a customer's brand or image colors are out of gamut, the resulting print can have dull, disappointing colors, muddy shadows and off-color logos. In short, small gamut output loses its punch.

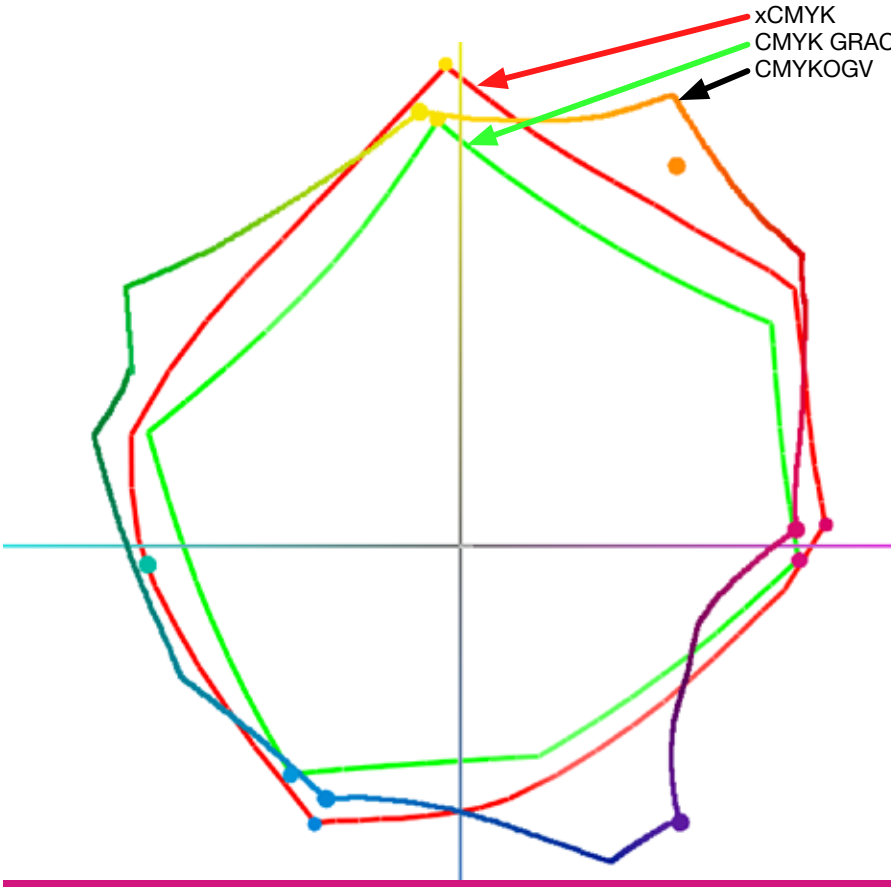
It's good to know if the system is capable of hitting those Pantone colors, or if it will be able to match the color your customer is aiming for. Knowing the gamut can indicate whether process colors will reproduce the image well or if spot inks are needed. Further, knowing the gamut of every process in the plant shows how much shared gamut the whole plant

Gamuts are very much a 3D phenomenon, and effective gamut evaluation and comparison should always be done in three dimensions.

By Steve Upton, President, CHROMiX



3D gamut.



Gamut color comparison between four- and seven-color printing systems.

can produce. When it comes to reducing differences between jobs and between different printing technologies, knowing gamut capabilities is essential.

Expanding Your Gamut

What makes the biggest difference (and is often the easiest) is changing the substrate. The brighter the white, the bigger the gamut, which affects saturated colors as well as whites and near-whites. The substrate can also affect how much total ink can be held as well as the appearance of dark colors.

Also, the substrate's invisible coating can make a surprising difference. Uncoated media absorbs ink into itself, allowing the grain of the substrate to rise up and scatter light before the ink has a chance to color it. This means your print's saturation is battling against reflected white light, which reduces how saturated and dark the colors appear to the eye.

One CHROMiX customer discovered a coating problem by graphing the gamut of the test patches and seeing that the entire gamut was shrinking. Considering coatings are typically invisible and mostly unmeasurable, this was quite a feat! It also resulted in a media refund of over $100,000!

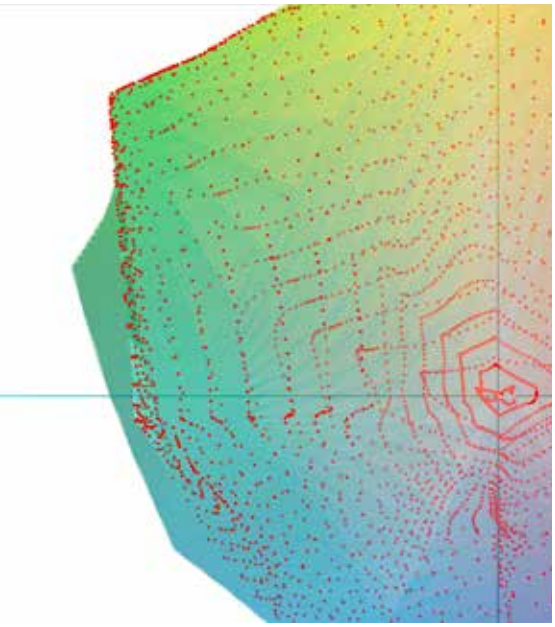
UV printing systems — those that "fix" their ink with UV light immediately after application to the substrate — tend to leave the ink on top of the substrate, reducing the surface bumpiness and increasing image color gamut.

Alternative or Additional Inks

Most printing systems use the typical four CMYK (cyan, magenta, yellow and black) inks to produce their ranges of color. Printing with high-density inks can increase output gamut while not adding the complications of additional channels. High-density inks incorporate more pigments or dyes into the same amount of ink fluid, but there are limitations to how much can be carried, and users rarely have control over such things in the world of inkjet output.

Some printing systems use light versions of each ink to smooth tones and hide speckling in highlight colors. Though light cyan, light magenta and gray inks are fairly common in inkjets, they typically have no effect whatsoever in the size of the gamut produced.

However, additional chromatic inks, such as orange, green and violet, can have a significant effect on print gamut. Some companies have also added pink, yellow



This graph compares overall printer gamut to the color range the ICC profile will allow you to print (red dots).

or orange fluorescent inks to enlarge the gamut in order to hit specific color ranges.

Neutrals (grays from black to white) are an important part of any print gamut. It's worth noting that while inks other than CMYK are effective at enlarging the gamut, they are almost never used to create grays in the gamut's center. C, M and Y, in balance, along with K, are the inks used to create grays and near neutrals. This is why G7 calibration — which concentrates on gray tone calibration and gray balance — is very useful for both CMYK and CMYK+ printing systems alike.

Metallic inks containing silver- or gold-colored flakes can produce visually striking output, but they tend to have no effect on the overall gamut that can be produced.

Cautions and Limitations

Stretching a printing system to print a gamut larger than necessary can cause a variety of issues. When ink is over-applied, it stops filtering the desired colors, and its impurities start filtering new colors. This causes the ink's hue to shift, making calibration and profiling difficult. Neither process printing nor spot color does well with inks that shift color as they get thicker on the paper, so beware of over-inking.

Just because a printer can create saturated colors doesn't mean the profile will allow them to print. In some cases, this is expected and acceptable when you choose to limit inking levels. Many substrates can't handle higher than 250% - 300% ink coverage reliably, even if that could result in darker colors.

Some profiles, however, will not allow fully saturated colors to print. When printing with any profile, colors are converted into printable colors using the profile's rendering intents. Colors that are originally in-gamut for the printer will often get printed as a similar color, while out-of-gamut colors must be mapped to pleasing, printable colors. This gamut mapping compresses the original gamut into the printer's gamut, but an alarming number of profiles over-limit the resulting gamut and render some colors permanently unavailable.

Black Ink's Impact

Black ink is important to printing in a number of ways. Black text, for instance,

Gamut Comparison Indices for Industry Standard Spaces

Gamut	Volume	GCI	% represented
CRPC 6 GRACoL2013	389309	(reference)	
XCMYK	569984	1.46 vs CRPC6	46% larger than CRPC6
CMYKOGV	652201	1.14 vs XCMYK	14% larger than XCMYK

(data courtesy of Kiran Deshpandeet al paper 2015)

Number of Pantone Colors Available in Several Color Gamuts

Ink set/CRPC	Colors in gamut	% Colors in Gamut
CMYKOGV	1560	77%
CMYK(subset)	1403	69%
GRACoL	1437	71%
SWOP #3	1321	65%

From Pantone Coated set: 2036 colors

has fine details that multiple inks can blur if not aligned properly. When cyan, magenta and yellow inks combine at a full 300%, their impurities limit them from producing the darkest maximum black the images demand. Adding black ink allows the image to get much darker and remove fairly equal amounts of color inks. In fact, adding black ink can increase the gamut volume by 25% or more.

While not a gamut issue per se, black ink helps create more stable printing through gray component replacement. As colors pass through an ICC profile, equally gray amounts of CMY inks are replaced with black ink. This reduces the total amount of inks used — saving money and drying time — while reducing the percentage levels of the remaining color inks. As a result, any variation in a single print channel resulting from clogged nozzles or paper absorption effects has a lower chance of visually affecting the color balance of the image.

Gamut Metrics

Gamut graphs are impressive for their visual shape and are useful for comparison with other gamuts and image colors, but sometimes numbers offer more reassurance. One of the first gamut metrics created was gamut volume.

Having a volume shell shape means being able to calculate the volume using a variety of different techniques. CHROMiX prefers the technique of slicing the gamut horizontally into thin slices, calculating the area and estimating the volume of each slice, then adding all the slices together. Others find a point within the gamut and calculate the volume of tetrahedrons emanating out from the center point to triangles on the gamut surface. Either way, the result is a single number representing a gamut size.

Unfortunately, due to the warped nature of Lab, not all colors are represented equally. Also, a single volume number does very little to help when comparing two gamuts. The specific parts of the gamuts that intersect (or don't) tend to be quite important. Still, when comparing profiles of different media on the same printer with the same inks, it's not a bad metric. To make the numbers as meaningful as possible, avoid comparing dissimilar gamuts.

There has been some work toward creating metrics that effectively compare two different gamut shapes. One comparison technique receiving attention is the Gamut Comparison Index (GCI) by Kiran Deshpande. GCI involves comparing separate sections of the gamuts and combining the results to create a single number that enumerates how one gamut compares to another.

For example, high-density xCMYK has a GCI of 1.46 compared to GRACoL CMYK — meaning it's 46% larger. Comparing seven-ink CMYKOGV to xCMYK produces a GCI of 1.14, showing it's still 14% larger. These metrics still don't reflect that parts of the xCMYK gamut are "inside" CMYKOGV, but they're an improvement and accurately reflect the portions that overlap.

Recreating customer brand colors often involves dealing with Pantone-specified colors. Another print gamut evaluation technique is finding how many Pantone colors (typically from a specific library, such as Pantone Coated) can be reproduced with acceptable error — and hence be considered in-gamut.

The Calibration Effect

Calibrating a printing system can affect gamut in two ways. The first, is the maximum ink level setting in each channel. It's fairly obvious that reducing how much magenta ink can be laid down will shrink the gamut accordingly. But it may come as a surprise that linearization, which affects the distribution of the inks between paper and maximum inking, can also affect the gamut.

This is especially visible in dye sublimation printing, which often requires printing on a transfer paper and heat pressing the image onto the final substrate. If there's too much ink applied to the paper (something it can often handle without problems), the excess ink base can actually impede the transfer of ink. This can result in density reversals, where the saturation of the ink that's transferred is reduced. Effective linearization will stop this reversal, save ink and actually increase the saturation of the transferred ink — increasing the resulting gamut size.

Steve Upton is President of CHROMiX, the 20-year-old Seattle-based firm providing color management products, consulting, training and technical support to visual content creators in various industries. He is the creator of the award-winning ColorThink color profile graphing and analysis package, the architect of the Maxwell online color management system and co-developer of Curve. With years of computing and photographic experience, and a degree in computing science and optics, Steve is uniquely qualified to manage color fidelity in the digital realm.