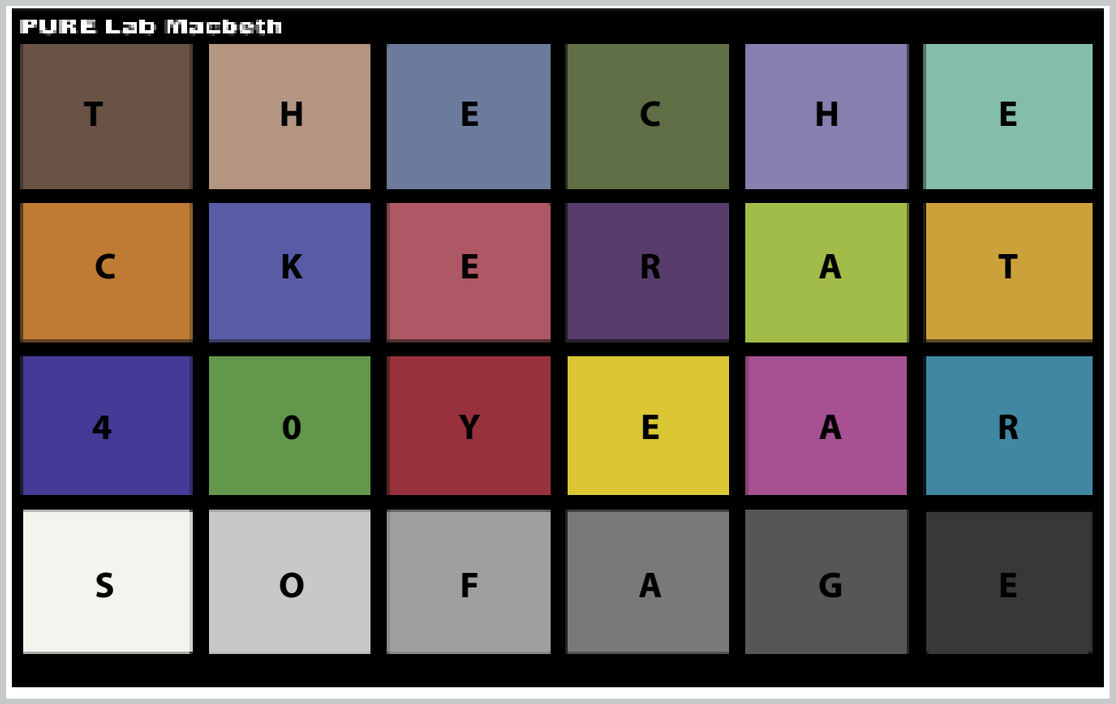
Macbeth at 40

Mike McNamee takes an appreciative look at the most famous 24 squares in photography!

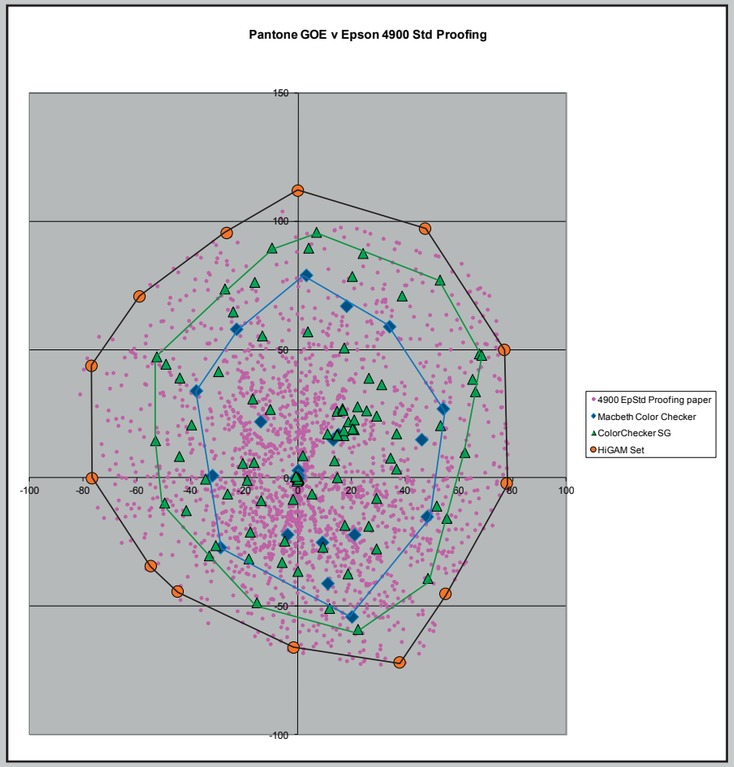


This year sees the fortieth birthday of the Macbeth* ColorChecker Color Rendition Chart. I have in my possession a copy of the original paper from the *Journal of Applied Photographic Engineering* authored by CS McCamy, H Marcus and JG Davidson. It is dated Summer 1976 and entitled '*A Color-Rendition Chart*'. It is doubtful that the creators imagined it would still be around all this time later and highly improbable that they would have foretold the chart to be even more popular once digital imaging became established, indeed digital was yet to emerge from the laboratory – the chart was designed for television use with a nod to film and movie-making.

Their new chart took on the shape and format that has remained ever since: 2x2-inch squares arranged in a six wide by four high matrix. The colours have remained essentially the same with a minor tweak in formulation in 2014 and are known by their common descriptive names along with their names from the Munsell nomenclature. The common names are noted on the diagram above. The top row are 'known' colours, the second two rows are colours from around the gamut including additive and subtractive primaries, the bottom row is of course a grey scale. It is interesting to note that the authors described the colour selection as intending to fill 'a wide gamut', although by today's standards the gamut is very small. The ColorChecker Classic (as is it is now designated to differentiate it from the many others) is plotted along with the gamut spread of its sibling Color Checker SG and the gamut of the Epson UltraChrome K3 HDR ink set, the largest around so far but recently extended with the addition of violet to the K3 inks available from Epson.

LEFT: Cal McCamy pictured at Munsell HQ in 2012

BELOW: The gamut of the ColorChecker Classic (blue line) is smaller than the ColorChecker SG (green line) . The much larger gamut of the Epson Ultrachrome K3 Vivid Magenta HDR ink set is shown in pink and is tacked by the patch set of Imagemaker's *HiGAM patch set.*



Gretag recognised the restricted gamut of the CC Classic and introduced a ColorChecker DC for Digital Cameras. This had issues initially and was quickly superseded by the ColorChecker SG. This has a larger gamut than the Classic but still falls short of today's inkjets. Even so, in our hands we have achieved some spectacular results with the CC SG and the X-Rite i1 Profile software – more on that later.

The use of test charts has become an established feature of digital workflows; at the last count Colour Confidence list 19 different charts and this is not all of them, many profiling software providers also have their own charts. Some 'charts' are not physical artefacts but data streams for checking digital outputs to defined protocols. The range of tones in the charts varies from one (typically a grey card) to the many thousands that might be employed in offset press calibrating software.

A selection of the charts that we have used is tabled and includes two new variants from X-Rite intended for use in video and building on the workflows developed with stills digital. The prevalence of a video capability in today's SLR means that these new charts are both useful and timely – indeed it was they who spawned this entire feature!

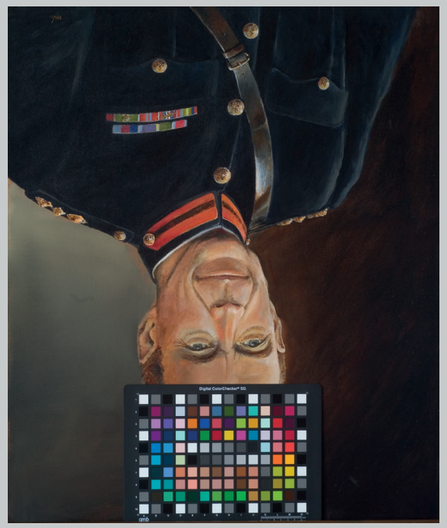
How to Choose and Use Charts

Self-evidently the charts range from simple to complex and where a photographer or videographer joins the party largely depends upon the application (subject) and how bad their OCD happens to be! Doing nothing (that is shooting with the camera on auto white balance and using the file 'as is') is an option, particularly if you have good control of your monitor calibration, but many prefer a higher level of control than this. The first rung of the ladder is to white balance a Raw file in Adobe Camera Raw (ACR) using the White Balance eye dropper on a part of the image that is required to be neutral – if this is a calibrated target so much the better! A grey card (with a neutral, nominally 50% density) will do, but bespoke targets preferably use a tone closer to white (ie nearer to a highlight) when performing white balancing.

The next rung up is to correct white balance AND correct exposure by adjusting ACR sliders until the 50% grey card delivers equal RGB values of 120 points in sRGB or Adobe RGB and 107 points in Pro Photo RGB. This produces a neutral, mid-tone-exposure-corrected image, but takes no account of dynamic range which might push highlights and shadows to places they should not reside, ie too dark or too light. In order to adjust for highlights and shadows (effectively the contrast range of the image) a grey 'scale' is required of about six patches or so.

At this stage, adjusting the image can become a little laborious even if the resulting correction is 'auto-synchronised' across a number of images for the same shoot/scene. Software has been developed to take away this legwork and once the power of mathematics is brought to bear it is but a small step to begin to include correction of colour saturation and hue. The correction task can now be performed across several colours (R, G and B primaries in the case of ACR) or with the complex charts across almost the entire colour gamut (using up to 5,000 colours).

By now we have moved away from a quick swish of the ACR sliders (to create a 'pleasing image') up to a full-on, whole gamut press! Such concerns are matters for those doing product shots with fickle art directors or very accurate reproductions such as fine art. Gamuts are like jelly in string bags – poking a finger in one side makes something else bulge out on the other side! Again, however, the power of maths comes into play with the power of



ABOVE: When it comes to accurate repro of paintings nothing beats a bespoke profile made for the exact conditions.

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'iteration' – the software tests many different adjustments and creates the minimum overall error in colour.

This, then, is why there are so many charts and so many ways of using them – they have been developed to service the myriad of colour problems that our business throws up for its different users.

Software

A number of software applications have been written which all exploit some or most of the charts available. In rough ease-of-use order, they are as follows:

1. Adobe Camera Raw
2. X-Rite ColorChecker Passport
2a. Datacolor SpyderCheckr
3. ACR Calibrator (only up to CS4 which also limits the Raw files you can handle)
4. Adobe DNG Profiler
5. i1 Profiler Publish (for numerical quality analysis as well as profiling)
6. Babel Color (for analysis and certification procedures)

They all have different strengths and uses, and certainly a huge range of complexity – almost anybody can use ACR but if you want to really get to grips with Babel Color you might need an engineering or maths degree. ACR is far and away the simplest and may be more than adequate for the majority of tasks.

How Good Are They?

This is a valid question; there is little point in investing time and effort into something that either does not work or over-eggs your pudding – if you cannot distinguish the effect of a calibration on your workflow then it is either wasting your time or, importantly, confirming your eye judgement. The latter can be important if you are handing off photographic files to another user such as a design studio – if things turn out with wonky colours the photographer is often the first to be blamed; having calibrations removes any uncertainty.

If you do end up squabbling over colours then you had better get to grips with error values, rather than running into circular debates about whether a pink is a 'bit too cerise' or not. Errors are measured using a number of parameters, the most important of which are 'Delta E 2000' (ΔEoo) and 'Delta E ***Lab*** (1976)'. Both are measures of how far apart a pair of colours are in the three-dimensional space of the gamut; low is better and values less than unity (ie 1) are considered just on the threshold of human detection. ΔEoo is a more sophisticated measure which takes better account of the human perception of colour in real tests and is the one preferred at *Professional Imagemaker* ('coz we can do hard sums!). The printing industry is ahead of the game in terms of accurate reproduction although you might not think so looking at your local freebie rag! Contract proofs for press use regularly show average errors of less than 1.0 ΔEoo across the entire printing range. Good monitors can show quality in the same ballpark, as can scanners and cameras. Uncalibrated ink-jet printers achieve average values of around 5ΔEoo, with maximum errors around 8ΔEoo, although the figures are variable. Video and broadcast standards are quite different and relatively more relaxed.

How Important Are They?

The standards for printing press work are well documented and universally understood by top-end printing companies. For the jobbing photographer we have more prosaic guidelines, the level 'at which the photographer starts bitching at the laboratory' and then the level 'at which the bride's mother starts bitching at the photographer'. Again these are variable, but photographers' tolerances with the laboratories are around the 4 to 5 mark and the bride's mother is out at the 10 to 15 mark. Trust me, if the bride's mother is legitimately on the warpath you are in deep technical trouble!

For perspective, when we bespoke profile a paper using ink-jet we achieve average errors of less than 3.0ΔEoo and occasionally get a low as 1.0 ΔEoo – this is really good shooting, using best practice all round.

How Did We Do?

The average error values obtained by various workflows and testing methods for cameras (only) are tabled below. The specialist softwares do not perform any better than a simple correction using ACR in conjunction with a CC24 chart. Significant improvement was obtained using the CC SG chart with i1 Profiler.

METHOD	ΔEoo Avg
ACR by hand	3.9
Passport CC	3.5
ACR Calibrator	3.5
Spyder ColorCheckr	3.9
i1 Profiler onto CC SG	1.6

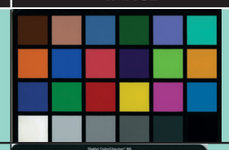
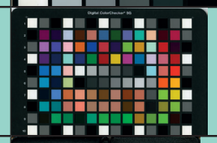
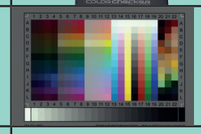
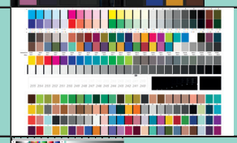
ABOVE: An SG ColorChecker is overlayed with the target values on top of the actual image file (some have been highlighted in white). Just a handful of the colours could be differentiated in this very accurate rendering, although the most obvious errors were in the dark monochromes.

Using Other Targets

The other targets in our table are less popular in photography but more popular for printing particularly offset press work. They are not even physical items but files and data sets which allow them to be added to a print (in what is known as the slug) and measured using a spectrophotometer and software (i1 Profiler Publish or BabelColor). The software also analyses the data and may be printed to a label which marks the print either a pass or fail according to internationally agreed standards. These are stringent and even more stringent for neutral tones, the most sensitive to the eye.

RIGHT: The IDEAlliance printer's target has some measurable control swatches along with a wide range of subject types.

The Charts and Software for Target Devices and Calibrators

NAME	IMAGE	PATCHES	GAMUT	SOFTWARE	COST
ColorChecker Classic		24	Small	Various for Cameras, Monitors, Projectors	£59
ColorChecker SG		140	Extended	Various for Cameras, Scanners	£245
ColorChecker Passport Photo		48	Small	X-Rite Bespoke	£80
ColorChecker Video		27+	For Video	Bespoke X-Rite	£92
ColorChecker Passport Video		27+	For video	Bespoke X-Rite	£105
IT8 7/2		286	Film	Profiling Software for Scanners, eg Lasersoft	$50 to $340
Fogra Ugra V3		72	CMYK Press	i1 Profiler Publish Edition Babel Color EFI GMG	£419 (Licence) FoC i1 Publish
Gracol IDEAlliance		48	CMYK Press	i! Profiler Publish Edition Babel Color	FoC
Spydercheckr		48	Small	DataColor Bespoke	£87
Imagemaker HiGAM		216	High Epson K3 HDR	Babel Color ($125)	NA
IDEAlliance		NA	NA	Visual	FoC
Kodak Grey card (with Q19)		1	NA	Adobe ACR	£21 Q19 Set £14 Grey Card Only

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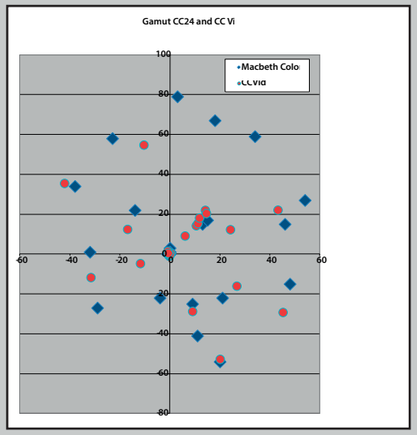
The X-Rite ColorChecker Passport Video and ColorChecker Video.

These targets are new and are designed to deal with video light balancing to broadcast standards. Software such as Adobe Premier, Apple Final Cut Pro, DaVinci Resolve and Avid have 'vectorscopes' which display the tones in a frame and may be used with sliders to adjust the colour balance of the scene. The same device can also be used to ensure that all scene colours are within the gamut for broadcast standards. Although we are not expert in the use of the vectorscope, the whole of the workflow seems quite crude in relation to print industries and perhaps the range of screen tones you can see in the average TV shop indicates a rather low expectation of colour accuracy! For most video applications a simple framing of the colour patches is required, followed by full automatic correction, it really is that simple! The only requirement is to ensure that the rather glossy deep black patch is not catching unwanted reflections.

The passport Video includes a white-balancing target page along with a focus target and then the same format as the larger CC Video. The colours of the target are relatively low saturation from around the colour wheel and are displayed alongside those of the CC Classic.



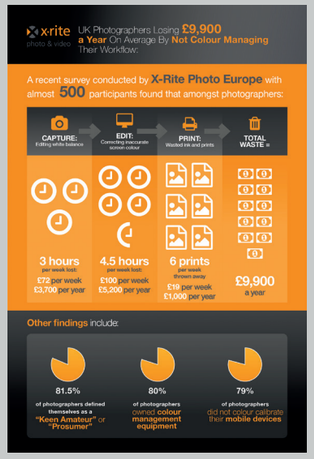
Further Reading

BabelColor have a website that is stuffed full of useful stuff including statistical data from the measurements of dozens of Macbeth charts; they even have a ColorChecker tab on their site! There are a number of technical papers on colour management issues that are also a valuable resource for anybody researching the topic.

Overall

Many Happy Returns ColorChecker – where would we be without you? X-Rite recently conducted a survey from which they estimate that the average non-colour managed photographer wastes £9,900 per year chasing inaccurate colour. This breaks down into 3 hours per week at the capture stage and 4½hours per week at the post/editing stage. Now I spend 2½hours each week drinking coffee so I am looking forward to trousering £60 per week when I give it up!

That not withstanding, the benefits of accurate colour are obvious and the original aims of McCamy et al. have been fulfilled many times over. The accuracy of colour reproduction available throughout the workflow (and right down to enthusiast level) are of a quite different order to what they used to be. Those of a certain age will remember Chromalins – they took hours to make, cost hundreds and then only looked a little like the print output; we have come a long way in 40 years!



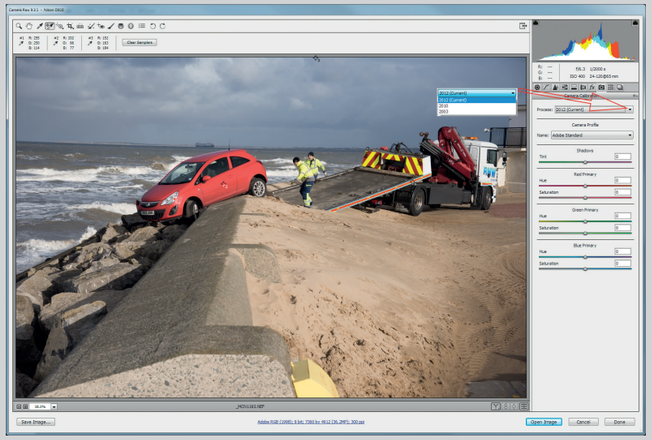
Camera profiling using a Macbeth ColorChecker Classic (or Passport ColorChecker)

For cameras, a Raw file is preferred if a calibration target is to be used. However, i1 Profiler can only examine an uncompressed TIFF file, mainly because we con the system into thinking our camera image is a scan – there is no tab in i1 profiler called 'camera calibration'.

In ACR, the opening, Basic Tab includes adjustment for White Balance and Exposure parameters. In the scene shown the camera has auto-white balanced and auto-exposed the shot. The scene is tonally ordinary (of an extraordinary piece of parking!) and the white balance 'as shot' was within a couple of hundred points (ie accurate). The visual change when we white balanced on some white in the scene was imperceptible. It is important in this technique to deal with clipping before calibrating with i1 Profiler.

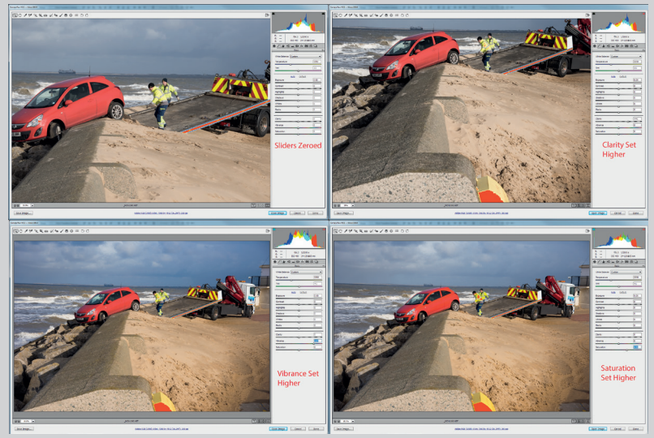
The highlight clipping indicates that the yellow flashes down the side of the tipping trailer are clipped, that is, more than 255 points, delivering 255 Red, 250 Green and 114 Blue. This is in an Adobe RGB working space. The values fall to 240 Red, 247 Green and 118 Blue in a pro Photo RGB space. Conversely the clipping increases if the image is pushed into the smaller sRGB colour space.

The eight tab along is the Camera Calibration panel which includes adjustments for Hue and Saturation of individual Red, Green and Blue primaries. It also provides for three variants of ACR processing, namely, 2003, 2010 and 2012. As they get younger the processing engines create less clipping.



The sliders which can affect clipping in the Basic Tab are Clarity, Vibrance and Saturation, and they increase the strength of clipping in that order also. Clarity prioritises the mid-tone micro-contrast, Vibrance prioritises the low saturation tones; Saturation boosts (or desaturates) as tones equally. All the sliders have both negative or positive contributions available.

For the scene depicted, none of the values was known and we were forced to make adjustments only using the available sliders in ACR. If we introduce a test target to the scene, for which the colour parameters are known, we are suddenly in a very strong position where even colour-blind operatives can make accurate corrections. This method is a much more considered approach better suited to studio work under controlled light such as portraiture or product photography. The target is placed into the scene, the corrections are then made and synchronised for the remaining shots, taken without the target in place.



Correction of the target shot can be accomplished by white balancing on the mid grey patch (below the yellow) and then tweaking the exposure until the patch reads equal 120 points on all three channels (ie, R, G and B). In our tests just this simple correction brought the average error down from 6.0ΔEoo to 3.6 and the worst error was reduced from 13.7ΔEoo down to 8.3 and shifted from the red to blue patches. Using the entire patch set of the CC24 and iteratively adjusting the camera calibration settings (seven sliders using ACR Calibrator) had little effect on the average error (it actually went worse).
For the ultimate in correction the Macbeth SG chart was used as a calibration target, the exposure was adjusted so that no clipping occurred, the white balance was corrected and then the file was saved as a TIFF. This was then presented to i1 Profiler as though it were a scanned image and 'scanner calibration' carried out to make an icc profile. This profile was then 'Assigned' in Photoshop before conversion to the working colour space. This fully corrected file was the audited for colour accuracy as shown in the table on Page 64 – the results are extremely good!