Implementing Imaging Standards: The Longest Yard

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Introduction

Imaging standards and best practices are constantly being discussed within the cultural heritage community. Standards are incredibly important for cultural institutions especially as museums and libraries not only need to satisfy short term requirements for image licensing, publications and online applications, but the long term preservation and access to this material is of utmost importance. While there are existing, as well as emerging imaging standards that may be used, there is little consensus worldwide as to best practices. Many users are simply adhering to a cocktail of imaging guidelines garnered from industry trade shows, well meaning trade organizations, and independent consultants.

I mention the "longest yard" in the title of this document because in my opinion, the challenge users face with standards and objective capture methods is that these practices are becoming increasingly difficult to apply in the field. Standards tend to level the playing field. To some extent this waters down the competitive advantage in the marketplace. Why would Adobe® support a toolset that would allow you to achieve the same results as a competitive product? Why would Canon® benefit from supporting tools that allow users to get the same results from a Nikon®? It is in this context that we need to discuss imaging standards. How can the community achieve it's long term goals against the competitive realities of the marketplace? How can we help manufacturers become comfortable with open, international standards in a competitive landscape?

It is important for the industry and end users alike to realize that encouraging the adoption of international standards enhances the value of digital content in an increasingly data driven world. A body of objective, consistent digital content can easily be exchanged and optimized for any number of applications now and in the future. If the user community allows the computer industry alone to dictate standards I am afraid that the goal of building a worldwide body of consistent, authoritative cultural images will be difficult, if not impossible, to achieve.

An example of my concern is a simple experiment that anyone can perform. Just perform a Google® image search of your favorite artwork and you will see that there is clearly room for improvement in image quality and consistency. While one can say that this is an unrealistic exercise, a search within the web site of a particular institution will often result in similar inconsistencies. While we cannot expect to change what content is already out on the internet, it is the responsibility of museums and other cultural institutions to present authoritative representations of collections *(see Figure 1).*
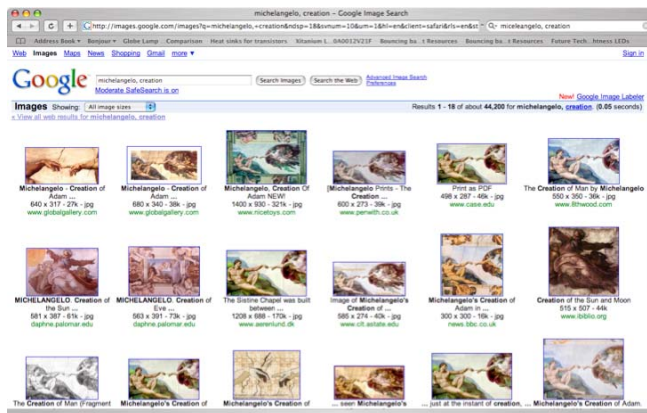

Figure 1   Results of a Google® image search "Michaelangelo Creation". Can you find the authoritative image?

Testing First Phase

In the summer of 2007, while working for the Rijksmuseum in Amsterdam, The Netherlands, on a complete overhaul of the photography department, a capture-to-print test was undertaken to help establish and document best practices. The testing involved photographing a series of paintings using measured photography and ICC color management. A growing majority of European print vendors already follow ISO 12647-2 printing guidelines so the testing was initially based on this output definition. As the tests were being prepared, Cecile van der Harten, the new manager of the Rijksmuseum photography studio wondered if it would be possible for work from other museums to be incorporated into the testing to provide a point of comparison. The idea was accepted by the museum management and we began to invite several other museums to participate in this evaluation. Along with the Metropolitan Museum of Art, several other museums participated including the Guggenheim Museum, The Yale Center for British Art and the Victoria and Albert Museum. These museums were not chosen based on any particular criteria other than we knew that all employed ICC color-managed workflow methods. The Metropolitan and the Rijksmuseum used Leaf® Aptus™ 75 cameras; the Guggenheim and the V&A used Sinar® 54H cameras; and the Yale Center for British Art was using a Hasselblad® HD39MS camera.

Unlike formal benchmark studies that have attempted to evaluate the practices of various museums, we approached this testing from a perspective of using the same process for each site by simply asking each museum to photograph a painting using an XRite® Color Checker DCSG™ chart for measured exposure, and to create a custom camera input profile. As the Sinar® and Leaf® cameras have this as a built-in feature, these sites had no problem with this task. The Hasselblad® camera needed to be calibrated externally using XRite® ProfileMaker™ software. Our only requirement was that we did not want images that were subjectively edited after capture. Upon receipt, the images were opened in the various capture applications and the data was exported directly to four different working color spaces: Adobe RGB1998, ProPhotoRGB, eciRGBv2 and an experimental working space called ProStarRGB. ProPhotoRGB (also known as ROMM RGB) is actually an ISO standard, while eciRGBv2 is in the process of becoming an ISO

standard, and Adobe RGB 1998 is being considered as a technical specification as I understand that Adobe wishes to maintain control of this working space. http://www.eci.org/doku.php?id=en:projects:digitalphotography .ProStarRGB was created by CDI as part of a test to evaluate the feasibility of an L* based wide gamut working color space and is not under consideration for standardization at this stage. I am hoping that the possibility of a wide gamut L* based workflow could be further explored for preservation purposes, and that such a working space would be considered as a possible internal RGB space for digital cameras and raw processors to prevent clipping of sensor data too early in the workflow.

It is important to note that this first phase of testing was based upon the measurement of chart exposure values in the respective capture applications and resulting 16 bit TIFF exports. We did not set out to compare the various camera brands. Our goal was to simply capture data from ICC profiled cameras as an average user would be expected to approach an objective capture process. CDI worked directly onsite with each museum with the exception of the V&A to verify the actual capture process. The test images were laid out on a test form along with several technical targets separated by working color space *(see Figure 2)*.

Figure 2   Sample of the RGB working space testform. AdobeRGB1998 / eciRGBv2 / ProPhotoRGB / ProStarRGB

Each test form included three special charts created just for this project. One was created by building a file in L*A*B* color and creating a 100 step gradation. This L*A*B* file was saved to each respective RGB working space to capture the relationship of each L*A*B* source value to the final printed output value *(see Figure 3)*.
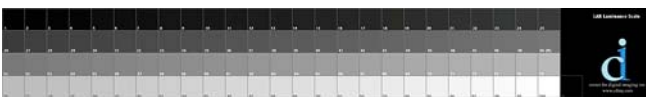

Figure 3   CDI 100 Step scale

The second chart was created using the averaged measurements of Kodak Q-14 grayscale targets *(see Figure 4)*.

Figure 4   Kodak® Q-14 Gray Scale values

This is a very important target as the Q-14 grayscale is in use worldwide, it is inexpensive, and the gradations are density based. The last chart was created by taking the published L*A*B* values of the XRite Color Checker DCSG chart and Color Checker chart and converting these values to the respective RGB working spaces *(see Figure 5 and 6)*.
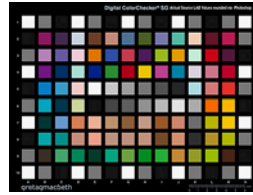

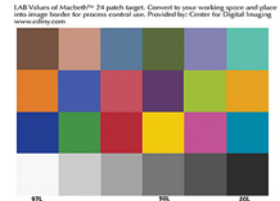Figure 5   XRite® DCSG™ chart values
Figure 6   XRite® Color Checker™ chart values

Along with the captured data, the charts allowed us to measure and record tones lost or gained through the production process. Of particular interest was the effect of the working color spaces on the tonal gradations.

Images were proofed on an Epson® 7600 proofer using ICC based Proofmaster® software. The proofer was verified using XRite® ProfileMaker™ as well BasICColor® Control™ software to verify that the proofer met ISO print standards.

The print run was on a brand new KBA® press in The Netherlands, which had been verified to ISO standards. As this test was primarily to help build printing guidelines for museum print vendors, the press was configured to exceed ISO guidelines in each critical area, verified using BasICColor® Control™ software. Test sheets were run and the results were reviewed under a standardized D50 viewing booth along with measurement of the 100 Step L*A*B* grayscale charts.

Review of First Phase Testing

The results of the measurements indicated that the ICC color management process did a good job of normalizing the tonal response across all four working spaces. The differences between each set were marginal at first glance; further scrutiny confirms the slight differences in quality. Under the D50 viewing conditions the eciRGBv2 images were observed to be slightly cleaner looking than the other working spaces, especially in the shadow areas of the darker images.

While the relative differences between working spaces were minor, all painting reproductions appeared dark, dull and lifeless-especially the darker toned Dutch master paintings. Subsequent measurement of the 100 step grayscale control file shed some light on this issue. Measurements indicate that the original linear gradations of the RGB source data were compressed and distorted. In an effort to explore this further, we ran an experiment based upon creating a tone curve adjustment to compensate for these tonal distortions which was applied to each source image. The results were improved, (see *Figure 7)* but the general consensus was that the painting images still looked dull and dark.
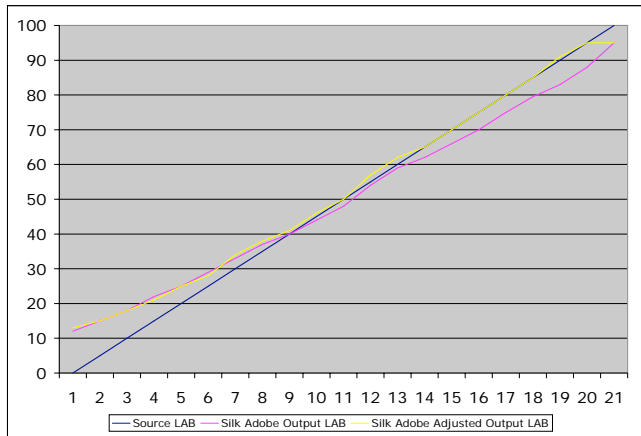
Figure 7   Comparison of the llnear source values of the 100 step L*A*B* test
            chart with the measured output values before and after a
            compensation curve was applied to the source data

While the tone curve compensation did drive the various targets closer to the original input values, clearly this process would not be an effective workflow solution as each press and paper stock would require unique adjustments. While tonal compression is to be expected to some degree upon output, it is important to note that we were not specifically evaluating ISO print standards; this was simply the environment utilized for this phase of the project. RIT is currently in the process of evaluating printing standards which may shed some light on standardized output practices and help resolve some of these tonal losses.

The testing in the first phase helped verify that we could arrive at repeatable results using standardized objective capture methods and that original captures could be verified as accurate to the original artworks. We also found that the paintings looked dull and dark upon output even after compensating for the tonal losses to the press. If this testing had been performed at one isolated site or with one type of artwork using printers that were not verified, one would assume that this could be an isolated result. However, when the work of five museums using different cameras capturing to the same chart values all output on the same carefully calibrated press were only partially successful, it was time to dig deeper.

Beyond the obvious loss of dynamic range between the RGB source and CMYK destination, the dullness that we experience can be attributed to a very specific phenomenon. Taking spectral measurements of an original artwork, in this case a Vermeer, you find that the lightest luminance (L*) value in the image is 85, the forearm of the woman is exactly 50, and the darkest shadow is 5 (see *Figure 8*).

When a printer is calibrated using bright white stock you may find that the brightest white L* value is about 97 and the darkest black may be 15. When you convert an image from RGB to CMYK the image is tonally compressed to the output gamut (see *Figure 9).* There is no logic applied in the RGB to CMYK conversion to evaluate the image itself. The conversion assumes that an image uses the entire tonal range. As the actual painting is in fact much darker than paper white, or the white of the DCSG target, the literal translation to CMYK is less than satisfactory. Of course each press, paper, and CMYK standard will yield different results.

Figure 8   Measured L* values of original artwork [5,85,50]
            (The Kitchen Maid c. 1658 Johannes Vermeer Oil on canvas
            45,5 x 41 cm SK-A-2344 The Rijksmuseum, Amsterdam)

Figure 9   Measured L* values of press output [15,47,78]
            (The Kitchen Maid c. 1658 Johannes Vermeer Oil on canvas
            45,5 x 41 cm SK-A-2344 The Rijksmuseum, Amsterdam)

This also begins to explain why three-dimensional images are generally more successful using the same output scenario. When 3D objects are lit, in almost every case, there is a distinct highlight area and shadow area, and in most cases these points are generally equal to the lightest and darkest patches on the DCSG color checker (7 and 97 L*) therefore the images appear to be bright and fully toned.

A Problem of Perception

When we view a painting in person, our eyes continuously adapt to the scene and we perceive the lightest part of the woman's bonnet to be white, and the shadow to be black. A digital camera can only record the literal values. To make matters worse, master painters tend to play games with human perception to make paintings more dynamic and to draw the eye into a scene. Again, the literal capture and output process is simply blind in this regard.

Second Phase Testing

While objective digital captures may be accurate to the original artworks, they are not not necessarily optimized for successful output. This is not a new problem, but it is clear that far too many users are capturing and editing images to output far too early in the workflow as opposed to capturing and storing accurate data. We set out to explore methods that would allow accurate painting captures to be output more successfully while avoiding subjective editing.

The options discussed were as follows:

1) Save the calibrated capture as a master image and then using adjustment layers or a separate file derivative make subjective visual adjustments on a calibrated display to the original artwork. Possibly use soft proofing to simulate the destination view.
2) Save the images as captured, and subjectively edit the images on an as needed basis for a particular output device.
3) Explore methods that would enable the needed interpretations to be applied in an automated way tailored for specific output conditions.

Many museums today employ the first option. However, while they may save the calibrated capture and possibly the raw source file, the visual editing opens up a very real possibility that the edit created is moving the artwork further away from accuracy. For example: if the display is calibrated to 6500K, users will tend to create images that are artificially warm (yellow). If the viewing environment is not stable, edits will vary from hour to hour, and day to day. If different users work on images, each user will have a different subjective take on what the mage should look like.

For museums that employ the second option and edit to output, say a calibrated ink jet printer, or more commonly an ink jet printer calibrated to simulate a printing standard, there are similar issues. The most common problem is a blind faith among editors that the print is a hard reality. Ink jet printers often suffer from metamerism, where colors will appear to shift under different viewing conditions. Images edited to match an artwork under a D50 viewing booth may look completely wrong under another viewing condition. In addition, many times, the UV whiteners of the paper stock used in the ink jet device are simply difficult to read. In lighter areas of an image, these paper color casts throw off our perception; often the edits required to compensate for the media itself force the image editor to move the file very far away from reality. Lastly, if the final use of an image is not clearly defined, all of this editing becomes more of an unknown.

We decided to use this body of work and to invite even more museums to begin to explore the possibility of using automated methods to derive images that would output more successfully. There are two reasons for this approach. First, we felt that there was little value in exploring new ways to visually edit images; this is something we would prefer to have people move away from. Second, we have found that carefully created, calibrated captures have consistently been measurably closer to the actual artworks. A simple method for this verification is to measure multiple

locations in an actual artwork using a spectrophotometer, and then enter the L*A*B* values in the Adobe Photoshop Color Picker to create spot color fills for each location on a separate layer. If the measured L*A*B* values match the captured L*A*B* values one can be reasonably confident that the color and density values are correct. Of course the actual artwork L* A* B* values could be compared to the image L*A* B* values to calculate Delta E differences, but the visual comparison method can be quite effective (see *Figure 10).*

*Figure 10   Actual L*A*B* values added to image file for visual assessment*
S0168V_1962, Peita (after Delacroix) 1889 (Detail)
Vincent Van Gogh (1853-1890), Van Gogh Museum, Amsterdam

Last summer we started working with the Van Gogh Museum in Amsterdam, The Netherlands. As part of this project we began a collaboration with Hans van Dormolen of the National Library of The Netherlands. It was wonderful to meet with a person who shared the same passion for objective capture practices, and the author of the very logical and practical Metamorfoze imaging guidelines (Metamorfoze | Programme). We discussed the results of our phase one tests at length. Early on we decided to apply the Metamorfoze imaging guidelines as part of our work with the Van Gogh Museum. While we have always advocated the use of targets and measured photography, Hans lays out a very convincing argument for religiously matching all the Kodak Q-14 grayscale values for any capture program, and any camera brand. Our testing and collaboration has been very successful. We have found that the two disciplines of measured photography and ICC camera calibration go perfectly hand in hand. In addition, the eciRGBv2 working color space fits perfectly into this workflow. When properly applying the Metamorfoze imaging guidelines (the capture component) you can photograph a scene with any number of color or grayscale targets and all numbers will agree. (*see Figure 11)* These guidelines, when applied properly, truly underscore the meaning of the Dutch phrase "Maten is Vaten" (to measure is to know).

Figure 11   Metamorfoze imaging guidelines spell out very clear methods for configuring and verifying an accurate capture workflow

Image Optimization Automation Tests

The second round of tests were laid out to compare calibrated images straight off the camera to images adjusted using two approaches to automated image optimization. In order to gain a truly worldwide sampling of international collections we revisited our original first phase test partners, and additionally invited the Van Gogh Museum, MoMA, and the Palace Museum of China to participate. (See Figure 12)
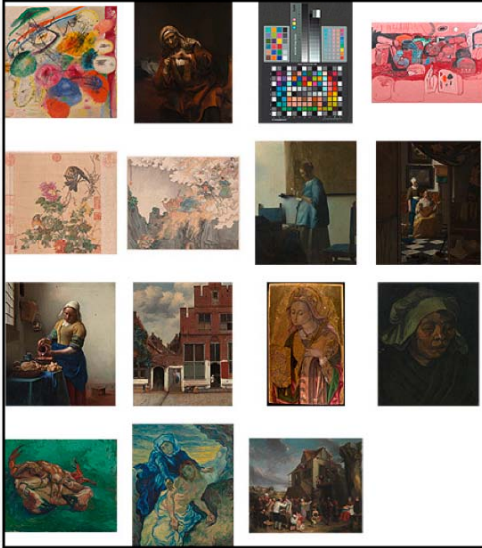

Figure 12   The full set of test images used to evaluate image optimization

The first method, using Adobe® Photoshop™, has proven to work well in most instances, but can only be partially automated. We included this process in the testing as we feel that while limited, it is a step in the right direction.

In Adobe® Photoshop™ CS3 and later you will find the ability to adjust the luminance of an image file without destroying the color relationships. This is done utilizing the Levels dialog. You define the black point and white point, and the threshold values, then save this as a default parameter. The challenge concerning relying on this as an automated process is that peripheral information in the image can skew the results. If there are spectral highlights in the image and the uncropped image has areas that are already pure black or pure white, the results can be thrown off. This is the exact workflow for each image:

1) Crop into the live area of an image, and select the settings as shown *(see Figure 13)*.
2) Save the resulting levels adjustment.
3) Exit the levels dialog (do not apply the adjustment).
4) Uncrop the image.
5) Apply the saved levels adjustment.

Note: each image is unique, so this process needs to be performed on each image individually. Keep in mind that this type of image adjustment is nothing new; we have only included it in the testing because of it's universal availability and to illustrate the concept.
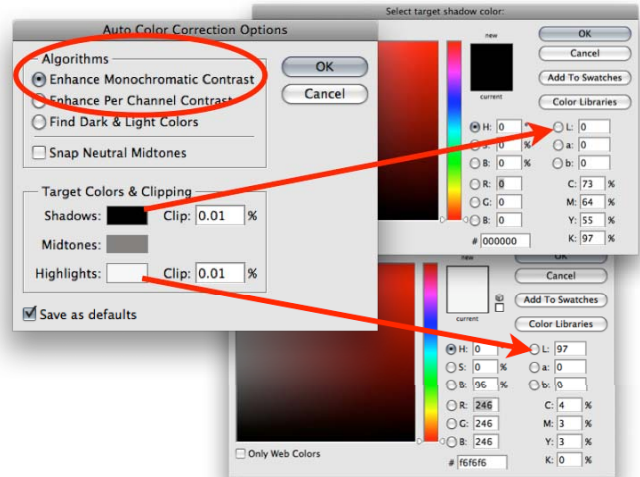

Figure 13   Adobe® Photoshop™ "Enhance Monochromatic Contrast" *algorithm*

This method of auto adjusting images is not without flaws. If for example, an image is predominantly dark and there are few lighter tones, the process will over-compensate resulting in a poor interpretation that is too light. Applying this approach to an overall painting and the crop of a signature from the same image file will yield two very different results.

Even if this process could be consistently applied, the larger problem is that there is no way to automate this process in a digital asset management (DAM) system. Ideally, if a museum housed a body of objective artwork captures with no visual editing applied, we would want to develop intelligent, automated transformations for various output scenarios such as print, web, etc. Thus, the disparate short term and long term needs of a museum could be programatically realized.

The second optimization method that shows great promise is a tool called Perfectly Clear™ from Athentech®. This company has a patented algorithm that explores an image on a pixel by pixel basis, remapping tonal relationships based upon human perception. Though this technology is primarily used for corporate applications such as large consumer photo labs and on-demand book publishers, we felt it would be an interesting tool to explore due to it's ability to lighten shadow areas while maintaining important color relationships. After considerable time testing across various artwork types from different collections, we began to see some very encouraging results.

The unique aspect of this software is that it dynamically applies transformations based on image content. It has an incredible ability to open up details in shadows without sacrificing the highlight details. A further advantage is that the software is designed to integrate with image servers as a Windows DLL library so the process may be integrated into automated download tasks of a DAM system. Of course there are still workflow challenges to implement this into an active collection; if there are two images, an overall view and a detail view of a signature, the signature detail would be more aggressively transformed than the same section of the overall image (to a lesser extent than the Adobe Photoshop method tested.

It is critical to point out that we are applying this tool only to create optimized derivatives from source images that have already been carefully captured using measured photography with custom camera profiles in the L* based eciRGBv2 RGB color space; thus the content is already valid. Not enough testing has been performed to give definitive recommendations for the use of the software at this stage, but the results show great promise across the body of work tested so far. Hopefully others can expand on this research. This round of tests is scheduled to be output in the USA on a G7™ (GRACoL) press condition as part of our ongoing evaluation.

Final Observations

What started as a capture to print test for a single museum became a two year exploration involving museums around the world. My work on this project is a public record of tests and observations related to the real world application of existing and emerging standard practices. As with any endeavor of this nature, the results of initial tests opened up new questions and drove further explorations.

The most surprising outcome of this work was a realization that images that are measurably accurate to the original artworks in color and density consistently reproduce poorly in print without some form of optimization. As seen in the comparisons below (see Figure 14,15) an "accurate" image may not be a "pleasing" image when output.

Figure 14   Original image, Adobe™ Photoshop® Auto Adjustment, Athentech™ Auto Adjustment.
S0168V_1962, Peita (after Delacroix) 1889 (Detail)
Vincent Van Gogh (1853-1890), Van Gogh Museum, Amsterdam

Figure 15   Original image, Adobe™ Photoshop® Auto Adjustment, Athentech™ Auto Adjustment.
M-SK-A-4995 The Kitchen Maid (dertail) Johannes Vermeer
c. 1658,Oil on canvas,45,5 x 41 cm Rijksmuseum, Amsterdam

Unfortunately, this disparity is what leads people to manually edit images in an effort to improve upon digital captures. This subjective manual editing process introduces so many variables that the chances for success are greatly reduced. It is also important to note that over the course of this testing, the same images that appear dark and dull upon output appear accurate to the original artworks when viewed on a calibrated display.

This body of work begins to open up the possibility that there may be better ways to optimize images for various types of output, saving time and effort while still preserving the integrity of the original image. The goal of satisfying the dual requirements of preservation and cross media publication may be within reach. While our tests were performed with tools that generally support measured photography and ICC profiling, the fact is that many DSLR cameras and raw processors do not easily allow users to properly apply these protocols.

Through the course of this testing I have had the opportunity to collaborate with industry leaders and manufacturers from around the world in an effort to promote much needed support for objective internationally standardized capture methods.
I am glad to report that this work has already had a positive impact on the community as these dialogs have helped influence specific software updates such as Hasselblad® Phocus™ New Phocus software and camera system firmware available! and Adobe® DNG Profiler (Beta) DNG Profiles - Adobe Labs, as well as a host of colorful online discussions. Manufacturers are not always eager to listen to advocates of open standards. It is important to note that the issues related to standards are not limited to cultural heritage imaging. Any digital imaging workflow that relies on objective, repeatable imagery is affected. The medical community, law enforcement community, manufacturing, and retail industries, all need to rely on accurate consistent images to be successful. If imaging is to truly mature, standards need to exist. What is more important though, is that the tools we use must allow international standards to be more readily adopted.

With such a cross section of artwork one begins to gain a true sense of the value of standardized imaging practices. I only hope that the imaging community as a whole begins to work to tighten up standards, which in my opinion are still far too broad and far too difficult to implement. I envision a future where digital cameras are required to incorporate an "ISO Mode" which will deliver the controls required for true objective capture. All the technologies currently exist to make this a reality; all we need to do is to apply a good dose of vision.

Author Biography
Scott Geffert is President of Center for Digital Imaging Inc. www.cdiny.com. A New York based consulting firm specializing in digital imaging workflow. CDI consults museums and corporations worldwide. Scott has been involved in photography since 1975 and has been active in digital imaging since 1984.