Transitioning to International Imaging Standards at the Metropolitan Museum of Art: A Case Study

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Introduction

When reading this case study it is important to note that the evolution and adoption of standards do not occur in a vacuum. In many ways, the concept of standardization is at odds with the rapid pace of technology. Traditionally the process of standardization takes many years while it is not uncommon for technology to move on a six-month cycle. Some may argue that standardization in the digital arena is futile and standards for imaging are best maintained by industry. A strong case can be made that the industry has done a poor job in the "best practices" department. If there is one valuable lesson to be learned from the work at the Metropolitan Museum of Art, it is that there are ways to implement standards by taking an active role in the process as opposed to waiting on the sidelines. In short, standards bodies, researchers, and industry consortiums cannot be effective without the valuable experiences gained in the field.

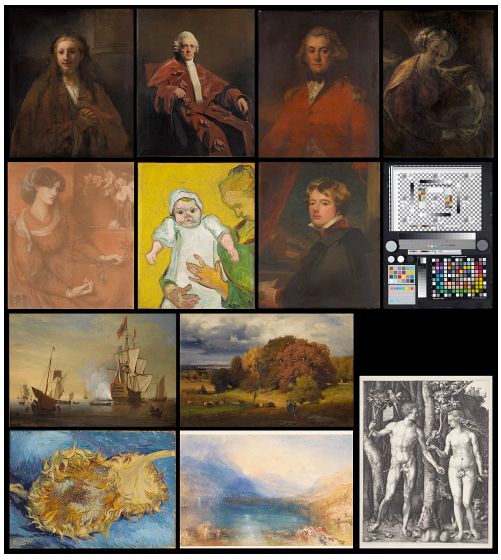
The adoption of international imaging standards at the Metropolitan Museum of Art has been a gradual process that began years ago with the early adoption of ICC color management. Prior to ICC color management, digital imaging programs were held hostage by the display of a local computer or worse a particular output device. During this time period digital imaging was often performed "by the numbers" but those numbers were often dictated by a particular workflow or camera system. By the summer of 2001 the completion of a formal internal evaluation of imaging practices set the foundation for the workflow of the Met Museum. This testing revealed without a doubt that carefully calibrated digital cameras and scanners encoded to a 16 bit ProPhotoRGB color space TIFF yielded a "master" image file that could serve as the source for subsequent media-specific renditions of an image asset. Based on this testing and subsequent evaluations, The Met Museum has avoided the temptation to subjectively edit calibrated digital captures up front to any particular output as experience has shown that in almost all cases, digital output is in constant flux. If editing to CMYK what CMYK? If editing for RGB Inkjet are we editing to Matte or Glossy media? If editing to a display are we editing for web typically 6500K or D50? To a great extent the modern imaging workflow relies on the ICC color management model. If edits are necessary this editing is performed on derivatives for a SPECIFIC use. While there are limitations with the ICC model it has proven time after time to provide a solid foundation.

During the time frame of 1999 to around 2007 the Met Museum enjoyed a period of very consistent output, as color management practices became the norm worldwide and cameras, scanner, displays and printers offered consistent support for the color-managed workflow. Around 2007 the imaging industry experienced a series of unrelated but unfortunate events that began to impact museum and library imaging programs worldwide. The advent of the DSLR and explosion of proprietary Raw file formats and Raw processing software coupled with a major consolidation in the color management industry led to a rapid decline in the use of ICC color management-especially for digital capture. Almost overnight, software tools that once supported custom ICC profiling moved towards increasingly subjective slider controls for color, tone, and all sorts of tools designed to make visual editing easy and attractive. The idea of capture by the numbers and objective process control was being replaced by proprietary consumer level controls. By 2007 it became painfully clear that the increase in subjectivity was having a negative impact on even the highest end camera systems. During this time period it became very difficult to maintain a capture workflow, as it seems that with each upgrade to camera software, the ability to create and utilize proper ICC profiles and meaningful numeric readouts became chaotic at best. Managing imaging quality for many became an exercise in frustration.

The efforts to explore the solution to this problem are well documented in my previous IS&T papers. The focus of this paper is on the efforts to apply emerging standardized imaging practices across a very large imaging operation of 11 full time photographers.

The Strategy

After having participated in previous rounds successful evaluations of the Metamorfoze Digital Preservation Imaging Guidelines with other institutions worldwide, the decision was made to formally evaluate the process internally with a cross-section of artworks from the collection. Tests were performed during the summer of 2009 using the museum's existing Hasselblad, Leaf and Sinar Cameras.



Metamorfoze or FADGI?

For the initial testing we focused on the most critical aspects of the Metamorfoze protocols related to tone and color reproduction.

People may ask why not evaluate the FADGI imaging guidelines? At the time of this initial work, the FADGI guidelines were not formally published (formally published in August 2010). The good news is that the FADGI guidelines and Metamorfoze point to the same ISO standards and differ only in the fact that the Metamorfoze protocols were mature enough at the time (already being used in Europe) AND offered published tolerance tables for all common working color spaces. To date, the FADGI guidelines only offer tolerance tables for Adobe®RGB. While Adobe®RGB is a popular RGB space it is NOT an ISO standard. The existing ProPhotoRGB (ROMM RGB) is an ISO standard and the eciRGBv2 L* based color space recommended by the Metamorfoze is near finalization as an ISO technical specification. It is important to draw a line between commercially popular proprietary environments and international standards. Years ago IBM dominated computing and Microsoft dominated operating systems. Imagine if each company had their own branded image encoding. Would you feel comfortable archiving cultural heritage images in IBM®RGB, Microsoft®RGB or even Google®RGB? If not, you will understand the desire to use an internationally standardized environment.
Adobe®RGB is a corporate branded, trademarked environment with a legal disclaimer regarding its use that is posted right on the Adobe corporate web site.

When you look carefully at the Metamorfoze and FADGI documentation you will find that they are almost identical in every respect in terms of operational tolerances and even general philosophy. Where they differ dramatically is that the efforts have spawned two new technical targets and analysis software tools: the UTT Universal Test Target cooperatively designed by Image Engineering in Germany and the Dutch KB, and the Golden Thread system developed by Image Science Associates in the US in conjunction with the FADGI effort. Efforts are underway to bring these two very similar protocols towards one universal protocol but this will take time. The most important development is that the current trend towards objective capture methodology is a welcome sign of an industry maturing. In the end, pixels, math and physics are universal and should have no geographic boundaries.

Test Phase

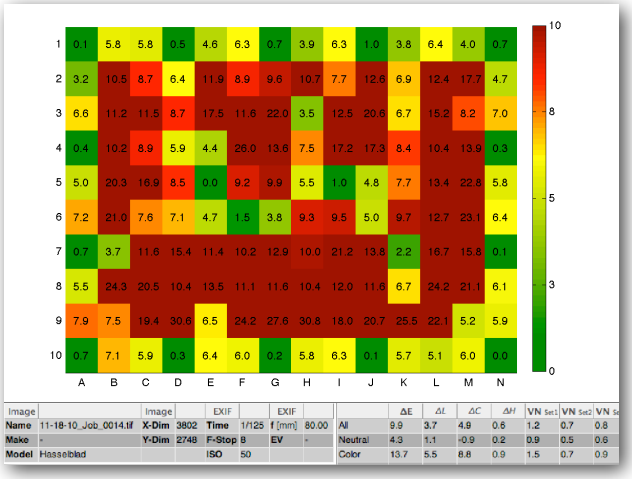
The capture tests were structured to be as realistic as possible, meaning we set out to test with existing cameras, existing lighting and common readily available color targets. If the protocols did not work with the tools the museum already owned they would be of little value. We were not evaluating the entire range of imaging performance metrics (just tone and color) at this stage.

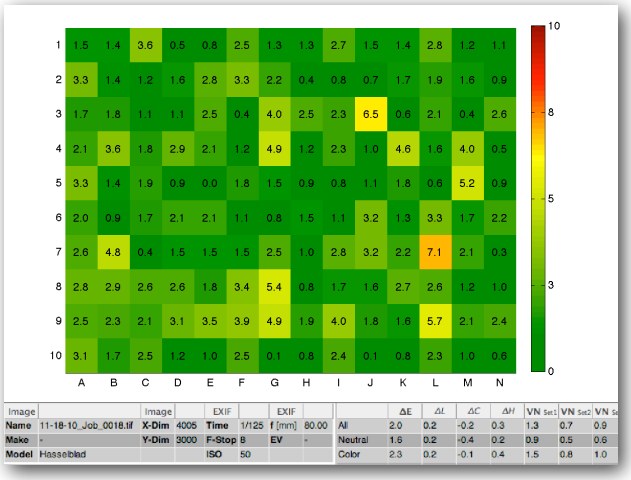
Regardless of camera make and model there are several steps that are followed to quickly dial in a camera system:

1) Set up a lighting configuration typical for copylight. Which in this case involved two electronic flash light sources and bounce umbrellas. Color temperature of the sources should be checked if possible to be within an acceptable tolerance of 100 degrees Kelvin.
2) If the camera system supports “flat fielding” (or custom scene reference generation) this may help achieve more precise results. It is important to note that in practice utilizing custom scene references could complicate workflow or even reduce quality if not applied properly. Unlike an ICC profile, scene references are specific to camera height, lens aperture etc.
3) Create a custom ICC camera profile. Each brand of camera system and capture software offer varying degrees of support for creating custom ICC input profiles. During our testing we decided to evaluate several popular profiling tools. We used the X-Rite DCSG color chart for all testing.
4) After generating an ICC profile and selecting it as the source space in the capture application the next step is usually to select the desired output color space and to verify that the destination tonal values are within the published tolerances. Depending on the camera system and profiling software used results will vary. On some systems we found that after profiling, tonal values were within tolerance requiring no further adjustments.
5) In cases where tone curves need to be adjusted to meet the published tolerances we begin with a linear curve, expose to white and make adjustments working down to black. The Camera profile and tone curve become a working pair for the particular lighting scenario.

Validation

Simply comparing RGB file values to the Metamorfoze tolerance tables) can be quite effective for checking the tonal response, as the tonal values are either in our out of tolerance. Checking colors can be more tedious, so we utilized several tools to check color accuracy: The Image Engineering IQ Color module and the Image Engineering Color Gauge software are both reasonably priced solutions that exist today and are both extremely useful tools. The Image Engineering tool works on the Mac platform AND Windows and it also supports the proper analysis of images encoded in eciRGBv2. The Image Science Associates software is less costly, but only runs on Windows and supports the L* based eciRGBv2 only by approximation (this may have been updated since this paper was written). Most importantly, both tools agree in terms of results as they point to the same standards.





This set of reports from IQ Color Module contains valuable information about imaging performance: Report 1 is a capture of an X Rite DCSG color chart using a manufacturer default configuration. The second report is a capture from the exact same camera that meets the Metamorfoze tolerances for color and tone (custom ICC profile & validated tone curve). The report clearly indicates that the illumination is uneven (notice deltaE value differences between patch 1N and 10A). A simple illumination adjustment would improve this capture even further.

For evaluation of color, the Image Engineering IQ Color Module was used to evaluate color and tonal response. Color and tone either agree or disagree with the published tolerances. In the case of the Metamorfoze, this is <=4 average deltaE (cie1976) and <=10 deltaE for a specific color. At the time of testing this was a pass/fail scenario. Our primary camera systems resulted in a consistent 1.6 average delta E result-well within the tolerances. Older cameras often ended up between 2-and 3 deltaE's. It is important to note that DSLR's using Adobe Lightroom in most cases hover just on the edge of the protocols usually 3-5 Average delta E's and 10-15 Maximum Delta E's. (This is using the common X Rite Passport Color chart and software validated using an X-Rite DCSG chart. We are BEGGING X-Rite to support the DCSG chart in the Passport software for Adobe Lightroom as many museums and libraries enjoy Lightroom for rapid capture projects. Adding support for the more precise DCSG color chart would immediately uplift the quality of these systems. There is limited value in validating to a 24patch chart for advanced museum imaging as it is simply not precise enough, but make no mistake, it is clearly better than no profiling at all.

Initial Capture Tests

After initial testing and visual comparison of files via chart measurement a series of artworks were imaged. While the initial results were technically accurate, there was considerable concern amongst the photographers about the perceived need to light paintings under perfectly even "copy light" illumination geometry when strictly following the capture protocols as if they were works on paper. The argument here is that paintings have various levels of impasto and surface treatment that often require complex lighting to bring to life. Additional tests were run and we found that changes to the lighting geometry had little impact on the overall color and tonal reproduction as long as careful attention was given to the initial exposure values. More on this later.

"ISO Film"

The idea that there may be flexibility in terms of lighting geometry is counter-intuitive to the imaging scientists that created the protocols, as an uneven pool of illumination would clearly fail if we placed a UTT or GoldenThread chart in an asymmetrically illuminated scene. However there is a hidden value in the use of objective capture protocols. I like to present these protocols to photographers as "ISO Film". By carefully following the protocols to configure the camera response under idealized conditions, the resulting tonal response curve and other technical aspects are clearly defined and normalized across any camera brand and any site worldwide. When a photographer captures using these protocols, the tonal response and color response is predictable and provides a solid foundation. Imagine "ISO Film" as a film optimized for 1:1 reproduction, a film that is not too flat or contrasty, just an accurate universal starting point. If lighting decisions are to be made, or certain objects and lighting scenarios require modifications, at least these changes can be documented and repeated as a protocol for the entire staff to follow across any camera brand. To document lighting geometry it is a good idea to place a smooth black ball bearing in the scene, as this surface will document the exact position and size of the scene illumination. This technique is borrowed from the RTI imaging techniques that are being discussed within the conservation community.

Dark Paintings, Light Paintings

The artworks selected for capture tests were intentionally selected to represent the most technically challenging, as this is the true test of any imaging system. Very dark paintings and very light artworks were included. The imaging of dark paintings has been an area of ongoing debate as many museum photographers will increase exposure at the time of capture in an effort to get more shadow information. You will often encounter the "Art is not Charts" argument, and there is some validity to this if the goal was a single fixed output such as CMYK printing where it is difficult to reproduce shadows. In this approach, the photographer will subjectively gauge exposure often making judgments on a calibrated display as a guide breaking away from the chart as a reference. In a way, this approach does satisfy the immediate desire for a "pleasing rendition" but as the photographer is making these subjective decisions, the ability to repeat the process over

time or across multiple photographers is diminished. In a large studio with over 11 photographers these subjective decisions can potentially become difficult to manage over time. For example: it is quite common for a painting to be fully documented prior to conservation. If a photographer captures an image using subjective methods and six months later the same painting (now stripped of varnish) requires photography you begin to see where the subjective model breaks down. Is it the same photographer? If it is the same photographer, how will he/she base the exposure? How can we know the net effect of the cleaning treatment? The fact is that only an objective capture method can deliver the repeatability required for this scenario.

After extensive testing of the various subjective and objective capture and exposure methods we have found that using today's cameras in conjunction with measured objective capture methods and high bit depth files that there is no loss of quality when capturing dark or light artworks via chart-based exposure and tone validation. In fact, we consistently find an improvement in accuracy compared to subjective methods based on actual spectral surface measurement of the artworks. Why the improvement? When calculating delta E values, one third of the formula is related to lightness (L*). When photographers make subjective adjustments to exposure and tone curve during capture, the L* values shift dramatically while in many cases, the A* B* values will be within tolerance. The bottom line is that, accurate exposure DIRECTLY IMPROVES delta E differences not just from chart to image file, but from actual artwork spectral measurements to the file values. Smaller delta E values translate to better image quality. Where results are dramatically improved are in the very dark and very light regions. Depending on the ultimate use of the content there is a place for subjective editing to create "pleasing renditions" for limited gamut media such as CMYK publications, but making subjective assumptions regarding output at the time of capture does not necessarily help as the decisions are difficult to manage and are not easily reversed.

Standards and Raw files

It is clear that the entire industry will slowly move towards Raw file formats and more advanced dynamic encoding methods for both input and output. Unfortunately until the industry matures and truly standardizes not just Raw file formats, but Raw processing tools, we need to make the best use of current technology. One other caveat of current Raw processors and even digital camera capture software is that many assume sRGB or AdobeRGB working space internally with no ability for users to change these "under the hood" parameters. So even when users think they are working with the full information from the sensor encoding, they are actually quite limited. An example of this can be found in the current versions of Adobe Camera Raw and Adobe Lightroom. In ACR users can select AdobeRGB, ProPhotoRGB, and for some strange reason ColormatchRGB? working color spaces with accurate readouts. While there is no option to select eciRGBv2. In Adobe Lightroom users have NO CHOICE of working color space and RGB readouts are completely undocumented. Clearly Raw file processing needs to be standardized to be useful for any objective imaging applications. Adobe product managers have described Raw processing as "a black hole" and this is a perfect description. It is important to note that the DNG file format itself is not the problem and most experts agree that the format is quite advanced and can be quite viable for archiving. The problem lies in the DNG editing tools and an almost complete disregard for standardization.

Output Evaluations

The images created at the Metropolitan Museum of Art are used across every conceivable media and therefore the assets created must be robust and flexible. It is not an option to create collection images based upon any single form of output. The goal of the operation is to achieve maximum quality both technically and aesthetically. The primary interest in evaluating these standardized practices is driven by the desire to continually improve quality and productivity.

The initial rounds of tests were evaluated against existing captures onscreen, and via ink jet output as well as informal CMYK proofing tests. The immediate impact of the Metamorfoze captures was a noticeable improvement in shadow and highlight accuracy, and consistently smaller delta E differences between file and actual artwork samples.
The results of deltaE value differences are interesting to note because it speaks to the "Art is not Charts" debate. Tests across Paintings drawings and photographs indicate that on average, the charts agree with actual artwork samples. The tests specifically involve measuring the artwork using a handheld spectrophotometer and then measuring the actual digital file values for comparison as well as visual comparison of L*A*B* samples on display and print.

Creating accurate digital captures that measure near 1:1 with actual object colors does not necessarily guarantee that viewers of digital output will find the result "pleasing". What we do find is that in terms of viewing on calibrated displays, the visual matching is very successful across a wide range of artworks from dark paintings to light works on paper. When the same artworks are output on ink jet or CMYK devices (with no further editing) you begin to see the limitations of current output technology. As these devices are often smaller gamut, dark images are often perceived as too dark. It is critical to separate capture from output issues. An accurate digital capture can always be adjusted via post-production or automated methods, but an inaccurate capture compromises any form of output and compromises preservation goals.

Publication Tests

The next step was to begin to utilize the Metamorfoze captures as part of ongoing projects. Images encoded in both ProPhotoRGB and eciRGBv2 were pushed through various live initiatives for print, web, signage and all other possible outputs for comparison. This real world testing is critically important. It is difficult to be very scientific when evaluating images as part of normal production cycles as it is not the traditional role of a photograph studio to perform pure research.

RIT Study

By pure coincidence the Metropolitan Museum of Art was invited to participate in Franziska Frey and Susan Farnand's Mellon

artwork reproduction study. As we had already started to migrate to the Metamorfoze protocols the timing could not have been more perfect. In December 2009 the package of charts and artworks arrived from RIT. We captured using the Metamorfoze tolerances methods earlier in this document and verified to the DCSG chart using the Image Engineering IQ Color analyzer software. Images were exported directly from the camera software in eciRGBv2, AdobeRGB1998, and ProPhotoRGB as we wanted to see how these three encodings performed through this very formal study.

During the testing one of the paintings had a deep impasto and once more the photographers were concerned that the copy type lighting used for charts was not representative of how they would normally light an artwork. So we decided to deliver two versions: "by the book", and the photographer's own lighting. While the study has not been published yet, it appears that the "bridge" painting was one of the most highly ranked images in the entire study. We learned through this experience that the aesthetic lighting skills of a photographer could fully co-exist with event the most precise technical protocols.

There were a few artworks that did not far as well in the RIT study. There were a couple works on paper that had a slight warm tone. In our particular test, these artworks resulted in files that were best described as "Hyper-Neutral" in that while density was spot on, the near neutral colors of the artwork were de-saturated. As with other images delivered to the study, we refrained from any post-production, as we wanted to see raw results right off the camera using the capture protocols under evaluation. We know that we can edit files to rectify any problems, but the real value of a study like this is identifying problems and getting to the core source.

We learned much later that the particular version of capture software we had used during the testing had a bug (sometimes called a "feature") that de-saturated near neutral tones. It is interesting to note that the DCSG chart results for the RIT still passed the Metamorfoze tolerances. This brings up and interesting topic: How precise can we expect to be? Some people worry that the tolerances of the Metamorfoze and FADGI protocols are unrealistically tight. This experience indicates that the protocols could possibly be too wide or it may simply mean that we could use a different type of color chart. Considering the overall results are improved by using these methods, the real answer may simply be that problems in the workflow can be more easily identified and resolved. In the case of the de-saturated neutrals, a simple software update took care of the problem. In the end, the RIT study was an incredibly important effort.

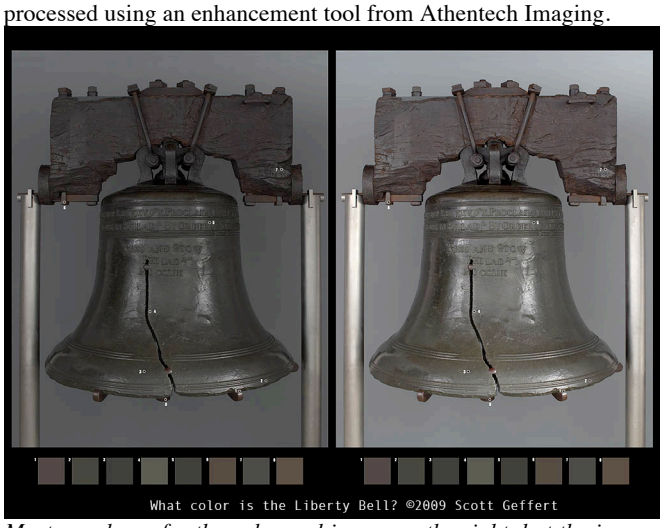
Going Live

With such positive test results, the decision was made to migrate the entire workflow to the Metamorfoze protocols (Tone and Color) as part of a planned rollout of camera system updates.
One notable project was the recent publication *Stieglitz, Steichen, Strand: Masterworks from The Metropolitan Museum of Art*. This important collection of photographs was to be photographed for the publication. The files for this publication went directly from the camera to the museums separator with no additional editing. The publication has been extremely successful. One of the most striking things about this exhibition is that these iconic photographs are incredibly subtle. Many film-based and early digital images of these photographs suffered from subjective interpretation and are almost always overly saturated and too contrasty. The new images faithfully convey the surface qualities of the original photographs. It is very fortunate that we were able to use these methods for this important collection.

Metamorfoze and 3D Objects

The concept of "ISO film" provides a certain foundation across various cameras and capture software packages. So far this "ISO film" is based on an ideal 1:1 reproduction (tone and color) of an evenly illuminated 2D object. Due to the complex nature of how light falls on 3D objects using these settings will often result in lifeless "flat" images.

This image of the Liberty Bell is a perfect example. The image on the left is a color correct image in that the measured L*A*B* values of the actual Liberty Bell match the image data. The version on the right has been adjusted to create a pleasing output rendition, but the color delta E color differences are unacceptable. You can see the differences when you drag measured color swatches from the bell over the adjusted image. While the settings are technically correct in every way, the resulting images can be perceptually unappealing. Most people prefer the image on the right that was processed using an enhancement tool from Athentech Imaging.



Most people prefer the enhanced image on the right, but the image on the left is measurably accurate to the actual Liberty Bell.

There are no formal protocols for 3D object photography, but extensive testing has revealed some findings:

1) The same verified color profiles used for Metamorfoze 2D captures can be used for 3D captures and consistently improve color accuracy over the manufacturer profiles.

2) Many cameras come with a "Linear Curve" and a "Film Curve". For 3D capture simply switching to a Film Curve gives a more pleasing result and surprisingly good color. The Hasselblad systems offer a "Reproduction Mode" option which is used for 2D captures, when this setting is turned off, the tonal response for 3D Capture is

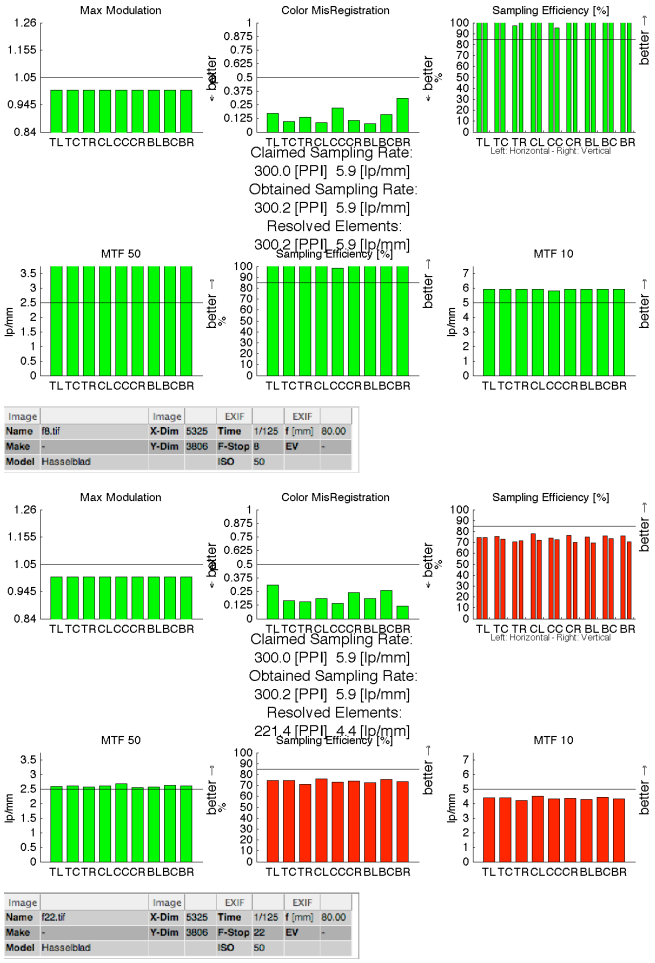
quite pleasing.

3) Avoid adjusting tone curves for each capture. While this is an old rule of thumb it still holds true. A tone curve adjustment has a direct impact on your lighting. For example: if you place an object in a scene using a linear tone curve, you will need to use a smaller, more directional light source to add contrast to the scene. If you begin with a contrasty tone curve, you will find that highlights will become over-exposed very easily and you will need to utilize a large diffuse light source to compensate. Using a single tone curve over time is essentially like using the same film emulsion. Photographers are able to learn to light to a more consistent foundation. Why is this important? Tone curve adjustments at capture lead to inconsistencies and these inconsistencies lead to increased post-production, and increased post-production leads to lost time and more inconsistencies. Digital cameras are inherently stable devices; adjusting tone curves at capture often leads to instability. *Note: This applies to tethered studio photography where color accuracy is critical using studio lighting equipment.*

4) Tests have proven time after time that images are higher quality when lighting adjustments are used as opposed to post-capture tone curve adjustments.

What about the UTT and Golden Thread?

Both the Metamorfoze and FADGI efforts were born within the library / preservation community and not necessarily museum photography community. Libraries, especially large national libraries face massive digitization volume challenges and often work is outsourced to mass-digitization vendors. These efforts to create protocols and unified charts are specifically designed to monitor digitization quality as a critical part of project management. In the ideal implementation scenario, a high volume digitization facility would capture a single chart that on a preset schedule (every morning) to monitor the process and to identify problems. In many cases, the digitization is performed on a fixed copy stand, or a flatbed scanner. A great portion of the protocols and targets are related to geometric distortion, resolution, homogeneity and other aspects of imaging that require a locked down capture situation that is not very common for museums or even conservation labs. For the most part, the primary tool utilized at the Met Museum has been the X Rite DCSG chart and verification software to monitor color and tonal response over time. This chart also provides the key for color calibration.
The UTT and Golden Thread Charts are used primarily when evaluation new camera systems. As well as on copy stand workstations used for reproducing works on paper. Two interesting applications of the UTT chart were evaluating the resolving power of lenses at different apertures, and comparing the real resolving power of various camera systems. In one such evaluation, we learned that the 39MP Leica S2 digital camera performed on par with the 50MP Hasselblad camera in terms of real resolving power. While one would think at first glance that more megapixels immediately translates into more resolving power, this test illustrated that there is still a value in precise optics.



This UTT test chart report is the performance of a camera system at f/8 and f/22. Photographers have known for years that stopping down a lens decreases resolving power. This report shows just how dramatic the losses can be. The horizontal bars represent Metamorfoze tolerances.

The leap to apply Metamorfoze capture protocols can be squarely attributed to Marianne Peereboom of the Van Gogh Museum as she had the vision to bring experts from the library environment together with experts from the museum photography environment. My first efforts with Hans Van Dormolen (author of the Metamorfoze protocols) at the Van Gogh museum led to the realization that certain aspects of the protocols provided the "missing link" of process control for art museums. While we all use color management, the concept of advanced process control element was simply a missing part of museum imaging at the time. The application of advanced process control at the Van Gogh has proven to be incredibly successful. After Visiting the Van Gogh Studio, Barbara Bridgers Manager of the Metropolitan Museum of Art studio made the decision to follow this path.

Following the adoption of these protocols has been an extremely rewarding experience as the work of the imaging scientists, library experts, museum photographers, standards organizations and researchers has built enough momentum to begin to influence camera manufacturers and ultimately Adobe, Apple, and the industry at large. It is encouraging that the work of a handful of people can have such a worldwide impact.

Author Biography

Scott Geffert is President of imagingetc inc. www.imagingetc.com. A 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.