

# Teaching Students About Color Management

Dr. Jerry Waite, Assistant Professor  
Department of Industrial Technology  
University of Houston

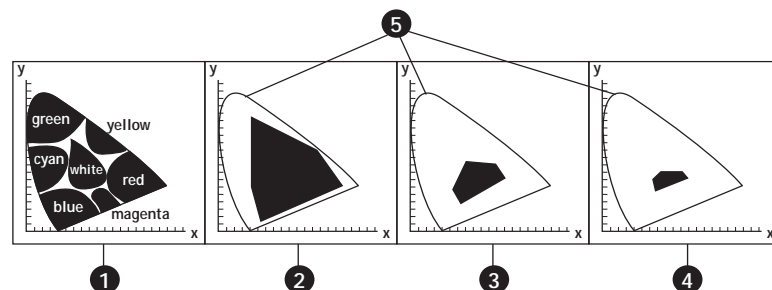
Several years ago, color theory, color separation, and color correction were considered high-level skills that were taught in advanced courses in technically-oriented colleges and universities. However, technical advisory committees are increasingly pointing out that color theory, separation, and correction are indeed basic skills in today's printing and publishing industry. Snyder (1997) did an extensive industry analysis and concluded that color theory must be considered a "fundamental as opposed to an advanced course."

The advent of personal computing and desktop publishing has made the task of teaching color theory, color separation, and color correction both easier and more difficult. Teaching these topics is easier today than in the past because of the relatively low cost of personal computer workstations and powerful software such as Adobe Photoshop—it is certainly easier for schools to provide students with desktop computers than drum scanners! However, the variability inherent in computer monitors, desktop scanners, and color output devices has made the teaching of color separation and correction more difficult than it was years ago. The original mantra of desktop publishing—"what you see is what you get"—has proven to be an absolute falsehood when it comes to judging on-screen color. Due to numerous print production factors, the real mantra today is "what you see is not that you get." Graphic Arts teachers have had to teach their students to disregard what they see on the screen because the monitor itself does not display accurate color and because ink characteristics, dot gain and paper color, coating, and absorbency will all change the color of the printed job. Instead, students must be taught to perform color correction "by the numbers" (Margulis, 1995). From the student's perspective, it must be very difficult to look at a brilliant green image on the screen and imagine what it will look like based upon the CMYK values that Photoshop will use to reproduce it. Color correction would be much easier if the on-screen image were reliable.

## ***Impediments to On-Screen Image Reliability***

There are two major impediments that must be overcome if the color of an on-screen image is to be trusted. First, the monitor itself must be adjusted so that its white point accurately simulates white paper. Unfortunately, the default white color produced by color monitors—i.e. when their red, green, and blue phosphors are all completely energized—is a blue-white rather than the brownish-white associated with most white printing papers.

The second impediment to reliable on-screen color is the varying color gamuts of different color devices. A gamut is the range of visible or reproducible colors of a viewer or device (X-Rite, 1996). By definition, the human eye (as determined by a "standard" viewer) can discern the widest gamut of color. The gamuts of all color reproduction methods are smaller than the human eye's gamut. In addition, the gamuts of different color reproduction processes vary. For example, color film can record more colors than a computer monitor can display, but fewer than the eye can distinguish. CMYK printing has a different gamut than RGB monitors—monitors can display some colors that CMYK cannot reproduce, and CMYK can print a few colors that cannot be displayed on a monitor. Because color gamuts vary, it is important to understand that no reproduction process can provide the same number of colors that the human eye can see. Therefore, all reproductions are less colorful than reality. Figure 1 provides a visual representation of some gamuts.



**Figure 1. Gamuts of selected reproduction processes: 1. Visible gamut of colors 2. Color gamut that can be reproduced by color film 3. Color gamut that can be reproduced using CMYK inks with offset lithography 4. Color gamut that can be reproduced using newsprint 5. Boundaries of visible gamut**

The difference in CMYK and RGB gamuts is the major reason that on-screen color is not reliable. Unfortunately, too many colors—especially bright greens, blues, purples, and oranges—look beautiful on the screen but appear muddy when printed. In order for an on-screen image to reliably predict the press performance of an image, many brilliant RGB colors must be artificially muted (remapped) so that they appear within the gamut of CMYK.

## Color Management Systems

Both impediments to reliable on-screen color can now be solved by using a color management system (CMS). A CMS is software that converts colors from one gamut to another to compensate for differences between input, display, and output devices (Kieran, 1997). Macintosh computers provide a built-in system-based CMS called ColorSync. Windows 95 users, as of this writing, must purchase a separate CMS, such as Image Color Matching (X-Rite, 1996). However, future releases of Windows will probably contain a built-in CMS.

To be effective, color management systems must know the color gamuts of the devices used in a given production center, including scanners, monitors, color proofers, and color printers (including printing presses). The information regarding a specific device's color gamut is saved in a file called a profile. The CMS must have a profile for each device that will be used in the production of a particular image.

Profiles can be obtained in two ways: generic and custom. Generic profiles are based on the average of several identical devices. For example, profiles are created by manufacturers when random devices of the same brand and model are tested. Generic profiles are generally included on a disk when you purchase a device. Custom profiles, on the other hand, include the color characteristics of a specific device. If possible, it is best to use custom profiles rather than generic profiles because a generic profile does not take into account the peculiarities of individual devices (Oppman and Waite, 1997). Custom profiles can be made in-house for each specific device used in a printing firm or service bureau. Alternatively, many publications printers now provide custom profiles of their specific equipment. In some cases, printers upload the profiles to web pages so that they may be downloaded by clients.

## Creating Calibrated Profiles with Colortron

To fully understand the power of a color management system, students need to learn how to create custom profiles. Thankfully, graphic arts instructors can teach their students how to create profiles using a relatively inexpensive package called the Colortron Color System. The Colortron Color System as described in this article costs less than \$1,700 and works with both Macintosh and Windows computers—software for both platforms comes in the package. Unfortunately, as of this writing, the Colortron cannot perform monitor calibration for Windows computers because Windows lacks a system-based color management system.

The Colortron system is composed of four major components: a hand-held 32-band spectrophotometer, Colortron Calibrator software, ColorShop software, and Profile Factory software. The spectrophotometer is the measuring device that works with all three software packages. The Colortron Calibrator is used to create monitor profiles on Macintosh computers and to simulate varying white point color temperatures. ColorShop is a program that is used, in conjunction with the spectrophotometer, to capture colors from objects, compare colors to one another, measure density, and many other useful tasks. Profile Factory is used to build profiles of color scanners and color output devices. To create custom

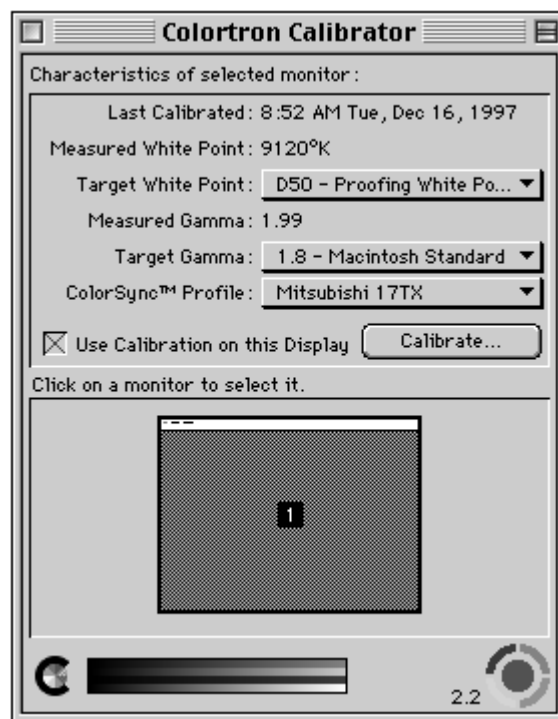


Figure 2.



**Figure 3.**

profiles, a user must have the spectrophotometer, Colortron Calibrator software, Profile Factory software, and a color scanner.

### ***Profiling Monitors with Colortron***

Before a monitor is profiled, it's smart to reduce as many variables from the environment as possible. Room glare or natural light from a window or skylight can affect the appearance of calibrated monitors. In the printing industry, a glare hood made of black mat board should be affixed to the monitor. Room lighting should be made consistent—lighting should be either always on at a consistent level of intensity or always off. Color experts recommend diffuse fluorescent lighting with complete spectrum (5,000°K) tubes.

Apple suggests that monitors be calibrated on a regular basis. Once each month is probably adequate for school-lab computers. Begin the process by installing ColorShop on the Macintosh. Turn the computer off, then connect the spectrophotometer to the proper port. Restart the computer, then, from the Apple Menu, choose Control Panels. Select Colortron Calibrator to display the Colortron Calibrator dialog box. Figure 2 illustrates the Colortron Calibrator for a Mitsubishi 17TX monitor that was last calibrated on December 16, 1997. Note its measured white point is 9,120°K, substantially higher than the 5,000°K white point used by most printers and publishers in the United States. The Target White Point pop-up menu is used to alter the monitor's white point to match one of eight different lighting conditions, including D50 (5,000°K) and D65 (6,500°K). D50 is the

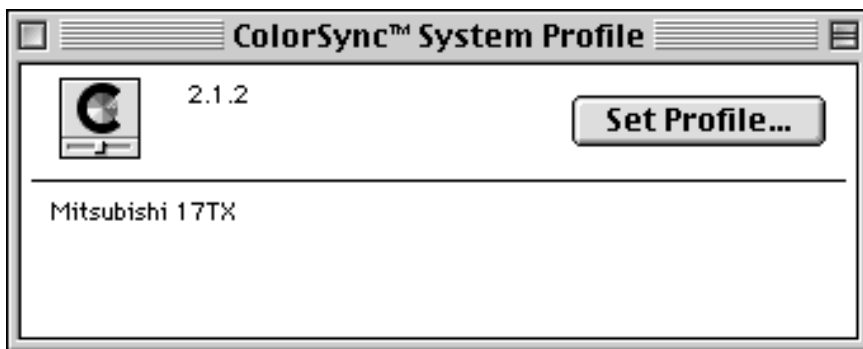
appropriate choice in the United States, while D65 is generally used in Europe and Asia.

To calibrate an uncalibrated monitor, or to recalibrate a monitor, click the Calibrate button and follow the on-screen instructions. At a given point during the process, the spectrophotometer must be affixed to the face of the monitor as shown in Figure 3. Once the spectrophotometer has been installed, the Colortron Calibrator software displays a range of colors on the screen. The spectrophotometer measures each of those colors and provides the measurements to the software. When the measurements have been completed, the software creates a profile that must be given a name and saved in the ColorSync Profiles folder. (System 8 places the ColorSync Profiles folder in the Preferences folder within the System folder.) Once the profile is saved, the Colortron Calibrator dialog box should be closed. The Colortron Calibrator dialog box can be used at any time to recalibrate the monitor or to change the Target White Point. (Note: Once a monitor is calibrated and its profile saved, the Gamma Control Panel that comes with Photoshop should not be used. Use the Extensions Manager to disable it).

The ColorSync System Profile dialog box can be used to select a specific monitor profile (Figure 4). From the Apple Menu, choose Control Panels, then select ColorSync System Profile. If the monitor has already been calibrated with the Colortron Calibrator, the name of the appropriate profile is indicated on the left side of the dialog box. To choose another profile, click Set Profile, navigate to the ColorSync Profiles folder, and choose the appropriate profile.

### ***Profiling a Scanner***

Once the monitor is calibrated and profiled, the second step in color management is to profile the color gamut of the scanner. This process involves scanning a target and using the spectrophotometer to physically measure a graybar (gray scale) and a colorbar. The



**Figure 4.**



**Figure 5.**

Colortron Profile Factory software then compares the colors scanned by the scanner to the measured colors of the colorbar and graybar and creates a profile that takes into account the characteristics of the scanner.

Before a scanner profile can be created, the Profile Factory Reflective Scanner Profile Target must be scanned using the appropriate scanner. The target consists of two parts: a colorbar consisting of eight color patches and a separate 21-step graybar. The graybar must be temporarily taped to the colorbar before scanning (Figure 5). The scanner software must be set to 100 pixels per inch (ppi) resolution at 100%. In addition, any automatic correction settings must be disabled. The scanned target must be saved as an uncompressed TIFF file and placed in the Scanned Targets folder within the Profile Factory folder.

To profile a scanner, launch Profile Factory. The Profile Factory Control dialog box will appear (Figure 6). Use the Device Type pop-up menu to choose RGB scanner, then click Create Profile. The Create Profile dialog box appears (Figure 7). Click the Measured Graybar pop-up menu and choose Measure. Then, measure each step of the 21-step graybar using the spectrophotometer and save the measurements in the Graybar Palettes folder within the Profile Factory folder. After the graybar has been measured, click the Measured Colorbar pop-up menu and choose Measure. Then, measure each of the eight color patches on the color target. Save the measurements in Colorbar Palettes folder within the Profile Factory folder.

Once both the Graybar and Colorbar have been measured, click the Scanned Image pop-up menu and choose Open. Navigate to the Scanned Targets folder and open the TIFF file of the Profile Factory Reflective Scanner Profile Target. A representation of the four



**Figure 6.**

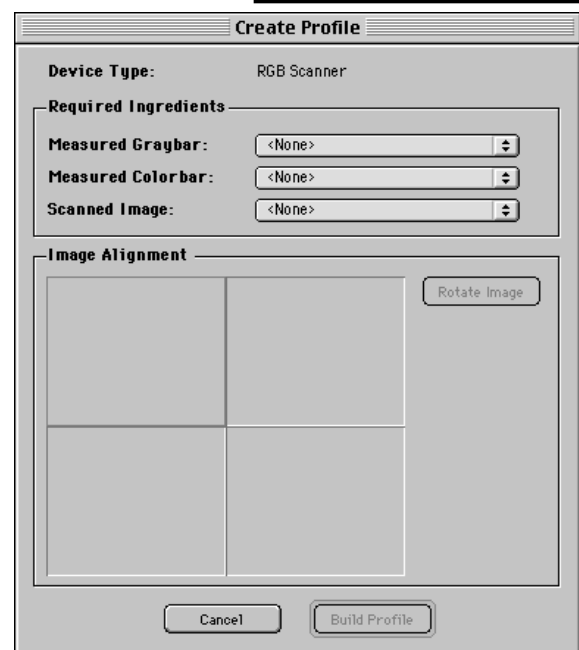
corners of the scanned target will appear in the Image Alignment window (Figure 8). The mouse is then used to drag the colored alignment guide to the actual corner of the scanned image in each quadrant. After the image is properly aligned, click Build Profile. After the profile has been created, a Save As dialog box will appear. Navigate to the ColorSync Profiles folder and save the profile with a descriptive name.

A separate scanner profile should be created for each scanner that will be used in the lab or prepress area. If scanned images are obtained from outside sources—i.e. service bureaus, printers, other labs, and so on—profiles of those scanners should also be obtained and placed in the ColorSync Profiles folder. In essence, a scanner profile should be available for every scanned image used in a facility.

## ***Profiling an Output Device***

The final step necessary to prepare a color management system is the preparation of output device profiles. To create an output device profile, an Output Profile Target must be printed on each color output device to be profiled. Several different types of output devices may be profiled (see Figure 9).

The Output Profile Target may be printed from within Profile Factory or from within another program such as Photoshop or QuarkXPress. In fact, it is recommended that the target be printed from within QuarkXPress if that is the program generally used to output finished documents (Light Source, 1996). In addition, if film



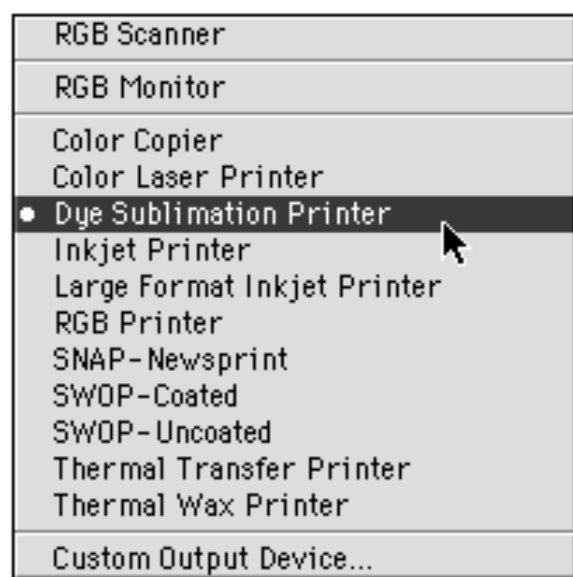
**Figure 7.**

separations are required, the target may need to be output from a page layout program or Photoshop so that a "print separations" option is available. To print the target from a program other than Profile Factory, open or place the TIFF file named "Output Target CMYK" using the applicable program. The file can be found in the Printable Images Folder within the Profile Factory folder.

To print the Output Profile Target from within Profile Factory, click the Device Type pop-up menu on the Profile Factory Control dialog box and choose a type of output device (Figure 9). Then, click the Print Chart Button and use the subsequent Page Setup and Print dialog boxes to print the Target.

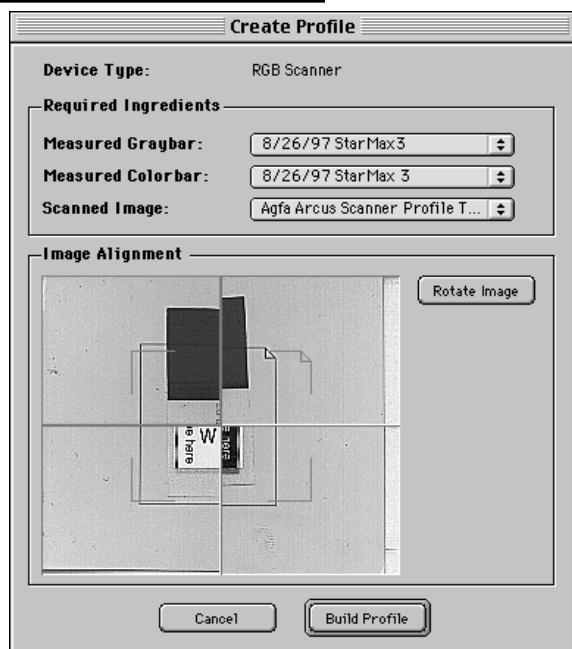
If the output device is a color printer, the machine will produce a completed color Output Profile Target similar to the black-and-white illustration in Figure 10. If separations are output, those separations must be imaged using a printing press or a proofing system such as Imation Matchprint. In any case, the completed target must be a full color image that can be placed on the bed of the scanner.

Once the Output Profile Target has been printed, temporarily tape the 21-step graybar to the area reserved for it on the lower left side of the target (see Figure 10), then scan the target. The scanner software must be set to 100 pixels per inch (ppi) resolution at 100%. In addition, any automatic correction settings must be disabled. The scanned target must be saved as an uncompressed TIFF and placed in the Scanned Targets folder within the Profile Factory folder.

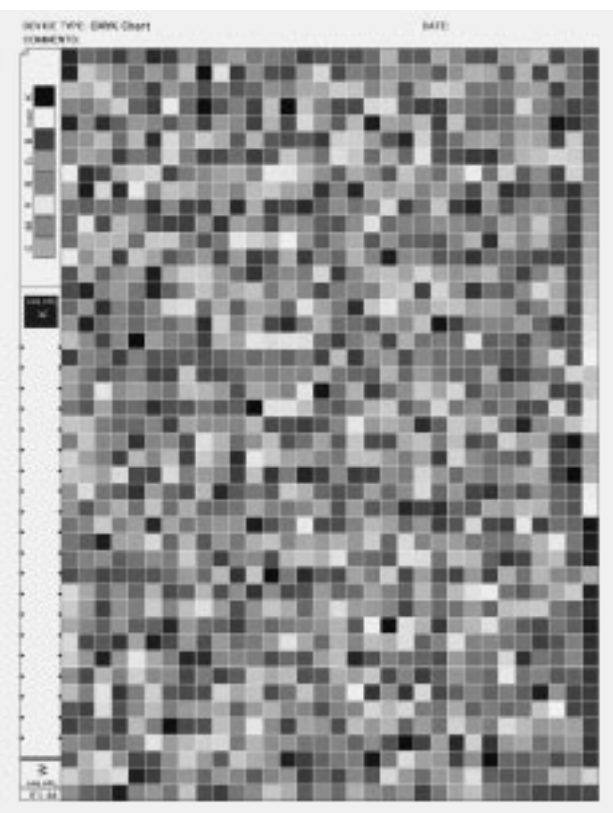


**Figure 9.**

To create an output device profile, choose the Device Type in the Profile Factory Control dialog box (see Figures 6 and 9), then click Create Profile. When the Create Profile dialog box appears, use the Measured Graybar and Measured Colorbar pop-up menus to specify the appropriate files. Then, click the



**Figure 8.**



**Figure 10.**



**Figure 11.**

Scanned Image pop-up menu and select the Output Profile Target TIFF file that was scanned from the printed output of the device to be profiled (Figure 11). A representation of the corners of the scanned target will appear in the Image Alignment area. Use the mouse to drag the colored alignment guides to the actual corners of the scanned image. After the image is properly aligned, click Build Profile. Wait until the Generating Profile progress bar indicates that the profile is complete, then save the profile with a descriptive name in the ColorSync Profiles folder.

### ***Scanning Images to be Used With Scanner Profiles***

Whenever images are scanned, it is important that as many variables as possible are eliminated from the process. Most variables are automatically eliminated if the scanner is set exactly the same way it was when it was profiled. In particular, be sure that any automatic correction settings are disabled before an image is scanned. In addition, it is recommended that the 21-step graybar be scanned along the side of every image—be sure that the graybar is not cropped out of the scan (Figure 12). Scanning the graybar with the original ensures that the white point and black point are set exactly the same way as they were when the scanner was profiled.

To take full advantage of the power of profiles, all scans should be done in RGB mode—CMYK mode should not be used—and saved as uncompressed TIFF files. The CMYK mode should not be used during scanning because the output device profile will automati-

cally convert the RGB file into the color gamut of the chosen output device. If the file is converted to CMYK too early in the process, the image must be converted to RGB before the output profile can be applied. Each conversion from one color mode to another can result in loss of quality. Eventually, profiles will be able to work with images saved in formats other than TIFF, including PICT, EPS, GIF, and JPEG. However, as of this writing there are few application programs that work well with formats other than TIFF.

It is important to understand that the objective of scanner profiles is to reproduce images using colors that are as close as possible to those in the original. If the color balance in the original is skewed, the color balance in the scan will also be skewed. If the intention of the reproduction is to match the original, then such a reproduction will be acceptable. If, however, the intention is to match the colors in the original scene, color-balance correction will be necessary.

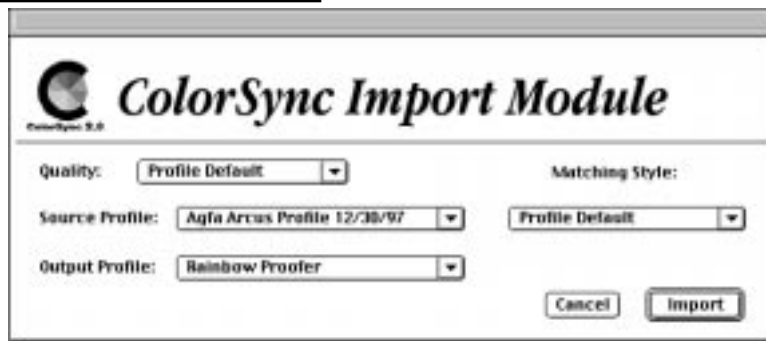
### ***Using Profiles With Adobe Photoshop***

Profiles can be applied in page-layout, vector-graphic, or bit-mapped graphic programs. However, for the purposes of this article, the use of profiles with Photoshop will be emphasized.

There are three profiles in use when an image is manipulated in Photoshop—Monitor, Input Device, and Output Device. The Monitor profile is applied to the entire Macintosh System by the ColorTron Calibrator dialog box or the ColorSync dialog box. The Input and Output Device profiles are applied to a given image by Photoshop when the image is opened, while it is open, or as it is saved. ColorSync uses all three of these profiles to create a “common ground” of colors that exist in the gamuts of the scanner, monitor, and output device. When all three profiles are applied



**Figure 12.**



**Figure 13.**

to an image, only those colors that all three gamuts share are displayed on the screen (X-Rite, 1996). Any colors that exist in one profile but not another are mapped into the common ground. Mapping colors into the common ground can be done in two ways: clipping and compression. Clipped colors are remapped to their nearest in-gamut equivalent. Clipping does not change most of the colors in the image. However, the relationship between adjacent unchanged in-gamut colors and remapped out-of-gamut colors may be unsightly. If a compression scheme is used, all colors (both those in-gamut and those out-of-gamut) are remapped to colors within the common ground. Because compression remaps all colors in an image, the overall lightness or darkness of the image may change. However, the relationship between all the colors in the image remains the same. Therefore, no unsightly juxtaposition of in-gamut and clipped colors occurs (Light Source, 1996).

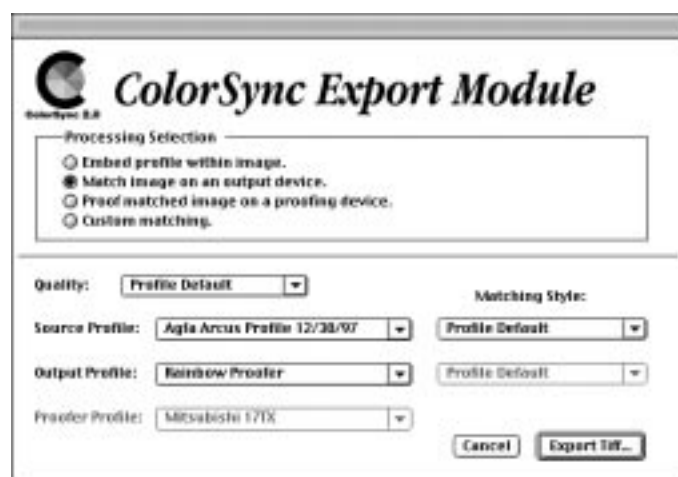
To apply profiles to images in Photoshop, three ColorSync 2.0 Plug-ins—ColorSync Acquire, ColorSync Export, and ColorSync Filter—must be installed in the Import/Export folder in the Plug-Ins folder within the Adobe Photoshop folder. These Plug-ins are available free of charge at Apple's Web Site (<http://swupdates.info.apple.com>). The Acquire Plug-in allows profiles to be applied to an image as it is opened. The Export Plug-in applies filters as an image is saved. The Filter Plug-in applies profiles to an open image. No matter which Plug-in is used, the original RGB scan file should never be changed then saved—always work on a copy of the original file or use Save As after changes have been made to the image. In this way, the original RGB file will be available in case it is necessary to apply a different profile to the image.

The choice of which Plug-in to use really depends on the way the user wishes to perform color correction on an image. If the user prefers to work in the RGB mode, the Export Plug-in is best because the image remains in RGB until it

is saved—the CMYK conversion is done at that time. If the user prefers to perform color correction in the CMYK mode, it is best to use the Import Plug-in because the image will be separated into CMYK as it is opened. The Filter Plug-in is not recommended because it physically alters the image as soon as it is applied. If the file is inadvertently saved without changing its name, the original RGB file will be lost.

To apply profiles as an image is opened in Photoshop, click the File menu, choose Import, then select TIFF with ColorSync Profile. Navigate to the file you wish to open and click Open. The Color Sync Import Module appears (Figure 13). Set the Source Profile to the device on which the image was originally created. If the image was scanned, choose the scanner's profile. If, however, the image was created or manipulated on a given monitor (so that the on-screen image is the desired appearance), the Source Profile should be the monitor's profile. Click the Output Profile pop-up menu and choose the profile of the output device. The Quality pop-up menu should be set to Profile Default. In most cases, the Matching Style pop-up menu should be set to Profile Default or Perceptual. (The Perceptual Style uses the compression method of remapping.)

To apply profiles to an image when it is saved in Photoshop, click the File menu, choose Export, then select TIFF with ColorSync Profile (Figure 14). Choose one of the options in the Processing Selection. "Embed profile within image" simply copies the source profile into the header of the TIFF file so that it can be read by another ColorSync-aware program. "Match image on an output device" converts the image from the gamut of the source device to the gamut of the output device. This



**Figure 14.**

option forces the ColorSync color matching to become part of the image at this point. It should only be used when the output device is known and if a profile for the output device is available. "Proof matched image on a proofing device" converts the image from the gamut of the source device to the gamut of the output device then to the gamut of the proofing device (Light Source, 1997). Once the Processing Selection option has been chosen, choose the appropriate Source, Output, and Proofer profiles. Quality should be set to Profile Default, while Matching Style should be Profile Default or Perceptual. Click Export TIFF to save the file.

## **Conclusion**

Even though color theory, separation, and correction have become basic skills in the printing and publishing industries, graphic arts instructors have had a difficult time teaching these skills because the image on computer monitors has not been even remotely the same as the final printed image. Color Management Systems, such as ColorSync, are making it easier for students to learn how to manipulate color because such systems cause the image on the screen to become reliable predictors of press performance. To fully exploit the power of Color Management Systems, students need to learn to create the device profiles that Color Management Systems use to standardize color. The combination of Photoshop in conjunction with a relatively inexpensive package—the Colortron Color System—makes it possible for graphic arts instructors with tight budgets to teach the basic skills of color management.

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**Jerry Waite**  
**assistant professor**

Dr. Jerry Waite is an Assistant Professor in the College of Technology at the University of Houston. Jerry teaches courses in graphic communications technology and communications systems. He and colleague Cheryl Willis have written three textbooks for graphic arts education, including texts for QuarkXPress and Photoshop. Jerry earned his doctorate at UCLA and his Masters and Bachelors degrees from California State University, Los Angeles. Before assuming his current post at the University of Houston, he taught high school and community-college courses at the Don Bosco Technical Institute in Los Angeles.