



## **Step-by-Step Instructions to Use ITD's GA Workstation**

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This booklet provides the step-by-step instructions on how to set up the graphic arts workstation in the Imaging Technology Department. It describes how to characterize the peripheral devices using ICC profiles, how to set up the operating systems, and how to configure the software applications.

If you wish a color version of this document, you can retrieve it from <http://www.hpl.hp.com/techreports/1999/HPL-1999-110.html>

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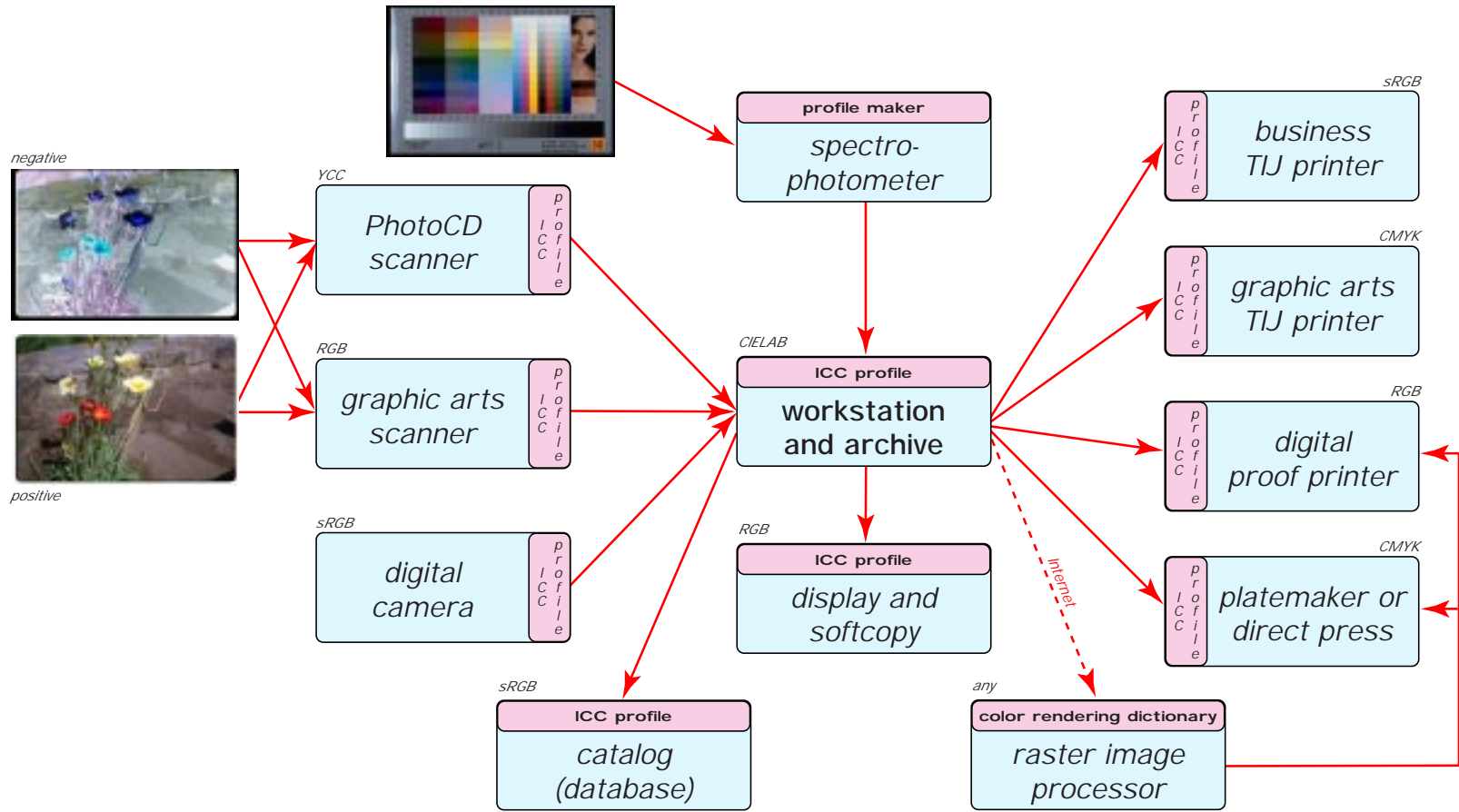
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## 1.0 Rationale

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In digital reproduction, images are represented by numerical quantities. Input/output devices use analog-to-digital or digital-to-analog converters to transduce visual stimuli to and from this numerical representation by *counts*. The converters perform a linear mapping from/to the real world of photons, electrons, etc., to/from a discrete world of digits by binning and counting.

The versatility of computers allows us to easily exchange digital images between workstations or the devices connected to a workstation. Because the peripherals can be very different, devices can transduce a given signal (count) quite differently, leading to a different interpretation by the workstation or stimulation of the human observer.

This problem of device dependency of image representations can be solved by modeling the human *observer's perception* of signals. In this approach the images are represented in a device-independent fashion by using a colorimetric representation, e.g., the CIELAB values of a color that matches a particular color in an image.

It is then necessary to *characterize* all transducing devices — or peripherals — with a model that predicts the perception of a particular signal (count) when transduced by that device. For some devices it is possible to find elegant analytical models, while others are so complex that it is necessary to build conversion tables where values can be looked up or interpolated.

Hans Neugebauer in his Ph.D. thesis had derived an analytical model for a color printer. After determining the colorimetric property of inks (and their mixtures) and the printer's dot gain, a software program can predict the amounts of ink required to produce a specified color stimulus. This model does not always work well, and in 1956 at Xerox Neugebauer invented a simpler model based on table look-up.

Ricardo Motta and Mark Gorzynski of RIT in 1988 developed an analytical model for cathode ray tube (CRT) displays. Louis Silverstein of VCD Sciences in Scottsdale developed a model for liquid crystal displays (LCD), which are far more complex to model than cathode ray tubes.

In 1986 Maureen Stone from Xerox with John Beatty and William Cowan from the University of Waterloo improved the methodology by making allowances for the difference in the color gamut that can be handled by a particular device to that of another device; their system was used for several years to produce the SIGGRAPH proceedings. Concomitantly, Mik Lamming from Xerox and Warren "Dusty" Rhodes from ChromaTech devised a perceptual device characterization that took into account the rendering improvements proposed in 1967 by Kodak's J.A.C. Yule; they coined the term "WYSIWYG color."



Meanwhile in 1985 William Schreiber of MIT invented a system comprising a scanner, a computer, and a printer that uses table lookup to achieve colorimetric color reproduction and allowing for rendering intent. Schreiber's system was closed.

In 1978 Yoichi Miyake and Franz Tomamichel developed the first *color management system (CMS)* at the ETH in Zurich. A CMS allows open color reproduction systems, where devices need not to be known a priori and can be added at any time. The algorithm used by a CMS to transform color values is called *color management method (CMM)*. Since there is no universal device model, a good CMS has several CMMs among which applications or users must chose for each case.

In 1982 John Warnock and Douglas Wyatt of Xerox invented the concept of device independent graphics, based on the notion of graphic context. In 1987 Robert Buckley, also from Xerox and an expert in gamut compression and color image coding, created the Xerox Color Encoding Standard, which allows the exchange of colorimetrically defined images. That same year, Giordano Beretta from Xerox consolidated all the above technologies in the first modern color management system, including device profiles, a selection of CMMs, tight integration with the operating system, and for the first time with a better performance than conventional device dependent systems. Although this technology was immediately deployed in Xerox products (mostly for the Federal market), the details remained a trade secret.

A year later, in 1988 Gerald Murch and Joanne Taylor of Tektronix unveiled the first commercial CMS — TekColor — for the X-Windows system. At about the same time Efi Arazi's Electronics for Imaging created for the Macintosh a commercial but somewhat arcane version of Schreiber's system called Cachet. A few years later in 1993 Gerald Murch of Apple created the first CMS that was both modern and commercial: ColorSync. In 1994, with strong leadership from Stefan Bruess of FOGRA, the ColorSync architecture became the seed for the International Color Consortium (ICC). *ICC profiles* are color space descriptions that allow the total portability of color management data. In the mid-90s, Stefan Bruess of Logo developed the Profile-Maker software.

Color management and ICC profiles allow the user to maximize the capabilities of a graphic arts system at the cost of a high complexity. To a large extent this complexity is due to trade secrets, industrial competition, and internal turf wars. To permit the communication of images for casual users, Ricardo Motta and Michael Stokes of Hewlett-Packard in 1995 introduced the sRGB color model, a baseline system for users outside the graphic arts community.

All Hewlett-Packard products comply with the sRGB standard and you do not have to do anything to obtain consistent quality color reproduction. If you use graphic arts devices, the following step-by-step instructions walk you through the creation of an ICC-based system.

Disclaimer: The following description is for Imaging Technology Department's (ITD) graphic arts (GA) system. Other systems may be different, but they will still be somewhat similar in their colorimetric principles. Furthermore, ITD's system was assembled from surplus material left over from past projects and demos. As better components can be scavenged, the system improves and the procedures or profiles will have to be adapted.

For more historical data see the proceedings of IS&T's 1995 Non-Impact Printing conference in Hilton Head. There is also a number of PARC videotapes from the roaring Eighties. The above notes are from memory, which fades with time; corrections and comments are welcome.

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## 2.0 Viewing conditions

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The science on which all this technology is based, is colorimetric color reproduction. This assumes that all your work is executed under certain reference viewing conditions.

- If your viewing conditions are different from these reference conditions, you will obtain unexpected results
- You could use a color appearance model and a detector as described in U.S. patents 5,521,708, 5,532,848, etc. but this technology is not yet ready for routine use

The reference observer is the CIE 1931 2° standard observer.

### 2.1 Reference display conditions

For the display, the reference conditions are

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**TABLE 1.**

Reference display conditions

<b>Display parameter</b>	<b>Reference condition</b>
Luminance level	80 cd/m <sup>2</sup>
White point	D <sub>65</sub>
Gun/phosphor gamma	1.8, 2.2, or 2.4

There are religious issues on which is the most appropriate value for the gun/phosphor gamma. You should standardize on a value depending on your application and cross out the other values in the above table.

If you use a two-headed machine, e.g., one display for the image you are working on and one for the palettes, then the displays should be sufficiently separate as to avoid electromagnetic interference between the two CRTs. You can determine this visually if you create a white window, extend it over

both monitors, display a grid, and change the distance between the monitors.

The instructions in this document are for CRT displays. You cannot calibrate a flat panel display using a contact spectroradiometer, because physical pressure on the LCD changes its color performance. There are inexpensive sensors with a large-diameter contact area to minimize this problem, e.g., by Radius (Miro Display) and Color Vision.

## 2.2 Reference viewing conditions

Your work area should conform to the following conditions:

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**TABLE 2.**

Reference viewing conditions

<b>Viewing parameter</b>	<b>Reference condition</b>
Background of the screen (appearance, wallpaper)	20% of reference display area
Surround	20% reflectance of the reference ambient illuminance level
Proximal field	20% of reference display luminance level
Ambient illuminance level	64 Lux
Ambient white point	D <sub>50</sub>
Veiling glare	1%

An alternate standard for the ambient white point is D<sub>65</sub>. In that case you have to make the measurements in Section 3.5.4.1 on page 18 with this illuminant.

Note that the ambient should be rather dim and the veiling glare is very low. If your work area is very different, the ICC profile you build will be useless other than fulfilling an alibi function towards your customer. If you cannot change your work area's ambient lighting, you are better off if you build a profile visually instead of following the procedure outlined in Section 3.6, "Calculate monitor profile," on page 23. The viewing conditions at the ITD GA workstation are a luminance level of approximately 500 Lux (in my cubicle it is almost 700 Lux) of mostly F-11 type light with diffuse daylight intrusion.

Building an ICC profile visually can be easily achieved with a set of film swatches placed on the faceplate and comparing with an unfiltered patch on the screen. There are inexpensive commercially available filter sets with simple ICC profile builder software, such as GretagMacbeth's iCSync.

## 2.3 Stability

Characterization is only meaningful when everything is stable and reproducible.

- Always calibrate your devices
- Judge your prints only in a light booth
- If possible, use a self-calibrating display, such as Barco Calibrator, Mitsubishi SpectraView 1000+, Apple Studio 21, Radius PressView, etc.
  - If you have a USB display, you might be able to retrofit it with the iBug calibrator from Radius

## 3.0 Step One: Build profiles for your devices

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A device profile describes colorimetrically a device's color space, i.e., specifies the mapping between device counts and perceived color under specified viewing conditions.

### 3.1 Organize existing profiles

As color management finds acceptance, an increasing number of imaging application programs, operating systems & utilities, and devices are shipped with a variety of ICC profiles.

The file folder with ICC profiles tends to get cluttered. Organize the profiles in folders. The name of the root folder for ICC profiles varies according to the operating system:

#### 3.1.0.1 Windows NT path

C:\WINNT\system32\Color

#### 3.1.0.2 Windows 98 path

C:\WINDOWS\SYSTEM\COLOR

#### 3.1.0.3 MacOS 8.6 path

On the boot disk, System Folder:ColorSync Profiles

#### 3.1.1 Do not over-organize

There can be only one nesting level (on the MacOS this is a convention to temporarily hide unused profiles).

#### 3.1.2 Careful with links

Do not touch folders with links (a.k.a. aliases, shortcuts), they represent the currently selected profiles for the CMS. This is somewhat clumsy way for an operating system to store its state, and if you change it, the system will be confused.

## 3.2 Reboot the computer to flush cached information

You cannot do colorimetric color reproduction by brute force, because it is too expensive computationally. A large part of being able to implement a viable CMS is mastering the art of caching. Rebooting is the safest bet to make sure all caches are flushed.

Some caches might not be built during the CMS initialization. If you have problems with stale information, look for files that look like caches and delete them. They will be created with current information when the system is booted again and the CMS is initialized.

## 3.3 Run ProfileMaker

In this section we assume this is the first time you are using the system and setting it up. Later you have to perform only those steps that you need to change, for example if you change your scanner target.

### 3.3.1 Set general preferences

The defaults are good and you should not change them unless you have a good reason.

#### 3.3.1.1 Scanner profile size: medium

A medium size profile is the most appropriate choice for a modest professional graphic arts scanner.

#### 3.3.1.2 Printer profile size: large

Most printers are highly non-linear, so you need a large printer profile.

#### 3.3.1.3 Monitor profile size: small

We assume you use a high end CRT that you have calibrated.

#### 3.3.1.4 Check “save profiles in ColorSync folder”

This automatically saves new profiles where the CMS looks for them.

### 3.3.2 Scanner target: IT8.7 (Agfa)

Due to scanner metamerism you should do separate profiles for each medium/ink combination.

#### 3.3.2.1 Using a new scanner target

Before you can use a target, you have to measure it and store the data in the scanner reference data folder.

## 3.4 Calculate scanner profile

Perform this characterization for each scanner and each original artwork type (medium/ink/process). We assume that you always calibrate your scanner before each scan to avoid drift problems.

### **3.4.1 Scan target**

These steps are specific to our set-up. You may have a different scanner and different scanning applications.

#### **3.4.1.1 Locate the correct target**

Be sure that you scan the target for which the data was obtained. For a positive use the target with serial number C60705xx. If you have reason to believe the target has deteriorated, you should measure it again (see Section 3.3.2.1 on page 14).

#### **3.4.1.2 Scanner hygiene**

Clean the scanner platen and place the target using gloves (your hands secrete an acid liquid that corrodes the target, if you wash your hands, they will leave alkaline traces on the target). Use gloves; gloves are cheap, while damaged targets are very expensive.

#### **3.4.1.3 Scanning application**

Launch the MagicScan desk accessory (DA) and set the controls as follows. Consistency is crucial.

- Manual control
  - If you are using the DA as an import plug-in, remember to temporarily turn off ICC profile embedding in the application
- Flatbed (reflective)
  - or negatives/transparencies
- True color, RGB
- Resolution to optical resolution or lower (the PowerLook 3000 has an optical resolution of 1220 × 3048 dpi, 3048 × 3048 dpi in the marked region), e.g., 300 dpi
  - Increasing the resolution increases the number of pixels available for averaging
  - A good scanner is very uniform; you do not need too many pixels
  - A higher resolution makes it easier to crop accurately the region of interest
- No descreen
- No filtering
- Auto exposure or load a curve
  - Graphic arts scanners have a very large dynamic range to capture high-density artwork on very bright media. In most cases, the artwork you are scanning has a smaller dynamic range. To take advantage of the full sample depth, you have to adjust the scanner's exposure (see e.g., technical report HPL-97-30)
  - In the case of reflection artwork, you can get acceptable results with the auto exposure mode
  - The auto exposure mode does not work well for transmission artwork, especially reversal film

- The customary application of gamma curves also does not work well for transmission artwork; you need at least a sigmoidal tone reproduction curve to fully preserve the information in highlights and shadows
- Graphic art scanners allow you to download tone reproduction curves. With a custom curve for your artwork, you get much higher quality scans and we always recommend to use tone reproduction curves
- In our case building tone reproduction curves is very easy. The IT8.7 target has a gray ramp with known values stored in the target data file (see Figure 1 on page 17)
- Make a linear scan of the target and determine the counts for each patch in the gray ramp. Simply invert the obtained table to create a tone reproduction curve for that media type
- Use this curve both for scanning the target when producing the ICC profile and for scanning artwork of that media type
- For more details refer to Robert G. Gann, Ph.D.: *Desktop Scanners*, Prentice Hall PTR, Upper Saddle River, 1999, pp. 111–118

**3.4.1.4 Scanner calibration**

Set the MagicScan preferences to long calibration. Every device drifts and needs to be calibrated before each use.

**3.4.1.5 Scan archive**

You want to keep the target scans, so you can quickly compute a new profile with a better CMM. Set the folder to ProfileMaker/Scan.tiffs and chose a descriptive file name prefixed by “ITD” to easily identify it.

- The file format must be uncompressed TIFF
- My profiles have names like “ITD PL 3000 R C60705”, where R indicates reflective (T stands for slide or transmissive) and C60705 is the serial number of our Agfa IT8.7 target
- Check out Kodak’s profile “UMAX PowerLook 3000 Reflective” as an alternative to our profile, but it has an incorrect white point for our scanner (different unit, aging)

**3.4.1.6 Cropping**

Preview the image and crop the target exactly to the black border, as shown in Figure 1. If you crop incorrectly, ProfileMaker will average the RGB values of the incorrect pixels and generate an incorrect profile. If you use an imaging application to crop the target, remember not to perform any conversion and not to embed a profile.

**3.4.1.7 Scan the image**

Remember to load the tone map curve for the medium you are using.

**3.4.1.8 Store target**

Using gloves, put the target back in a dark, dry, and cool place.

**3.4.1.9 Quit the scanner application**

If you ran the scanner application from Photoshop, also quit this application, because you have to launch it to find the new ICC profile.

**3.4.2 Compute profile**

In ProfileMaker, select the target data and the scanned TIFF file for the target.

**3.4.2.1 Target colorimetry**

If there is no data for your target, measure it with the SpectroScan and create a data file (see Section 3.3.2.1 on page 14).

**3.4.2.2 ICC profile name**

In the highlighted scanner profile field, enter the name that will be displayed in applications; prefix it with "ITD" for convenient grouping when sorted by name. The name should be self-explanatory but brief.

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FIGURE 1.

Cropping margins for the IT8.7 scanner target



**3.4.2.3 Profile name and file name**

To avoid confusion, I recommend to use the same string for profile name and file name. This greatly reduces human error when you manage your profiles.

**3.4.2.4 RT-11 is here to stay**

However, in Windows the file name must be abbreviated to the ISO 9660 a.k.a. *8.icm format*, therefore this redundancy.



### 3.4.3 Compute profile

Click on the “calculate profile” button. The computation is very fast.

#### 3.4.3.1 The profile attributes

An ICC profile with the same file name will be stored in the profile folder.

Relevant typical profile data are

- Class = input
- Color = RGB
- Connection = LAB
- Size = 50 to 100 thousand bytes

## 3.5 Calculate printer profile

### 3.5.1 Determine workflow

Ask your printers or prepress service provider if they use an ICC workflow; if the answer is positive, get their CMYK profile, because it will be tweaked for their press.

### 3.5.2 Printer calibration

Calibrate the printer or purge the pens. For a very high quality job on an inkjet printer, the cartridges should be more than half full. You may also want to check the registration.

### 3.5.3 Print chart

Print the chart (reference target) for the printer’s native color space. Usually it is RGB for digital printers and CMYK for offset presses.

#### 3.5.3.1 Application

Make sure you are using the same application you will use for your print job. You never know if the application or a utility is massaging the data before placing it on the wire to the printer.

#### 3.5.3.2 No color correction

Make sure that no color conversion or management occurs anywhere. In this step you are characterizing the raw device.

- Verify the color management properties and the application properties in the print dialog
- Save files without embedding ICC profiles (there is a script to un-embed profiles in the right screen)

### 3.5.4 Measure the chart

This is the target you just printed.

#### 3.5.4.1 Place chart on SpectroScan

Place the print on the SpectroScan (any orientation) and select SpectroScan in the ProfileMaker “Read” pop-up menu

- The illuminant should be D<sub>50</sub> if you are in the US (see Table 2 on page 12)

**3.5.4.2 Lower spectrophotometer**

With the SpectroScan off-line, lower the Spectrolino. The measurement must be in contact with the reference white for the calibration.

**3.5.4.3 Set up spectrophotometer**

- Click on the “Setup” button
- Click twice (with 10 second pause) on “calibration,” then on “test”
  - Assert the validity of the test measurement
- Check the box “use sight utility”

**3.5.4.4 Define chart geometry**

- Press start
- Position on patch A1 and press “enter” on the SpectroScan
- Position on A21 and press “enter”
- Position on T21 and press “enter”
- The chart is now measured (duration: approximately 20 minutes)

**3.5.5 Save measurement data**

Save the data in folder ProfileMaker/Measurement data/Printer.

**3.5.5.1 File identifier**

Give the data file the same name as the profile and make sure you store it in the correct folder (not the ICC profile folder). This file contains the colorimetric data of your chart, not the device profile.

**3.5.5.2 Using a dedicated measurement PC**

You can also perform the measurements on a different PC with just the SpectroChart application. That application contains a database to manage your data (very useful when you are experimenting with inks or papers) and gives you total freedom to design your own charts or use somebody else’s charts (currently ganglion.hpl.hp.com is set up for this).

**3.5.5.3 Averaging measurements**

If you certify your spectrophotometer (see HPL-1999-2) you only need to measure once each patch. However, you might need to average over several print-outs of the chart if the printer is not self-calibrating:

- Color laser and liquid toner printers tend to be less stable and you can use ASTM Standard practice E 1345-90 to determine the number of charts you need to measure and average
- Dye diffusion/thermal transfer (D2T2) printer heads have a thermal memory; print the chart rotated by  $\pi$  and average the two measurements
- In thermal inkjet printers the actual dither patterns and the temporal sequence of dot placement may depend on the print direction; print the

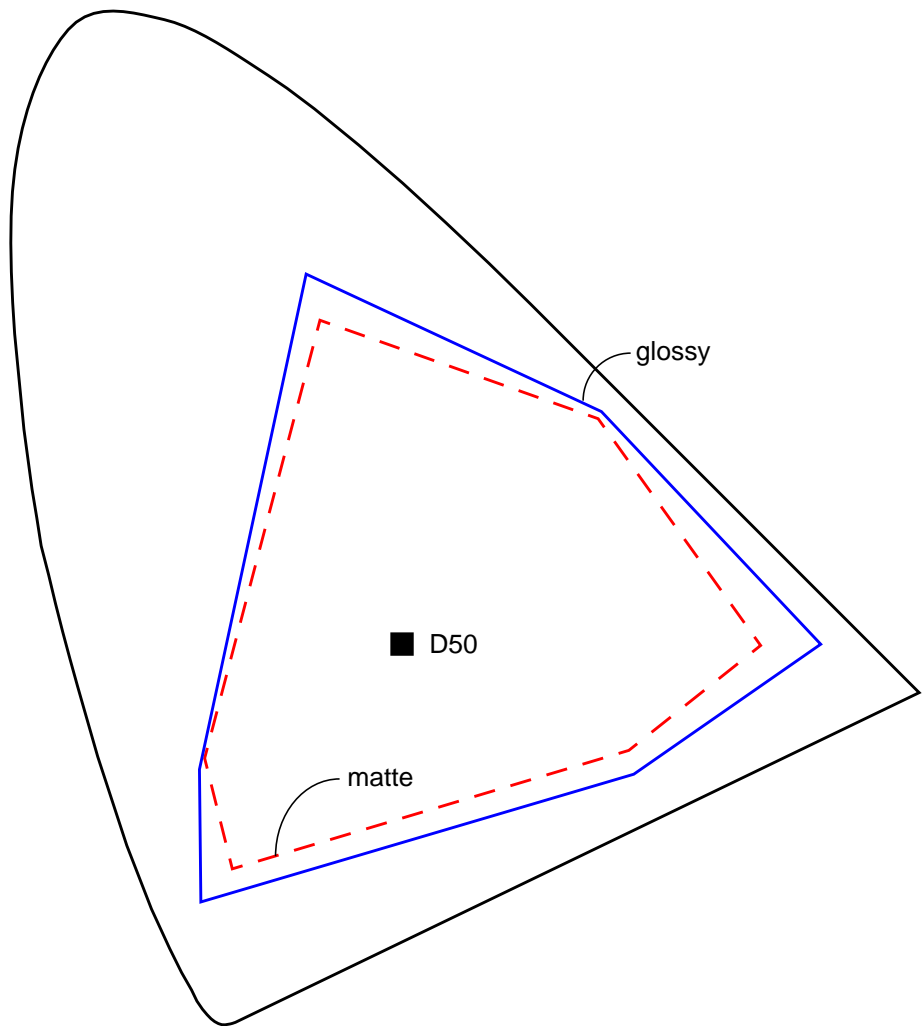
chart at the four  $\pi/2$  orientations and average the four measurements; you may also want to use ASTM Standard practice E 1345-90 to determine the number of charts you need to measure and average in each orientation

- You cannot average over print quality settings and media types; you need to generate a separate ICC profile for each combination (see Section 3.5.8 on page 21)

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FIGURE 2.

Gamut of a premium paper in a glossy (outer polygon) and a matte finish



### 3.5.6 Name profile

Select a meaningful printer profile name prefixed by “ITD,” e.g., “ITD 930 Glossy” or “ITD 2500 Matte Heavy.” In this example the name is composed

of the ITD acronym for implicit grouping, the printer model number, and the media.

**3.5.7 Compute profile...**

Calculate the printer profile; an ICC profile will be stored automatically in your profile folder.

**3.5.8 ...for each paper**

Repeat for each paper you use. Each paper interacts differently with a given ink and will generate different densities and different dot patterns. In Figure 2 you see a chromaticity diagram with two gamuts. They refer to the same paper used in the same printer; the outer gamut is for the glossy finish of the paper and the inner gamut is for the matte finish.

The relative densities for each dither pattern are also very different for the two finishes. The process black density on the paper is 1.85 on the glossy paper and 1.38 on the matte paper. If we use a photo paper in the same printer, we can achieve a density of 2.15 for process black.

It is clear that with such differences in the color gamut, the ICC profiles of a printer will be quite different for the various papers.

**3.5.9 ...for each printer**

Repeat for each printer you use.

**3.5.9.1 Digital printers are RGB**

Remember, Hewlett-Packard printers are sRGB printers, and sRGB is an RGB space, so use the RGB target, not the CMYK or CMY target. Figure 3 on page 22 shows how the color gamut changes when we print 100% red, yellow, green, cyan, blue, and magenta with the same high-end printer on the same premium paper using either the RGB, CMY or the CMYK color space without color management. This data was obtained by sending raw counts from the application and turning off any color management.

We can understand why the gamuts are so different when we look at the rendering of 100% of the primary colors. Figure 4 on page 23 shows the measured patches under a 200× microscope. The equipment is somewhat old and not in its best condition, so the image and color quality is poor, but it is sufficient to understand what is happening in the printer.

In the left column the CMY patches show that 100% cyan and yellow are printed with spurious amounts of magenta, while 100% magenta is printed with a non-zero percentage of cyan. This explains why a larger gamut is obtained when the RGB color space is used to specify color.

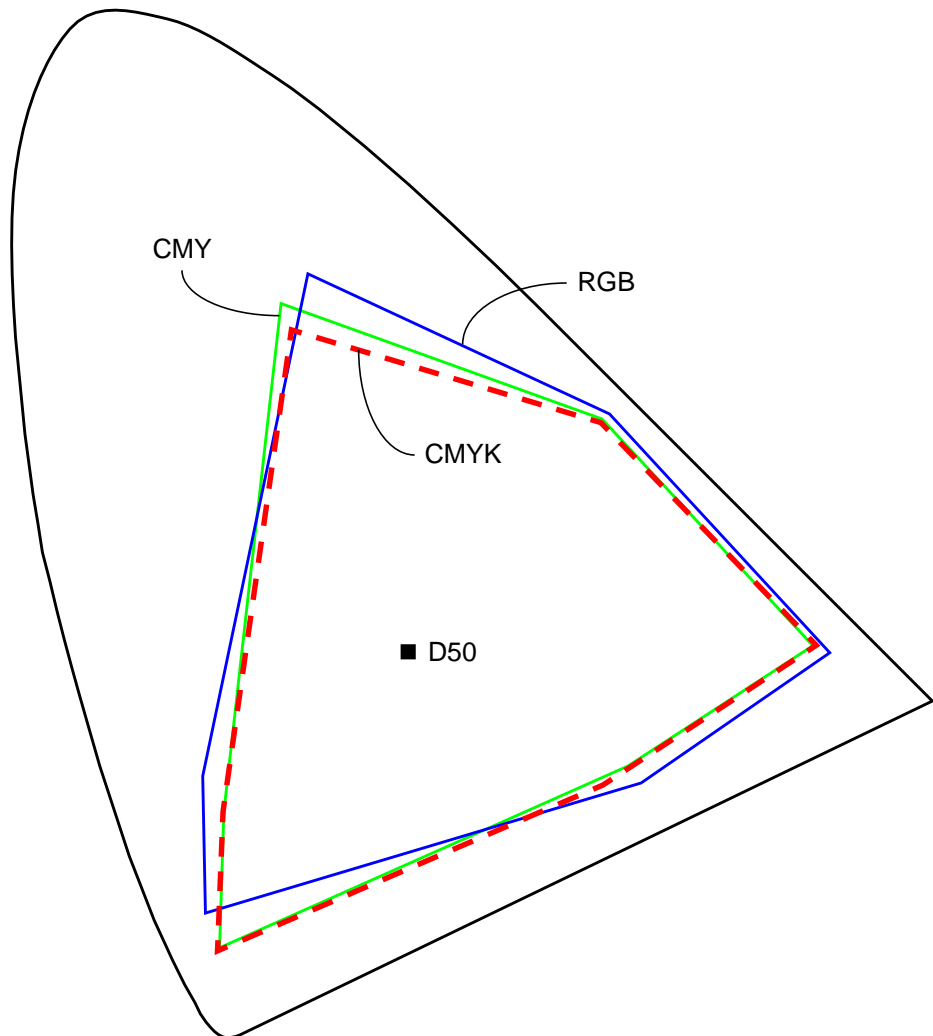
The RGB patches show that the ink coverage is not complete even when the RGB color space is used. Effectively this desaturates the ink colors because white from the background is added, with a net result of a reduced gamut.

This behavior might change when you upgrade your operating system, printer driver, printer firmware or even the pen.

---

**FIGURE 3.**

When the color space is changed, a given color specification will yield a different color. No color management is used

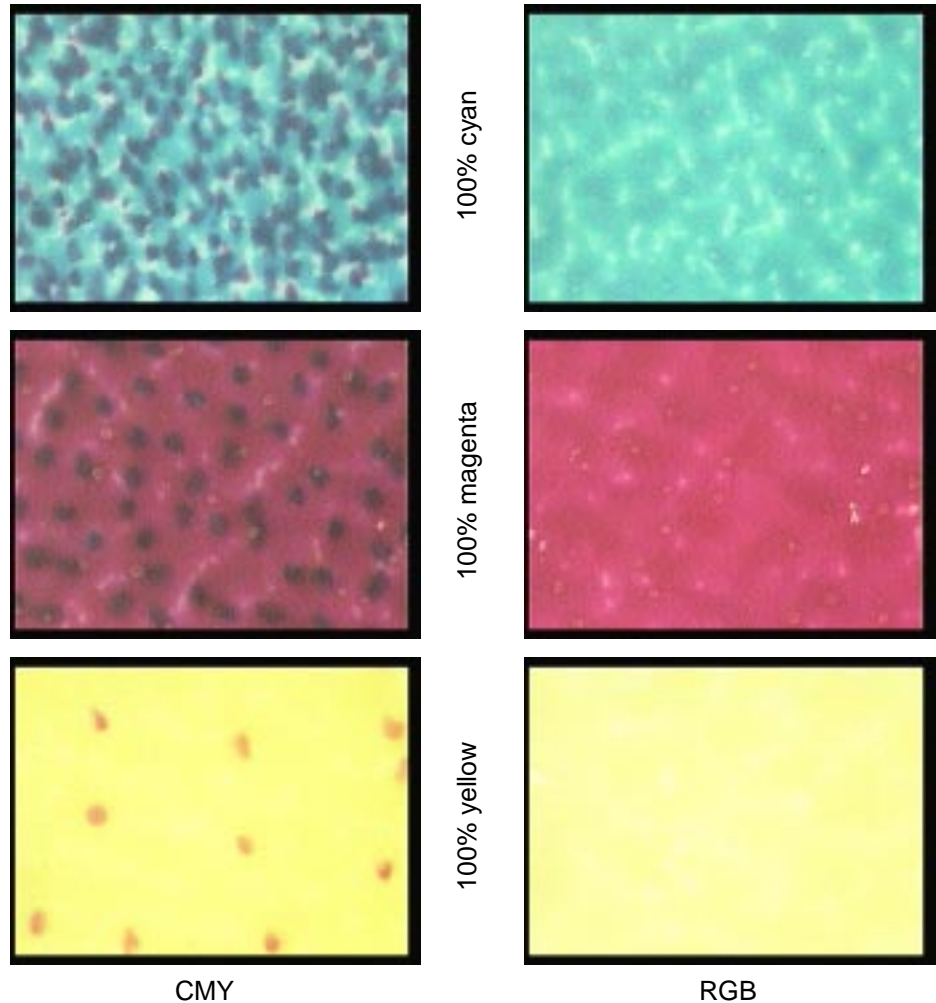


### 3.5.9.2 Printer drivers

Generate your own PCL to achieve a larger gamut. Printer drivers have to optimize a large number of parameters; for a high quality job you want to optimize mostly for color quality.

FIGURE 4.

Rendering of 100% cyan, magenta, and yellow using the RGB and the CMY color space. No other parameters have been changed. The difference in color is due to poor calibration of the video camera (white balancing)



### 3.6 Calculate monitor profile

You have to repeat the steps below for every monitor attached to your system. To avoid problems with adaptation in your visual system, you want to have all monitors to be colorimetrically equivalent.

Read the next five paragraphs if you think you do not need a profile for your monitor, otherwise proceed to the next section.

You may think all you need to do is to calibrate your monitor. Indeed, this is only the first step. After you have calibrated to a standard white point like

$D_{65}$  and adjusted the offset and gain for the three guns, you still need a profile for the steps from your application's data structure to the monitor.

Today's display controllers for general purpose computers are optimized for rendering 3-dimensional geometry at a very fast pace, not for color fidelity; as long as it gushes realistically from wounds, the accurate colorimetry of blood is irrelevant. The tone reproduction may be less accurate than you suspect.

As Alan J. Perlis used to explain, complex software systems like operating systems are not maintained according to a pure architecture; instead, they evolve like organisms. Alan coined the term *organithm* for such a system, a contraction of organism and algorithm.

We can see this clearly in the case of monitor device drivers. The system's original architects may probably have implemented a driver for a simple display controller with just three digital-to-analog (DA) converters. When later first one then three look-up tables (LUT) were added, a module for controlling the gamma might have been added in a layer at the top of the system, rather than negotiating a new driver with an "owner" of the original driver, who might be paranoid about compatibility and performance for bare-bones machines.

Each improvement is thus added on the top as the organithm grows and evolves. Now there is no way to reliably predict the system's colorimetry other than by calculating a monitor profile, to cut the bull's head as they say in Italy.

### **3.6.1 Warm up time**

The monitor must have been powered on for at least half an hour.

### **3.6.2 Set white point**

Set the monitor's white point to  $D_{65}$  using the controls on the monitor. The out-of-the-box default is often  $D_{93}$  to make the monitor look brighter (the same energy is applied to all guns).

### **3.6.3 Do not pollute you retina**

The monitor background (a.k.a. wallpaper) must be a neutral gray (see Table 2 on page 12 for recommended values).

### **3.6.4 I cannot dim my work place**

If you use a glare filter because it was decided you work with manufacturing lighting, keep this filter in place for all calibration steps. You want the spectroradiometer to see what you see. You should also consider building your ICC profile visually (see Section 2.2 on page 12).

### **3.6.5 Set up display controller**

Open the "Monitors & Sound" control panel and click on the "Color" icon.

**3.6.5.1 Baseline characterization**

This is a little bit ugly, but one day this legacy code will be redesigned.

- Chose a profile close to that of your monitor and click “Calibrate”
- Follow the instructions on the screen to generate a visual calibration, i.e., setting the offset, gain and gamma for your viewing conditions

**3.6.6 Real characterization**

In ProfileMaker, select “calculate monitor profile” and enter a meaningful name with an “ITD” prefix, e.g., “ITD Studio 17 D65 Vu-Tek” or “ITD Ultra VGA 1280.”

**3.6.7 CRT non-uniformity**

Make sure the patch is in the middle of the screen.

**3.6.8 Set up spectroradiometer**

**3.6.8.1 Instrument selection**

Select “Spectrolino” in the “Read” pop-up menu.

**3.6.8.2 Calibration**

In a first step the Spectrolino is calibrated on its white reference.

**3.6.8.3 Instrument application**

Affix the Spectrolino on the display’s front glass using the supplied suction attachment.

- The attachment is fragile, we already junked one
- Do not put spit on your faceplate, it may leave a permanent mark in the anti-glare coating

**3.6.8.4 Instrument connectivity**

The Spectrolino can be tethered from the SpectroScan or attached directly to the PC.

**3.6.8.5 Perform measurements**

Follow the instructions on the screen. Essentially, a sequence of patches is displayed on your screen and automatically measured. The measurements are kept in memory.

After ProfileMaker has performed all measurements, it calculates a profile and stores it in the ICC profile folder.

**3.7 You are done characterizing**

At this point you have created profiles for your devices.



### 3.8 Reboot

Quit ProfileMaker and reboot the computer to flush all color management caches.

### 3.9 Checking on a profile

If you want to see the information about a profile, open the profile folder and drag the profile on top of the droplet "Show profile info."

#### 3.9.0.1 Profiles must be registered

This script only works if the profile is in the profile folder, i.e. known to ColorSync or ICM.

#### 3.9.0.2 Script can be used also on embedded profiles

You can use this droplet for any image that can embed a profile to get the information on its embedded profile.

- The currently supported file types are TIFF, JPEG (JFIF), and GIF
- EPS,<sup>1</sup> PDF, PICT, and PSD are not yet supported by this droplet, but you can embed ICC profiles in them

### 3.10 Digital cameras

You can create a profile for a digital camera using the same steps as for the scanner. This is meaningful only if you are working under controlled conditions; in technical report HPL-97-164 we have described how to build a portrait studio for digital photography.

## 4.0 Step Two: Set up the operating system's color management system

---

A color management system uses the input and output profiles to convert with a CMM the color counts so that the original image's colors closely match those of the copy's. Due to gamut differences, non-linearities, and performance requirements, this color matching conversion is more art than science.

When I implemented my CMS in 1987 I was very lucky, because I had direct access to all source files for every single instruction executed on the computer. All I had to do was to change Cedar's ColorImager to use device independent color and call the various color management functions I wrote. The device profiles had a descriptive file name and a simple data format. Everything was implemented using registration/callback mechanisms, so it was easily extensible at run time. Since I had also access to all application pro-

---

1. In a PostScript workflow you normally use color rendering dictionaries (CRD). ProfileMaker can calculate CRDs in addition to ICC profiles.

gram sources, I could extend them to control the CMM parameters. The complete user instructions easily fit on a single page.

In today's competitive commercial world the situation is much harder: turfs are established, information is secret intellectual property, and committees fight out interfaces known as APIs or application program interfaces. Even operating systems are compartmentalized and designers have access only to "their code."

One consequence of this modus operandi is that interfaces wander as openness changes (or implementors change employers). The complication for the user is that some functions are controlled by a color management system bolted on top of the operating system (OS) and some functions are implemented in the application. Still other functions are not available, like Windows NT 4, whose hardware protection shield prevents CMSs to interface the display controller.

There are three kinds of CMSs: integrated in the OS, stand-alone, integrated in the application. "Integrated in the application" is often called "built-in," which is fitting because the code is usually bolted on whatever piece of software the designer has access to, rather than being embedded in the overall architecture.

In general it is best to install all CMMs and use the CMM targeted when an ICC profile was built. The reason is as follows. The ICC profile format was reached by consensus and limited by intellectual property concerns. Profile makers can improve their CMM's performance by adding private hints in a profile. Due to the private nature, only a given manufacturer can take advantage of a given hint and achieve superior color rendering.

In this section we set up the CMS integrated in the OS, following the above guidelines.

## **4.1 Open the ColorSync control panel**

On the Windows operating systems, this control panel is called ICM.

## **4.2 Select the "profiles" tab**

### **4.2.1 The "System Profile" pop-up menu**

The "System Profile" pop-up menu can be used to specify the monitor's profile. However, the CMM may not have access to all display controller functions (e.g., the gamma), so this parameter should not be set here. Treat the CMM's system parameter as read-only.

#### **4.2.1.1 Select the monitor profile in "Monitors & Sound"**

Use the "Monitors & Sound" control panel to select the monitor profile you built in Step One.

**4.2.1.2 If you have more than one monitor, specify the one you use for previewing**  
Normally, you use one monitor for the image(s) you are working on and one for the various control panels. You may want to use the faster display controller for the main monitor.

**4.2.2 Set the default RGB color space**

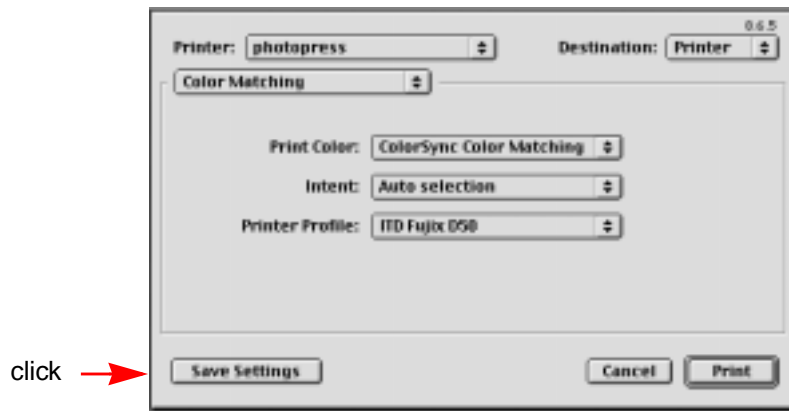
The “RGB Default” pop-up menu is used to specify the color space of images that do not have an embedded profile or whose profile is unknown.

- This parameter is only the default for application's open dialog and can be changed when a file is opened
- This handles legacy files, created before using managed color; enter the color space of the device used to create your images
- Since we use the scanner application with manual control without embedding a profile, it is convenient to set this parameter to the scanner profile
- The most convenient method to embed a profile in an image is to simply drag it on top of the appropriate droplet on the computer's desktop
  - These droplets are simple scripts that just embed an ICC profile in an image, describing the input device's color space
  - The image data itself is not converted by these scripts and a file can be restored by un-embedding a profile (yes, there is a script to do this)

---

FIGURE 5.

Printer set-up on the MacOS



**4.2.3 Set the default CMYK color space**

The CMYK default pop-up menu is used to similarly set the default profile for generating CMYK separations.

- Note that digital printers such as LaserJet, DeskJet, and Pictography are treated as RGB devices
  - For these printers the CMM is not called by the application but by the printer driver instead

#### 4.2.3.1 How and when to specify the printer's ICC profile

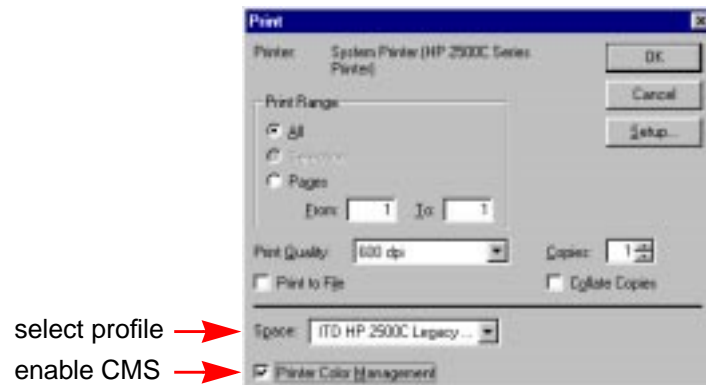
The user interfaces are shown in Figure 5 for MacOS 8.6 and in Figure 6 for Windows 98.

- Each time you print an image, you specify the printer's profile
  - In the print dialog, select the "Color Matching" panel
  - For "print color" select "ColorSync Color Matching"
  - Unless you know what you are doing, leave the intent on auto selection
- In the printer profile menu select the profile for this printer
- You may want to save these settings, since you probably rarely change the profile name for a given digital printer

---

FIGURE 6.

Printer set-up in Widows



#### 4.2.4 Specify the CMM

- Select the CMM tab
- For the reason explained earlier (hints), you want to leave the preferred CMM on the automatic setting
- Every application will then use the same strategy, ensuring that for example an image in InDesign will have the same appearance it had when you created it in Photoshop
  - For Apple and Microsoft operating systems, the built-in CMM is usually Heidelberg's
  - Photoshop ships with Kodak's CMM, but there is also a built-in CMM from Adobe
  - PageMaker's built-in CMM is Kodak's
  - Illustrator's and InDesign's built-in are two different versions of Adobe's RB2Connection CMM

## 5.0 Step Three: Set up the application's color management system

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You should read the sections on color management in the manuals of the applications you regularly use. The notes in documents are just a summary to get you running immediately, but they do not attempt to explain what the various applications do in terms of color management and in particular the semantics of the various user interface elements. Reading the manual allows you to become familiar with a particular implementor's understanding of color management.

### 5.1 Photoshop

The application we consider here is Photoshop 5.0.2 and 5.5. In other applications like PageMaker, Illustrator, InDesign, QuarkXPress, etc. the basic principles are similar, but unfortunately the implementations and user interfaces are still different at this time. We are sure, in the near future all applications will be harmonized on all platforms.

Color is managed at the moment files are opened or saved, or as an explicit image transformation. Therefore, once we have set up the ICC profiles and the CMS, the application is where it is decided what happens to color. Consequently, it is very important to understand what happens here, otherwise you do not have control over color.

I have read the Photoshop manual and Adobe's various documents on color management, but when I actually went and looked at what Photoshop does, there is not full agreement. In the following I am not describing what is in the documentation but what I think Photoshop does. Of course I do not have access to the source code, so I might be making incorrect assumptions.

When I added color management to Cedar, I was lucky. Warnock and Wyatt had written a very well structured Color imager, where color was a completely encapsulated class that was very high up in the class hierarchy and low in the system architecture. Applications were simply drawing in contexts and treating color as an abstract object. I was running the code on a very powerful Dorado, Russell Atkinson had added a lot of caching in Stone's gamut mapping, and Lamming had implemented a super-fast color matching module.

With this I could implement and debug the entire CMS in just two months, including achieving compatibility in all applications. My profile connection space was CIELAB and this was also the de facto working (a.k.a. native) color space for the applications. The color path looked as shown in Figure 7.

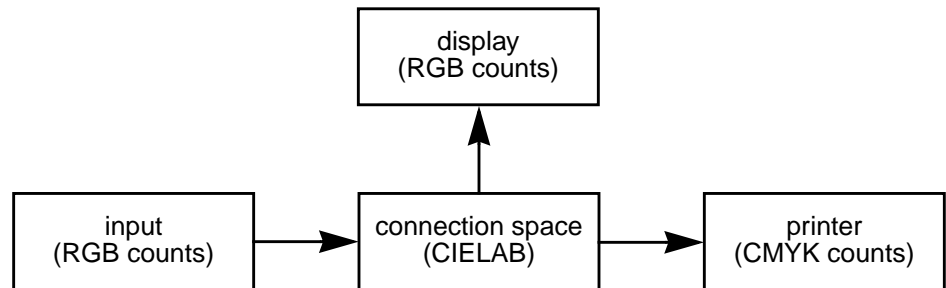
By contrast, Photoshop had to run on a slow Macintosh SE and probably Adobe did not have access to the underlying system. In fact, for example in

Windows nobody can access the display controller because of the hardware protection shield.

---

FIGURE 7.

A simple CIELAB based color path



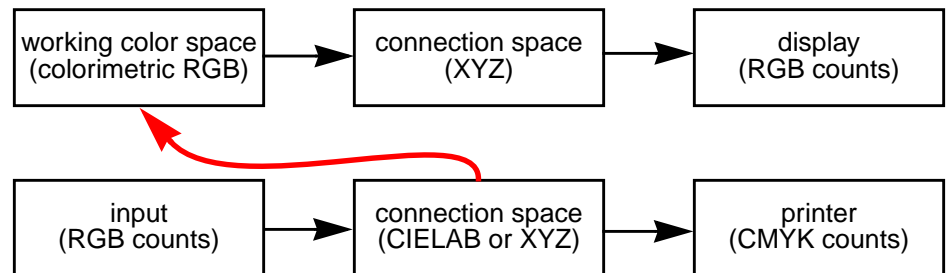
So Photoshop does not work on the connection but instead on what in the documentation is variously called the working color space or the native color space. Before color management, Photoshop had only one single color space, namely the display's device color space.

To achieve a certain degree of device independence while maintaining the efficiency of operating on RGB counts, Adobe introduced an abstract color space, namely this *native or working color space*, which refers to an ideal display. The color path then looks as shown in Figure 8:

---

FIGURE 8.

A color path based on a display-independent working color space



When an image is opened, it is converted to the RGB color space that is specified as the working color spaces. All operations take place in this space. When the image is saved, the data is in this working color space and the ICC profile for this space is embedded in the file. There is one important *exception*; when the image is converted to CIELAB instead of RGB, then the image is saved in the CIELAB color space, and the CIELAB ICC profile specified when the file was opened, is embedded in the file.

The *display color space* is the device dependent RGB space for your particular monitor that you measured in step one and set as the system RGB profile in step two. Since your monitor changes as your phosphors age, you change the controls or the viewing conditions, this is an ephemeral space. The working color space is that of an ideal monitor that never changes and is the same for everybody working with the image. The transformation from working color space to display color space occurs on the fly through an XYZ connection space.

The choice you have to make is that of an adequate working color space.

### 5.1.1 RGB color spaces

The differences between these various RGB spaces are:

- gamut size
- white point
- gamma non-linearity

Table 3 shows the characteristics of a few color spaces, while Table 4 shows the chromaticity coordinates of the various phosphors. The gamuts are plotted in Figure 9.

---

**TABLE 3.**

Characteristics of some RGB color spaces

Color space	Phosphors	White point	Gamma
Adobe RGB	SMPTE-240M	D <sub>65</sub>	2.2
ColorMatch	P22-EBU	D <sub>50</sub>	1.8
sRGB	HDTV (CCIR 709)	D <sub>65</sub>	2.2
Wide Gamut	n/a	D <sub>50</sub>	2.2

---

**TABLE 4.**

Chromaticity coordinates of the phosphors in Table 3. The gamuts are plotted in Figure 9

Color space	Red		Green		Blue	
	x	y	x	y	x	y
Adobe RGB	0.6400	0.3300	0.2100	0.7100	0.1500	0.0600
ColorMatch	0.6300	0.3400	0.2950	0.6050	0.1550	0.0770
sRGB	0.6400	0.3300	0.3000	0.6000	0.1500	0.0600
Wide Gamut	0.7347	0.2653	0.1152	0.8264	0.1566	0.0177

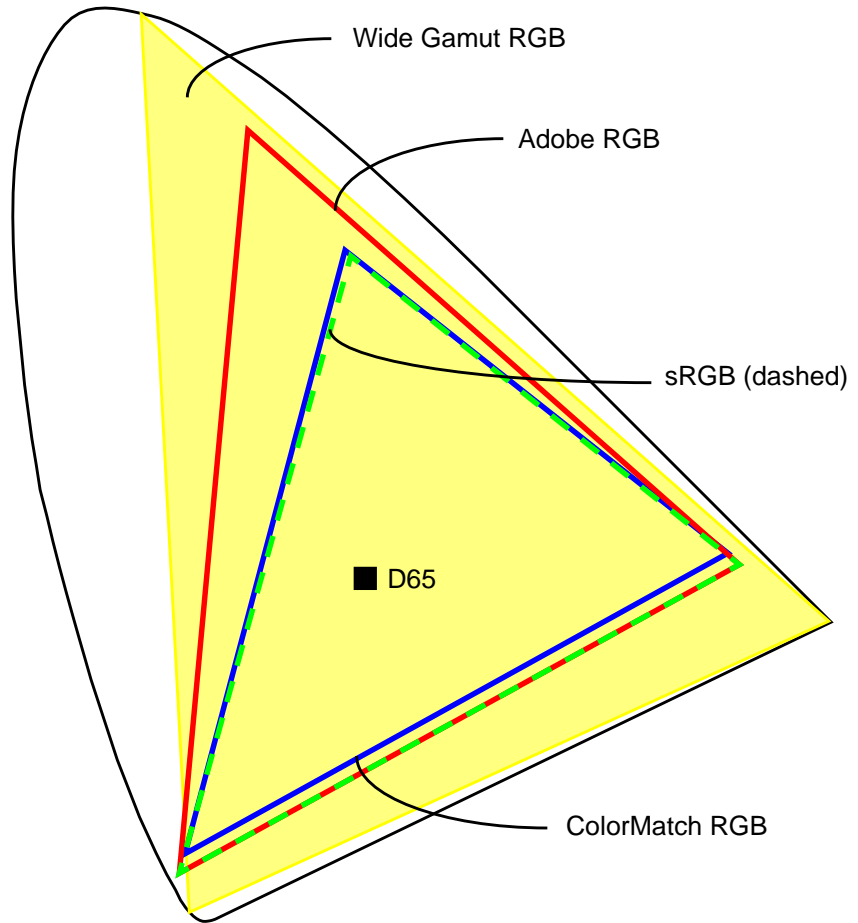
**5.1.1.1 sRGB**

The default is sRGB. I do not recommend this color space for graphic arts applications because it has a very small gamut; a large number of colors you get from the scanner will get lost during the gamut mapping.

---

**FIGURE 9.**

Graphical illustration of the gamuts in Table 4



**5.1.1.2 Wide Gamut RGB**

You could use the Wide Gamut RGB device space to capture a large gamut. However, this gamut is much larger than any real world display gamut; when you edit colors, you will not see a change on the display for vivid colors, because they are clipped.

**5.1.1.3 ColorMatch RGB**

If you pass on the image to a graphic arts or pre-press shop, consider to use the ColorMatch RGB device space; this is close to the displays common in the graphic arts. Note that the white point is  $D_{50}$  and the gamma is 1.8.



#### 5.1.1.4 SMPTE-240M (Adobe RGB)

If the image remains on site, I recommend to use the SMPTE-240M (a.k.a. Adobe RGB 1998) color space.

- Its wide gamut ensures you do not discard colors from the scanner
- The gamma and white point are the same as that of our display
- But: watch out for out-of-gamut colors when you edit

In any case, I recommend to manipulate and archive images in the CIELAB color space.

#### 5.1.2 Working with an image

Now we are ready to actually work with Photoshop. We first review what happens when a file is opened, then we describe the settings and finally we return to opening a file.

When an image is opened, acquired, or imported, the color space of the embedded ICC profile, or *defined color space* for short, is compared to the working color space

- If the two spaces are the same, no color matching (a.k.a. conversion) occurs
- If the defined color space is CIELAB, the color is converted to CIELAB
- If the defined color space is RGB, then the color is converted to the working RGB color space

---

FIGURE 10.

A PhotoCD contains a virtual Photo folder with Pict images



Name	Date Modified	Size	Kind
APPS	Fri, May 17, 1999, 11:47 AM	12.2 MB	folder
Photos	Fri, May 17, 1999, 11:47 AM	918.4 MB	folder
1536 x 1024	Fri, May 17, 1999, 11:47 AM	267.1 MB	folder
192 x 128	Fri, May 17, 1999, 11:47 AM	14.2 MB	folder
3072 x 2048	Fri, May 17, 1999, 11:47 AM	512.2 MB	folder
384 x 256	Fri, May 17, 1999, 11:47 AM	28.5 MB	folder
768 x 512	Fri, May 17, 1999, 11:47 AM	96.1 MB	folder
PHOTOSHOP	Fri, May 17, 1999, 11:47 AM	509.7 MB	folder
IMAGES	Fri, May 17, 1999, 11:47 AM	504.0 MB	folder
IMG0001.PCD;1	Fri, May 17, 1999, 11:47 AM	3.9 MB	document
IMG0002.PCD;1	Fri, May 17, 1999, 11:47 AM	4.3 MB	document
IMG0003.PCD;1	Fri, May 17, 1999, 11:47 AM	4.5 MB	document
IMG0004.PCD;1	Fri, May 17, 1999, 11:47 AM	4 MB	document
IMG0005.PCD;1	Fri, May 17, 1999, 11:47 AM	4.4 MB	document

#### 5.1.3 Importing a PhotoCD image

A PhotoCD is mounted with two appearances. As shown in Figure 10, One folder is called "Photos" and contains folders with the images at various resolutions. If you open one of these images, it will be converted by QuickTime from the YCC color space to the RGB color space using the generic transformation. Especially in the case of transparencies you will get inferior results.

Instead, you want to open the actual PhotoCD image packs, which are in the folder "PHOTO\_CD:IMAGES." By doing so you be using Kodak's Acquire module to produce an optimal color space transformation for the image.

When in Photoshop you open an image and navigate to an image, you get a dialog window as shown in Figure 12. On the left is the selected image's thumbnail and on the right are three containers with buttons outside their margins.

---

FIGURE 11. PhotoCD image information example



The PhotoCD container has four items

- Image: number of the image pack to be opened
- Image size: resolution of the image to be extracted from the pack
- File size: uncompressed size of the extracted raster image

---

FIGURE 12. PhotoCD Acquire dialog



Select the image size and click on the info button. You will get a window like the one shown in Figure 11. Reputable PhotoCD transfer services enter all relevant scanning information on each image's pack. If precise information is lacking, you can go by the product type. For reversal medium,

- if the first three digits in the product type are 116, the original was Kodachrome

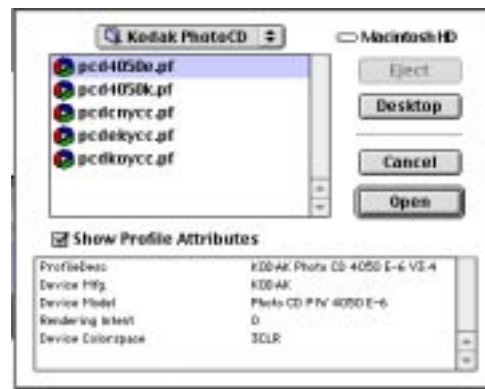
- 052 indicates Ektachrome or another brand

The second panel lists the source ICC profile. You need to find the ICC profile that is the closest match to the data in the information panel. Click on the source button to list the available ICC profiles to start a dialog like shown in Figure 13. You can find a number of profiles for PhotoCD in the “Kodak PhotoCD” folder inside the profile folder. Check the “Show Profile Attributes” box and compare the attributes with the image information.

---

FIGURE 13.

PhotoCD source dialog



The final step is to determine a profile for the destination color space (see Figure 14). A recommended destination profile is “Generic LAB” for a device-independent color space, or you can select the working (a.k.a. native) space (see Figure 8 on page 31) which will add an extra conversion.

As you can notice, Kodak’s granularity for the scanning parameters is quite coarse. If you work in a controlled environment, you can shoot an IT8 target and calibrate the entire process like a digital camera.

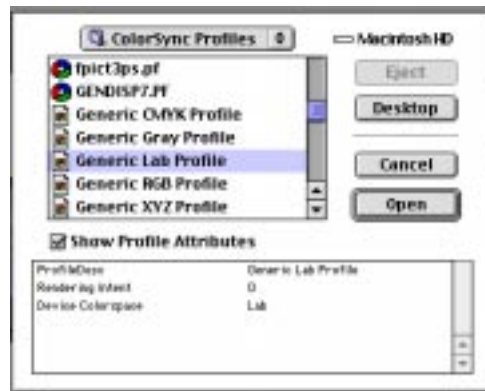
#### 5.1.4 Things to remember

- When an ICC profile is inserted in an image file, we say the profile is *embedded*; the color data remains unchanged, because the profile simply describes the device’s color space; you can easily write a script to embed profiles in your legacy images
- When the profile is applied and the color data is converted, we say the image is *matched* to a new profile
- When an image is saved, it is not converted back, instead the profile of the working space is embedded
- When an image is displayed, it is matched dynamically to the (system profile) display monitor profile specified in step two
- When an image is printed, it is matched to the printer’s profile

- When an open image is matched from one arbitrary ICC profile to another arbitrary ICC profile using the “Profile to Profile” command in the “Mode” sub-menu of the “Image” pull-down menu, then when the image is saved the working color space's *ICC profile is incorrectly embedded*; after saving the image you have to drag it to the “Unembed profile” drop-dlet and insert the correct ICC profile via a script

FIGURE 14.

PhotoCD destination dialog



The color information in an image is discrete. For example, in a 24 bit RGB image, the color values for red, green, and blue are each represented as an 8-bit unsigned integer. When a color is transformed, quantization errors are introduced and the image quality is degraded.

In the CIELAB color space a perceptually lossless representation (i.e., topologically compact color gamut) requires 8 bits per channel. In RGB 12 bits per channel are required, while in XYZ (the connection space for monitors) 16 bits per channel are required.

This yields two rules:

- Always convert an image as few times as possible
- If color quality is crucial and you must work in RGB, open the image without conversion, change the mode to 16 bits per channel, then perform the conversion using the “Profile to Profile” command in the “Mode” sub-menu of the “Image” pull-down menu

With this preamble we are now ready to enter the application's set-up information.

#### 5.1.5 Setting up Photoshop

In the “File” pull-down menu chose the “Color Settings” sub-menu, and there “RGB Setup...”

**5.1.5.1 RGB setup**

- This panel is used to control how color is displayed
- For RGB select “Adobe RGB (1998)” or “SMPTE-240M”
- Do not change gamma, white point, nor the primaries
- Check the box at “Display Using Monitor Compensation”; this enables the dynamic matching from the working color space to your monitor's effective color space as determined in step one

**5.1.5.2 CMYK setup**

The CMYK setup is only for creating separations for a press. Leave this setting alone. The recommended workflow is to give a CIELAB or RGB file to the printing company and then let them use their fine-tuned curves.

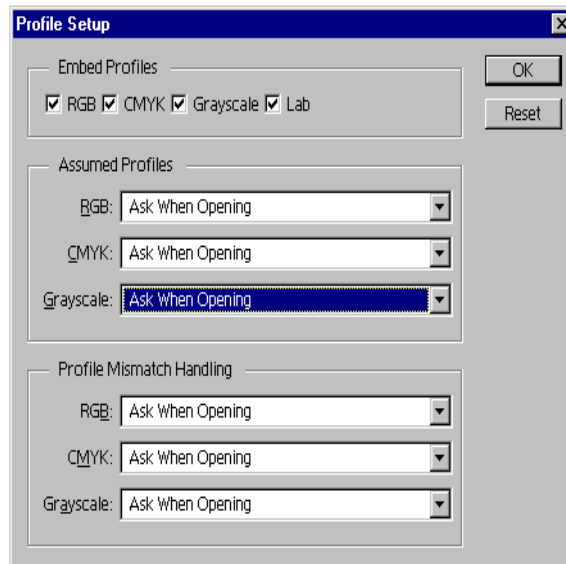
**5.1.5.3 Grayscale setup**

In “Grayscale Setup” select the RGB grayscale behavior; the black ink option is only for separations, where it is necessary to take into account dot gain

---

**FIGURE 15.**

Recommended profile set-up for our workstation



**5.1.5.4 Profile setup**

The “Profile Setup” controls how to handle ICC profiles. Figure 15 illustrates the recommended set-up for our environment.

- “Embed Profiles”: check all boxes; you always want to embed a profile when you save a file
- The only exceptions are test charts and desktop elements such as icons

- “Assumed Profiles”: in ITD we work in a heterogeneous environment without workflow; we can never make a priori assumptions on missing files, so set all three fields to “Ask When Opening”
- “Profile Mismatch Handling”: some legacy files had been converted manually using curves or come from experimental drivers; also here each case has to be considered individually and the options should be set to “Ask When Opening”

#### 5.1.6 Opening a file

When a file is opened, with these settings one of the following cases occurs:

##### 5.1.6.1 File has an embedded ICC profile

The file was previously saved with a profile and matched, hence it opens without a dialog.

##### 5.1.6.2 File does not have an embedded ICC profile

There is no embedded profile; the “Missing Profile” dialog comes up, defaulting to no conversion

- If the image was color corrected, click on “Don’t Convert”
- If it was not, select
  - The closest profile to the creation situation for the “From” option
  - “Lab Color” for the “To” option
  - ColorSync engine
  - Perceptual rendering intent

##### 5.1.6.3 The embedded profile does not match the current RGB working color space setup

If you followed the previous steps, the defaults are set up correctly:

- From: input device's ICC profile
- To: Lab color
- Engine: ColorSync
- Intent: Perceptual
- No black point compensation (does not yet work reliably)

Click on “convert” to match the colors

## 5.2 Illustrator

Illustrator 8.0 ships with a built-in CMS from Adobe called RB2Connection. Follow these steps to set up color management

### 5.2.1 Set-up steps

In the “File” pull-down menu, select the “Color Settings...” command.

- Color management is turned on by checking the “Use embedded ICC profiles option” box

- In the monitor RGB menu select your monitor, e.g., “ITD Studio 17 D65 Vu-Tek”
- I do not recommend to use a CMYK workflow, so you can leave this on the default “Adobe Illustrator Printer Default”
- For the engine specify ColorSync
- You probably want to select the “Relative Colorimetric” rendering intent for illustrations
- Make sure the box “Simulate print colors on display” is *not* selected
  - This options converts the illustration with the CMYK profile, then back to the monitor RGB
  - Simulation is used to gauge the effect of gamut mapping
  - The more common term for this feature is “softcopy”

## 5.3 InDesign

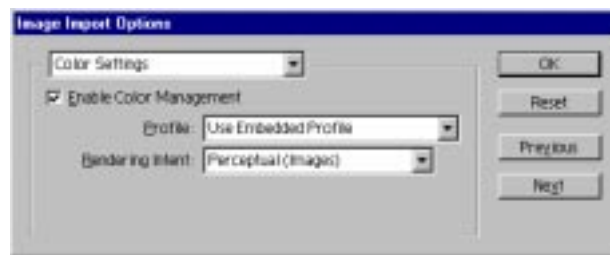
### 5.3.1 Raster image setting

InDesign allows you to manage each raster image with its own ICC profile. However, on the monitor color will be managed only if the display option in the general preference is set to “Full Resolution.” Figure 16 shows how InDesign allows you to change the ICC profile during image import.

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FIGURE 16.

InDesign allows you to set color options when importing an image



### 5.3.2 Document setting

Color management is enabled on a per document basis when the document is created. Figure 17 shows the document color settings dialog window, where you must check the “Enable Color Management” box. The source menus are used to specify the default for imported raster images and the profiles for artwork created in InDesign. As for rendering intent, the most obvious choices are as for Illustrator (solid color) and Photoshop (images).

### 5.3.3 Application setting

Finally, color management must be set up at the application level with the dialog shown in Figure 18. Use the same CMS engine as for the other applications and set the monitor profile to that of your display and the composite profile to that of the RGB printer you use for proofing.

- The first option is for softcopy (see Section 5.2.1 on page 39)
- The second option is for simulating the press on the proofing device, a step I do not recommend

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FIGURE 17.

Color management must be enabled explicitly for each document



- Finally, the third option will embed the input profile for each raster image into the PostScript file and let the proof printer's raster image processor (RIP) perform the color matching based on its downloaded color rendering dictionaries
  - You normally do not download the dictionaries with each print job, but each time you characterize the printer

## 6.0 Step Four: Communicating the job

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With the previous steps you have created a piece whose color is device independent. The last step is to pass on your work to the customer. This step has changed considerably in the past five years, as we have progressed from electronic publishing to on-line publishing and digital publishing.

- in *electronic publishing*, the producer would give you color separation tables with ink specifications, black generation directives, and dot gain data; your deliverable would be a digital file with the CMYK data for that particular job
- in *on-line publishing* you target to the minimum common denominator color space sRGB



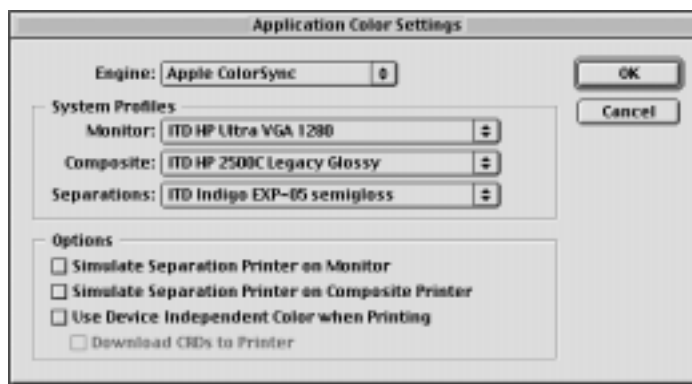
- in *digital publishing*, you retain the total color information so that your piece can be repurposed; the emerging ANSI standard file format for digital publication is PDF/X (CGATS12.1)

Here we are only interested in digital publishing. There currently are not yet any commercial products to create PDF/X files. Meanwhile, an easy way to create color device independent PDF files is to use Acrobat Distiller 4.0, which produces PDF 1.3 files.

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FIGURE 18.

Color management must also be set up at the application level



## 6.1 Configuring the Acrobat Distiller

- In Distiller, select a “Job Option” from an existing set close to your job, e.g., Press Optimized
- In the “Settings” pull-down menu, select “Job Options”
- Click on the “General” tab
  - For “Compatibility” select “Acrobat 4.0”
- Click on the “Color” tab
  - In the “Conversion” container, select the radio button “Tag Everything for Color Mgmt (no conversion)”
  - If your piece contains only images and black-and white text, chose the “Tag Only Images...” option; this prevents black text from undergoing color shifts and is my first choice
  - In the “Assumed Profiles” container, select the ICC profile you used as your working color space, e.g., SMPTE-240M or Adobe RGB
  - In the “Options” container, check at least the “Preserve Overprint Settings” option, just in case a CMYK object sneaked in your piece; the other options should not be necessary in a digital workflow
- Click the “Save As...” button to create a new set of job options

If your deliverable is hardcopy, all you have to do is specify your printer profile in the print dialog. As mentioned in step one for the profile creation, many digital printers today are sRGB devices. This is fine for home and business applications, but is restrictive for graphic arts applications. If you can, write your own PCL generator, so you can exploit the printer's full gamut. If you use a PostScript printer, ProfileMaker allows you to calculate a color rendering dictionary (CRD) that will let the printer's interpreter perform a color match, taking advantage of the full gamut.

Last but not least, remember that your end-users that will admire your piece in a Web browser will have viewing conditions very far from those described in Section 2.0 on page 11. In this case it is better to aim for color integrity rather than color fidelity.

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## 7.0 Acknowledgments

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As Johan Lammens pointed out at EI'99, commercial color management is still a nightmare that is in flux. Before you attempt any of the above at home, note the software version numbers I used; if yours are different, you need to find out how things have evolved. Acrobat: 4.0, ColorSync: 2.6.1, Illustrator: 8.0.1, InDesign: 1.0, MacOS: 8.6, MagicScan: 4.2, Photoshop: 5.0.2 and 5.5, ProfileMaker: 2.3.5, Windows: 98.