PDF/X, Characterized Printing Conditions & Color Management

The Trio that Provides the Foundation for New Workflows

by David McDowell, NPES/Eastman Kodak Company

A current IPA Webinar Series, being led by Mike Rodriguez of R.R. Donnelley, is called *PDF/X and Color Management* (for more information see www.ipa.org). With Mike's help I would like to build on that theme and provide additional resources relating to these topics.

First PDF/X

A lot has been written about PDF and PDF/X but it is always worth reviewing what PDF is, where it came from, and why some of us think it is so important for the printing and publishing industry.

PDF is the abbreviation used to refer to "Adobe Portable Document Format." It is a file format specification and is NOT any of the Adobe products such as Acrobat, Distiller, etc., that use PDF. Although Adobe has copyrighted the PDF manual they have also indicated it is their intention to promote the use of the Portable Document Format for information interchange among diverse products and applications. Adobe has given anyone copyright permission (subject to certain conditions) to prepare files; write drivers and applications; and write software that accepts input and displays, prints, or otherwise interprets the contents of the Portable Document Format.

If we are to have a file format for graphic arts data exchange that is robust and allows files to be exchanged unambiguously without any technical communication between sender and receiver, we must restrict what is allowed to be included in a PDF/X file.

The first PDF specification was published in 1993 and by 1996 CGATS and DDAP were in dialogue with Adobe to develop a subset of PDF for graphic arts data exchange. The existing standard for graphic arts data exchange, ISO 12639, TIFF/IT, which was developed by CGATS/IT8 and ISO/TC130, and endorsed and promoted by DDAP, was (and is) a raster data format that meets many of the needs of the high-end systems. However it is not friendly to desktop systems that often work more efficiently using vector data. What was needed was a file format that would allow both raster and vector based objects to be included and that would provide reliable exchange of print ready data without requiring additional exchange of technical information about the data. A PDF based data exchange format, with the emphasis on the "X" for eXchange, seemed like the logical solution and PDF/X was born.

The goal from the beginning was that PDF/X should always be a subset of PDF. In this way many of the tools and applications that worked with PDF itself would also support PDF/X. DDAP helped develop the requirements and provided "user" input to CGATS/SC6/TF1 which was responsible for developing the standard itself.

Many people have said "Why not simply use PDF? It has good support for color management, there are lots of tools available, it will do anything you want, so what is wrong with just using it?"

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That little statement "it will do anything you want" is the rub. If we are to have a file format for graphic arts data exchange that is robust and allows files to be exchanged unambiguously without any technical communication between sender and receiver (like the film separations of the 1970s and 1980s), we must restrict what is allowed to be included in a PDF/X file compared to an ordinary PDF file.

Time Inc. Support of PDF/X

In February 2002, Time Inc., one of the world's largest publishers, shook the advertising production world with its announcement that its preferred file format for digital advertisements for all of its 56 titles was PDF/X-1a, i.e., in accordance with ISO 15930-1. Recently, Time, Inc., has additionally announced that as of January 2004 it will only accept PDF/X-1a files (1000 - 2000 advertisements a week) and is seriously considering using PDF/X-3 for the transmittal of editorial content. This is a major commitment to, and support of, the standards effort.

Remember, the primary goal of the classic PDF file is to allow the receiver to do a reasonable job of reproducing the appearance of the data received with the available equipment. For example, if fonts used in the file are not available, the receiver can substitute the best available. If color reproduction is not available, black and white is OK. The color gamut of the receiving system is the gamut to be used for reproduction without regard to the gamut of the sending system. This does not meet the needs of the graphic arts which is used to having the appearance of the final reproduction predicted (proofed) by the sender.

The key requirement of the standards activity was to restrict the allowable options in PDF and provide the mechanisms to allow the sender to define the expected appearance of the final reproduction. This required interaction with Adobe to add features to PDF and to ensure there was a common understanding of the interpretation of existing PDF features. One example is that the PDF/X standards require that all fonts used must be embedded and that the embedded fonts must be used for output. With respect to color, this need also led to the addition by Adobe of the OutputIntents feature within PDF.

In addition, in developing the standard it was important to be able to define *exactly the capabilities that a reader needed to have to be able to accept any PDF/X compliant file*. Too many features and compliant readers would be too complex and expensive, too few and the general needs of the industry would not be met. The general rule of thumb used was to exclude all features that impeded print reliability. Things like motion, audio, transparency, encryption, etc., were all excluded on this basis.

The first PDF/X standard was published in 1999 as CGATS.12/1, *Graphic technology—Prepress digital data exchange—Use of PDF for composite data—Part 1: Complete exchange (PDF/X-1)* and was based on PDF Version 1.2. This attracted the attention of the international community and a new work item was created in ISO/TC130, Graphic technology, to create an international standard(s) based on the initial work by CGATS.

The current family of PDF/X standards is:
Graphic technology—Prepress digital data exchange using PDF:

- •Part 1: Complete exchange using CMYK (PDF/X-1 and PDF/X-1a);
- •Part 3: Complete exchange suitable for colour-managed workflows (PDF/X-3);
- •Part 4: Complete exchange of CMYK and spot colour printing data using PDF 1.4 (PDF/X-1a);
- •Part 5: Partial exchange of printing data using PDF 1.4 (PDF/X-2);
- •Part 6: Complete exchange of printing data suitable for colour-managed workflows using PDF 1.4 (PDF/X-3).

Part 1 was published in 2001 and Part 3 in 2002. Both are based on PDF Version 1.3. Since they were published, TC130 and CGATS have been busy revising them to incorporate PDF Version 1.4 and to develop PDF/X-2. These three new parts are in the final publication process and by the time this is published they will be publicly available. Part 2 was approved as a technical specification, which defined the requirements for PDF/X-2, but was never published so is not included as an official ISO document.

A word about PDF/X-1 and PDF/X-1a. In the initial development of the CGATS version of PDF/X, OPI was a key requirement identified by the user community. This carried into the preparation of 2001 ISO version. However, as the ISO version was being prepared, the need to support OPI was felt to be both too expensive to require everyone to support, and unnecessary for many applications. PDF/X-1a solved this need and differed from PDF/X-1 only in support for OPI. Since then, OPI seems to have diminished in importance with regard to complete exchange and is not included at all in the 2003 version. PDF/X-3 files are much like PDF/X-1a files except that they allow color managed 3-component

When we refer to color management, we are specifically talking about color management as defined by the International Color Consortium (ICC) and the profiles and architecture that are part of their approach.

(RGB, etc.) data in addition to CMYK and spot color data. PDF/X-2 provides for exchanges that make use of an OPI model but is otherwise just like PDF/X-3.

We will focus on PDF/X-1a and PDF/X-3 files as we look further at the integration of PDF/X and color management and the workflow implications of this combination.

Color Management

When we refer to color management, we are specifically talking about color management as defined by the International Color Consortium (the ICC) and the profiles and architecture that are part of their approach. The current draft of the ICC Profile Specification, ICC.1: 2001-12, File Format for Color Profiles (Version 4.0.0), is available at www.color.org. (This document is also in preparation as ISO 15076, *Image Technology-ICC Colour Management-Architecture, profile format, and data structure.*)

In simple terms, the ICC model consists of a reference color space called "profile connection space or PCS," profiles to provide the transforms between native device color spaces and the reference PCS, and a color management module (or CMM) to convert color information between native device color spaces using the transforms provided in the profiles. That model presumes that there is no connection between originator and user of color managed data. The originator of the image data colorimetrically describes the image data (and thus the image) in terms of an ideal reflection image in PCS color space by providing a source profile along with the image data. The recipient uses a destination profile appropriate to the application and output device to produce the best reproduction of the image with the available output gamut and capabilities. Further, the ICC makes no provision for the originator of the data to provide, or even suggest, the desired/expected output conditions.

The ICC model consists of a reference color space called "profile connection space" (PCS), profiles to provide transforms between native device color spaces and the reference PCS, and a color management module.

This model allows images to be truly device and application independent (if that is what is desired). It is the originators responsibility to fully describe the image colorimetrically so that every recipient will have the full gamut and tone scale of the original image available. The recipient is expected to make whatever compromises necessary to reproduce the image for their application needs. Unfortunately, this doesn't fit the typical graphic arts model where the originator is expected to show the client what the final reproduction will look like—to predict the results.

This assumption of independence between sender and receiver is very similar to the approach used in the initial definition of PDF and is a model that is good in many applications. However, it does complicate the use (and understanding) of color management by the graphic arts industry.

Fortunately, color management is only one part of our trio of tools that work together to facilitate graphic arts workflows.

As mentioned earlier, at the urging of the graphic arts community, Adobe added the OutputIntents key to PDF and this is the magic tool that allows the preferred printing condition data and/or output profile to be carried with the image data. More about how that works later.

There are a couple of additional color management issues that are important for graphic arts practitioners to understand. In dealing with destination transforms, sometimes we want the color data to be transformed so that the color stays the same, other times we want to produce the most pleasing result within the color gamut of the output device. The ICC calls the first transform "colorimetric" and refers to the second as perceptual. The term "intent" is sometimes used to designate which transform should be used. The ICC model also assumes that transforms usually should be a two-way street. For example using a destination profile we typically will go from PCS to device, but we also might need to go back to PCS from the device space if we want to move the data to some other device.

Typical destination or output profiles carry six sets of transforms—PCS-to-device and device-to-PCS for both colorimetric and perceptual intents as well as the same data for a third intent called saturation (used more by office type applications than graphic arts).

Let's elaborate on the two kinds of transforms (or intents) that are of most interest in the graphic arts—the perceptual intent and the colorimetric intent. (Although we will not go into detail, you should be aware that colorimetric intents can be used in two ways–absolute and relative.) If we start with the scanned image of a chrome and its input profile, it has a much larger color gamut and tone scale (even when converted to the reflection PCS) than we can reproduce on the printed sheet. It also has a different color gamut (larger in some areas and smaller in others) than we can display on a monitor. But it is the responsibility of the source to define this full gamut and tone scale relative to the PCS.

However, when we output this color image data we usually want to modify both the gamut and tone scale to provide a "best fit" to the available output. This is the job of the perceptual transforms in the destination profile. The color gamut of newsprint printing is smaller than that of Grade 1 sheetfed printing. Proofing systems may have even larger gamuts and CRT or LCD displays are different (larger some places and smaller others) than printed gamuts or each other. Perceptual transforms are intended to adjust the color data so that the gamut in the PCS is rendered (using gamut and tone scale mapping) in a pleasing way within the available gamut of the device color space. *Therefore each output (or class of outputs) needs its own destination profile*. However, these all work between PCS and device and are independent of the source (in this case the scanner) profiles.

If we want to transform color data between devices without changing the color (only the device code values) we use the colorimetric transforms in the profile. In graphic arts we typically use a perceptual transform to convert an image from the large gamut PCS to the available tone scale and gamut of our chosen printing process. We then may want to send this final image data to a proofing device which does NOT produce the same color from the same input values or may even have a different (larger) gamut. Here we would use a colorimetric transform from device to PCS (from the printing process profile) and a PCS to device colorimetric transform from the proofer profile. The colors stay the same but the device values change (CMYK values to the printing process may be very different from the values needed by the proofing device to produce the same color output).

Another issue to keep in mind is that CMYK destination profiles also carry instructions (transforms) for color separation and black generation. More about the impact of this later.

The basis of all profile transforms is something called characterization data. Characterization data is nothing more than a table of information that relates the code values of a device to the color equivalents of those code values.

Measuring the colorimetric values (CIELAB data) of a printed sheet and relating them to the CMYK values that produced them is characterization data. Scanning an IT8 color target and relating the color values of the target to the scanner code values (RGB) is characterization data for a scanner. It is important to note that characterization data is worthless unless the device settings and process control tools are in place so that the scanner, proofer, or printing device will produce consistent results. More about characterization data later also.

How is color management used? Let's look first at CMYK data. If we have CMYK data that has been prepared for a specific printing condition—SWOP, for example—and we want to proof it we have several options. We can use a proofing device that has colorants very close to the SWOP inks and that has been calibrated to mimic the tone reproduction and overprints of SWOP printing. In many situations that is the way a halftone proofing device like the Kodak Approval works. However, if we have an inkjet proofer or other device that does not directly emulate SWOP printing conditions but has a color gamut that matches or exceeds the SWOP gamut we can use color management to transform the data into the form required. The colorimetric device to PCS transform of a SWOP profile can convert the CMYK printing data into PCS. The PCS to device colorimetric transform from the profile of our proofing device can then transform the PCS data into the device values for the proofer that will produce the same color that the CMYK values would produce in SWOP printing. However, because the color separation technique and black printer are defined in the PCS to device transform (even for a colorimetric transform) these will not be the same in the proof as on the printed sheet. This is generally not a problem for non-halftone proofing systems. There are ways that the characteristics of the black printer can be preserved but we will leave that to another article.

Characterized Printing Conditions

We have already mentioned characterization data, but what are characterized printing conditions. The term reference printing conditions has sometimes been used instead of characterized printing conditions but both refer to the same thing. Our definition is the same as the one used in the PDF/X standards and is "*printing condition (offset, gravure, flexographic, direct, etc.) for which process control aims are defined*

Tools to Support PDF/X

There is a groundswell of support for PDF/X tools. Check DDAP's dedicated site, www.pdf-x.com, for a list of PDF/X developers as well as other useful information for understanding this format and its implementation.

The Version 6 release of Adobe Acrobat Professional has included a number of features supporting PDF/X files. In the **Document>Preflight** menu, one can establish various setups for creating and preflighting PDF/X-1a or PDF/X-3 from existing PDF files. Options for setting up OuputIntents are however limited to using the embedded profile mode.

The Acrobat Distiller, which is a part of Acrobat Professional, allows the creation of Settings that automate the creation of PDF/X-1a or PDF/X-3 from PostScript files. This allow for both named condition and embedded profile modes for OutputIntents. Finally, Acrobat 6 Professional has included a checkbox in its **Preferences>General>ColorManagement** menu for "Output Intent Overrides Working Space." This feature is very useful for PDF/X-1a soft proofing in that it will use an embedded Output Intent profile as the source profile for device CMYK data when rendering the color to the screen, regardless of the CMYK Working Space setting. A similar feature for soft proofing color managed RGB data in a PDF/X-3 file would need a comparable override check box in the **Advanced>ProofColors** menu. Apparently this was not able to be developed in time for the release of Acrobat 6.

and for which the relationship between input data (printing tone-values, usually CMYK) and the colorimetry of the printed image is documented." The importance of a characterized printing condition is twofold. First, it provides a reference that can be used by any printing process. Second, any color management profile building tool will (should) build the same COLORIMETRIC transforms from the same characterization data. Perceptual transforms will not be the same because each vendor has their own gamut mapping, black generation, and separation tools. This allows users to stick with their favorite color management vendor but also accept data from other sources.

The best example of a characterized printing condition is SWOP. The ink, paper, and process control aims for SWOP are documented in the SWOP publication and the characterization data is provided in ANSI/CGATS TR001:1995. While the process definition and aims are important to enable others to duplicate the printing process, the characterization data can also stand alone. For example, gravure publication printing takes CMYK data files based on SWOP offset printing aims and transforms that date into engraving inputs. The SWOP characterization data is combined with the gravure printing characterization data using color management principles to achieve a match between the offset and gravure printing of ads printed in multiple publications using both processes. This is an example of what is called "re-targeting" the data.

Other standards and industry activities are developing publicly available characterized printing condition data. CGATS has TR004 in final preparation to document GRACoL printing on Grade 1 and Grade 3 papers. IFRA has published characterization data for coldset printing on newsprint. FOGRA along with ECI has published characterization data for several of the printing conditions defined in ISO 12647-2.

At the urging of the graphic arts standards community, the ICC has established a registry of characterized printing conditions (see www.color.org). This registry includes a "reference name" that is used as a descriptor for the characterized printing condition and pointers to the source of the characterization and process definition data. As we will see later this provides a significant benefit for PDF/X files.

PDF/X & Color Management

PDF itself provides significant support for color management. It includes the ability to colorimetrically define input data using either the default color space approach or as ICC data. In addition, the OutputIntents array (available since Tech Note 5413 , pre PDF1.4, at the urging of the PDF/X development committees) allows either a reference to a characterized printing condition or a profile to be included to define the intended output printing condition.

PDF/X has gone beyond the basic PDF definition and requires that:
(1) all data in the file either device data or color managed data be prepared for a single printing condition; and
(2) that the OutputIntents array be used. When the printing data is in the same color space as the output device color space a pointer to the characterized printing condition in the ICC registry is sufficient. If the data must be transformed or if a characterized printing condition

pointer is not available a destination profile must be included in the OutputIntents array.

This means that every PDF/X file is self defining in terms of the intended color to be printed.

Admittedly many of the application currently on the market (including Acrobat 6) do not make it easy to implement all of the features intended by the standards community. Patience, user input, and time will hopefully help this situation. (However, very important, Acrobat 6 does introduce support for PDF/X, see sidebar: *Tools to Support PDF/X.*)

Let's look at the scenario envisioned by the standards community using SWOP printing as our example. If a PDF/X-1a file (CMYK data) is transmitted ready for printing, the OutputIntents array need only include "CGATS TR001" as the value of the OutputConditionIdentifier key and "http://www.color.org" as the value of the RegistryName key. This tells the recipient that the data is based on the SWOP characterization.

Compare this to a situation where someone wants to include their own characterization of SWOP printing. They will have to define their own name to be used as the value of the OutputConditionIdentifier key and they must include a profile as the value of the DestOutputProfile key. There will be no easy way for the recipient to identify the data as intended for SWOP unless they analyze the profile itself or have external communication with the sender.

In a PDF/X-3 situation, again "CGATS TR001" is used as the value of the OutputConditionIdentifier key and "http://www.color.org" as the value of the RegistryName key. This tells the recipient that the data is based on the SWOP characterization. However if the data being transmitted is RGB or some other non-CMYK encoding, an output profile must be included as the value of the DestOutputProfile key. This profile will be used to transform the three component data to the desired CMYK data for printing. Because this profile includes all of the separation, gamut and tone scale, and black generation information that the sender used to proof the file it is imperative that it also be used by the recipient. The pointer to CGATS TR001 again tells the recipient that SWOP printing is the intended destination. As described above additional color management transforms and/or device link profiles can be used to facilitate proofing, adjustments for the particular press to be used, or re-targeting to a different process.

If printing is being done under custom conditions, then the included profile allows the recipient of the file to accomplish proofing and whatever transforms are needed to successfully print the job as the sender intended.

Characterized printing conditions provide a shorthand definition that simplifies communication, pre-flighting of files, etc. and allows data to flow more efficiently between sender and receiver.

Summary

Color management allows significantly greater flexibility in the transmittal and use of print ready data in the graphic arts industry. The PDF/X family of standards allows the necessary information to be easily and concisely carried with the image data to enable color management. Characterized printing conditions and the ICC registry of characterized printing conditions allows simplified exchanges where data is prepared for common conditions such as those used for publications and newsprint.

Current ICC Registry

The following list represents the current entries in the ICC registry of characterized CMYK printing conditions. To learn more about each one of these characterized printing conditions go to http://www.color.org/drsection1.html and click on individual entries to bring up a detailed description.

CGATS TR001
FOGRA1
FOGRA2
FOGRA3
FOGRA4
FOGRA5
FOGRA6
FOGRA7
FOGRA8
FOGRA9
FOGRA11
FOGRA12
FOGRA13
FOGRA14
FOGRA15
FOGRA16
FOGRA17
FOGRA18
FOGRA19
FOGRA20
FOGRA21
FOGRA22
FOGRA23
FOGRA24
FOGRA25
FOGRA26
IFRA22
IFRA28

This trio of tools has the potential for simplifying the exchange of printing data and defining new and more efficient workflows for our industry.

My thanks to Mike Rodriguez of R.R. Donnelley for help with this article. Both of us (mike.rodriguez@rrd.com or mcdowell@npes.org or mcdowell@kodak.com) welcome comments and/or questions on these topics.