White Paper 31

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# Flexible color management for the graphic arts using PDF

## Introduction

Adobe's Portable Document Format (PDF) [1, 2] is widely used for documents intended for print production. This white paper deals with some of the issues faced by graphic arts professionals when creating and processing PDF documents.

PDF evolved from PostScript some 20 years ago and has seen substantial development during that time to support the needs of document creators in a wide range of application areas including document presentation on the internet, legal documents, engineering drawings as well as the needs of print production. Although great care has been taken by those extending the format to ensure consistency across these areas the format has become quite complex and care must be taken when creating PDF documents if they are to be interpreted unambiguously.

A subset of PDF (PDF/X) has been defined as a series of ISO standards [3]. These standards enable reliable exchange of documents for print production by ensuring that all of the data that is needed to print the document is included. This family of formats is now widely used and in part achieves its goal. However, there are some areas that need further consideration, particularly those relating to the way in which the colors of document elements are defined.

## Document preparation objectives

One goal when preparing documents is to create a document that can be reproduced with a similar look on a range of devices. An alternative, and somewhat conflicting goal, is to define a document that can be printed accurately, and in some cases preferentially, on a single device.

### Similar look on all devices

Achieving a consistent look in prints from different devices is a common requirement for advertising campaigns where material is often printed on different printing presses and is later presented together, for example a poster and a set of leaflets. It is usually important for the brand owner that at least brand colors match in this situation.

It is increasingly common that documents must be created before the method of printing has been determined. Such documents must be created without detailed knowledge of the printing system to be used to print them. With this in mind, colors in the documents should be encoded in a way that does not assume any particular printing system. In practice this is not always possible and a more realistic goal is to prepare documents for printing on a range of printing systems with similar printing characteristics, for example systems using similar inks and classes of substrate and with similar color gamut shapes.

**Accurate color on a single device**
This is a requirement when an advert that includes a company logo or important brand color is being prepared for submission to a magazine, a company brochure is being prepared, or a home-shopping catalogue is being printed.

**Achieving both objectives**
Both of these objectives can be achieved simultaneously if the range of colors is restricted to those colors that can be printed on all devices that will be used to reproduce the document. While this is possible when the printing systems are known in advance, and is often the solution adopted in practice, it is in many cases desirable to be able to use the full gamut of each device to be used for printing and to control the way in which different types of color elements are reproduced. PDF/X provides a framework where this goal can be realized if care is taken when constructing and rendering the document to screen and to print.

## Describing color in PDF documents

There are many ways in which color can be described in PDF documents. A more complete description is provided in [1, 2].

**Relative to imaging devices**
Device color spaces allow document colors to be defined in terms of device colorants. In the case of a printing press the device process colorants are usually cyan, magenta, yellow, black, and the printing press may support one or more spot colors. The PDF color spaces DeviceCMYK, DeviceN and Separation allow colors to be defined relative to press colorants. The color space DeviceGray is intended for black and white devices and has a well-defined relationship to DeviceCMYK.

In the case of a display or similar additive imaging device the set of colorants is usually red, green and blue and the DeviceRGB color space can be used to define such document elements by specifying the amount of each of these colorants to be used.

Caution is required when using PDF device color space definitions in documents. Because the colorants of imaging devices can be significantly different from each other, unless the intended device is known when device colors are used in a PDF document, such colors cannot be interpreted consistently. This means that device color spaces should never be used when creating PDF documents for print production unless further information is provided about the intended imaging device. In the case of PDF/X documents, information about the intended device is provided by the document Output Intent, usually in the form of an ICC Profile [4].

**Relative to the CIE 1931 standard observer**
Colors can be defined relative to the CIE 1931 standard observer using CalGray, CalRGB and Lab color spaces. These color spaces are most useful where a color to be included in the document has been measured by a spectrophotometer. One example is the use of Lab as the alternate color space to convey the measured value of a spot color.

Perhaps the most widely used set of color spaces is the ICCBased family of color spaces. This family of colour spaces allows 1-, 3- and 4-component colour data[1] to be included in a document with an associated ICC profile. These allow document colors to be defined relative to imaging devices but also provide sufficient information about the imaging device to allow these colors to be interpreted unambiguously. The Rendering Intent associated with such document elements modifies the color result of ICCBased elements[2].

**Indirect color**
There are a number of mechanisms in PDF that allow colors to be defined indirectly.

The Indexed and Pattern color spaces both provide mechanisms that allow the other PDF color spaces to be used indirectly.

**Object color interactions**
Colored elements can interact with other colored elements using two mechanisms of overprinting (slightly different between process and spot colors) and Transparency. These behaviors can result in print inconsistencies due to different printing system capabilities in handling these effects.

## Document operations

One way to think about documents is to consider the set of operations that will be performed on a document in its lifetime. For the purposes of this discussion we will consider the following subset of operations: creation, proofing, printing, and retargeting; other document operations such as editing, merging or repurposing are beyond the scope of this discussion. When a document is created ideally the set of operations that will be performed should be known so that the set of data needed for each operation can be communicated to those processing the document.

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[1] This includes colour spaces based on Gray, RGB and CMYK data and also makes provision for more exotic colour spaces such as CIELab, Ycc, etc. Colour conversion is expected to be performed using a destination profile (that is sometimes included in the PDF document) using the standard ICC profile connection space.

[2] ICC profiles can include multiple rendering intents. Each rendering intent provides transforms between device values and colorimetric values. The ICC-absolute colorimetric rendering intent relates device values to colorimetry that is relative to a perfect reflecting diffuser. The Media-relative colorimetric rendering intent relates device values to colorimetry that is relative to the device maximum white. The Perceptual intent relates device values to colorimetry on the ICC Perceptual Reference Medium, which is a standard virtual print medium designed to enable perceptual gamut mapping when retargeting documents.

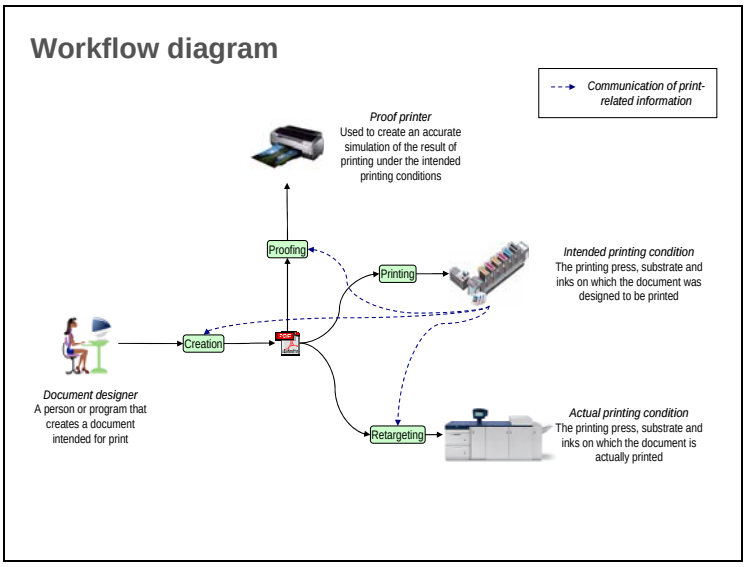


**Figure 1: Workflow for creation, proofing, printing and retargeting of documents**

## Proofing

It is usually desirable to be able to see how a document will appear when it is printed. In graphic arts print production 'proofing' is often a separate step in the process. During this step a prototype print is made that accurately predicts key features of the final print as closely as possible. This includes correct simulation of all colored elements including those elements that are combined using overprinting or transparency effects. Increasingly 'soft proofing' is used for this step where the printed is simulated on a display whose viewing environment and color response is carefully controlled.

## Printing

At some point the document will be printed and in the simplest case the printing system for which the document was prepared will be used to print it.

## Retargeting

In some cases, a document is prepared for printing using one printing condition (printing system, inks, substrate, printer settings) and then must be printed on a different printing system. This is almost always the case for today's print production where standardized reference printing conditions are used for document exchange[3]. In many cases the actual printing system is similar to the intended printing system and uses the same set of printing inks and substrate. In these cases, the printing press can be calibrated to match the standard. In other cases, particularly when digital printing presses are used, the printing characteristics are substantially different from those anticipated by the document's creator. In these cases, the document colors must be adjusted in more complex ways to achieve a satisfactory printed result.

[3] In many cases, one of the default options in Adobe's Creative Suite is used: U.S. Web Coated (SWOP) v2, Coated FOGRA39 (ISO 12647-2:2004) or Japan Color 2001 Coated. While these reference printing conditions will work reasonable effectively, there are other options available in each region which may better reflect current printing aims.

## Requirements for document elements

We now wish to review the requirements to be able to proof, print and retarget PDF documents. The set of data needed for these operations depends on the document content and so in this section we will look at different types of PDF content in order to understand what additional data is needed.

## CMYK, gray and black elements

If properly qualified, DeviceCMYK and DeviceGray color spaces can be used in PDF/X documents.

When it is important to be able to define color relative to the printing inks, rather than by reference to a specific visual color, in order to ensure a high-quality printed result, then these color spaces can be used to achieve this.

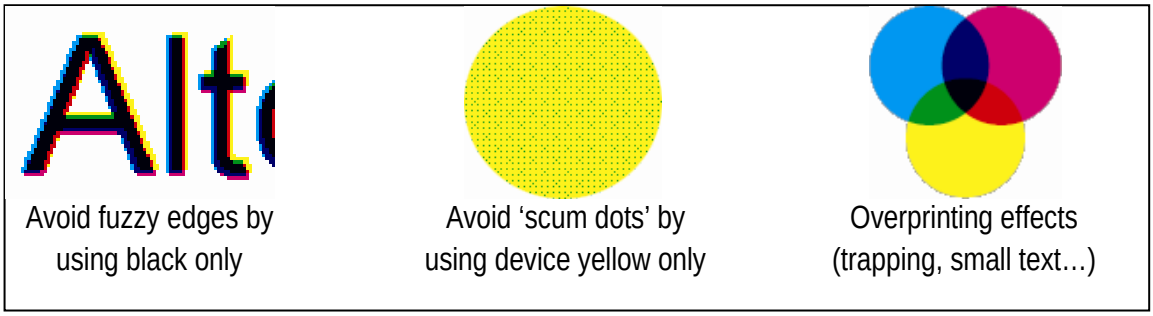


**Figure 2. Graphics requiring direct specification of colorant values**

Figure 2 shows some examples where the ability to specify device colors directly is important.

When black text is printed it is usually desirable to use black ink only because if all four colors are used ugly fringing may appear around the text caused by slight misalignment of the printed separations. In this case it is desirable to specify to use the black colorant on whichever print system is used, rather than to be concerned about how one black colorant may differ from another.

Some pure colors look unsightly if small dark dots of another color are added (sometimes referred to as 'scum dots') and in such cases it is usually more important to keep the color pure than to keep it accurate. In such cases it is desirable, as it is with black text, to specify to use the specific colorant on whichever print system is used, rather than to be concerned about small hue differences in the colorants.

Trapping is often used in order to hide the effects of misalignment of printing separations. This is especially important for some kinds of packaging printing and is often achieved by creating small elements using one or two device colorants. In many cases today the trapping stage is closely integrated with the printing system and the need to be able to communicate trapping information in PDF documents directly is likely to continue to decrease in future.

### Print and Proof

Some printing systems require the total area coverage (total percentage of all ink in a region) to be limited. When creating documents that directly specify DeviceCMYK amounts, care must be taken

to ensure that the total area coverage limit of the intended printing system(s) is not exceeded, otherwise the document may not be printed correctly. This total area coverage limit must be communicated separately or inferred from the ICC profile that defines the printing condition.

**Retargeting**
There is currently no mechanism in PDF to indicate whether pure colorants (e.g., black text or avoiding scum dots) or accurate color is the objective for a particular element. This means that retargeting can only be done successfully if additional constraints are imposed by the document creator and when processing the document. It is common to assume, for example, that black-only text should remain black-only when the document is retargeted and that elements that involve only pure color should be retargeted using the same set of colorants (although the amount of each may be changed).

If object-based retargeting is performed to create a modified PDF document, elements that make use of object color interactions such as overprinting or transparency may be reproduced incorrectly and so this form of document retargeting should be avoided where possible.

## ‘RGB’ Images and other ‘RGB’ elements

DeviceRGB is not allowed in PDF/X for a document intended for print as it is essentially undefined.

ICCBased RGB color spaces do provide a useful mechanism to allow images that were captured as RGB to be retained as RGB until the time of printing. These encodings are useful when accurate and preferred color reproductions of a document element is desired, rather than printing with pure colorants. With such ICCBased RGB source colors, the elements can be converted for print using the RGB ICC source profile provided with the document element in combination with the actual press profile of the print system to be used.

In traditional graphic arts workflow, images are converted for press before they are included in documents, typically using Adobe’s Photoshop or a similar application. The image’s source ICC profile and the press ICC Profile are used to perform an RGB to CMYK conversion. When performing this conversion, users select the rendering intent to be used and can choose whether or not to perform Black Point Compensation [5], which scales the source encoding black point to the black point of the output device.

PDF/X incorporates the concept of ‘virtual CMYK’ in that image data and the transforms needed to convert them to the desired print CMYK percentages are included in the document: the source ICC Profile and the press ICC profile (in the PDF Output Intent) and the rendering intent to be used. One serious limitation in PDF (up to and including PDF 1.7) is that the use of Black Point Compensation cannot be specified. This limitation has been removed from PDF 2.0.

**Print and Proof**
It is a serious limitation that PDF has no way to indicate whether Black Point Compensation should be applied when transforming the source data to data for the output device. Especially when ‘RGB’ images are incorporated, a separate communication between the creator and the recipient of such a

document may be needed in order for a satisfactory print to be produced. A document creator could indicate, for example, that Black Point Compensation should be applied when converting all image content. In absence of such a communication it is only safe to assume that no Black Point Compensation should be done.

With V4 ICC source profiles, the perceptual rendering intent might be desirable to provide a consistent preferred source interpretation across a number of print systems.

We hope that workflows based around the use of PDF 2.0 and later versions will enable this aspect to be addressed more effectively.

**Retarget**
Retargeting may be more difficult to achieve when ICC v4 profiles are not used as there are in some cases problems when mixing v2 profiles from different suppliers. As noted in the Print and Proof discussion, v4 source profiles can be used to improve consistency when printing to multiple printing systems[4].

## Spot colors

Special printing inks are often used to print company logos or to achieve a particular design effect. Such colors are referred to as spot colors and are often selected from a swatch book and identified by name.

Traditionally, from a designer's point of view, these kinds of elements are device specific as they anticipate a particular ink being available and a particular tone response of the printing system.

PDF supports this kind of color using Separation and DeviceN color spaces. These color spaces allow the designer to identify a color by name and also to provide a mechanism to convert to an alternate color space, providing directly or indirectly a color interpretation for use with process inks, when the specified spot ink is not available. This alternate color definition can be used to describe how the spot color looks (using CIELAB) or to provide an alternative process colorant mixture (using CMYK) to be used when the spot colorant is not available. In some cases, the visual results of using process inks as compared to using spot inks may be quite similar, but since spot colors are often used for colors that are outside of the CMYK color gamut of the press, they are usually different.

Since PDF only allows the definition of a single alternate color space definition, document creators must decide whether it would be more useful to define the alternate color in terms of CIELab or in terms of process equivalent CMYK.

**Print**
The document creator and all those involved in processing the document must agree on the set of names to be used to define spot colors or to communicate by private means details of the ink to be used. This is often done by means of a printed color swatch book that can be referred to by both the

[4] This situation is not helped by some commonly used applications which convert ICC version 4 profiles to 'equivalent' version 2 when creating PDF/X documents.

document creator and printer. Swatch books provide a reasonably good way to communicate colors by name but have some serious limitations as they are subject to print-to-print variations and (more significantly) change color as they age. In addition, the printing substrate used in printing the swatch book may not match the substrate of the print job, in which case the visual color result may be significantly altered.

It is often important to be able to specify the color of a tint of a spot color as well as the color of the solid. This information can be communicated in PDF if a CIE based color space is used as the alternate color space. Including CIELab color values for the solid and for each tint of a spot color provides sufficient information to allow the press operator to calibrate the press to match the colors specified by the document creator.

**Proof**

Proof printers usually have a significantly larger color gamut than that of the printing processes they simulate. In many cases the colors of the spot inks can also be printed by the proof printer and this means that a proof can be made that shows the result of printing including the spot colors. In order to be able to proof spot inks accurately a CIE based color space must be used as the alternate color space for spot colors[5].

**Retarget**

In the simplest retargeting scenario, a printing press with different tone value increase is to be used to print the document but the document will be printed with the same set of spot inks. In this case a correction must be applied to the tint value of the spot color in order to produce the expected result on the actual press.

In cases where the spot ink is not available on the actual printing press to be used the retargeting system has to perform spot-to-process conversion.

There are a number of possible objectives for this conversion. Typically, it is important to reproduce the spot color as a visual match as close as possible to the original specification. However, a competing concern for such spot-to-process conversion is that each visually distinct spot color in a particular print job should remain visually distinct when converted to use process colorants. As a result of these two competing desires, when the spot colors in a print job are converted to process colorants, it can be important to evaluate the conversion results of the spot colors in relation to each other. PDF does not currently allow these trade-offs and additional information about the intended result to be communicated.

[5] ISO 17972-4:2018 [6] specifies a set of encodings that can be used to communicate spot ink colour and additional information that allows overprint colours to be estimated. CxF/X-4 metadata can be added to PDF documents to enable improved handling of spot inks.

## Spot and process color combinations

It is quite common to combine spot colors with process colors or with other spot colors.

**Print**

In order to produce the correct color when printing, the printing sequence must be defined. For example, the color produced by printing orange on top of pink is not usually the same as the visual color result from printing pink on top of orange. There is no way to communicate this information in PDF 1.7 (and earlier) and so must be communicated by private means. This aspect has been addressed from PDF 2.0 and it is hoped that workflows based on 2.0 will provide much improved handling of spot inks.

**Proof and Retarget**

It is important to be able to estimate the color produced by the combination in order to produce a proof or to print the document on a different printing system. Specification of the opacity of each ink and the intended printing sequence is needed in order to be able to provide an estimate of the color combination. One way to measure the opacity of an ink is to print and measure patches printed on black (for example process black ink) and on white (for example the print substrate) and to use the difference in these values as a measure of opacity. This is the basis for CxF/X-4 (ISO 17972-4) metadata which is supported from PDF 2.0 and it is hoped that workflows based on PDF 2.0 will be able to provide enhanced handling of spot inks for proofing and retargeting.

It is usually impractical to create ICC Profiles for each possible printing combination of spot and process colors[6]. This means that the color produced by combinations of these colors must be defined and checked by some private means.

**Duotones, tritones…**

Multi-tones (duotones, tritones…) are defined using a small number of inks (often spot color inks) and are used in combination with printing a gray image to achieve a special effect such as sepia tones. These types of colored elements have essentially the same set of color problems as multiple spot colors however the possible color combinations are usually limited to a few hundred colors.

## Transparency

Determining the color of elements that use transparency is a multi-dimensional problem and is beyond the scope of this white paper. When printing and proofing, in some cases the results of transparency blending of different document elements, particularly when the elements are defined using different colorants such as spot over process, may be different due to the use of different blending spaces in the different printing systems.

[6] This and other functionality described in this White Paper is supported by iccMAX and workflows based on iccMAX [7] may be able to provide improved handling of spot inks and other coloured elements.

## Varnish

A varnish may be printed as a spot ink to achieve the effect of increasing the apparent color gamut, creating an area of high visual impact. This changes the appearance of the regions of the prints that include the varnish. There is no way in PDF to communicate the additional information needed to be able to produce an accurate simulation of this final printed result. When it is important to be able to simulate the effect of varnish additional information must be communicated.

### Print

Varnish inks must be clearly identified. There is no standard way to do this and so varnish inks are usually just identified using a name that includes the word ‘varnish’.

### Proof

The way in which varnish works is to change the surface finish of a print usually making it glossier. Unless a varnish ink is available for the proofing system it is not really possible to simulate the effects of varnish on a printed proof. One of the benefits of soft proofing is that such effects of gloss can be shown. Because currently there is no standard way to communicate the data needed to provide an accurate simulation of the effects of adding the varnish, this additional data must be communicated by private means to enable the soft proofing feature.

### Retarget

Unless a varnish ink is available on the actual printing system to be used some redesign of the document is usually necessary so that the needed impact can be achieved by some other means.

## Special inks

For some printing applications, especially in the area of packaging printing, special effects inks are used such as metallic, fluorescent and pearlescent inks. Accurate modelling of the appearance of such inks is an area of active research; there are however a number of models that predict the results to a useful degree.

### Proof

Models that allow the appearance of these inks to be predicted require knowledge of the lighting and geometry of the viewing environment as well as multi-dimensional measurements of the ink characteristics. This means that with the exception of a few critical cases it is impractical to derive and communicate the data that is needed to allow accurate simulation.

Some display proofing applications can simulate effects of special inks, but no standardized means exists to communicate the additional metadata.

### Retarget

There is really no way to provide a reasonable approximation to the appearance of these special inks using process colors and so unless the intended ink is available some redesign of the document is needed.

## Putting the elements together

If care is taken when creating them, most kinds of PDF document can be proofed, printed and retargeted reliably. In a number of cases, as outlined above, additional information about some of the document content must be communicated by separate means.

The separate means can be basic industry rules, for example ‘black-only text elements should remain black-only’ when the document is retargeted or may be ‘additional measurement data is needed to define the color and opacity characteristics of spot colors’. It is important that both the creator of the document and those responsible for subsequent processing know and understand the implications of the basic assumptions and understand when to convey and request additional information.

## References


[1] ISO 32000-1:2008, Document management – Portable document format – Part 1: PDF 1.7

[2] ISO 32000-2:2017, Document management – Portable document format – Part 2: PDF 2.0

[3] ISO 15930 series, Graphic technology – Prepress digital data exchange using PDF

[4] ISO 15076-1:2010, Image technology colour management – Architecture, profile format and data structure – Part 1: Based on ICC.1:2010 (see also ICC.1:2010)

[5] ISO 18619:2015, Image technology colour management – Black point compensation

[6] ISO 17972-4:2018, Graphic technology – Colour data exchange format (CxF/X) – Part 4: Spot colour characterisation data (CxF/X-4)

[7] ISO 20677:2019, Image technology colour management – Extensions to architecture, profile format and data structure (see also ICC.2:2019)