ICC color management for print production

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W Craig Revie

Principal Consultant

Fuji Film Electronic Imaging Limited

ICC Chair of the Graphic Arts Special Interest Group

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Tutorial outline

- About the ICC
- ICC color management concepts
- Creating ICC profiles
- Using ICC profiles
- Defining an ICC-based workflow

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About the ICC

- ICC History
- ICC Objectives
- ICC Membership
- Working groups
- Details from www.color.org

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ICC History - some milestones

- 1990 PostScript Level 2 released by Adobe
- 1993 FOGRA conference - Intercolor consortium formed
- 1994 Apple's ColorSync format adopted
- 1994 Version 2 ICC profile format defined
- 1995 Windows 95 with ICM
- 1999 PDF 1.3 has support for ICCBased colorspaces
- 2000 Photoshop 6 released
- 2001 Version 4 ICC profile format defined
- 2002 PDF/X-1a (and possibly PDF/X-3) standardized

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ICC Objectives

- Open systems color management
  - Portable, standard color profile format
  - Framework independent of device capabilities
- ‘Technical’ basis and broad membership
  - Develop a common understanding of color
- Not limited to print production
  - Basis of profile connection space is a reflection print which may limit areas of application

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ICC Membership and Organization

- Founding members
- Regular members
- Honorary members
- Observers
- Steering committee
  - Founding members + elected members
- Chair, vice chair, secretary and technical secretary
  - Lars Borg [Adobe], Uwe-Jens Krabbenhoeft [Heidelberg], Kip Smythe [NPES], Tony Johnson [London College of Printing]

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Working groups

- Focus on specific areas
- Examples:
  - Architecture Working Group
  - Workflow Working Group
  - Graphic Arts Special Interest Group
- Email discussion groups + 4 meetings per year

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ICC color management concepts

- Basic colorimetry, CIE standard observer
- RGB additive and CMY(K) subtractive color models
- ‘Device independent’ color
- Color transforms

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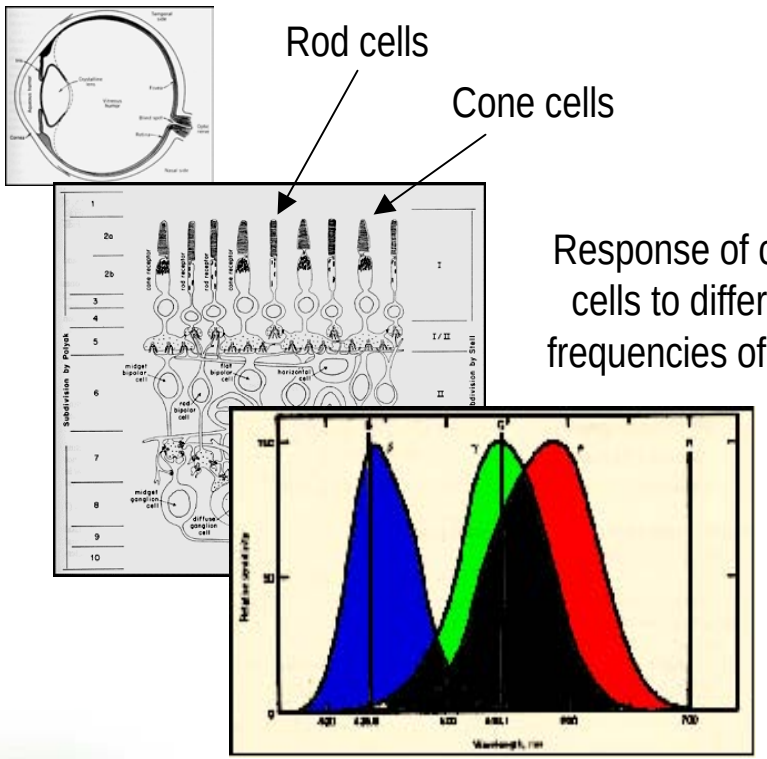
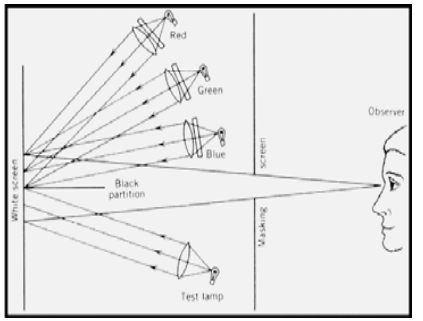
How we see color



Response of cone cells to different frequencies of light



The CIE standard observer

CIELab and CIEXYZ standards

- based on CIE standard observer
- describe colors as we see them
- used in both PostScript and PDF

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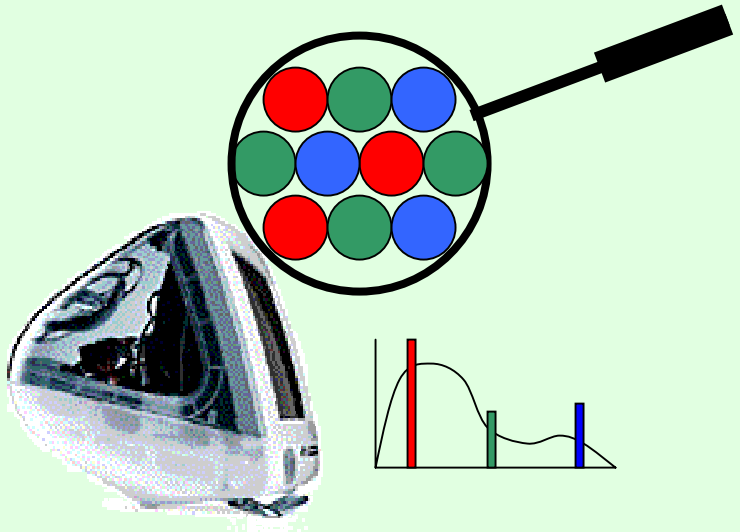
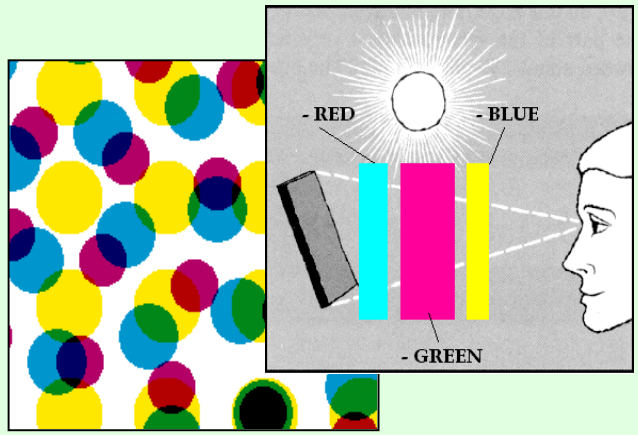
Color illusions

Additive color



Start with black and add
red, green and blue

Subtractive color



Start with white and subtract
red, green and blue

Many (but not all) colors can be
simulated in this way

Each device ‘sees’ color differently

Photographic printer

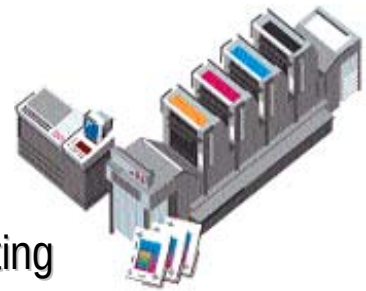
Image display

Ink jet printer

How can we convert colors from one device to another?

Digital camera

Scanner



Printing press

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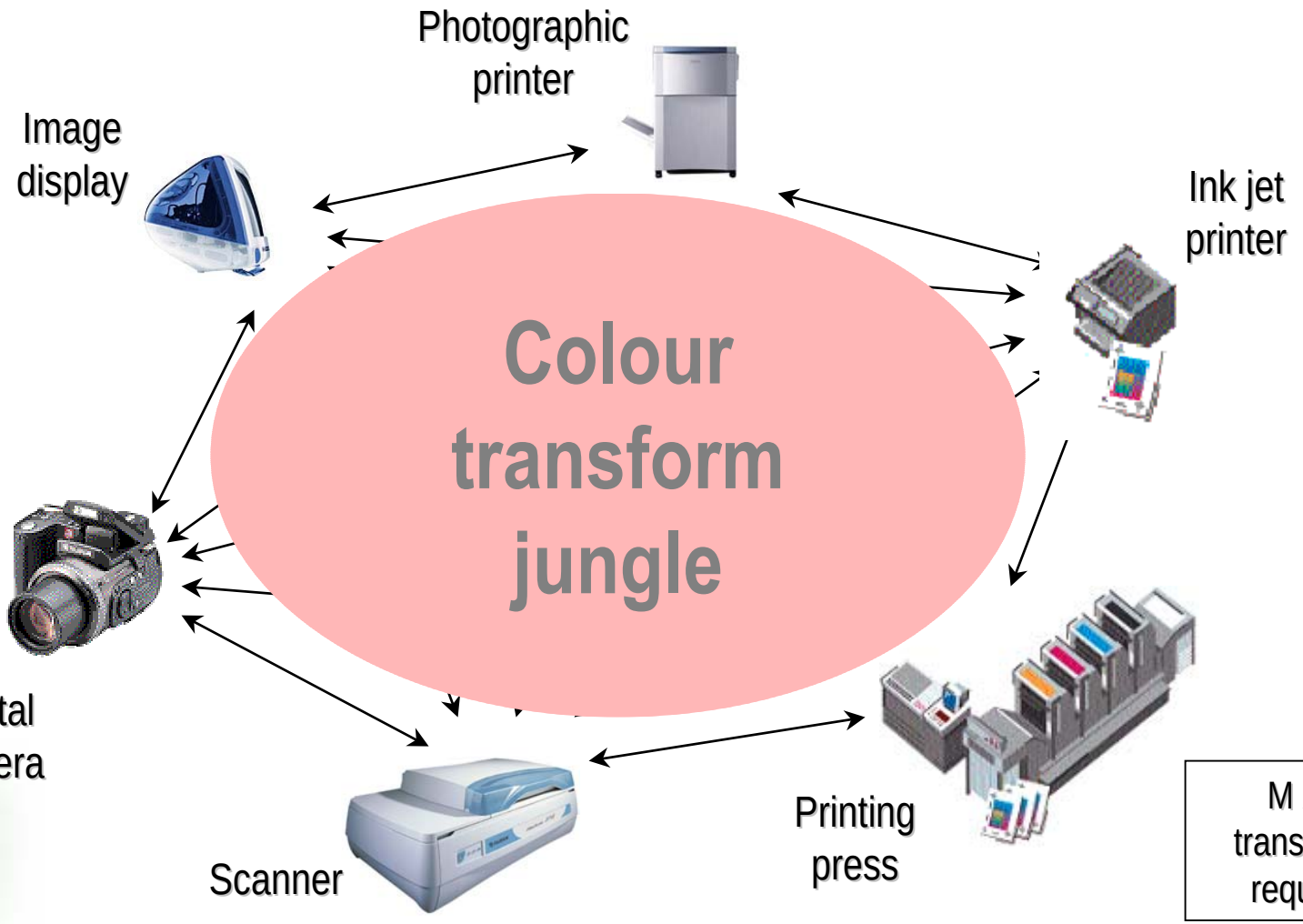
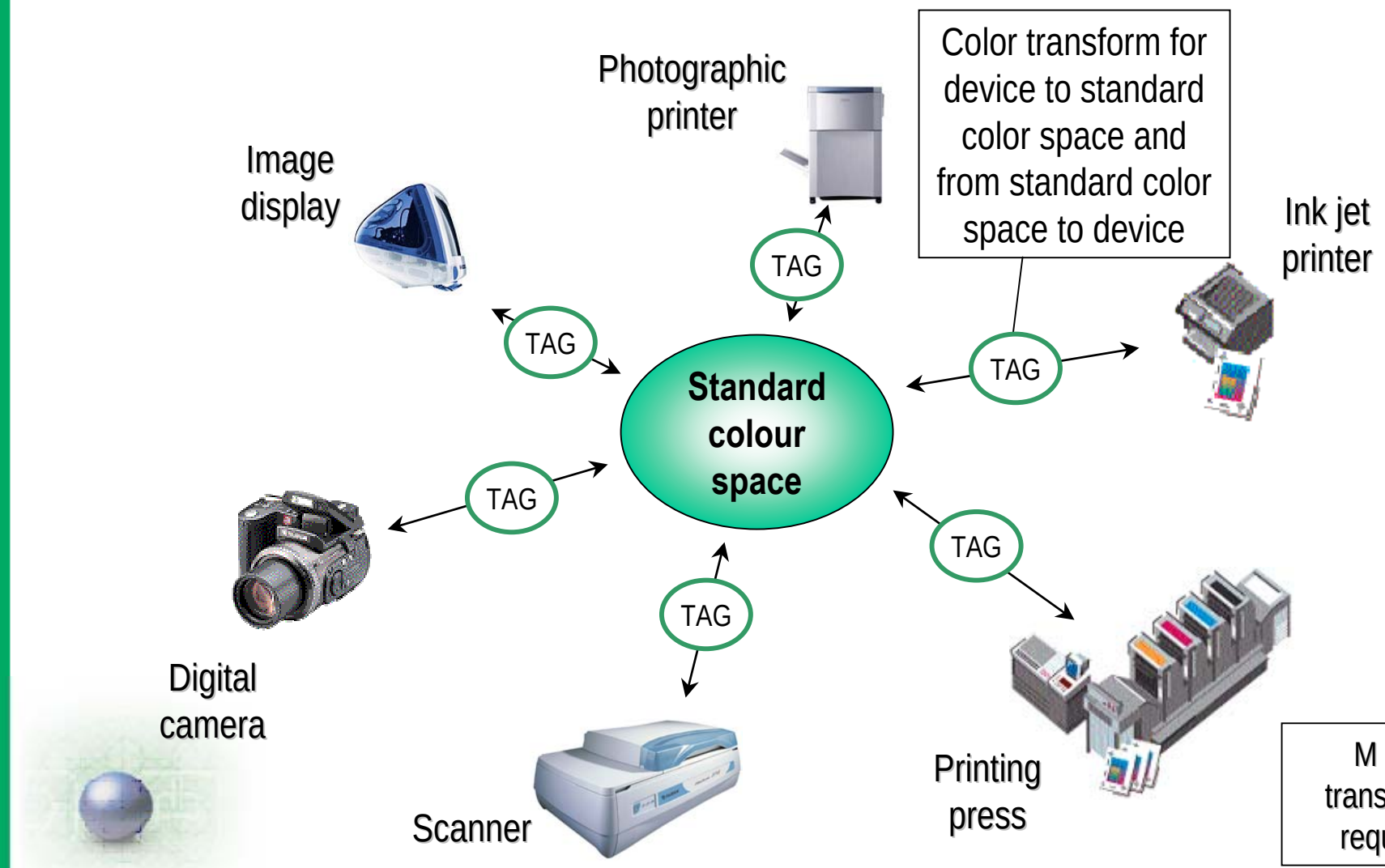
Device dependent solution



Device-independent solution



How ICC profiles work

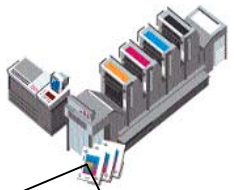
Given a colour calculate ink percentage required to reproduce that colour

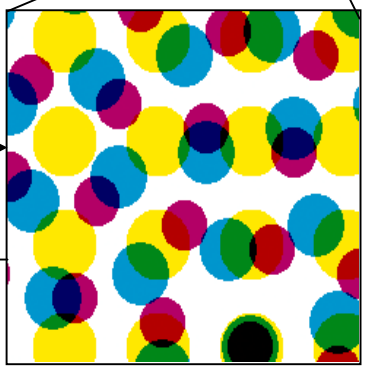
ICC Profile

BtoA tables

AtoB tables

Calculate colour produced by given ink percentages





Standard color space

[CIEXYZ or CIELab]

Ink percentage

[CMYK]

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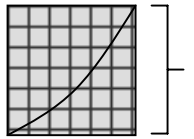
Basic color transform elements

1-D LUT

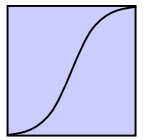


curve values

'count' samples

stored in profile

parametric curve



parameters defining one of a standard set of functions in profile

matrix

e1	e2	e3
e4	e5	e6
e7	e8	e9

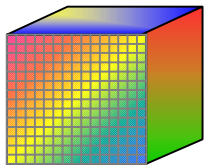
matrix coefficients stored in profile

matrix with offset

e1	e2	e3	e10	
e4	e5	e6	e11	
e7	e8	e9	e12	

matrix coefficients stored in profile

multi-dimensional LUT



values at each node of the 3- or 4-D table stored in profile

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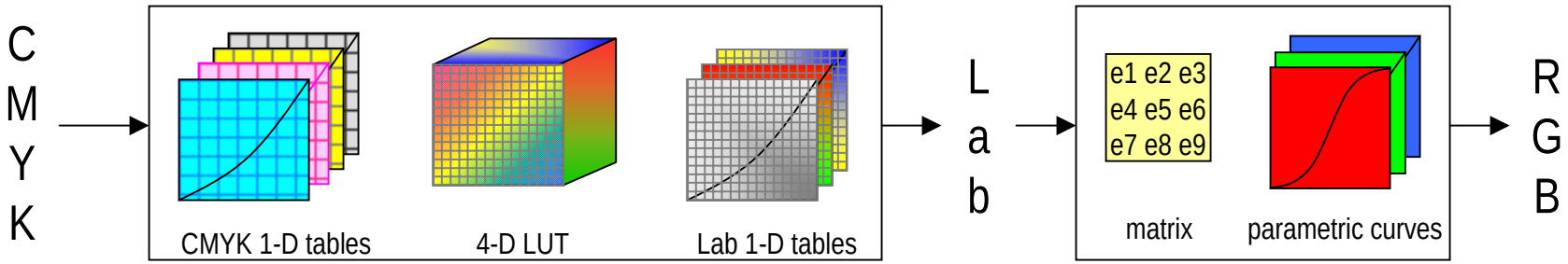
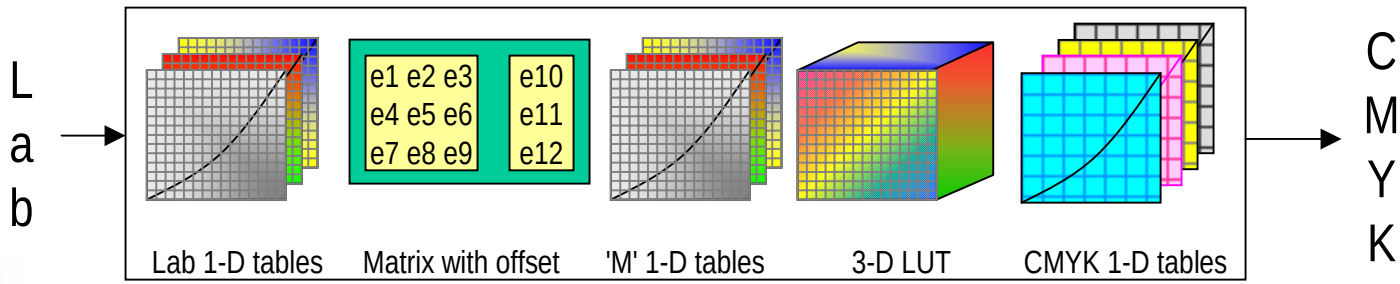
Putting the elements together



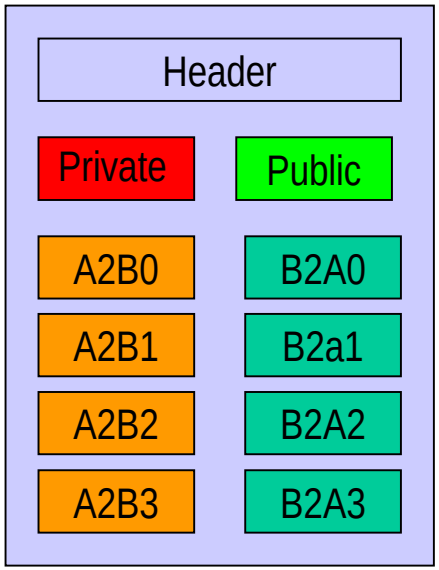
AToB tag from printer profile

tags from monitor profile



BToA tag from version 4 printer profile

Example ICC Profile



ICC Profile Inspector.lnk

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ICC color management concepts (2)

- Rendering Intent
- Profile connection space (PCS)
- Color Management Module (CMM)

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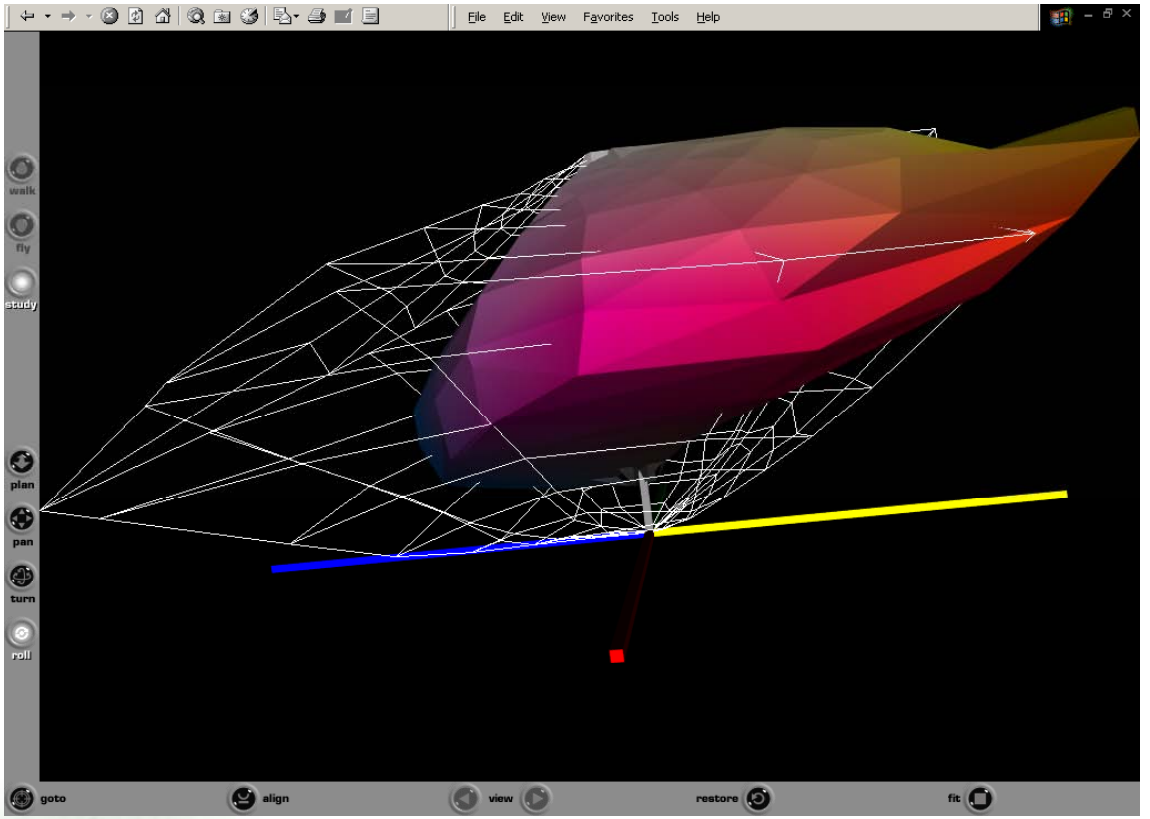
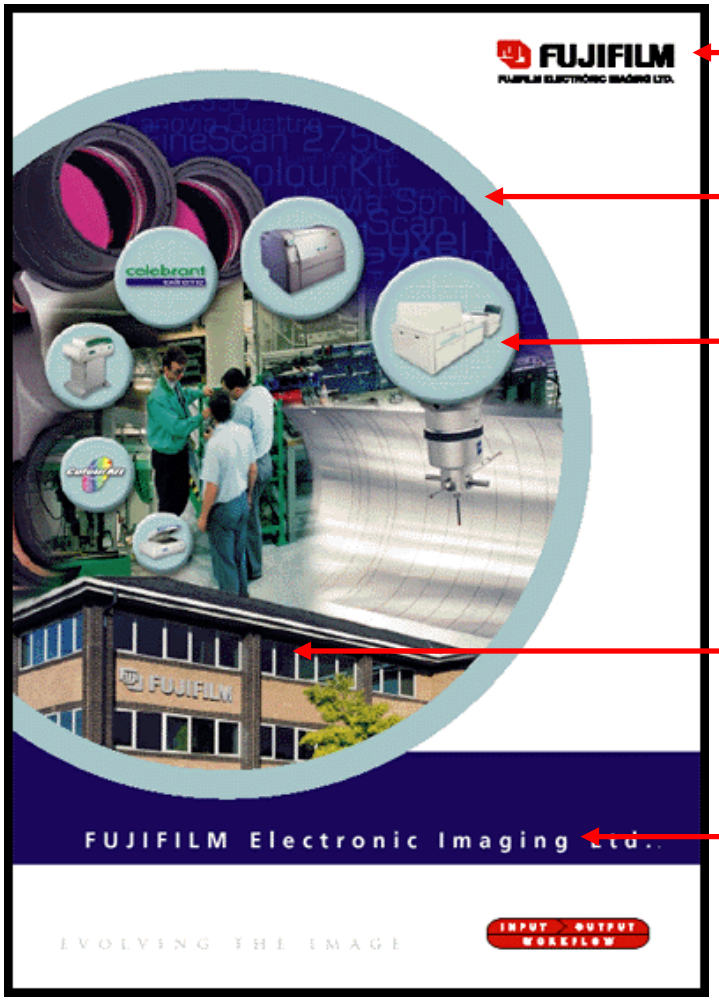
Color gamut comparison



Solid shape indicates gamut of print process
Wire frame indicates gamut of monitor

When printing colors viewed on screen some kind of trade-off must be made to determine how we should map one color gamut to the other

Gamut mapping depends on page element



Company logo

Tinted Areas

Illustrations

Photographs

Text

ICC Rendering Intents

- Four ICC Rendering Intents define gamut mapping
  - Absolute Colorimetric: measurement (relative to illuminant) of output color should match that of input color if possible
  - Relative Colorimetric: measurement (relative to paper) of output color should match that of input
  - Perceptual: color images should be transformed to produce desired appearance on the output
  - Saturation: color transforms should maintain saturation in colors where possible

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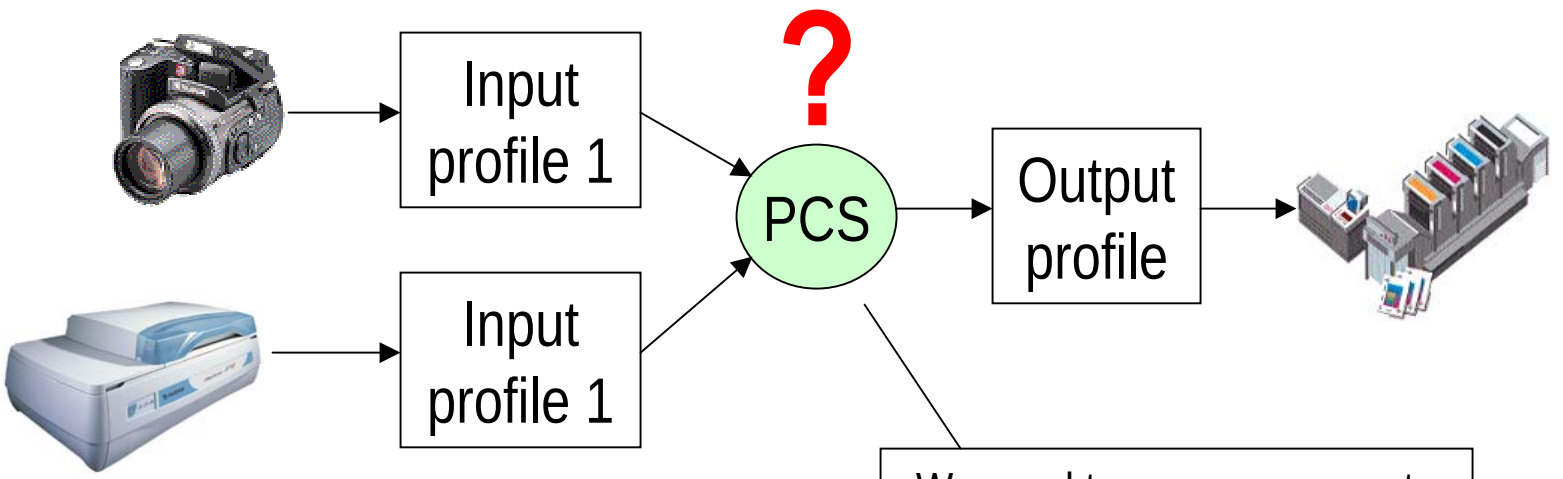
Perceptual Intent

Color images should be transformed to produce desired appearance on the output - but how?

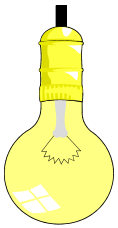


Images and input profiles are created independently of the output profile

Profile connection space definition

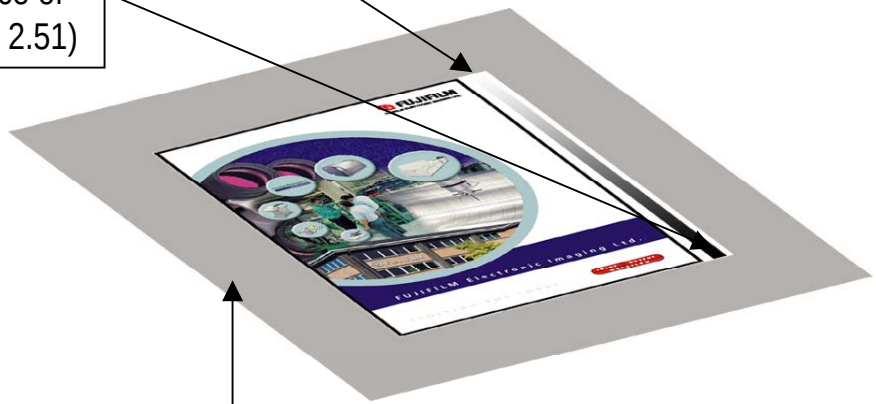
(Perceptual Intent)

D50, 500 lux light source



Media White Point has neutral reflectance of 89% (Dmin 0.0506)

Media Black point has neutral reflectance of 0,30911% (Dmax 2.51)



20% surround

CIE 1931 standard colorimetric observer adapted to viewing environment

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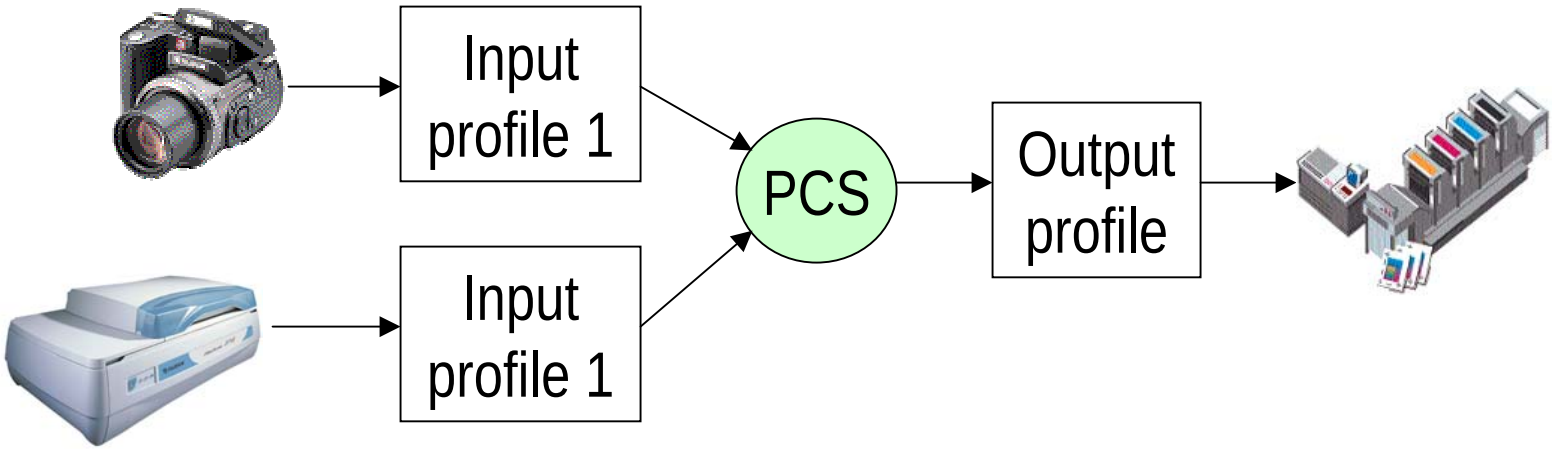
Now we can use Perceptual Intent

Color images should be transformed to produce desired appearance on the output



On input images and/or profiles can be adjusted to achieve desired result on (virtual) reference medium

Output profile creators can assume that images have been adjusted to achieve desired appearance and can perform necessary gamut mapping for printer

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Open question: How big / what shape is the PCS gamut?

- This is at present undefined
- Given the density range that has been defined gives us an idea of size
- ICC is studying the advantages and disadvantages of defining the PCS gamut more precisely
- Perceptual gamut mapping is vendor specific - "beauty is in the eye of the profile creator"

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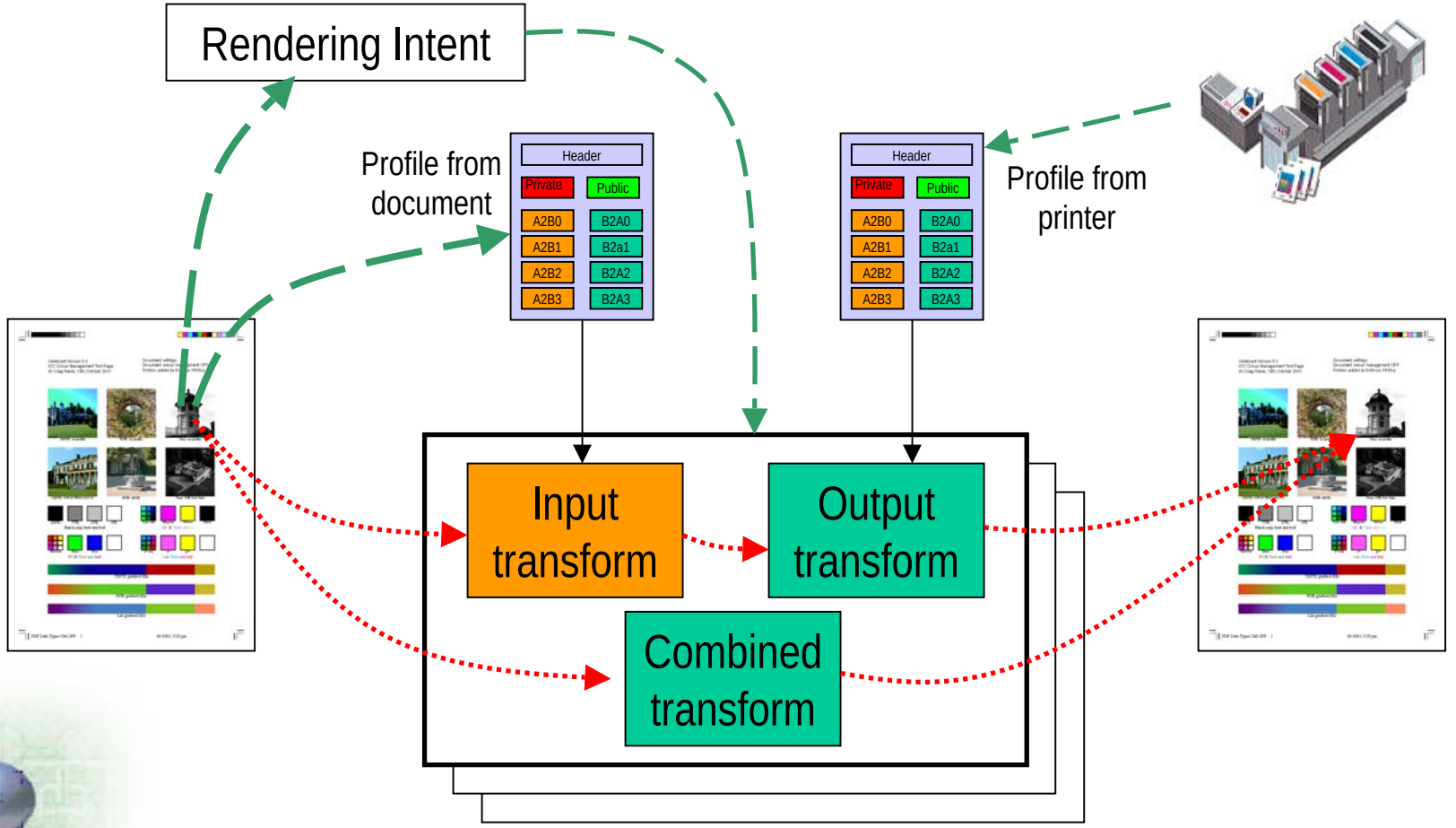
Color Management Module (CMM)



CMM - often part of OS usually more than one option

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Color Management Module (CMM)

- Applies transforms implied by profile data
- No formal ICC definition
- Why multiple CMMs?
  - Handling TRC profiles
  - Chromatic adaptation
  - Interpolation algorithms
  - Private tags
  - Some minor differences of interpretation

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Creating ICC profiles

- Creating a scanner profile
- Creating a monitor profile
- Creating a printer or proofer profile
- Creating a profile for a printing press
- Profile testing

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Classes of profile (1)

Input


May be Matrix+TRC type but is more usually LUT-based

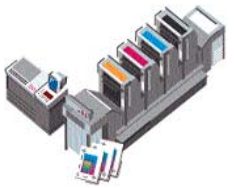
Must contain at least Device-PCS table for Perceptual Intent

Display

Usually Matrix+TRC type but may be LUT-based

Must contain both Device-PCS and PCS-Device tables for Perceptual Intent

Output

Must be LUT- based

Must contain PCS-Device and Device-PCS intents for all Rendering Intents

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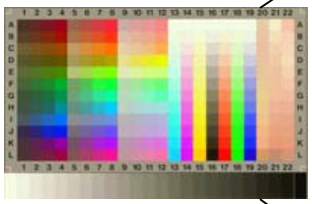
Scanner profile creation

Color target for media to be profiled

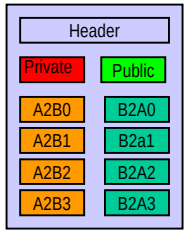


Color target patch colors measured

L*a*b*

Profiling package constructs profile

ICC Profile valid for selected media when scanned using reference scanner settings



RGB

Reference scanner settings selected

Note the media, scanner model and scanner settings - the profile isn't worth as much without them

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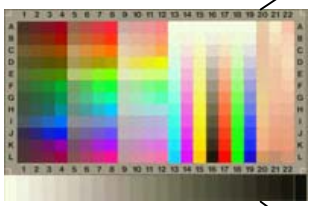
Digital camera profile creation

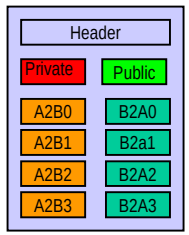
Obtain standard digital camera color target



Measure target patch colors

L*a*b*

ICC Profile valid for profiled viewing environment



RGB

Photograph target in intended viewing environment

Select reference camera settings

Warning: for a digital camera the viewing environment may be significantly different from that profiled

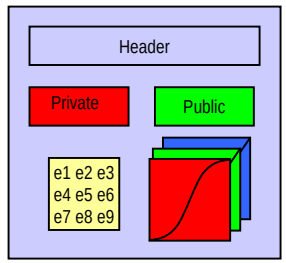
In many cases the use of a standard colorspace may be a better option

Creating a monitor profile

Measurement of each patch made and passed to profiling package

L*a*b*

ICC Profile valid for profiled monitor settings



RGB

Profiling package images colored patches from target in sequence on monitor

Note the monitor model, settings (WhitePoint, gamma, brightness, contrast...) and viewing environment - the profile isn't worth as much without them

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Printer profile creation

Measurement of each patch made and passed to profiling package

L*a*b*

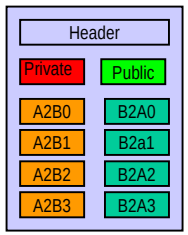
ICC Profile valid for printer when printing in 'reference state' on profiled media

Establish printer 'reference printing state' and print characterization target

CMYK patch description

CMYK

UCR, TAC, Black Printer control etc defined



Note the printer reference printing state, media and profile creation parameters (in particular how the black printer was controlled) - the profile isn't worth as much without them

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Classes of profile (2)

DeviceLink

Constructed from a number of device profiles

Used by CMMs to cache color transforms

Limited applications support

Abstract

Perform PCS-PCS transforms - eg removing color cast

Named color

Can be used to communicate named color palettes between applications

ColorSpace conversion

Used to describe colorspaces (sRGB->PCS)

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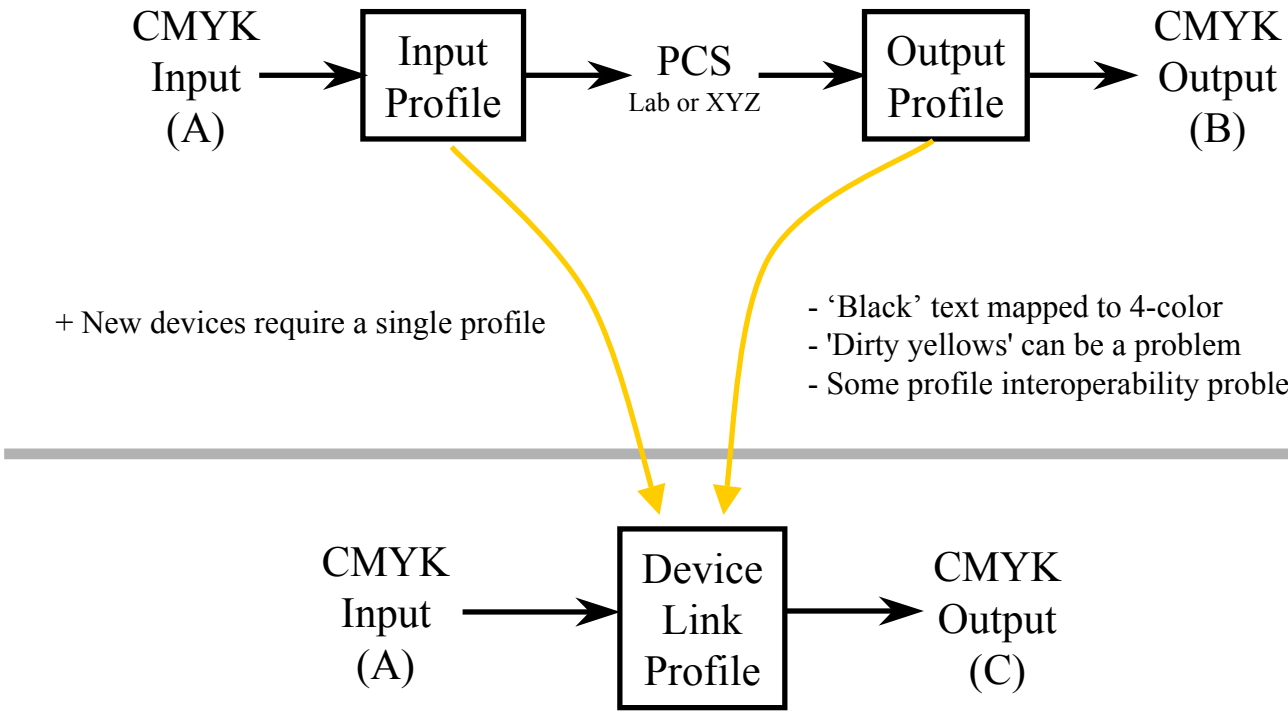
Component vs Device Link Profiles



+ Individual colors can be mapped when the profile is created

- New profile required for each input/output combination
- Can not be used for Device Independent Color
- Limited applications support

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Creating a profile for a printing press

- Three options:
  - Profile Individual press
    - the only way if no similar standard printing condition exists
  - Print to standard printing condition
    - relatively small effort to create a profile
  - Use profile for standard printing condition and adjust output to suit individual press
    - a useful route when it isn't possible to print to a standard

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Profile testing

- Accuracy
  - measure a profile's accuracy using a reference set of color patches
  - example IT8.7/3 basic set for a printer profile
  - Average and Maximum dE can highlight profiles with problems
- Quality
  - use the profile to process a number of standard test images and view the result
  - example SCID images
- Color accuracy vs color quality
  - just because a profile produces accurate color does not mean that the result looks good
- Fitness for purpose
  - make sure that the profile contains all of the information that will be needed by those wishing to use it

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Types of color management

- Image color management
  - scanners, digital cameras, Photoshop
- Document color management
  - Quark XPress, Adobe InDesign, PostScript, PDF, PDF/X
- Proofer color management
  - digital proofers, soft proofing

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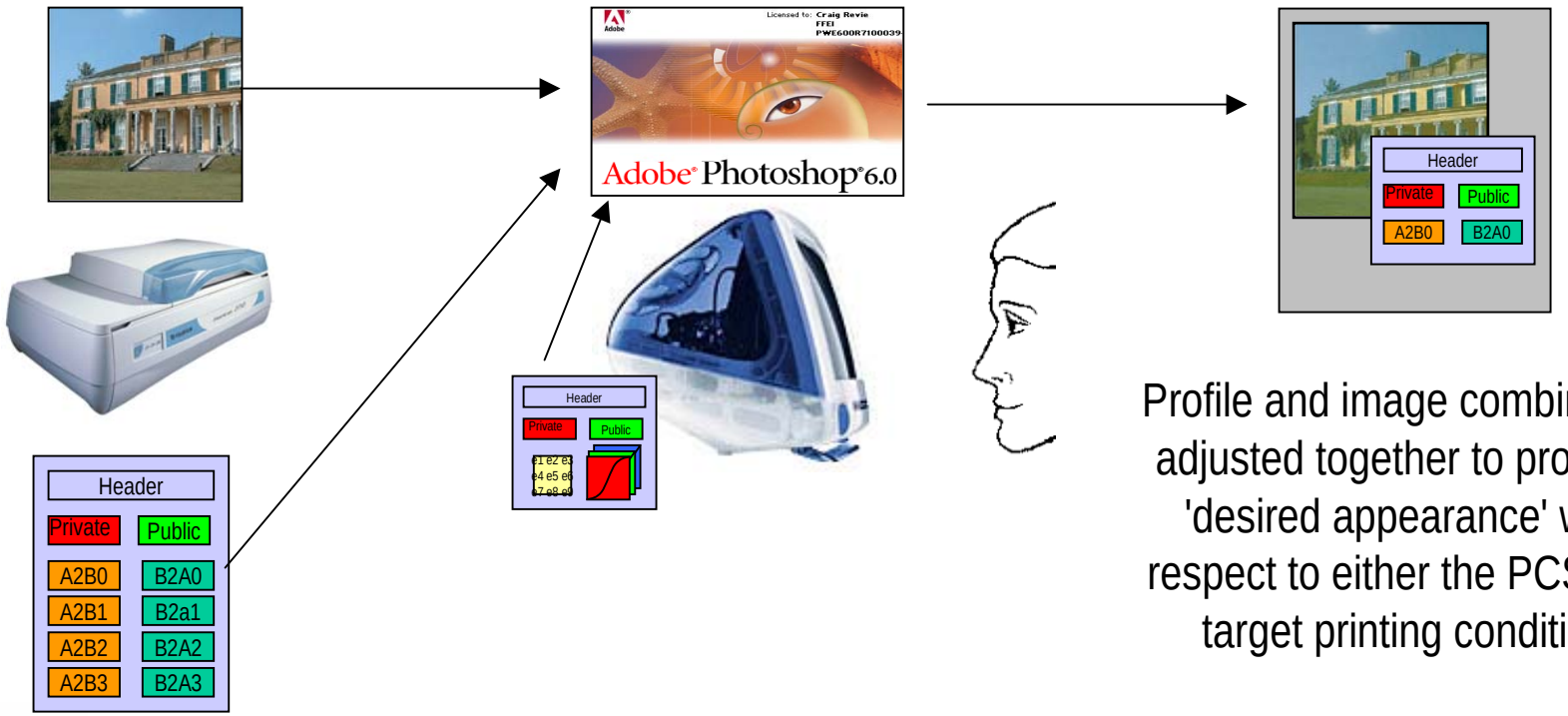
Image color management



Profile and image combination adjusted together to produce 'desired appearance' with respect to either the PCS or a target printing condition

Workflow decision:

Print-ready CMYK (closed)

Profiled and sharpened RGB (open)

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Document color management

Image capture



TAG

TAG

TAG

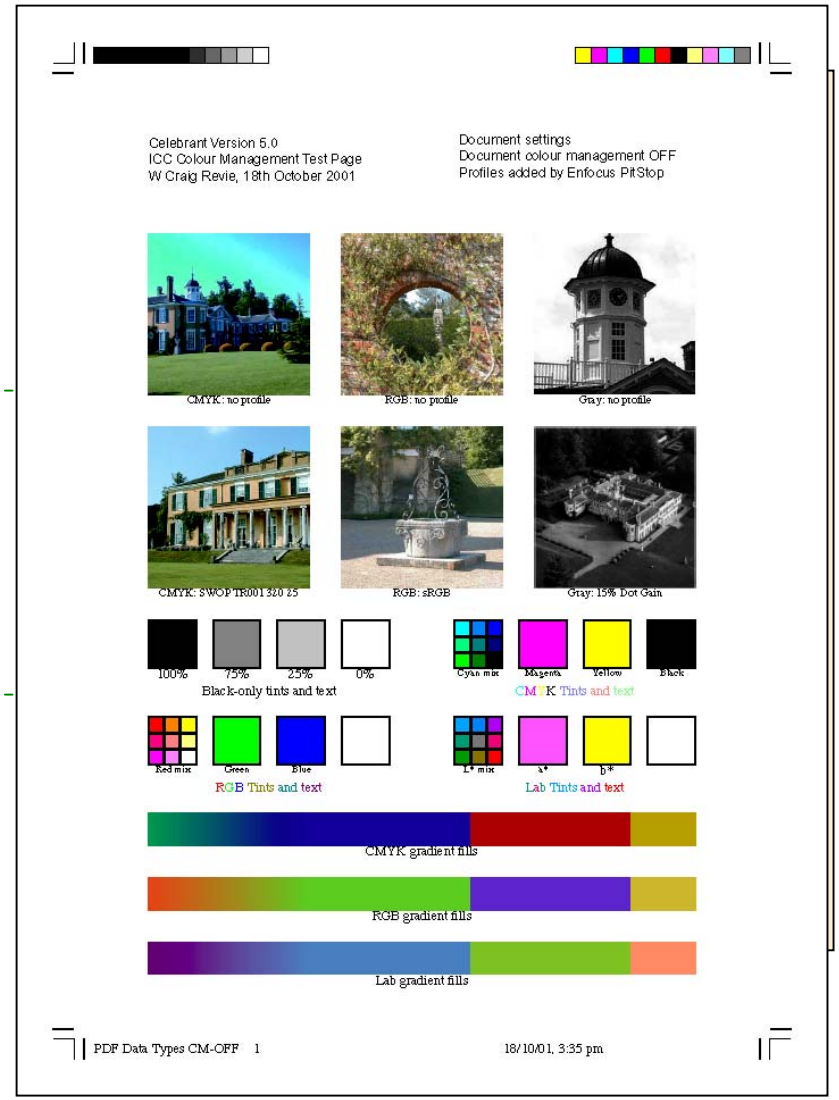
Image editing

TAG

TAG

Page composition


TAG



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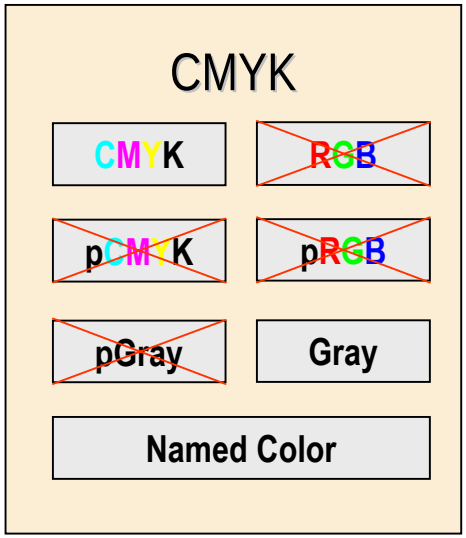
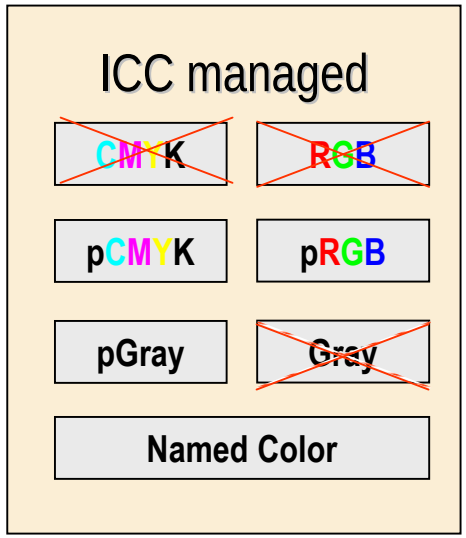
Document types

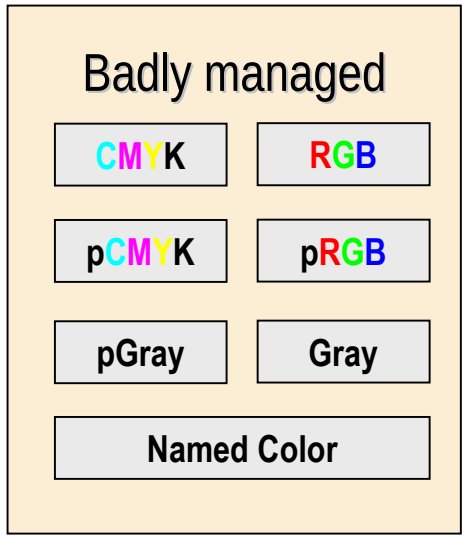


Colored elements converted to CMYK as soon as possible

Named colors converted to process or spot separations



Colored elements tagged with appropriate ICC profiles or PostScript CSAs



Some elements tagged

RGB elements present

'Incorrect' color profiles used

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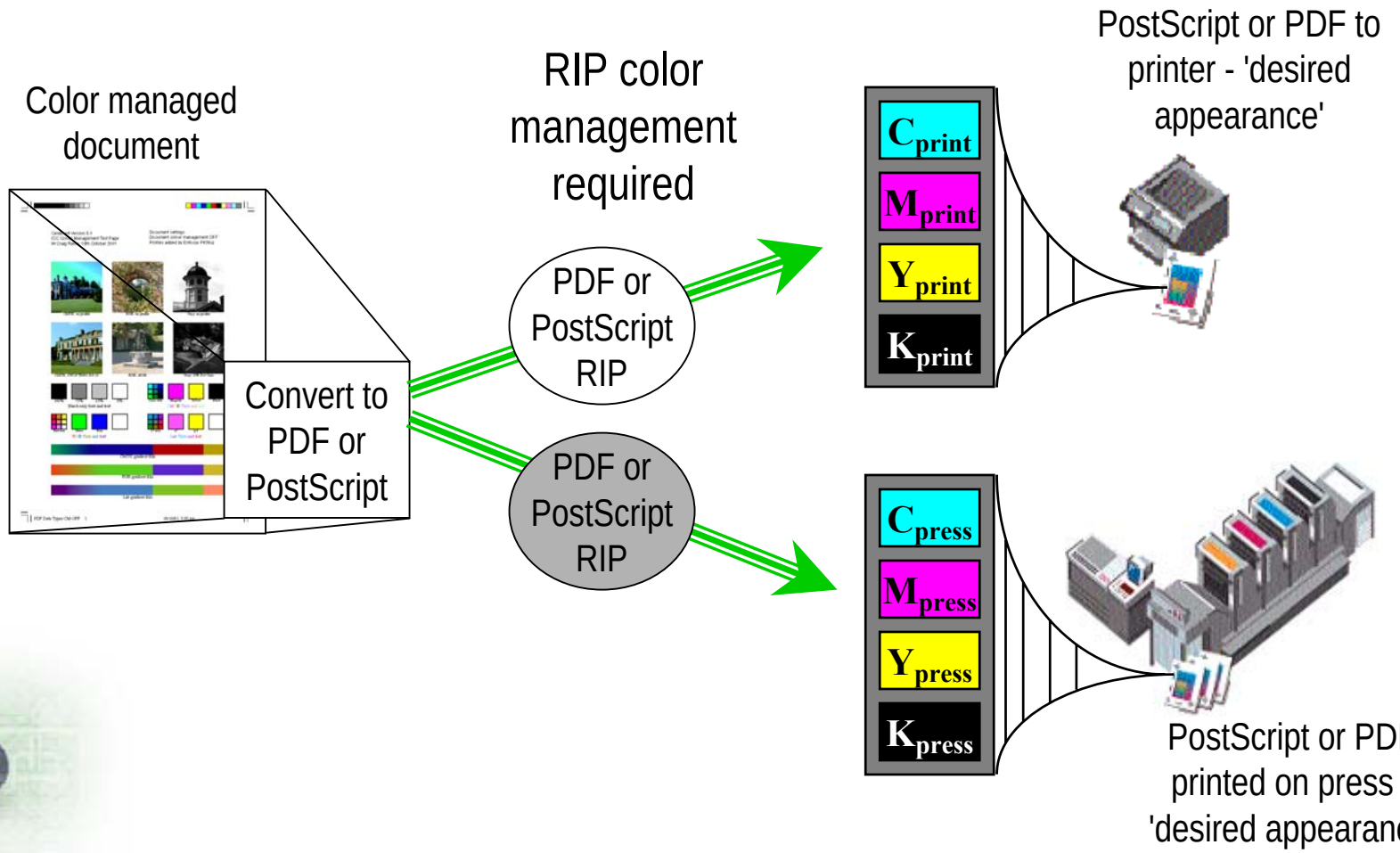
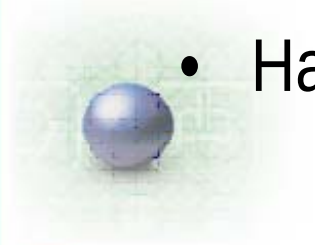
Document color management



Document color management issues

- Different types of page element managed differently
- Each image may need to be managed differently
- Rendering intent selection
- Output-specific adjustments/selections
- PostScript and PDF document descriptions
- Trapping, overprinting and transparency
- Perceptual Rendering Intent loosely defined
- Handling device-color elements (default profiles)



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PostScript colour management

- Colorspace arrays (CSA)
- Colorrendering dictionaries (CRD)
- UseCIEColor mechanism
- Relationship between ICC and PostScript color management

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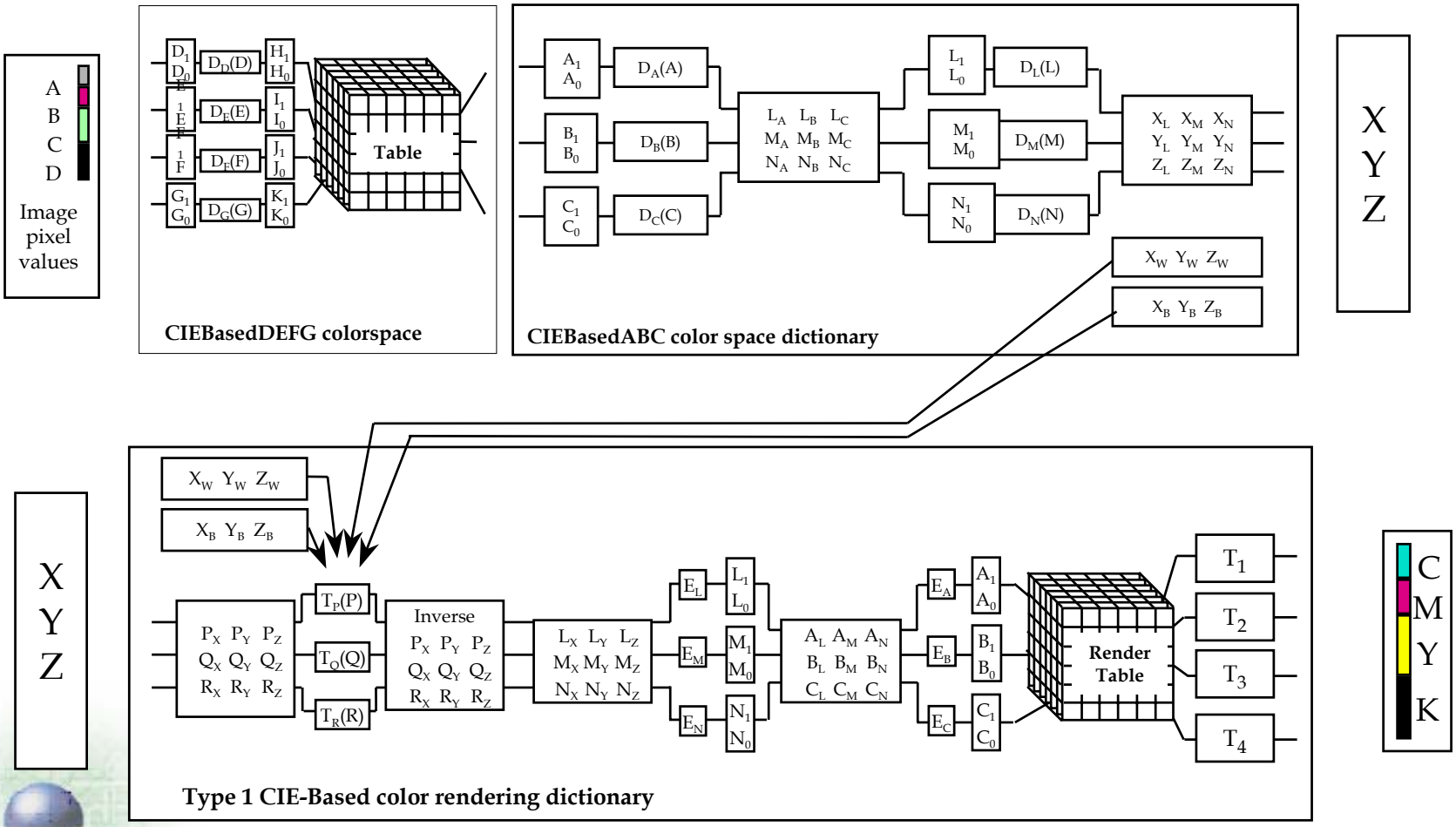
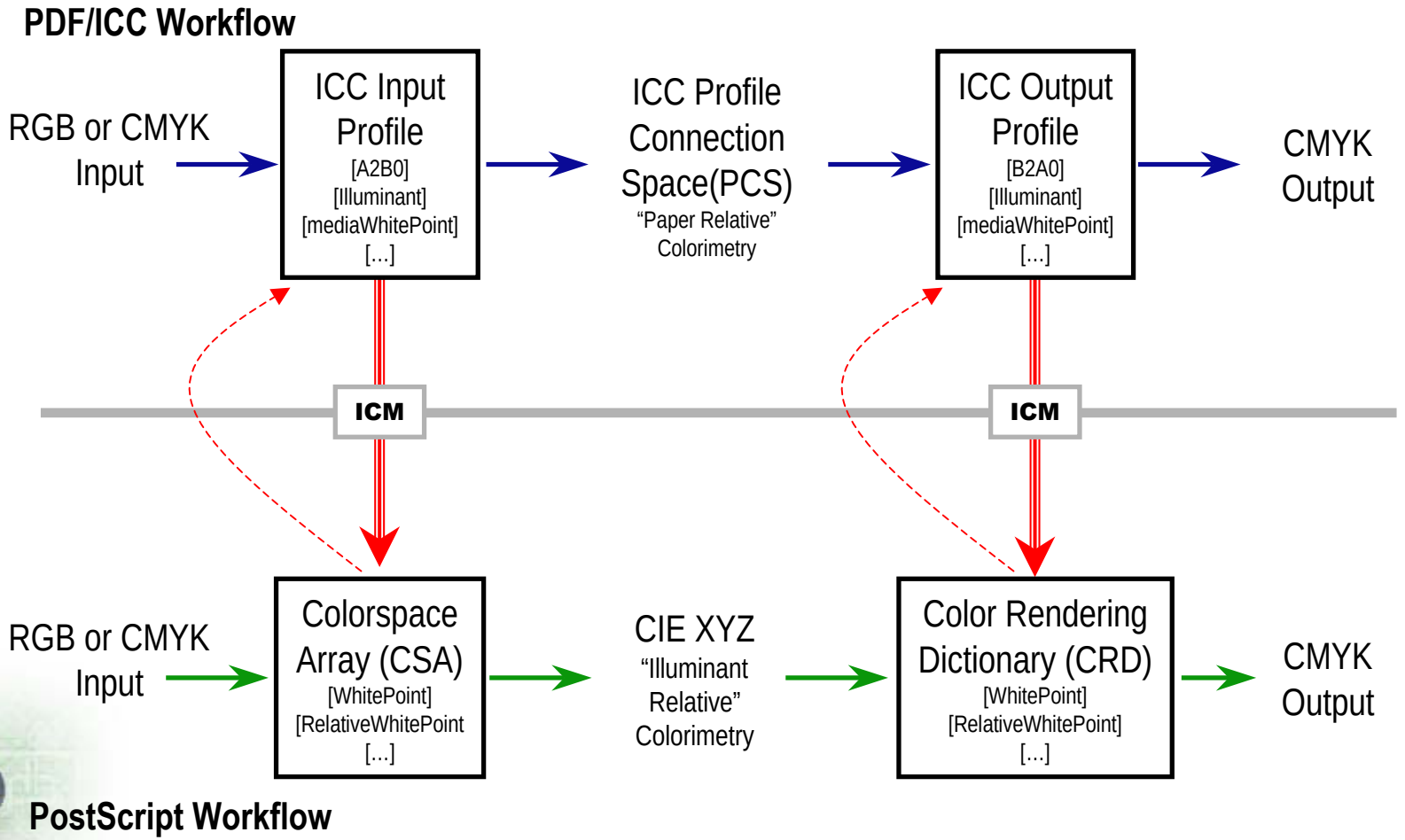
PostScript color model



PDF/ICC and PostScript Color Models



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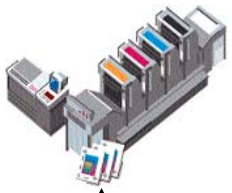
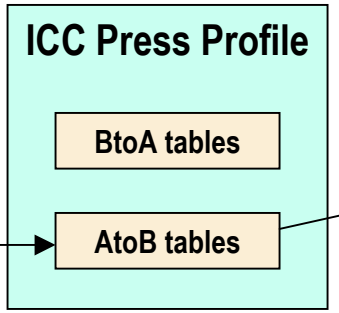
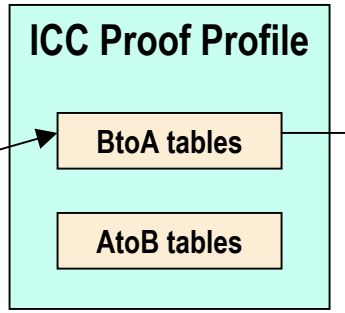
Proofer color management



Step 1: all document color conversion to CMYK performed as if the document will be printed on press



Step 2: calculate what colors will be produced for each CMYK when printed on Press



Step 3: calculate what CMYK values are needed to produce those colors on Press B

Digital proofer simulates a printing press or a well-defined printing process

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Proofer color management issues

- Element-based or raster-based color management
- Preserving black-only elements
- Avoiding ‘dirty’ yellows
- Proofing spot colors

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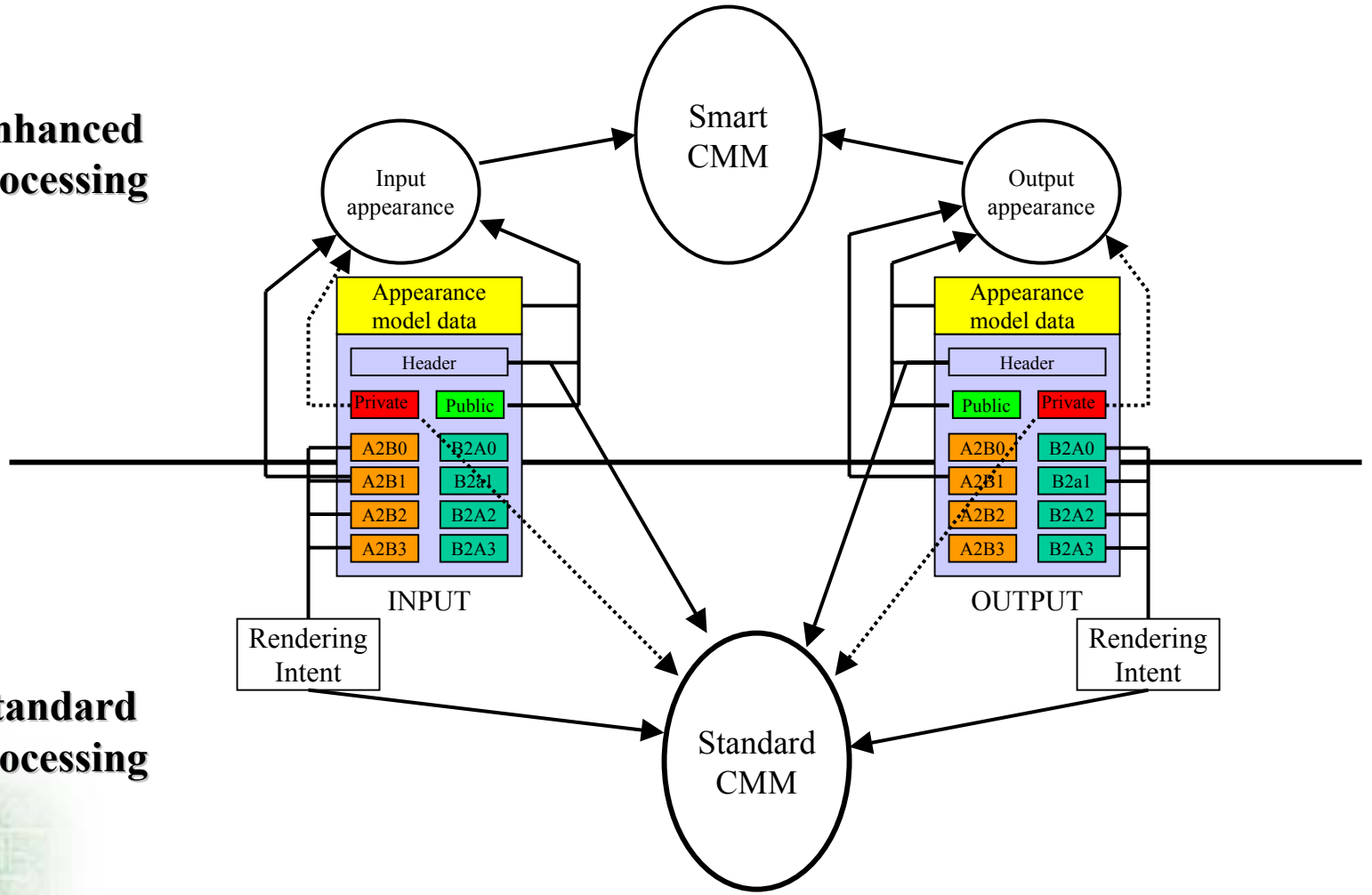
Possible extended ICC imaging model



Tutorial outline

- About the ICC
- ICC color management concepts
- Creating ICC profiles
- Using ICC profiles
- **Defining an ICC-based workflow**

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Defining workflow

- Start with Press definition
- Decide type of workflow
  - CMYK-early, Profiled RGB, Standard working space (sRGB)
- Establish rules for allowed color data types (PDF/X)
- Design workflow to minimize color conversions
- Test individual elements before putting them together
- Remember: garbage in still produces garbage out
- Adopting industry standards where possible can save a lot of work!

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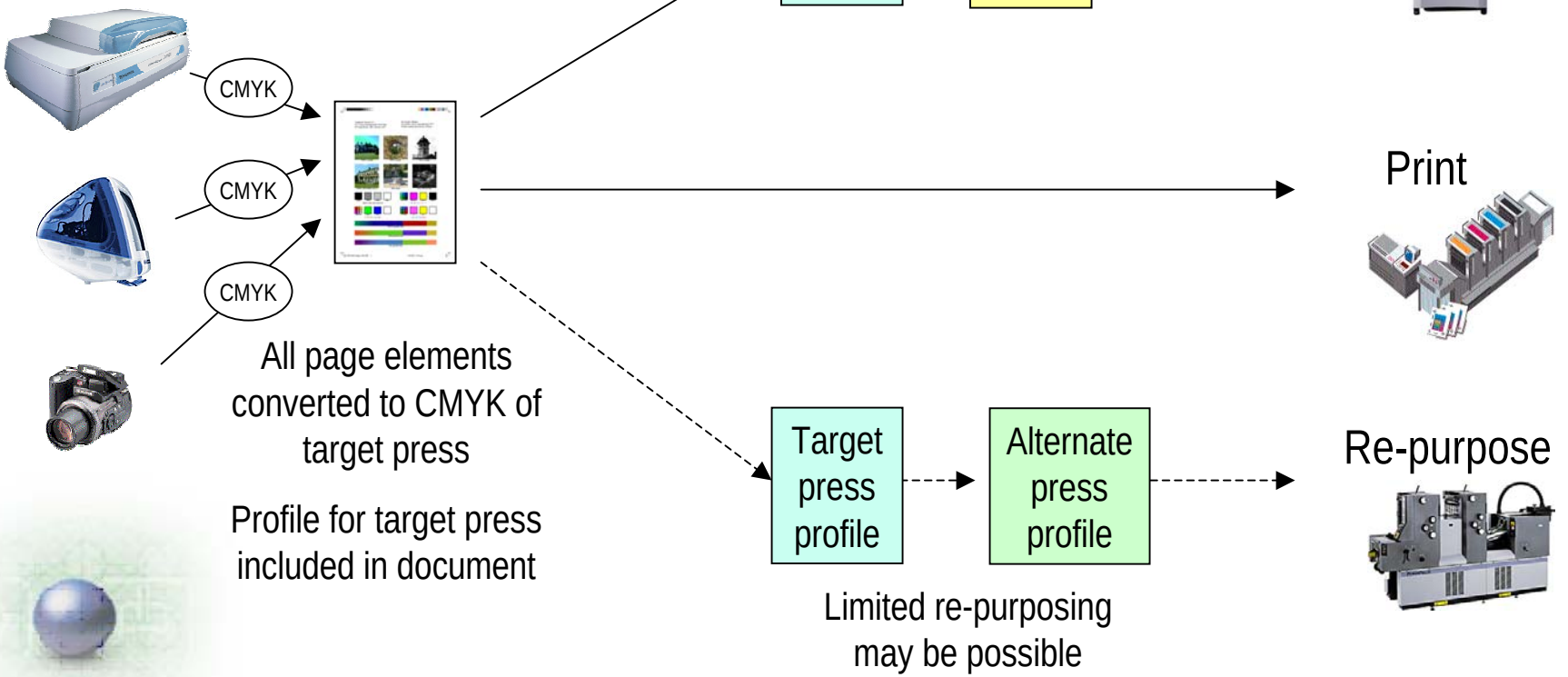
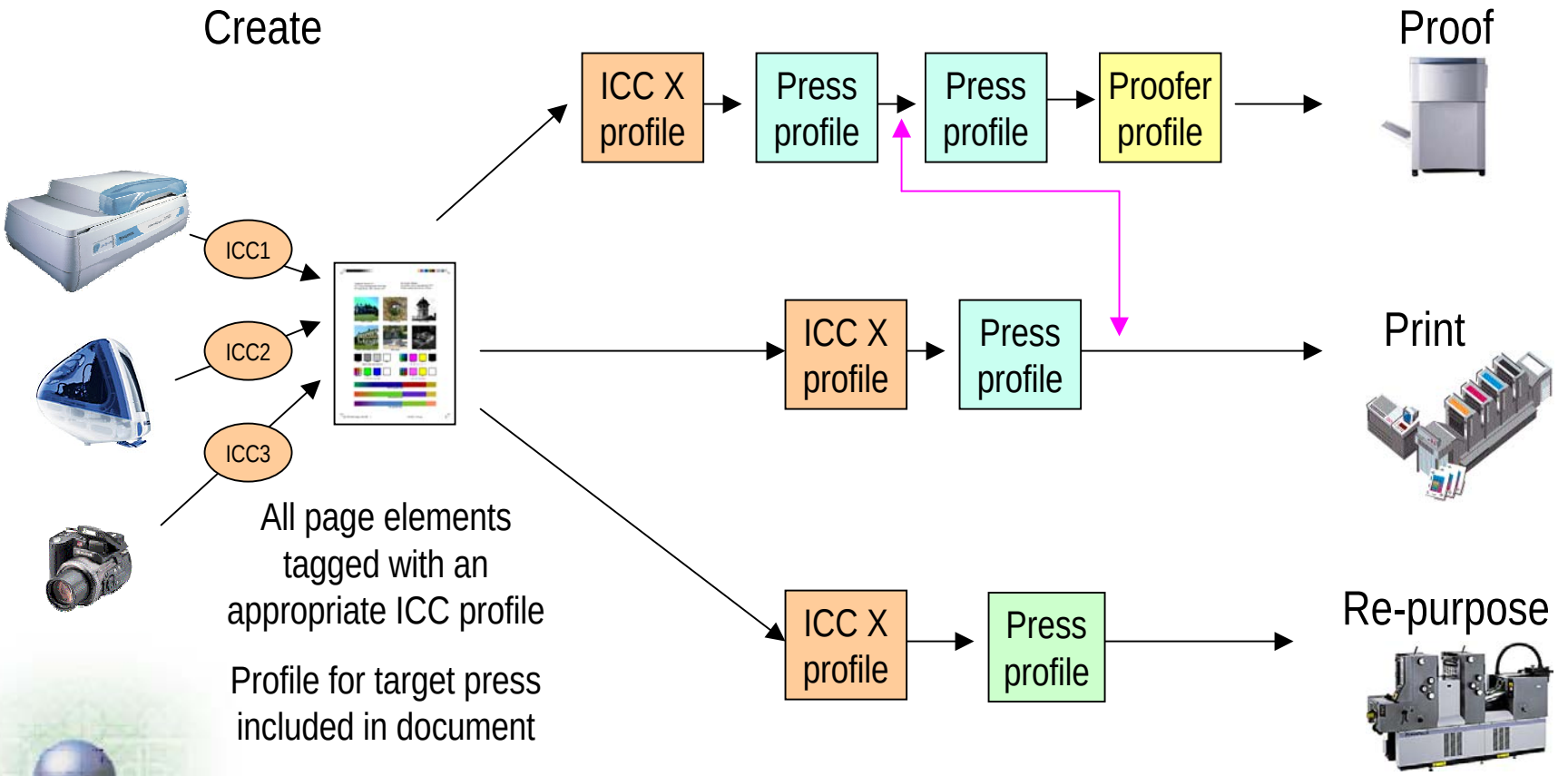
CMYK-early workflow example



Profiled RGB workflow example



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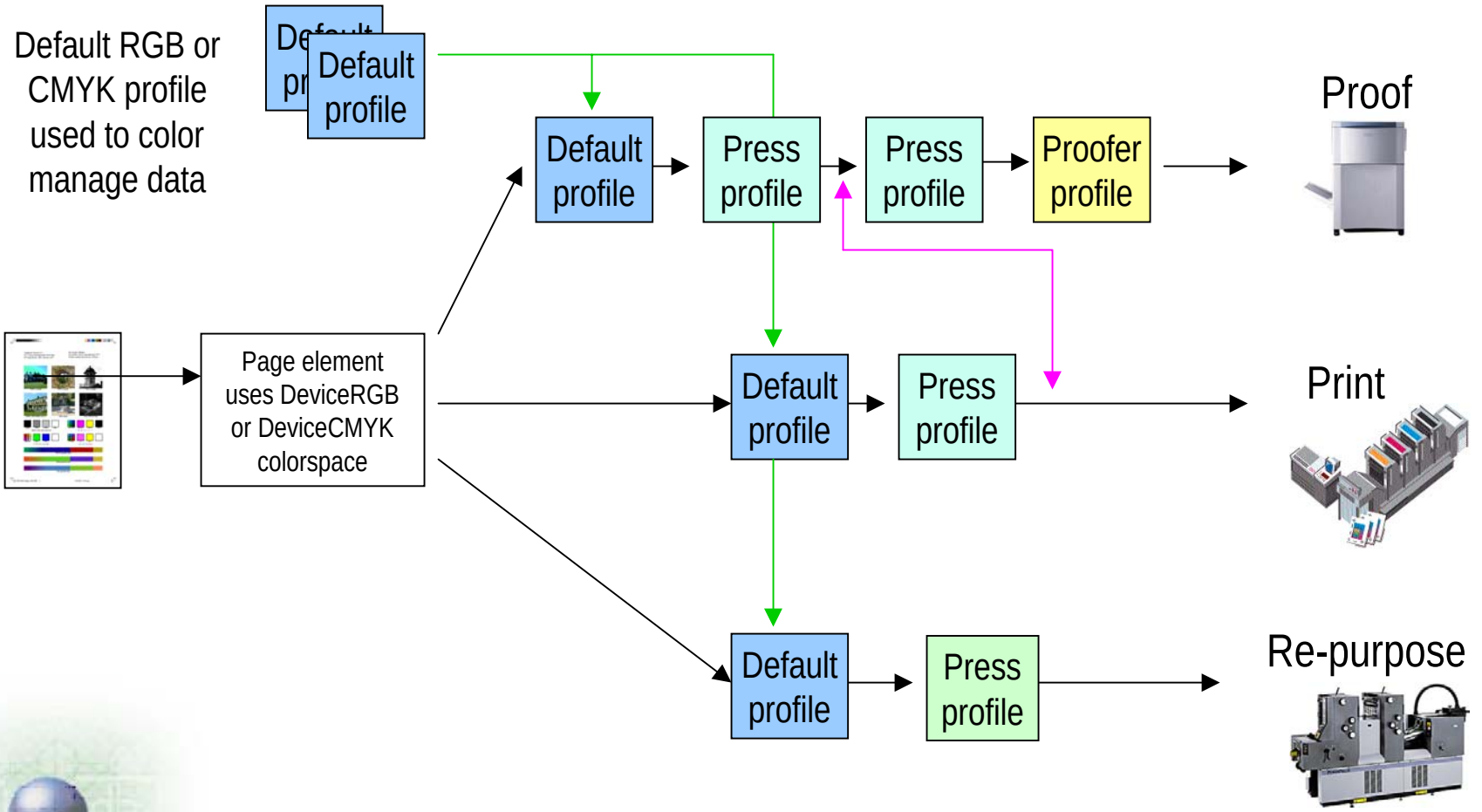
Correcting badly managed documents



PDF/X-1a

- Defined by ISO (ISO 15930-1)
- Designed for 'blind exchange'
- Based on PDF 1.3, documents must have:
  - all fonts and images embedded
  - all colored elements encoded as CMYK, spot or DeviceN
  - MediaBox, TrimBox and ArtBox defined
  - indication of whether file is trapped or untrapped
  - intended printing condition defined
- Widespread industry support
  - SWOP, DDAP, Time Inc, RR Donnelley

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PDF/X-3

- Currently being defined by ISO (ISO 15930-3)
- For 'blind exchange' within color managed workflows
- Based on PDF 1.3, documents must have:
  - all fonts and images embedded
  - colored elements encoded as CMYK or ICCBased (or equivalent)
  - intended printing condition defined
  - MediaBox, TrimBox and ArtBox defined
  - indication of whether file is trapped or untrapped
- Widespread industry support
  - ECI, FOGRA, Time Inc

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ICC Characterization data registry

- Maintained by the ICC secretariat
- Identifies standard printing conditions
- Short and long name for each printing condition
- Details given of how to obtain colorimetric data for printing process
- RGB data registry currently under construction
- Referenced by PDF/X-1a and PDF/X-3 standards

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Tutorial outline

- About the ICC
- ICC color management concepts
- Creating ICC profiles
- Using ICC profiles
- Defining an ICC-based workflow
- Questions and discussion

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