# everywhere you look

**Adobe** ®

# Why Color Management?

**James C. King**

*A Principal Scientist*

*Advanced Technology Group (ATG)*
*Adobe Systems Incorporated*

everywhere
you
look™

Adobe®

# Outline

- **Introduction to Color Management**

- **Basics of Conversions**

- **Color workflow issues**

- **Conversion Glitches**

    - **Where do things go wrong?**

- **A user's perspective -- Some thoughts on a better way**

# Introduction to
## Color Management

### Just the basics

# The Root Issue

## Devices Do Color Differently



Printer

Display 2
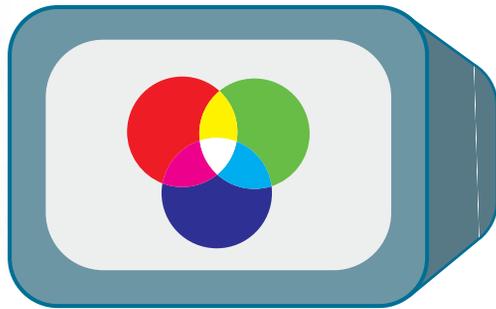
Display 1
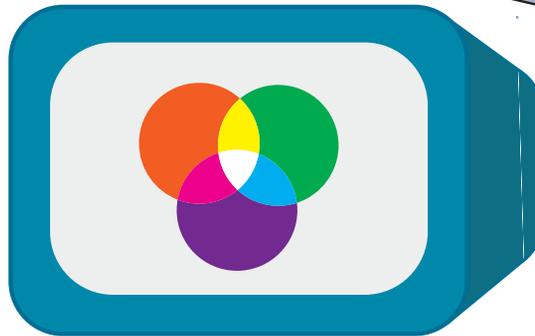
# Consistency

- **Same values produce different colors**
- **Same colors require different values**

# Color Value Conversions

- Transform:
  - *Table and interpolations*
  - *Device model formulae*

```
Source Color Values  →  Data Transformer  →  Destination Color Values
```

# The *n* by *m* Problem

- **(n x m) Transforms required**
  - *Both source and destination must be known for each*



n Sources      m Destinations
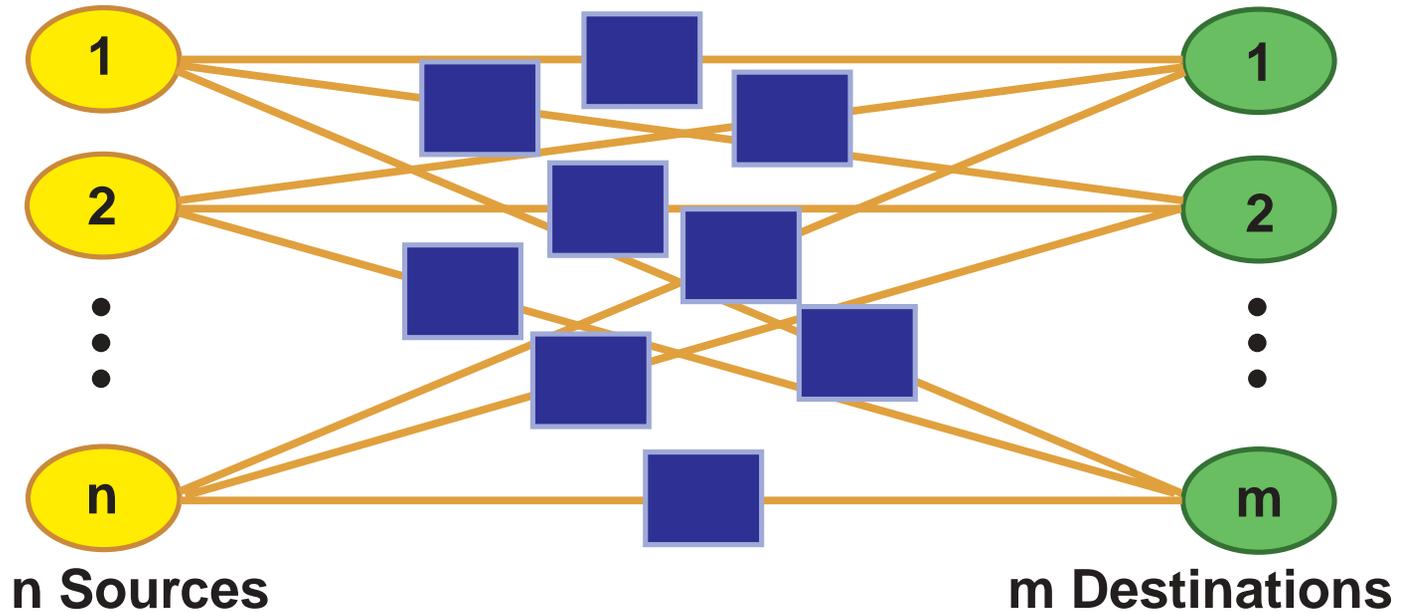
# Device Independence

- **(n + m) not (n x m)Transforms**
  - *Each source and destination handled independently*



n Sources     CIE XYZ     A Standard     m Destinations
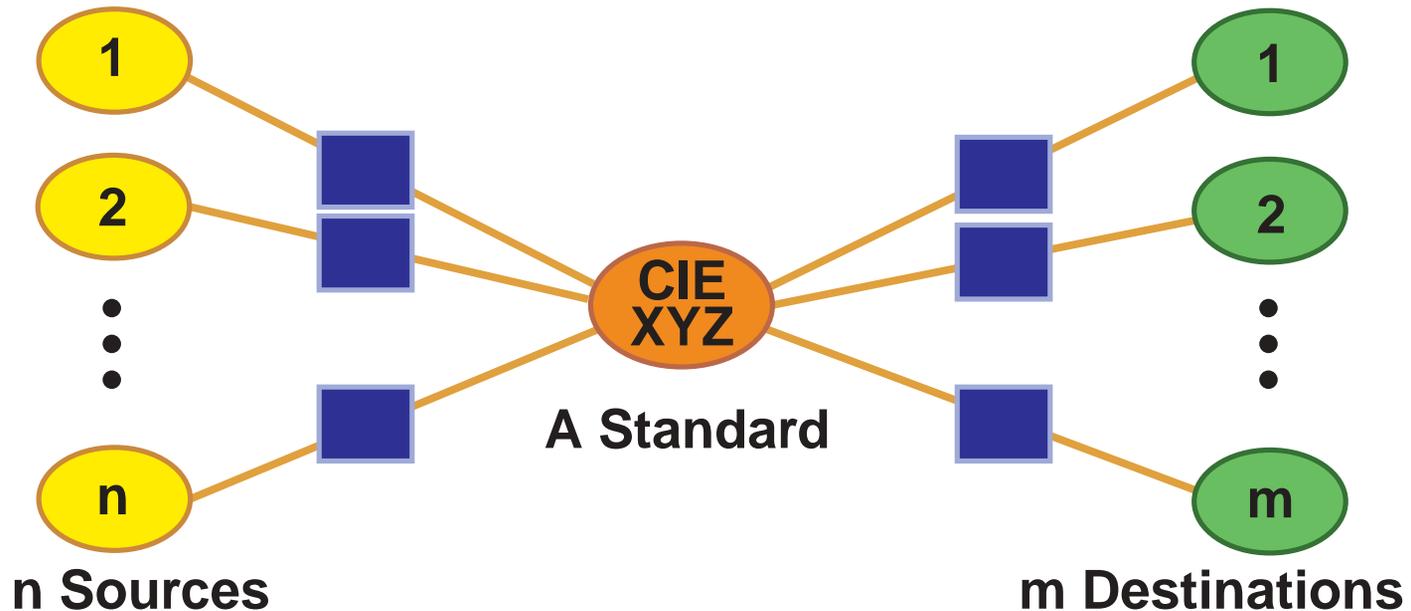
# Basic ICC Diagram
## (International Color Consortium)

- Composite conversion "compiled"
- ICC Profiles define colorspaces

**Source Profile**
(Colorspace Definition)

**Destination Profile**
(Colorspace Definition)

Source Color Values → **Color Matching Method (CMM)** → Destination Color Values

**Profile Connection Space (PCS)**

Adobe
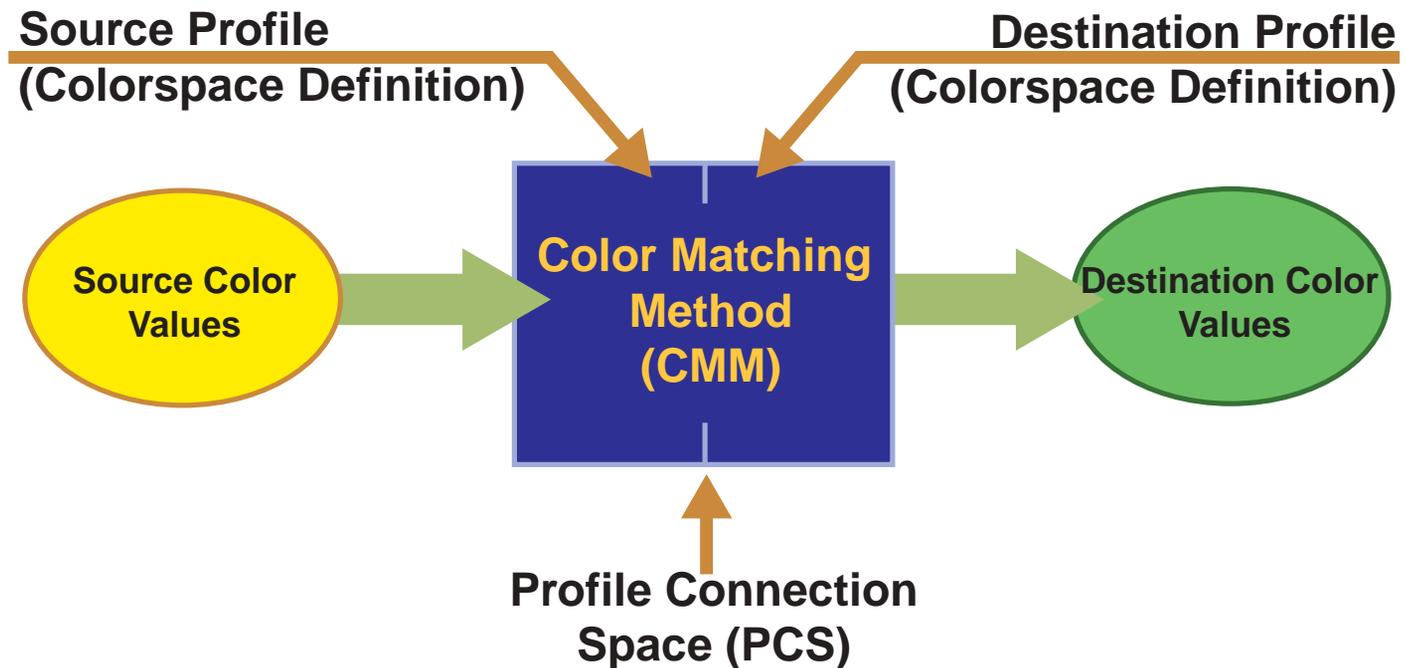
# Photoshop: Basic Workflow

- Monitor profile supplied by system
- Workspace profile set by user
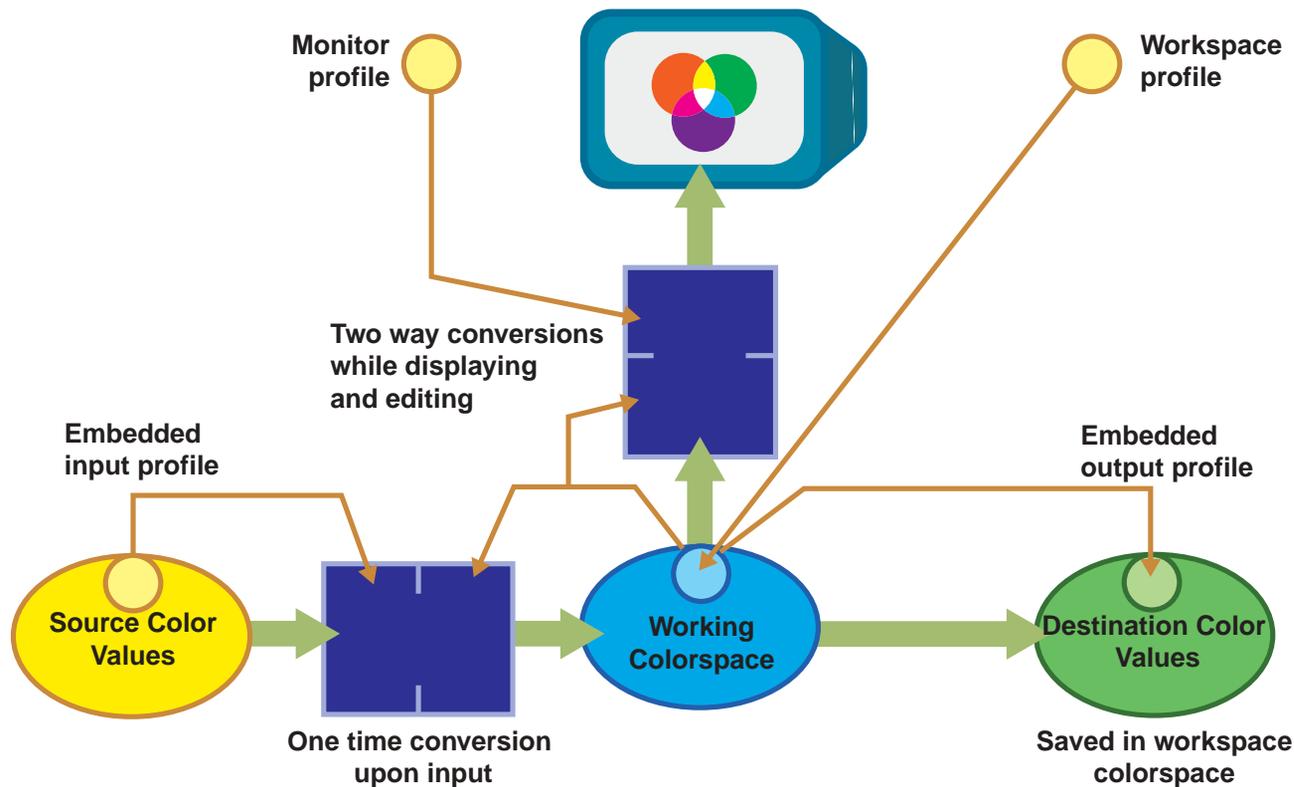
# Rendering Intents

- ## "gamut mapping"
  - *Destination colorspace "smaller" than source colorspace*
  - *Shrinking the range of colors in an object*

# Gamut Differences
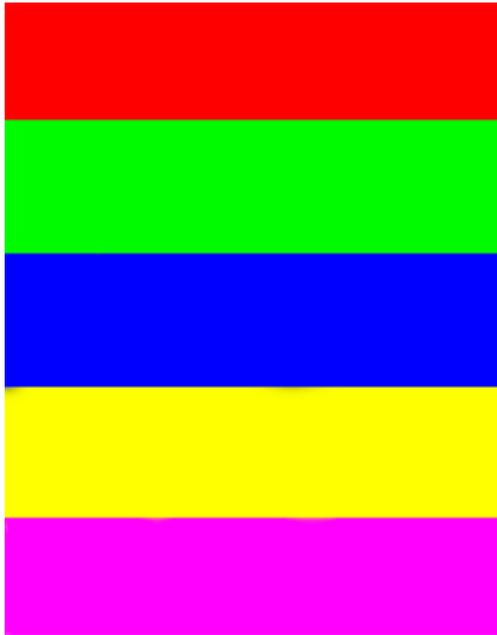


RGB

(Original)

CMYK

(Photoshop Swop Coated)

# Gamut Mapping

- **Four situations identified**
  - *Perceptual (pictures)*
  - *Saturated (graphics)*
  - *Relative Colorimetric (logos)*
  - *Absolute Colorimetric (strict conversions)*

# Rendering Requirements



**Logo-Colorimetric**

**Picture-Perceptual**
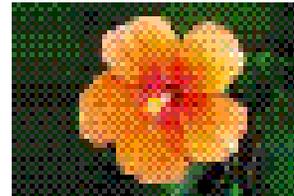
**Graph-Saturated**
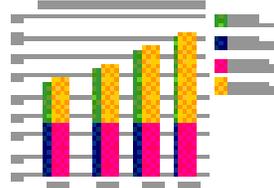
# Rendering Intents

RGB Original

CMYK-Perceptual

CMYK-Saturated

CMYK-Relative Colorimetric

CMYK-Absolute Colorimetric

# Rendering Intents

- **Intent is property of the source**
- **Action happens during output**
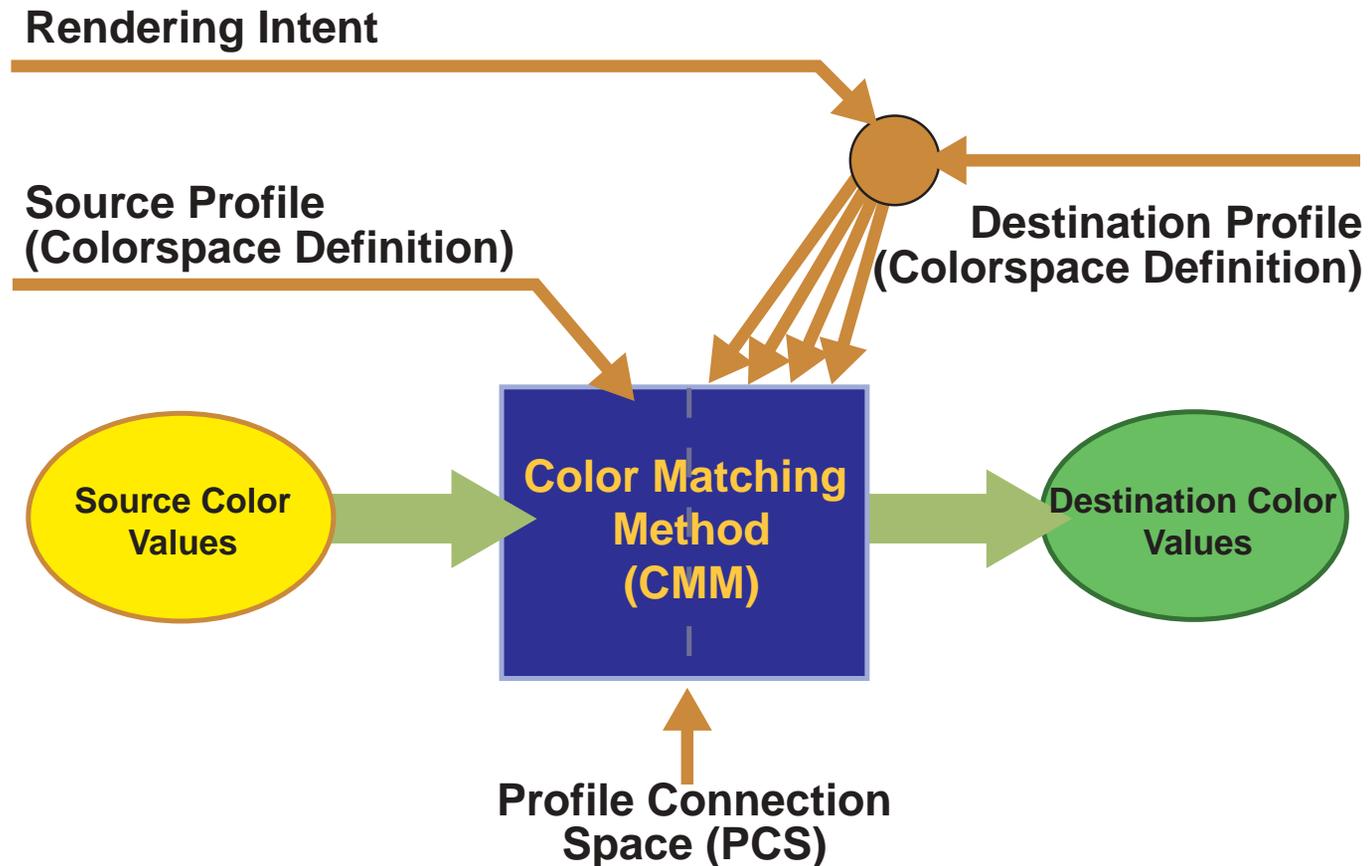
# Rendering Intents

- Monitor profile supplied by system
- Workspace profile set by user
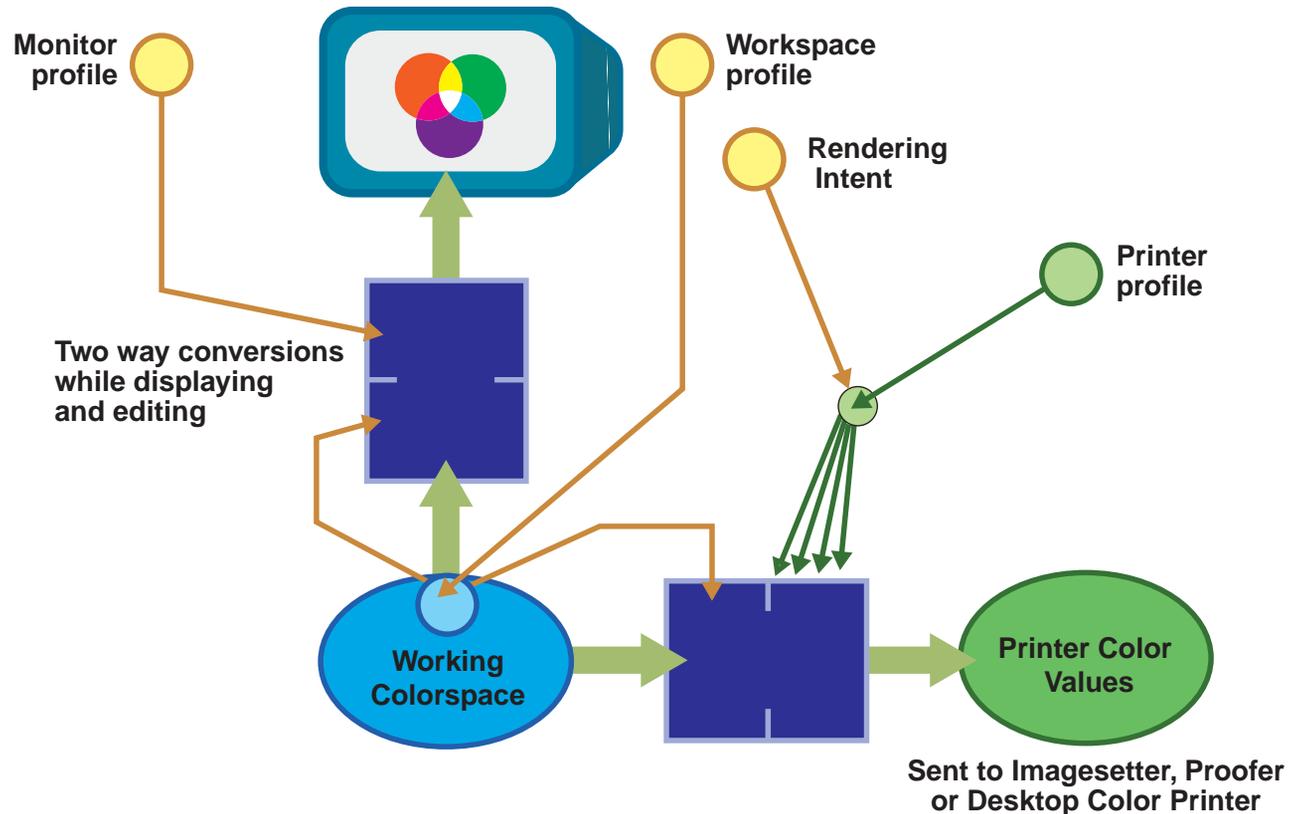
# Soft Proofing

- **What would it look like on my printer**
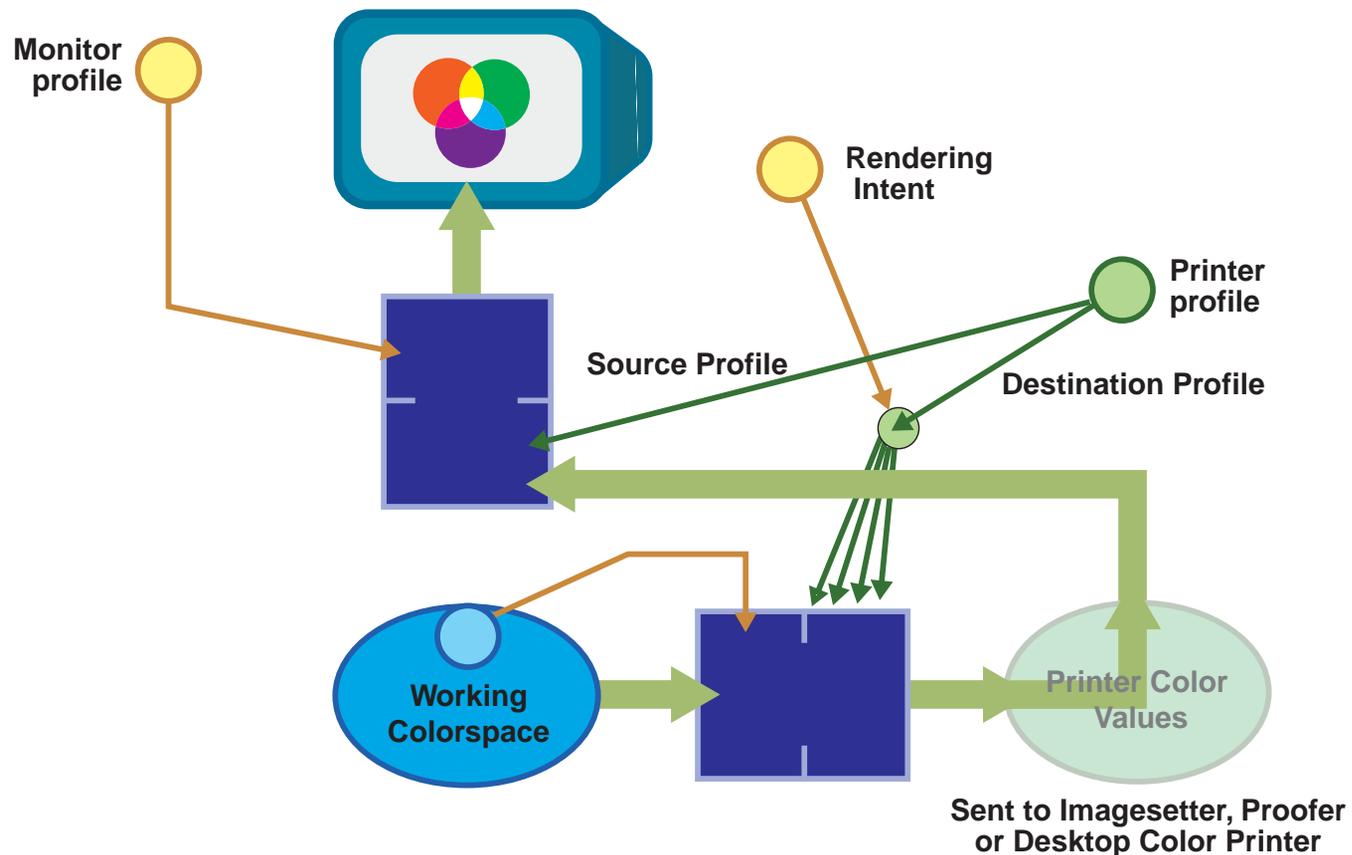
# Basics of Conversions

# Device Models

- **e.g., CRT Displays**

# Device Models (CRTs)

- **Linear Additive Devices**



**1-IN   1-OUT**
**Component Modification**

**1-IN   1-OUT**
**Component Modification**
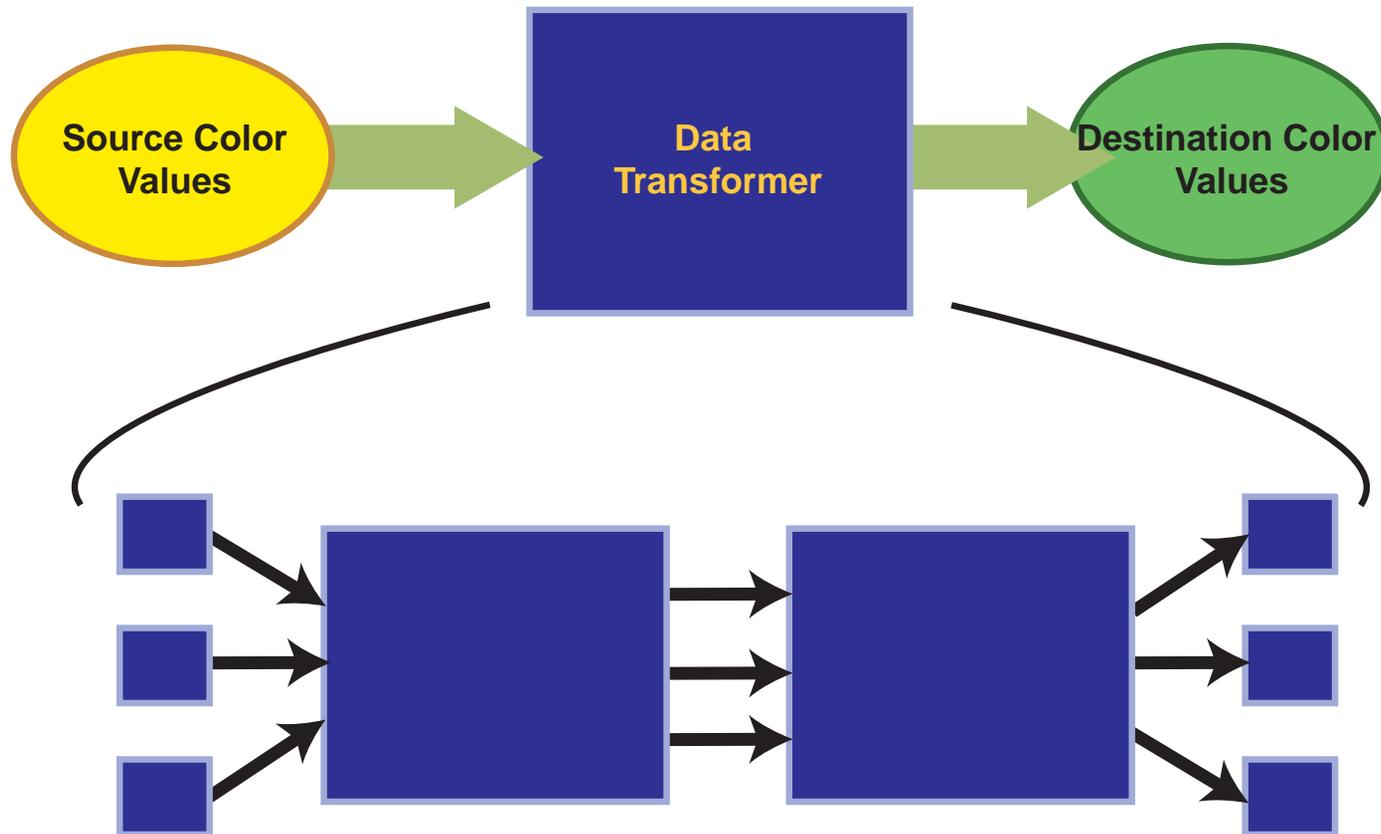
**3-IN   3-OUT**
**Linear Transform**

**3-IN  3-OUT**
**Linear Transform**
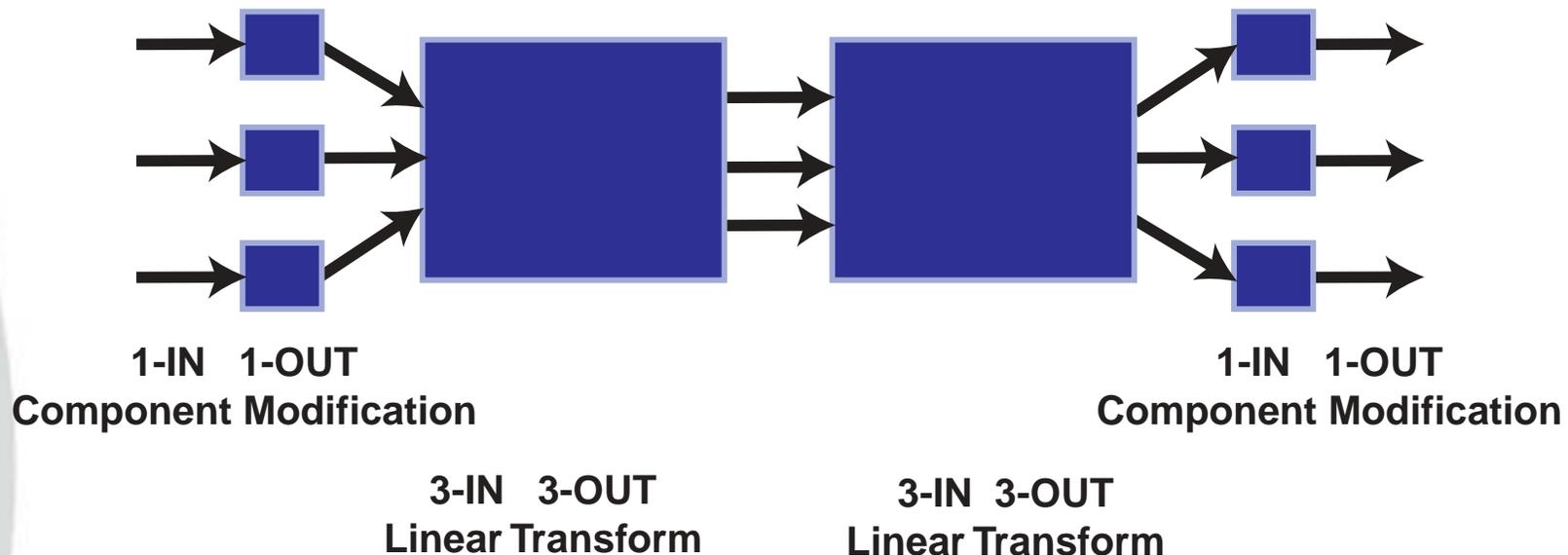
# Single Component

- **Things like Gamma adjustments**
- **"Linearize" the components**

1-IN   1-OUT
**Component Modification**
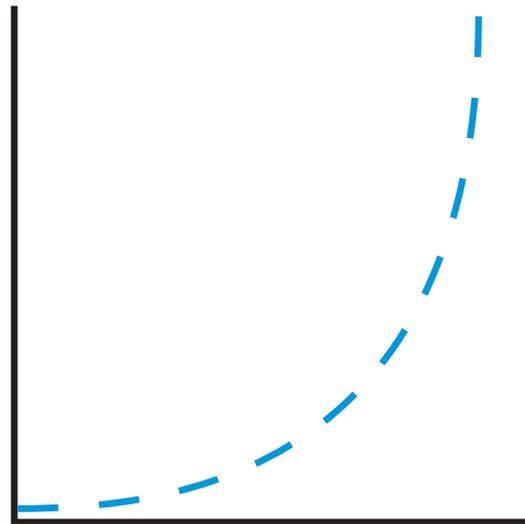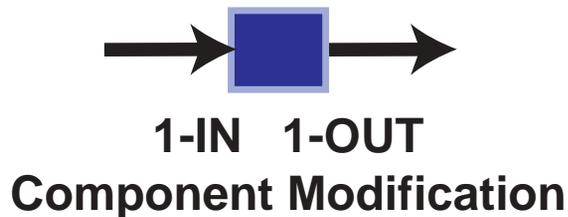
# The Famous 3x3
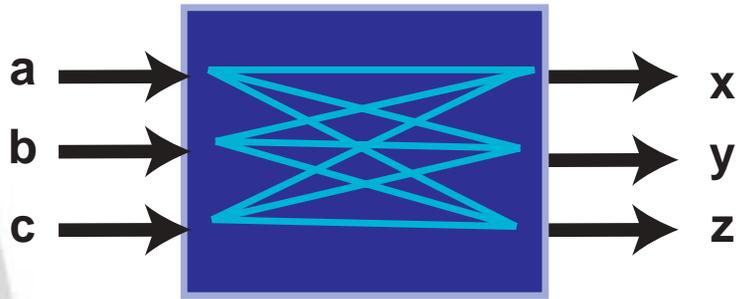
$$x = 1.0 \cdot a + 1.4 \cdot b + 0.8 \cdot c$$

$$y = 0.0 \cdot a + 2.5 \cdot b + 0.6 \cdot c$$

$$z = 1.3 \cdot a + 1.4 \cdot b + 1.3 \cdot c$$

**a** → **x**
**b** → **y**
**c** → **z**

**3-IN   3-OUT**
**Linear Transform**

$$\begin{pmatrix} 1.0 & 1.4 & 0.8 \\ 0.0 & 2.5 & 0.6 \\ 1.3 & 1.4 & 1.3 \end{pmatrix}$$

**3 x 3 Matrix**

Adobe

# Device Models (CRTs)

- ## Linear Additive Devices

**1-IN   1-OUT**
**Component Modification**

**1-IN   1-OUT**
**Component Modification**

**3-IN   3-OUT**
**Linear Transform**

**3-IN  3-OUT**
**Linear Transform**
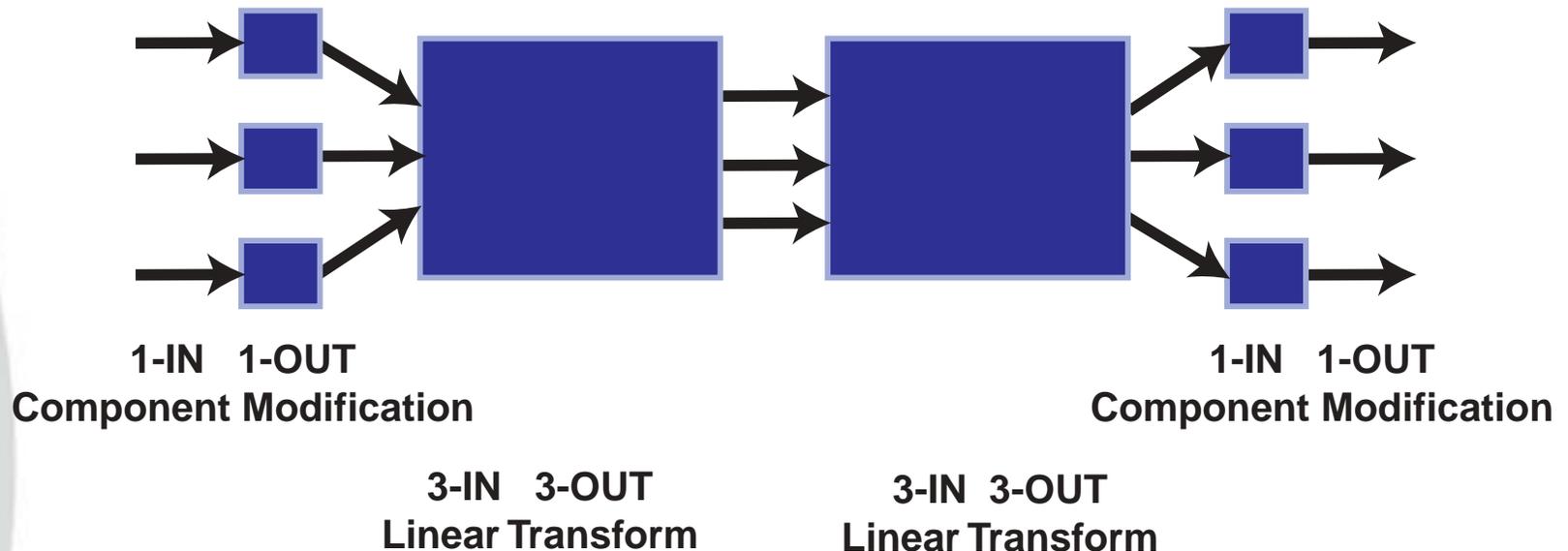
# Table Lookup

- **E.g., Printers**



X → [■] ↘
Y → [■] → **3-IN 4-OUT Lookup Table** ↗ [■] → C
Z → [■] ↗                                ↗ [■] → M
                                          ↘ [■] → Y
                                          ↘ [■] → K

**1-IN   1-OUT**
**Component Modification**

**1-IN   1-OUT**
**Component Modification**

**3-IN   4-OUT**
**Lookup Table**

# CRT to Printer



R → ■ ↘
G → ■ → [CRT Profile box] → X → ■ ↘
B → ■ ↗                         Y → ■ → [Printer Profile box] → ■ → C
                                Z → ■ ↗                         ■ → M
                                                                ■ → Y
                                                                ■ → K

← **CRT Profile** →     |     ← **Printer Profile** →

**CIE XYZ
(PCS)**

Adobe
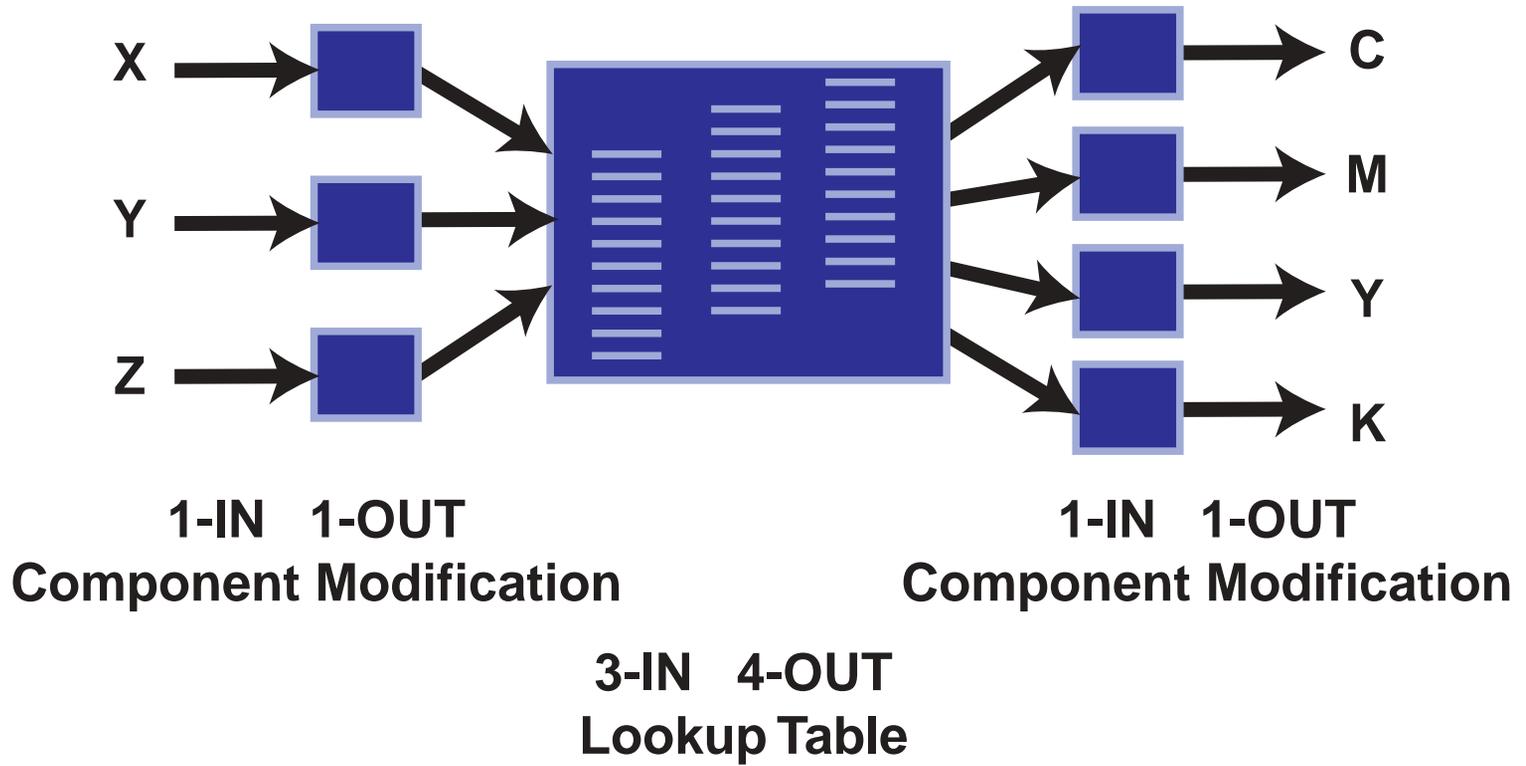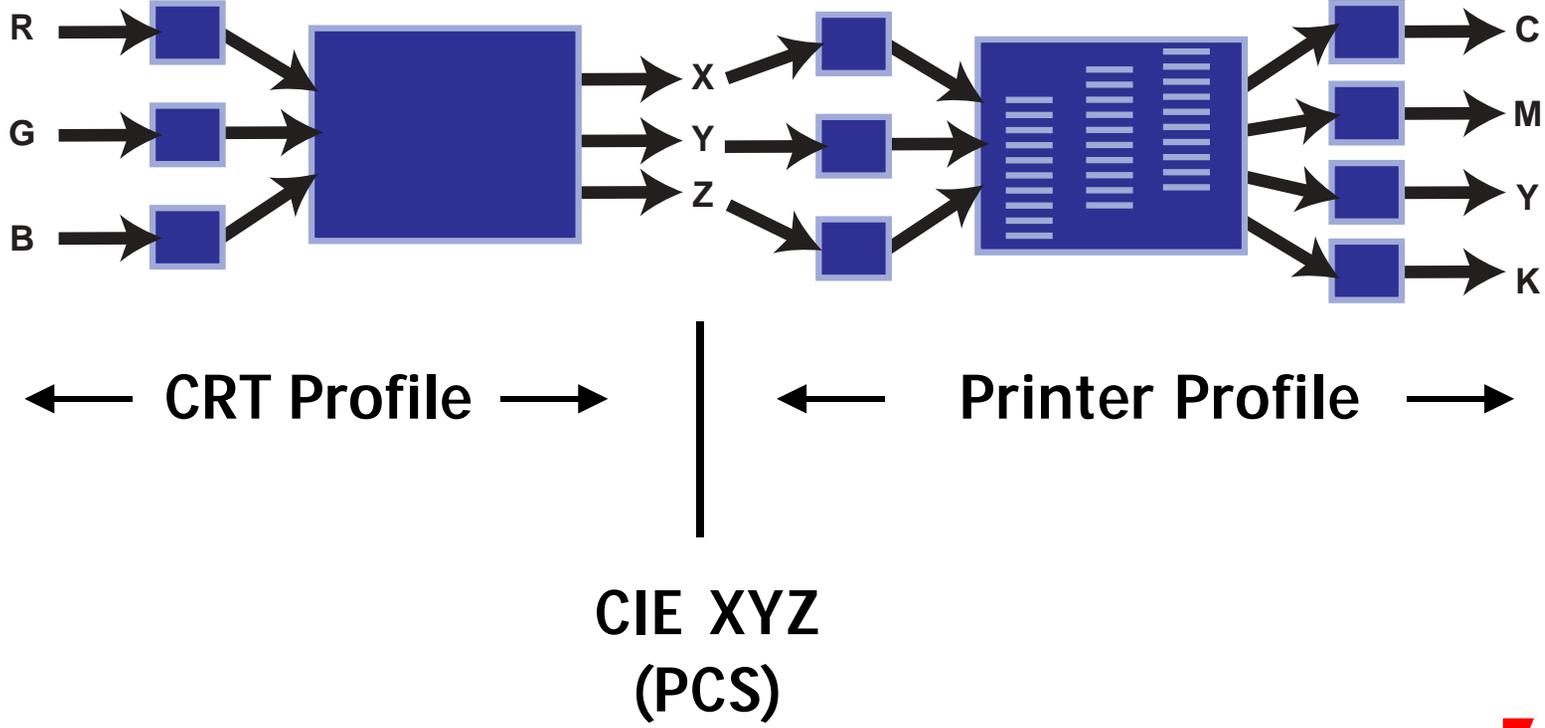
# White & Black Points
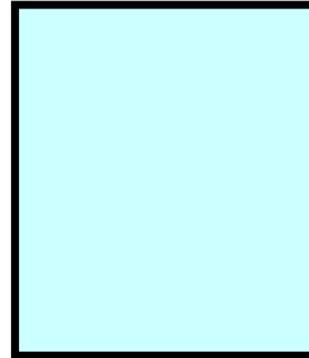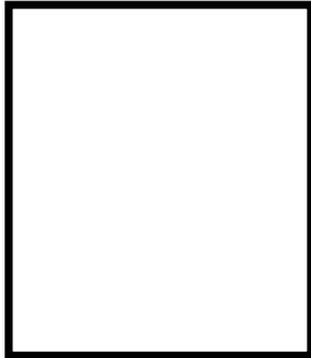
# Color Workflow Issues

# Both PostScript and PDF have what it takes

- ## PostScript
  - *Color Space Arrays (CSA) -- source profiles*
  - *Color Rendering Dictionaries (CRD) -- destination profiles*
  - *No direct support for ICC profiles but converters available*
- ## PDF
  - *Color Space Resources (CSR) -- source profiles*
  - *No destination profiles*
  - *Supports ICC profiles as option in addition to PostScript like source profiles*
- ## Both support
  - *Intents*
  - *Compound documents -- multiple colorspaces per page/document*

# Real Example

Hello World

Star -- **filled** with L*a*b* Yellow  ///  Star -- **stroked** with Calibrated RGB Blue

```
%PDF-1.2                      2 0 obj                        3 0 obj
1 0 obj                       << /Length 51 >>              <</ProcSet[/PDF/Text]
<<                             stream                        /Font <</F1 4 0 R>>
 /Type /Page                    BT                           /ColorSpace
 /Parent 5 0 R                  /F1 24 Tf                      <</CS1
 /Resources 3 0 R              1 0 0 1 260 600 Tm              [ /Lab << /Range
 /Contents 2 0 R                /CS1 cs                        [-128 127 -128 127]
>>                             63 127 127 sc                     /WhitePoint
endobj                         (Hello World)Tj                [ 0.951  1  1.089]
                               ET                                    >> ]    >>
                                                              <</CS2
                               100 0 127 sc                   [ /CalRGB <<
                                                                 /Gamma
                               /CS2 CS                        [2.222 2.222 2.222]
                               0 0 1 SC                          /Matrix
                              315 572 m                       [0.412 0.213 0.019
                              299 528 l                        0.358 0.715 0.119
                              339 554 l                        0.181 0.072 0.951]
                              291 554 l                         /WhitePoint
                              331 528 l                       [0.951  1  1.089]
                               b                                     >> ]    >>
                              endstream                      >>
                             endobj                          endobj
```

Example  08                                                                 Page 1

```
4 0 obj
<<
 /Type /Font
 /Subtype /Type1
 /Name /F1
 /BaseFont/Helvetica
>>
endobj

5 0 obj
<<
 /Type /Pages
 /Kids [ 1 0 R ]
 /Count 1
 /MediaBox
   [ 0 0 612 792 ] >>
endobj
```

```
6 0 obj
<<
 /Type /Catalog
 /Pages 5 0 R
>>
endobj

trailer
<<
 /Root 6 0 R
>>
```

Example  08                                        Page 2

Star -- **filled** with L*a*b* Yellow  ///   Star -- **stroked** with Calibrated RGB Blue

```
%PDF-1.2                          2 0 obj                    3 0 obj
1 0 obj                           << /Length 51 >>          <</ProcSet[/PDF/Text]/
<<                                 stream                   Font <</F1 4 0 R>>
 /Type /Page                        BT                      /ColorSpace
 /Parent 5 0 R                      /F1 24 Tf                <</CS1
 /Resources 3 0 R                   1 0 0 1 260 600 Tm        [ /Lab << /Range
 /Contents 2 0 R                    /CS1 cs                   [-128 127 -128 127]
>>                                  63 127 127 sc               /WhitePoint
endobj                             (Hello World)Tj            [ 0.951  1  1.089]
                                    ET                               >> ]     >>
                                                             <</CS2
                                    100 0 127 sc               [/ICCBased 7 0 obj]
                                                              >>
                                    /CS2 CS                  >>
                                    0 0 1 SC                 endobj
                                   315 572 m
                                   299 528 l                 7 0 obj
                                   339 554 l                 <</Length 345
                                   291 554 l                   /N 3     >>
                                   331 528 l                 stream
                                   b                         ... (ICC Profile) ...
                                  endstream                  endstream
                                 endobj                      endobj
```

Example 08

# A PostScript File Equivalent to Example 8

```
%!PS
% PostScript file
that generates same
output as example 08

/Helvetica findfont
24 scalefont setfont
260 600 moveto

[/CIEBasedABC <<
 /RangeABC
   [0 100 -128
        127 -128 127]
 /DecodeABC
    [{16 add 116 div}
      bind {500 div}
      bind {200 div}
      bind]
 /MatrixABC
 [1 1 1 1 0 0 0 0 -1]
 /DecodeLMN
  [{dup 6 29 div ge
    {dup dup mul mul}
```

```
   {4 29 div sub 108
841 div mul} ifelse
0.9505 mul} bind
 {dup 6 29 div ge
    {dup dup mul mul}
    {4 29 div sub 108
841 div mul} ifelse}
   bind
 {dup 6 29 div ge
    {dup dup mul mul}
    {4 29 div sub 108
841 div mul} ifelse
1.0890 mul} bind]
 /WhitePoint
    [0.9505 1 1.0890]
>>] setcolorspace
63 127 127 setcolor

(Hello World) show
```

```
100 0 127 setcolor
315 572 moveto
299 528 lineto
339 554 lineto
291 554 lineto
331 528 lineto

gsave
 fill
grestore

[/CIEBasedABC <<
 /DecodeLMN
   [{1 0.45 div exp}
      bind dup dup]
 /MatrixLMN
 [0.412 0.213 0.019
  0.358 0.715 0.119
  0.181 0.072 0.951 ]
 /WhitePoint
    [0.9505 1 1.0890]
>>] setcolorspace
0 0 1 setcolor
```

Example 08.ps                    Page 1

```
closepath
true setstrokeadjust
stroke

showpage
```

Example 08.ps                                                    Page 2

# Conversion Glitches

## Where do things go wrong?

# Limited Places for Error

- Quantization (truncation)

- Gamut compression

- White Point/Black Point Compensation

- Bad arithmetic

- Interpolation errors

# Quantization

- **8-bits isn't really enough**
  - *No room for mistakes*
  - *Some colorspaces not spaced right*

- **Move to 16-bits per component**
  - *It only doubles color value sizes*

# Gamut compression

- Avoid it
- Delay it
- Do it only once at the end

# White Point/Black Point

- ICC Specification hasn't been clear

- Change ICC model
  - *To be more like PostScript*

# Bad arithmetic

- Don't do it

- Get help

Adobe®

# Interpolation errors

- **Adjust table size for more accuracy**

- **Tables need fractional values**
    - *Get ICC to change*

# Compound Documents

## It gets complicated!

# Compound Documents
## (more than one colorspace)

- **Photoshop**

# Compound Documents
## (more than one colorspace)

- **PageMaker**

Monitor profile

Conversions while displaying

Individual Objects (each with own colorspace)

Compound Document

# Compound Documents
## (more than one colorspace)

- **PageMaker or In the RIP**

Printer profile

Printer Color Values

Rendering Intents

Sent to Imagesetter, Proofer or Desktop Color Printer

Individual Objects (each with own colorspace)

Each Object may have its own intent
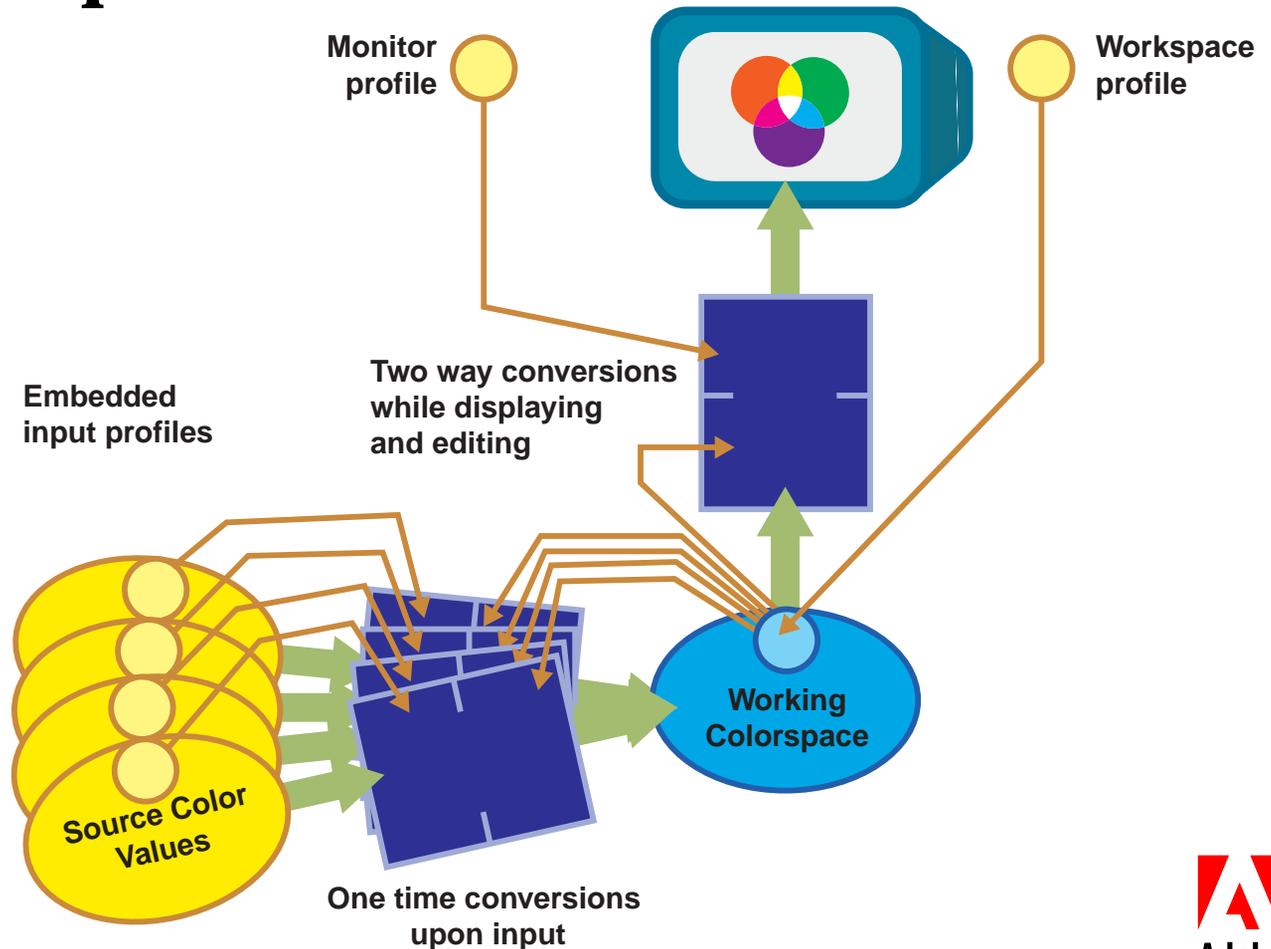
Compound Document
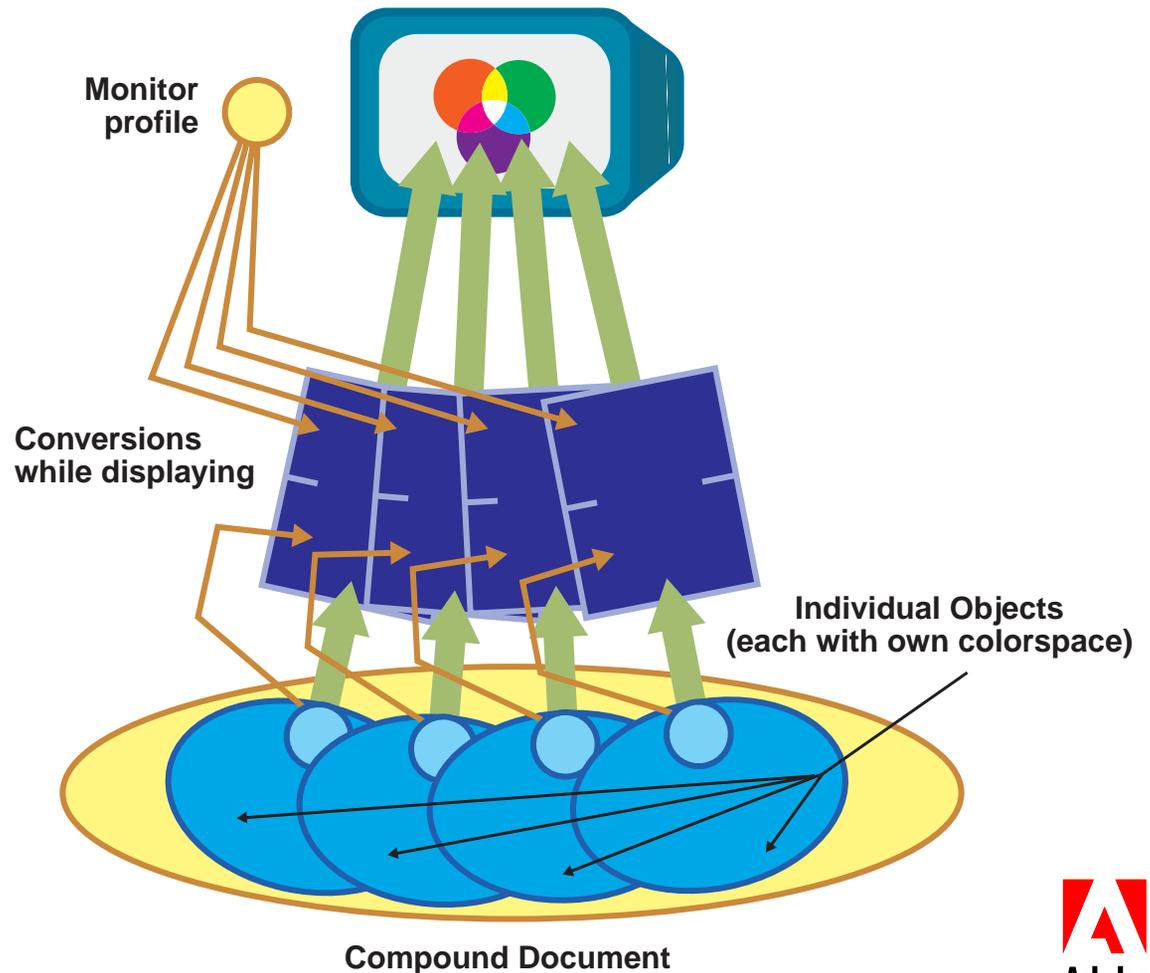
# A User's View

**And some thoughts
on a better model**

# A User's View

- ## What does a user want?
  - ### *This red color*
  - ### *What is a colorspace?*
  - ### *Why do I care?*

- ## Users don't ask for:
  - ### *a monitor colorspace*
  - ### *an ICC profile*

- ## They just want this red

# Now is Device Centric

- We move colors through device colorspaces
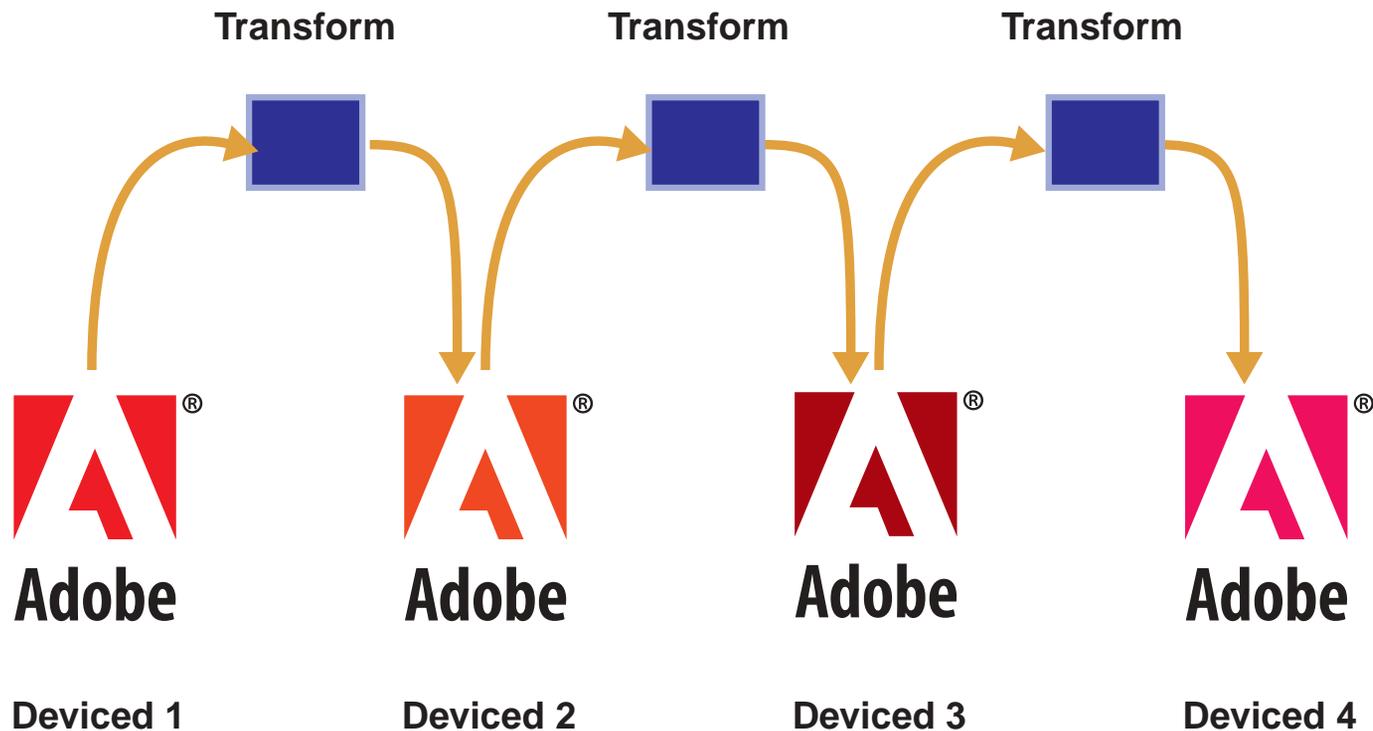
# We have it backwards!

- Should A slide over B
- Or should B slide under A

# Fixed Colored Data
## Just have Windows onto it

- Only Change the view of it
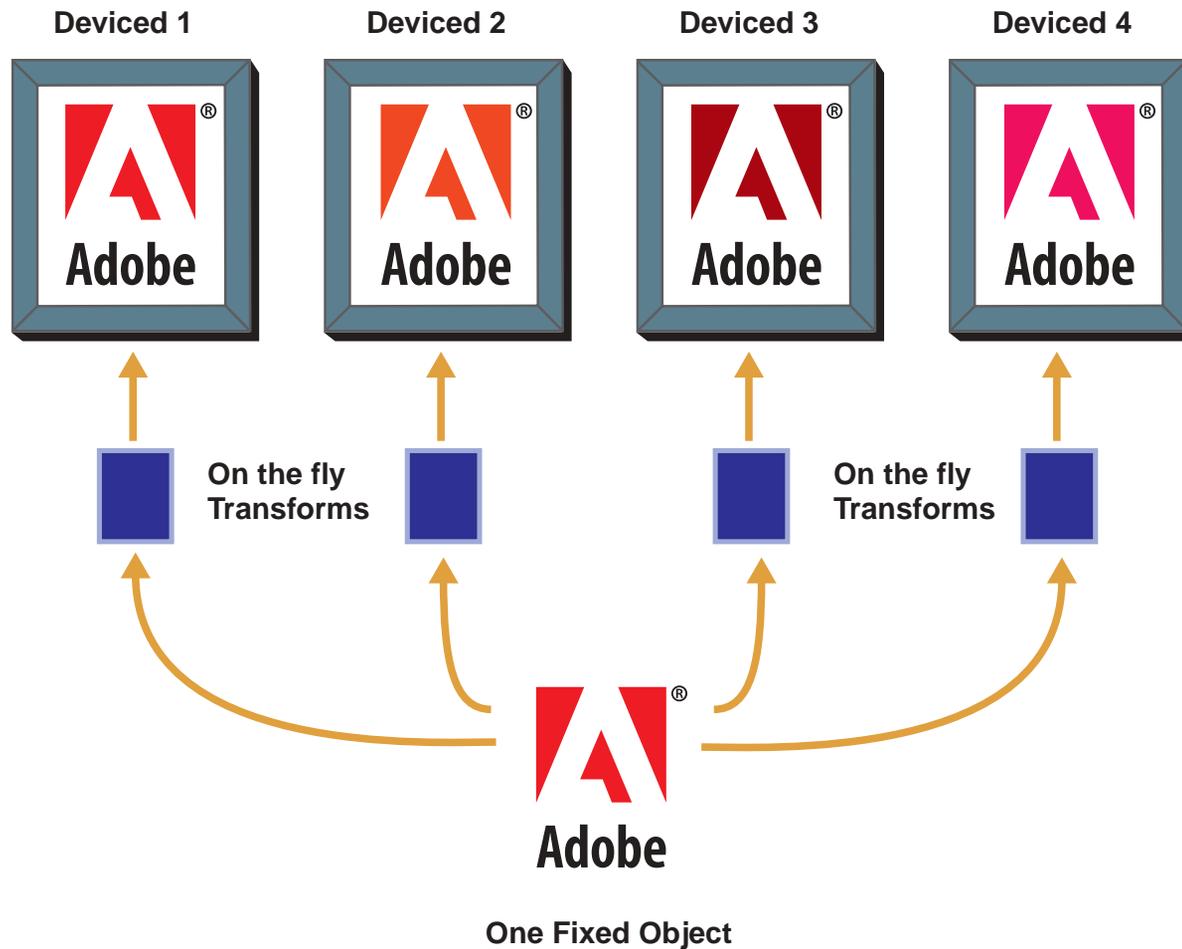
# Fixed Colored Data

- ## A universal colorspace

  - ### *Extend the idea of workspace*

- ## All colors visible by humans

- ## Enough bits to allow flexibility

  - ### *Precision*
  - ### *Range*

# Homework

- **How do you edit using this model?**