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Why Color Management?

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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

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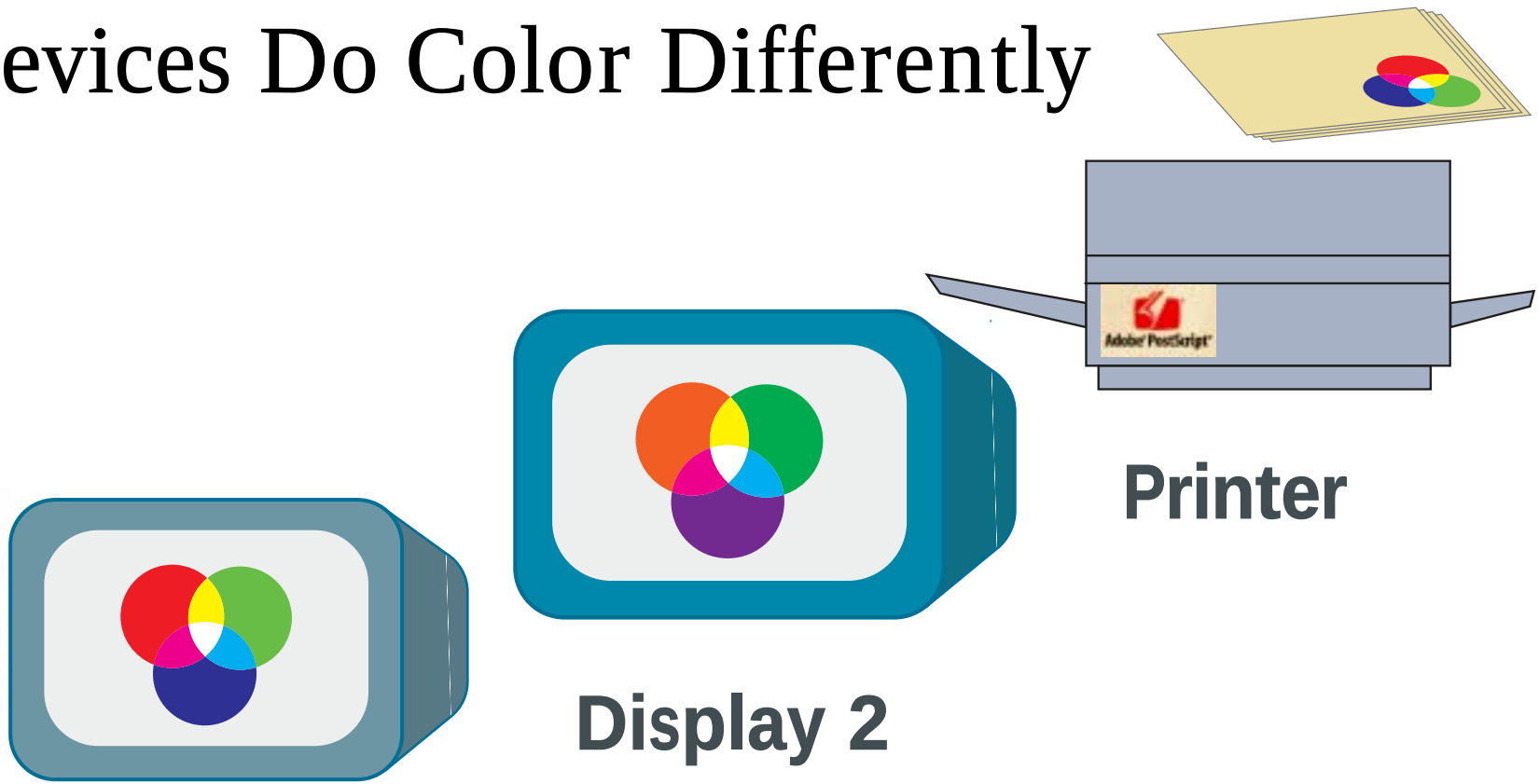
Introduction to Color Management

Just the basics

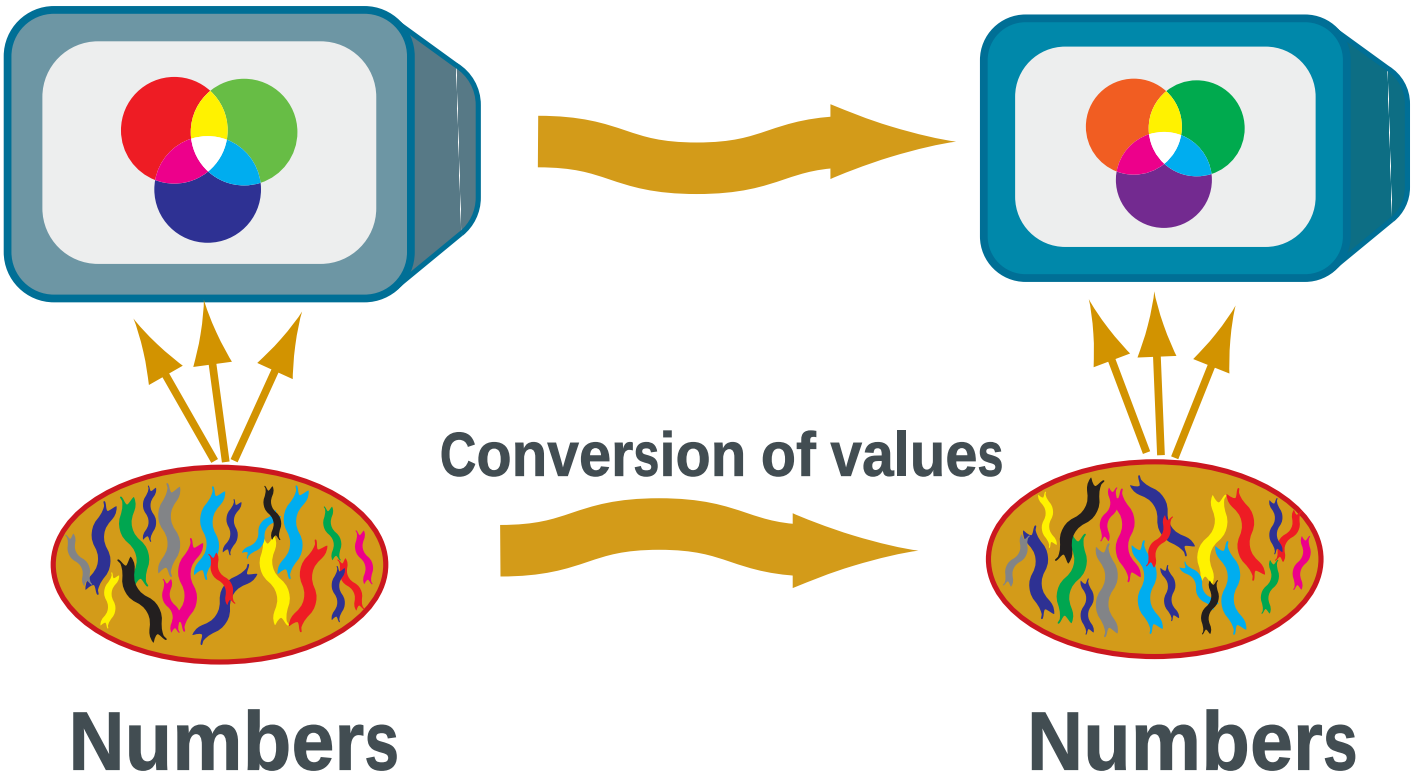
The Root Issue

Devices Do Color Differently



Consistency

Same results require different values



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Consistency

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

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Color Value Conversions

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

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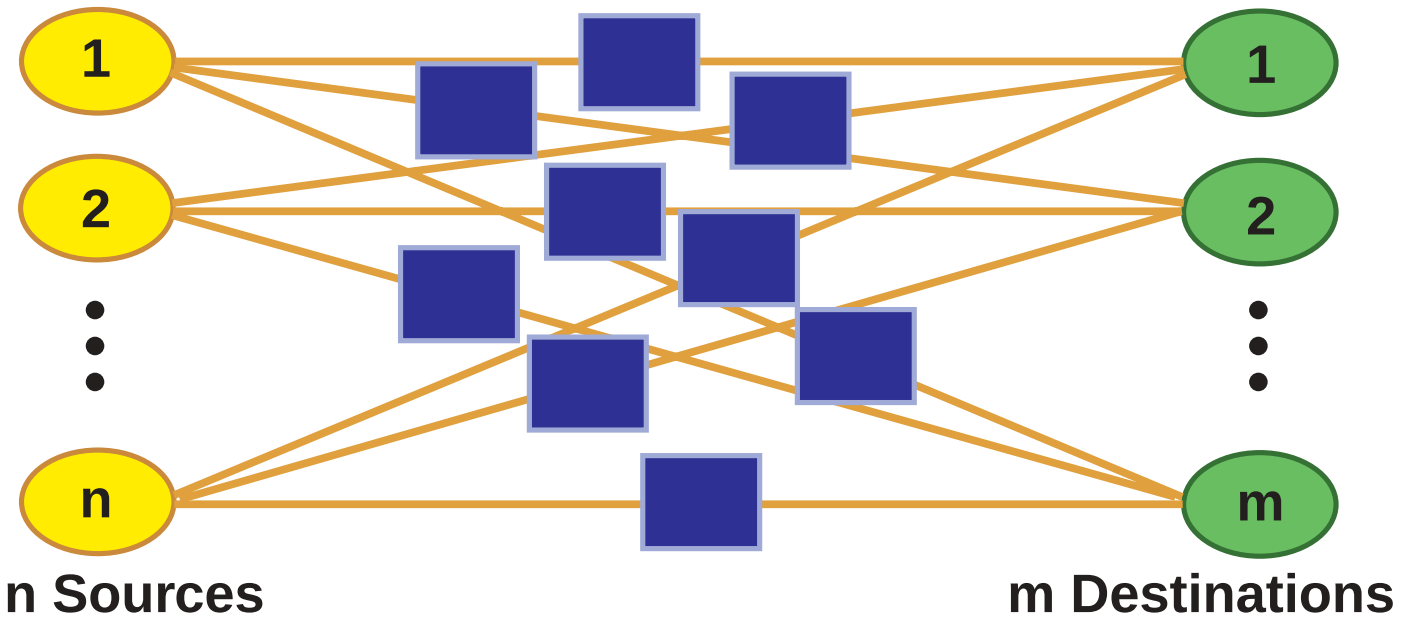
The *n* by *m* Problem

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



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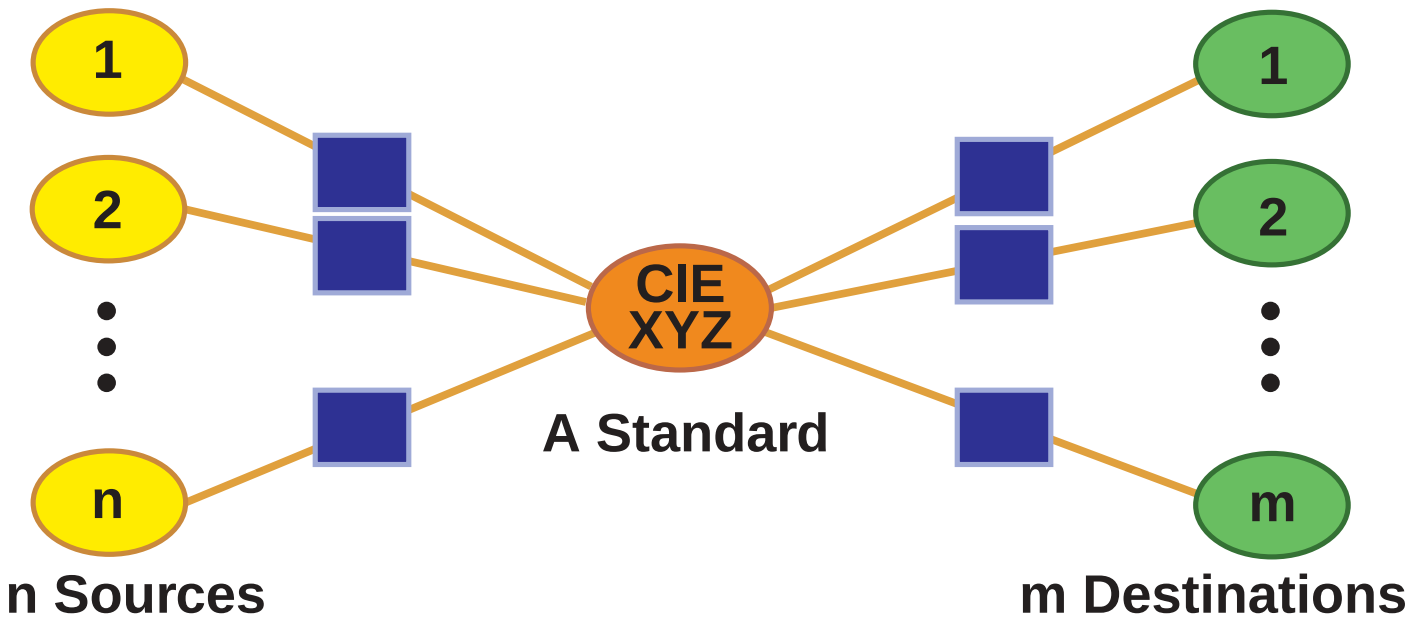
Device Independence

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



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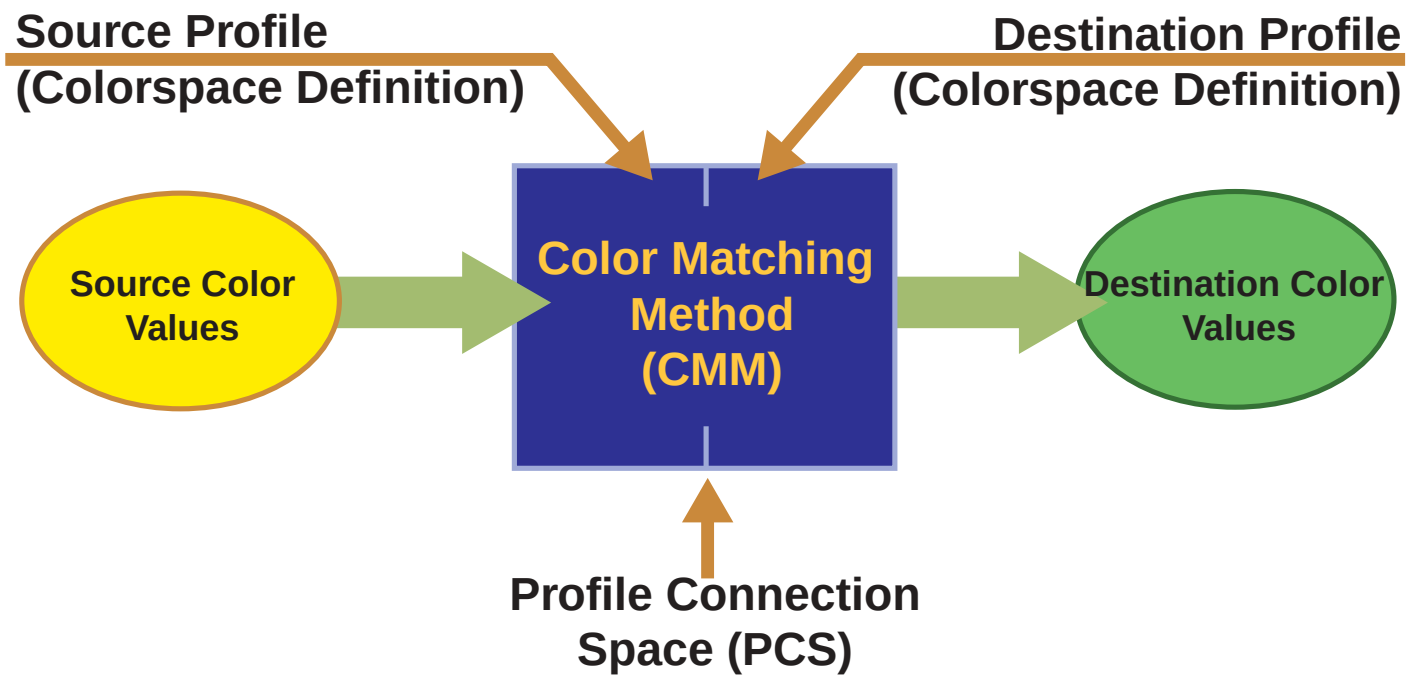
Basic ICC Diagram (International Color Consortium)

- Composite conversion “compiled”
- ICC Profiles define colorspaces



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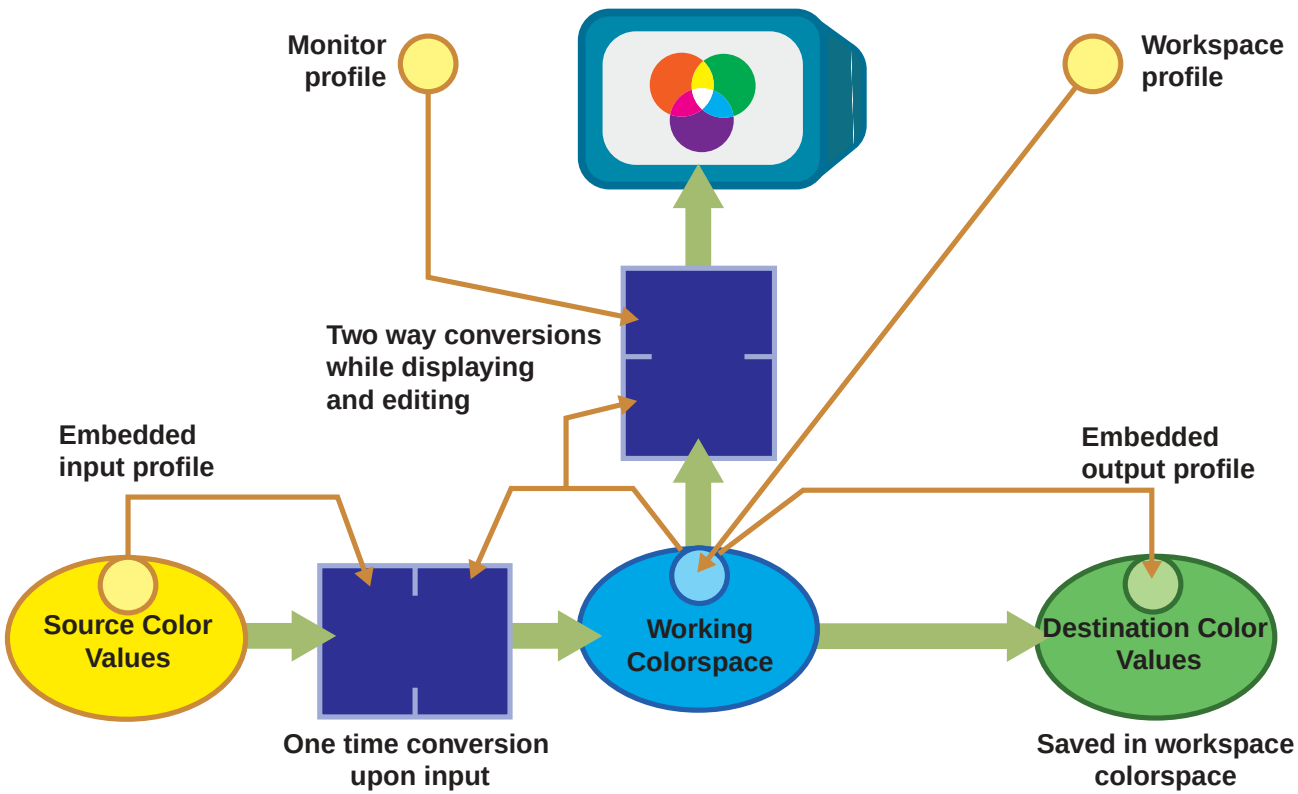
Photoshop: Basic Workflow

- Monitor profile supplied by system
- Workspace profile set by user



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Rendering Intents

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

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Gamut Differences

RGB

(Original)

CMYK

(Photoshop Swop Coated)

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Gamut Mapping

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

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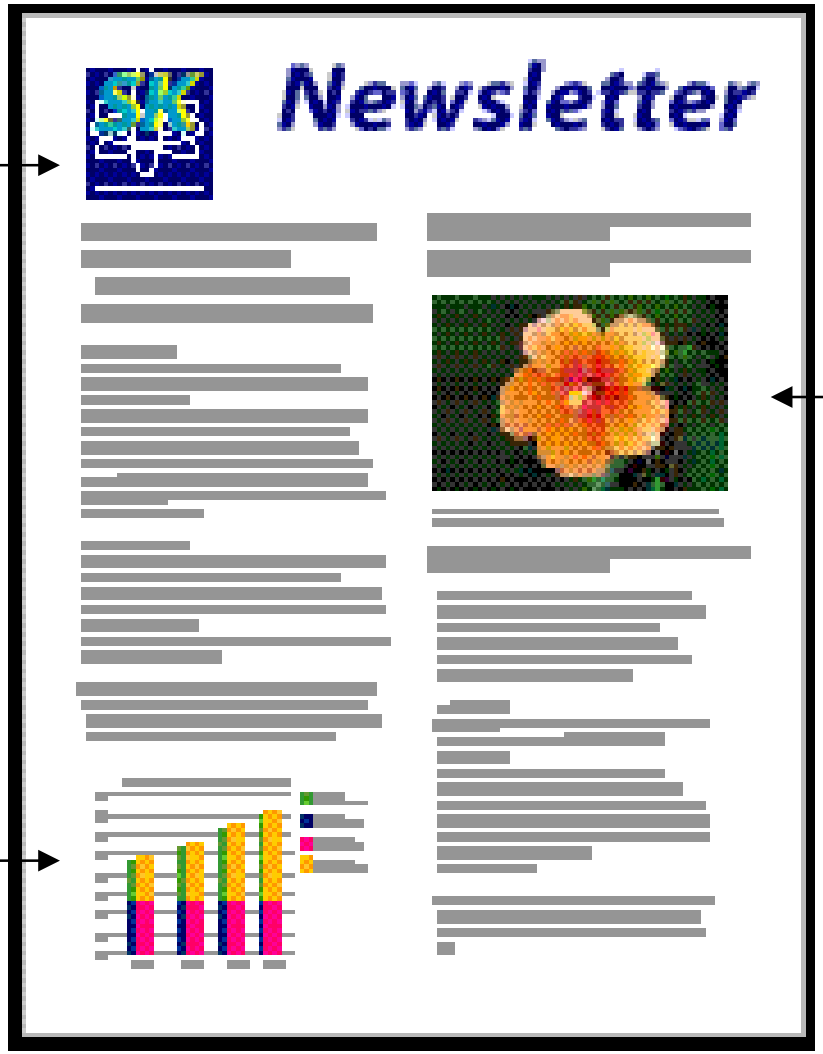
Rendering Requirements

Logo-Colorimetric

Graph-Saturated



Picture-Perceptual

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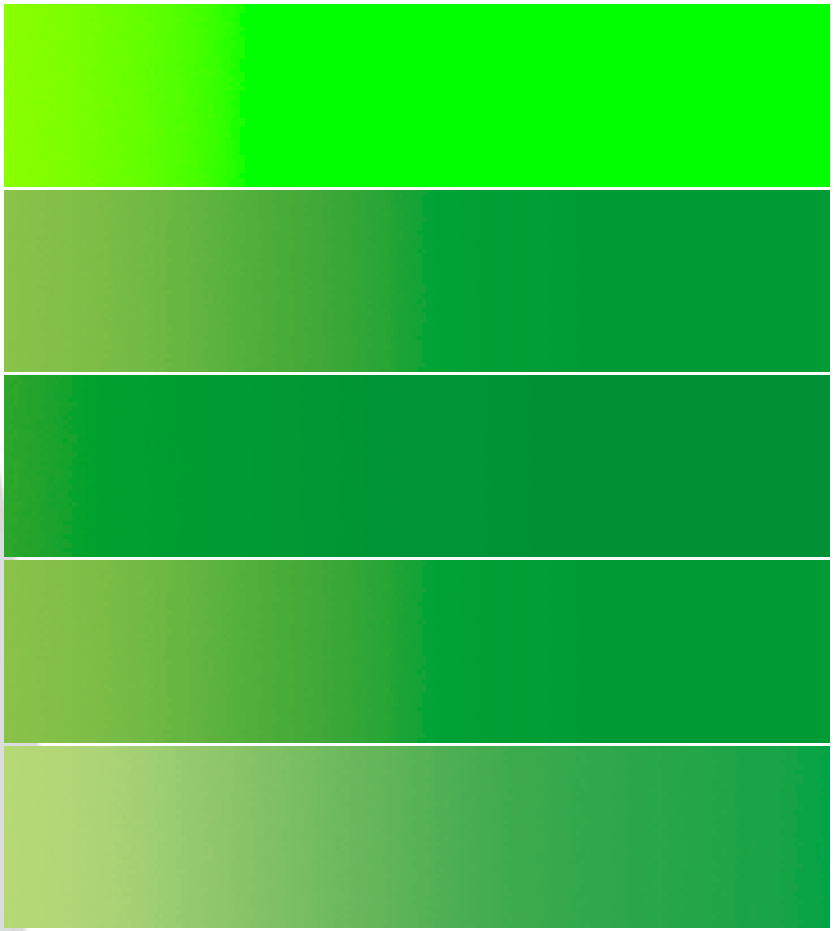
Rendering Intents



RGB Original

CMYK-Perceptual

CMYK-Saturated

CMYK-Relative Colorimetric

CMYK-Absolute Colorimetric

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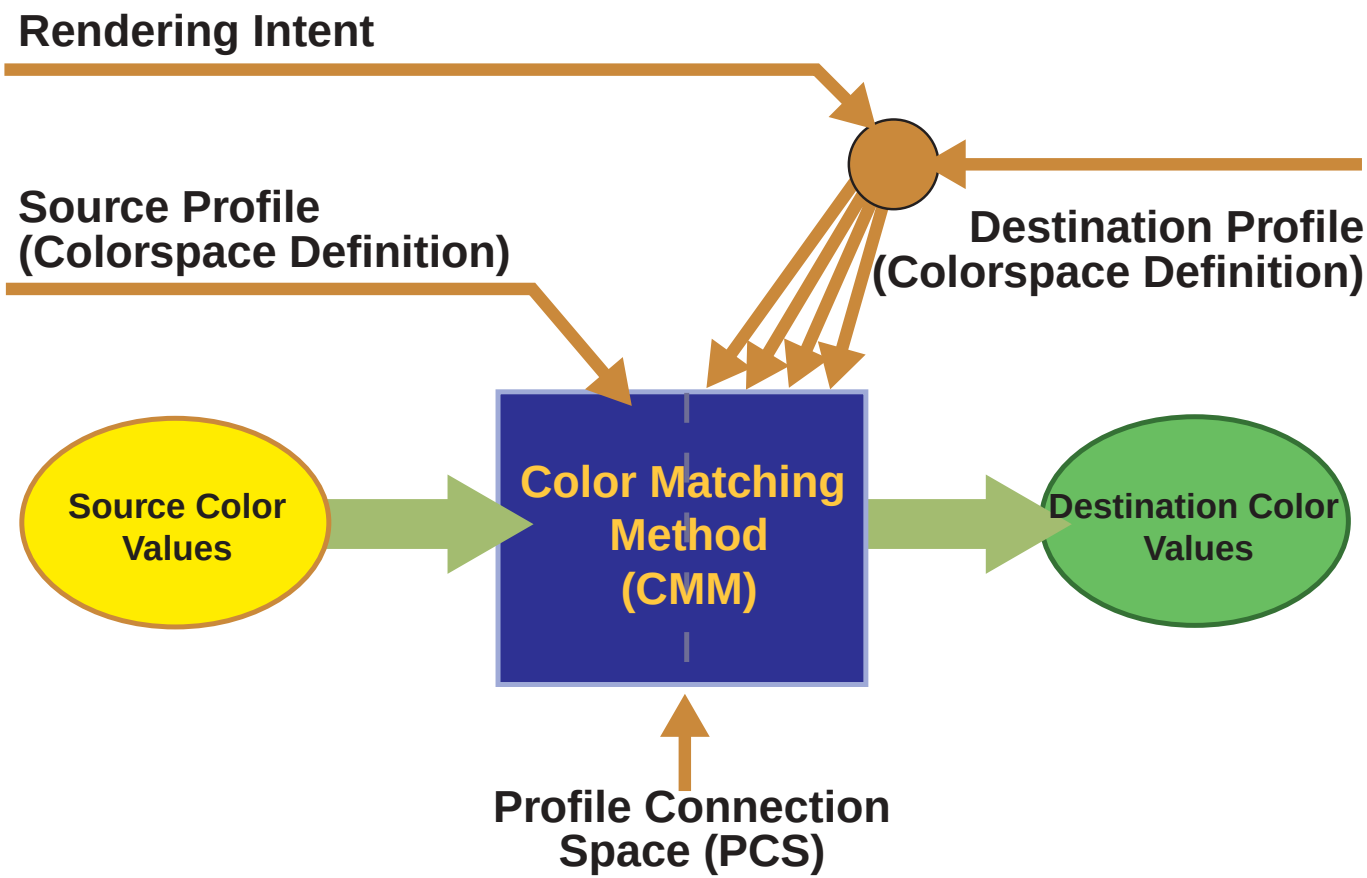
Rendering Intents

- Intent is property of the source
- Action happens during output



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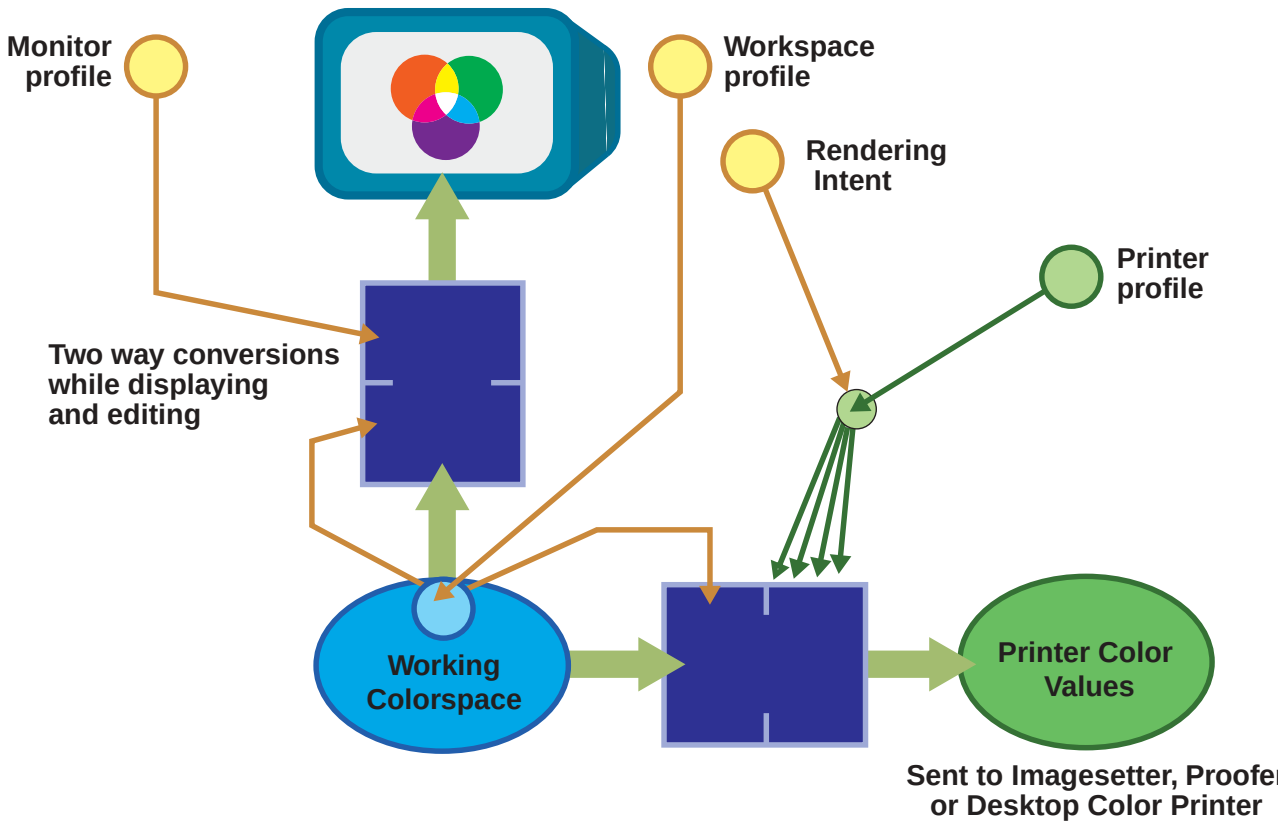
Rendering Intents

- Monitor profile supplied by system
- Workspace profile set by user



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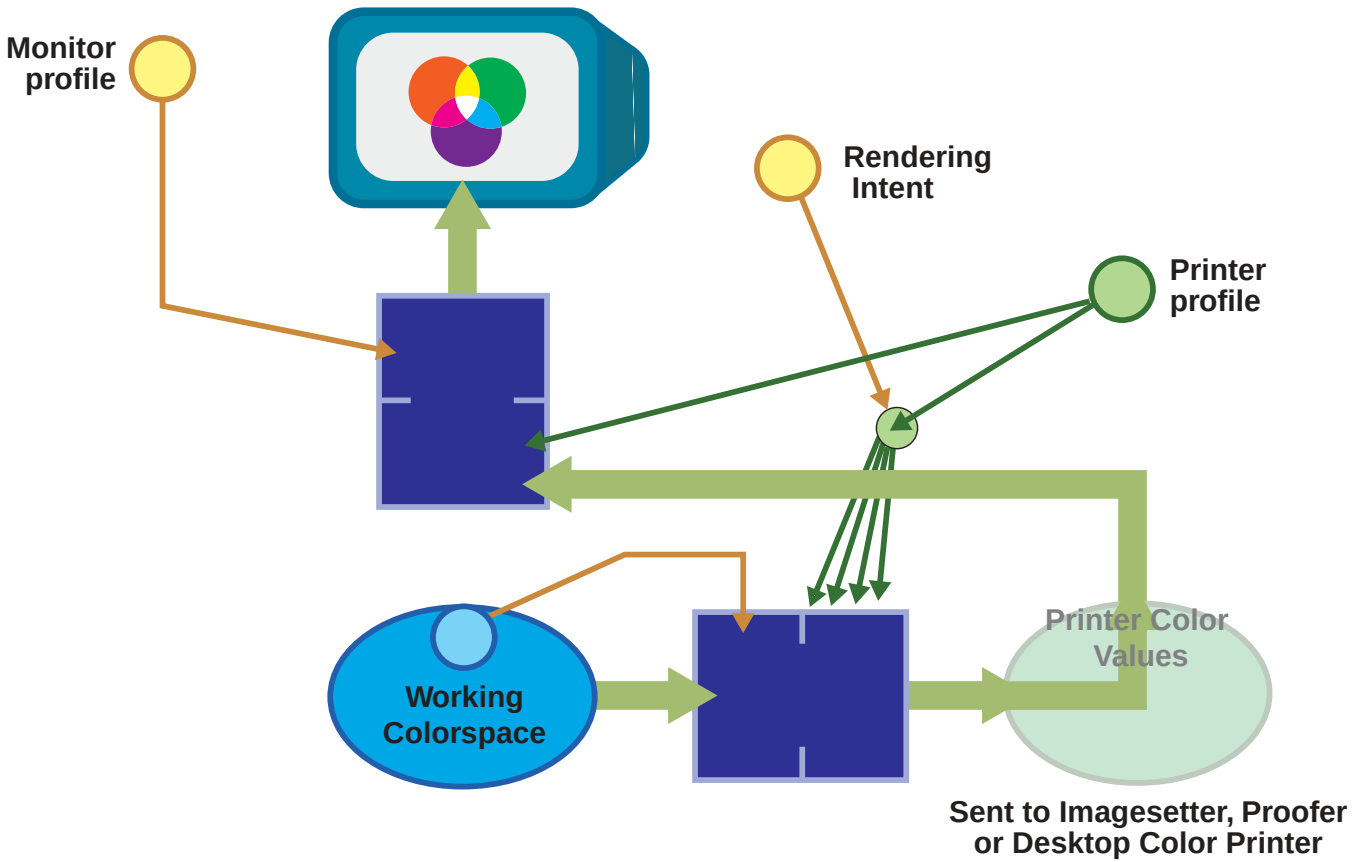
Soft Proofing

- What would it look like on my printer



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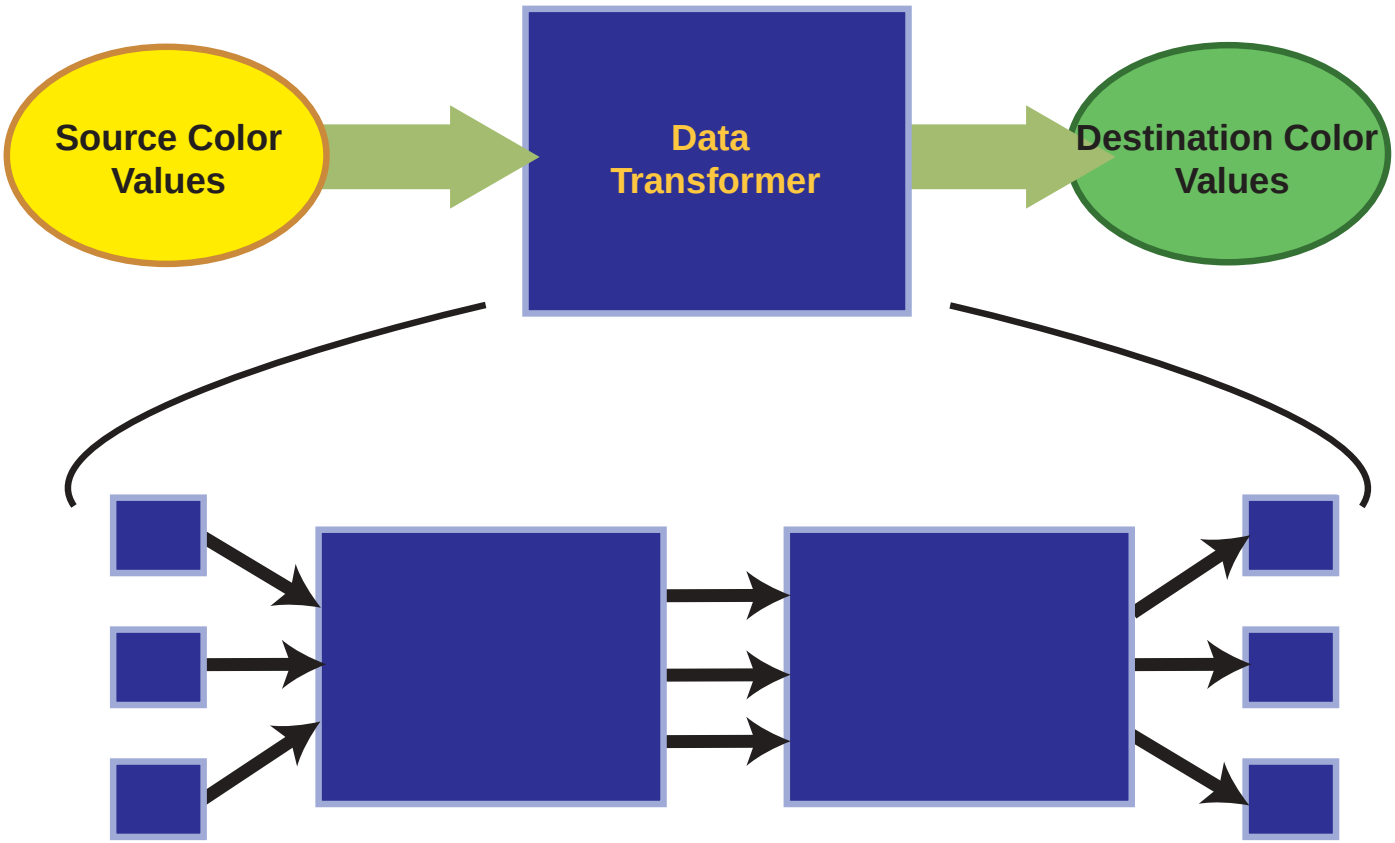
Basics of Conversions

Device Models

- e.g., CRT Displays



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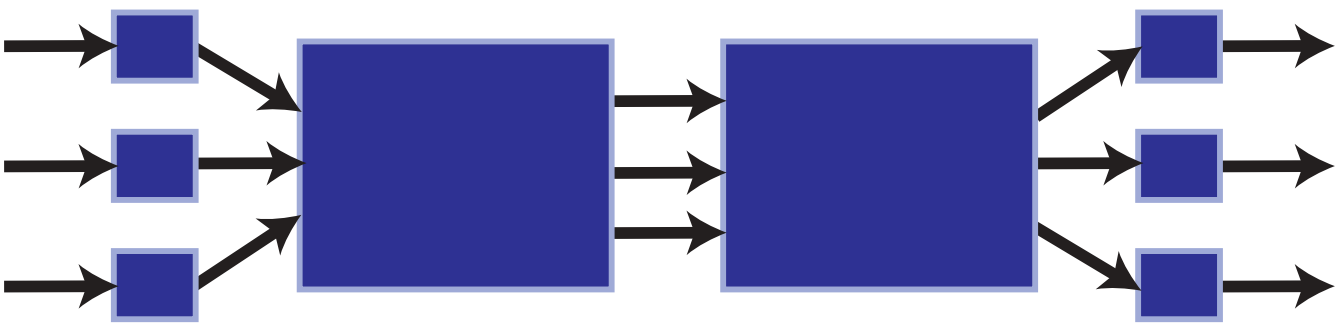
Device Models (CRTs)

- Linear Additive Devices



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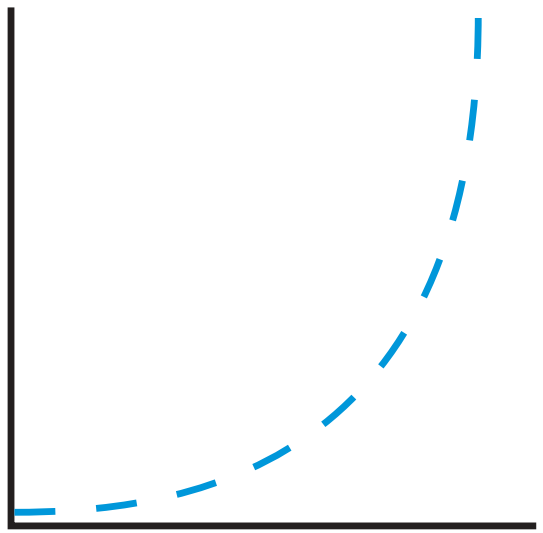
Single Component

- Things like Gamma adjustments
- “Linearize” the components

1-IN 1-OUT
Component Modification



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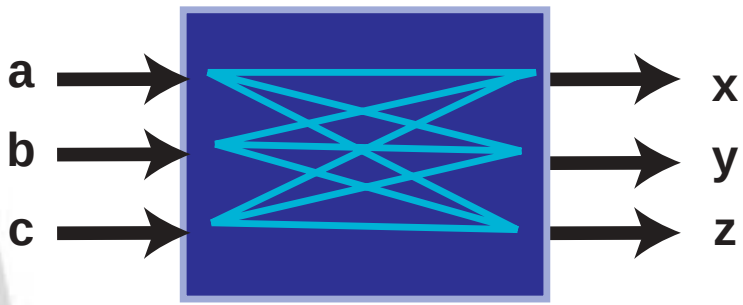
The Famous 3x3



3-IN 3-OUT
Linear Transform

$$x = 1.0 \cdot a + 1.4 \cdot b + 0.8 \cdot c$$
$$y = 0.0 \cdot a + 2.5 \cdot b + 0.6 \cdot c$$
$$z = 1.3 \cdot a + 1.4 \cdot b + 1.3 \cdot c$$

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

3 x 3 Matrix

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Device Models (CRTs)

- Linear Additive Devices

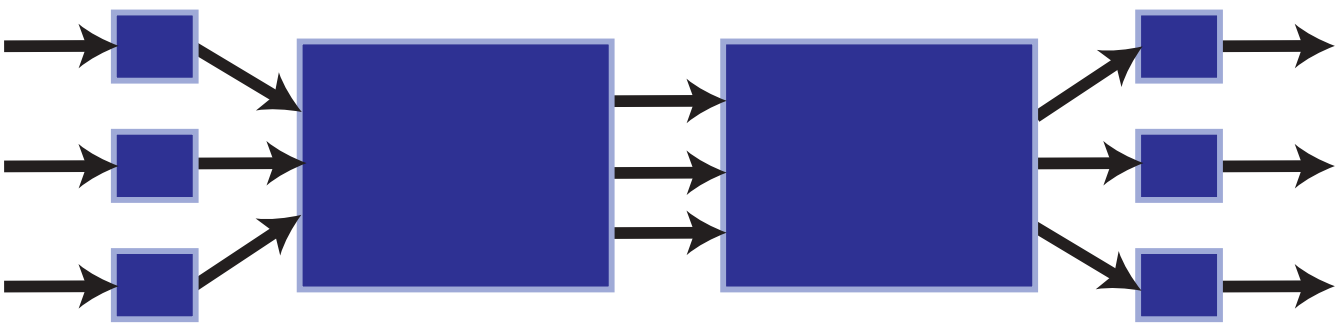

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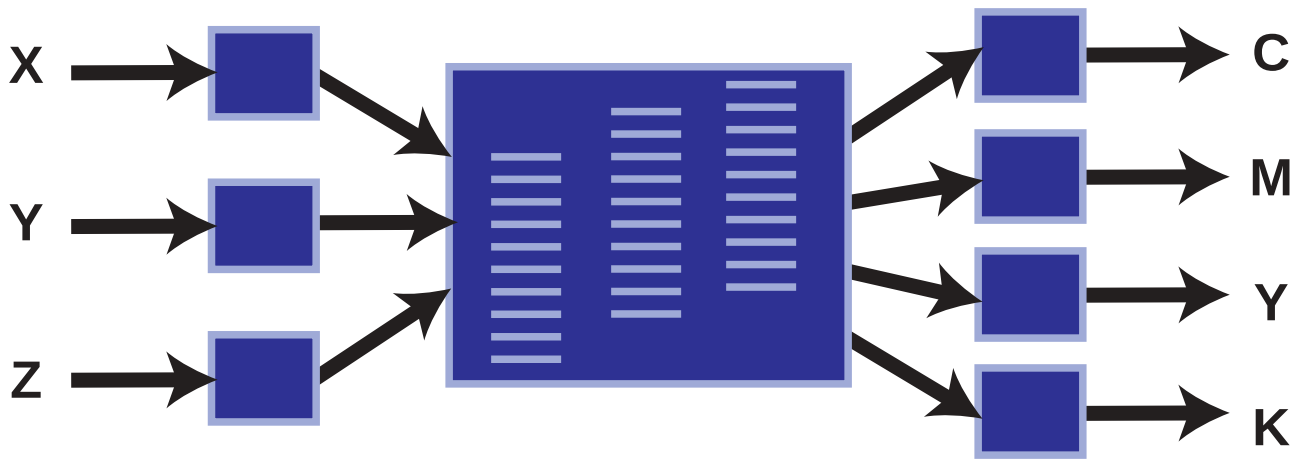
Table Lookup

- E.g., Printers



1-IN 1-OUT
Component Modification

1-IN 1-OUT
Component Modification

3-IN 4-OUT
Lookup Table

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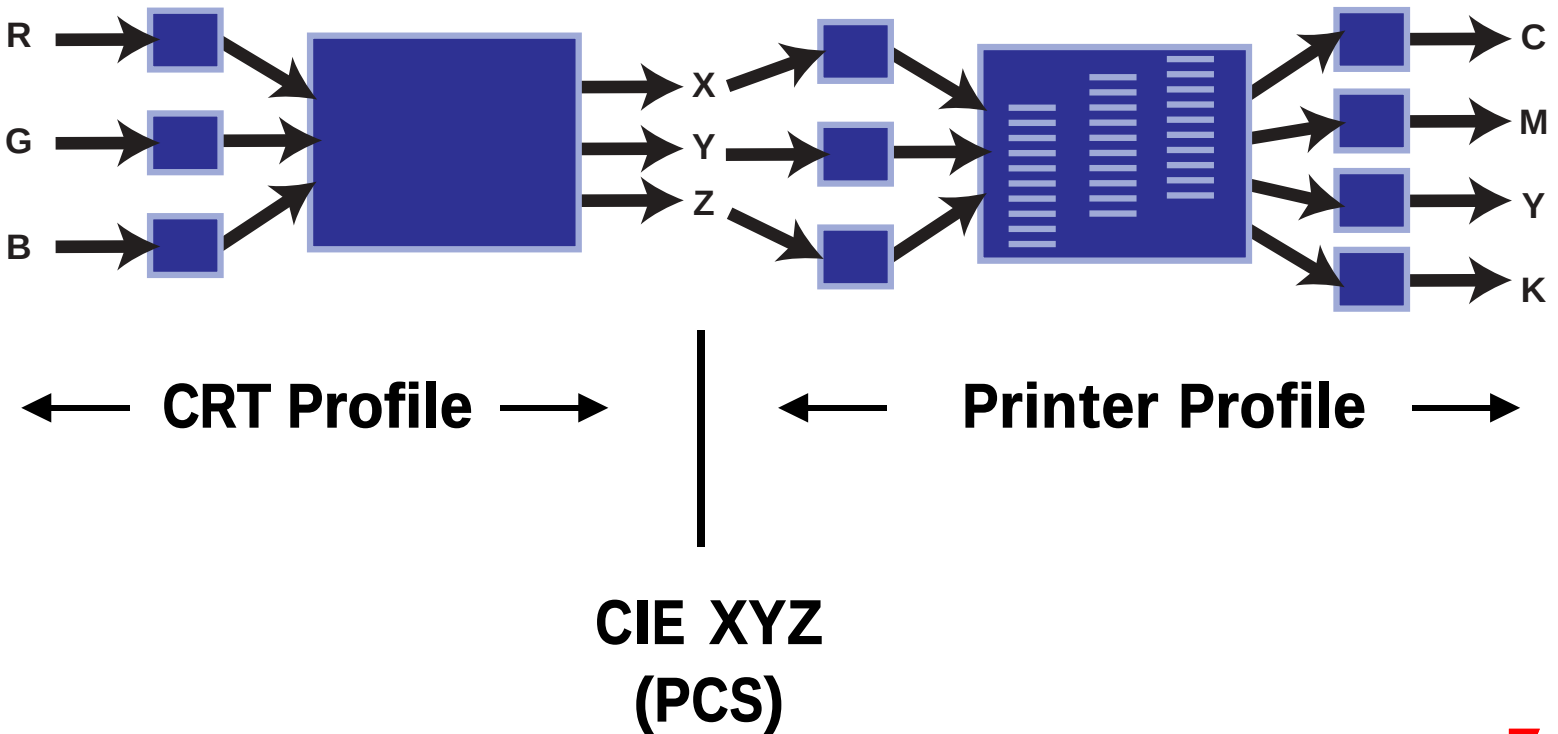
CRT to Printer



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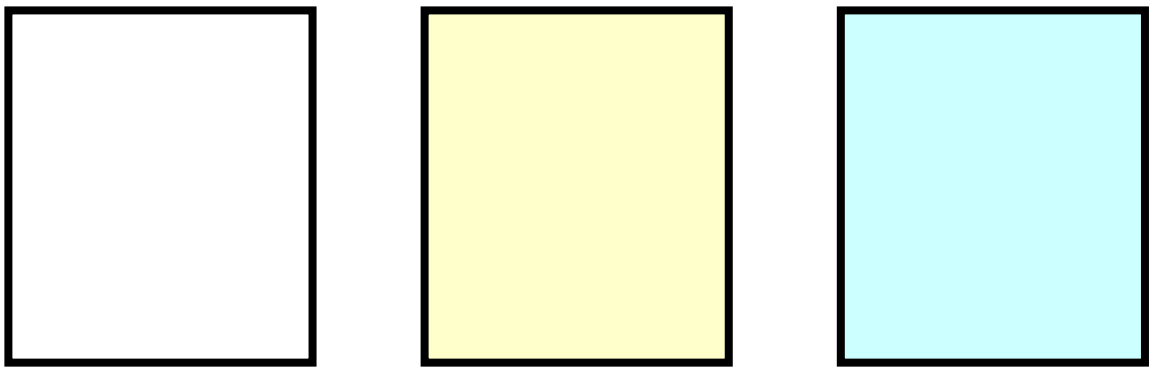
White & Black Points



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*

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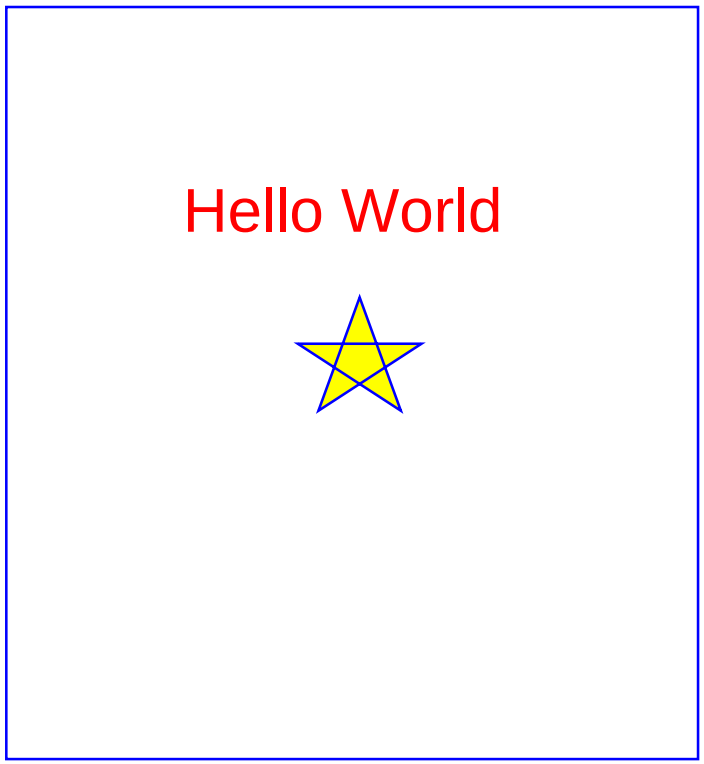
Real Example



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

```
%PDF-1.2
1 0 obj
<<
 /Type /Page
 /Parent 5 0 R
 /Resources 3 0 R
 /Contents 2 0 R
>>
endobj
```

```
2 0 obj
<< /Length 51 >>
 stream
  BT
  /F1 24 Tf
  1 0 0 1 260 600 Tm
  /CS1 cs
  63 127 127 sc
  (Hello World)Tj
  ET

  100 0 127 sc

  /CS2 CS
  0 0 1 SC
  315 572 m
  299 528 l
  339 554 l
  291 554 l
  331 528 l
  b
 endstream
endobj
```

```
3 0 obj
<</ProcSet[/PDF/Text]
/Font <</F1 4 0 R>>
/ColorSpace
 <</CS1
  [ /Lab << /Range
  [-128 127 -128 127]
    /WhitePoint
  [ 0.951  1  1.089]
        >> ]   >>
 <</CS2
 [ /CalRGB <<
    /Gamma
  [2.222 2.222 2.222]
    /Matrix
  [0.412 0.213 0.019
   0.358 0.715 0.119
   0.181 0.072 0.951]
   /WhitePoint
  [0.951  1  1.089]
          >> ]   >>
>>
endobj
```

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

```
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
>>
```

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

```
%PDF-1.2
1 0 obj
<<
 /Type /Page
 /Parent 5 0 R
 /Resources 3 0 R
 /Contents 2 0 R
>>
endobj
```

```
2 0 obj
<< /Length 51 >>
 stream
  BT
  /F1 24 Tf
  1 0 0 1 260 600 Tm
  /CS1 cs
  63 127 127 sc
  (Hello World)Tj
  ET

  100 0 127 sc

  /CS2 CS
  0 0 1 SC
  315 572 m
  299 528 l
  339 554 l
  291 554 l
  331 528 l
  b
 endstream
endobj
```

```
3 0 obj
<</ProcSet[/PDF/Text]/
Font <</F1 4 0 R>>
/ColorSpace
 <</CS1
  [ /Lab << /Range
  [-128 127 -128 127]
    /WhitePoint
  [ 0.951  1  1.089]
        >> ]   >>
 <</CS2
   [/ICCBased 7 0 obj]
 >>
>>
endobj

7 0 obj
<</Length 345
  /N 3   >>
stream
... (ICC Profile) ...
endstream
endobj
```

```
%!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
```

```
closepath
true setstrokeadjust
stroke

showpage
```

Conversion Glitches

Where do things go wrong?

Limited Places for Error

- Quantization (truncation)
- Gamut compression
- White Point/Black Point Compensation
- Bad arithmetic
- Interpolation errors

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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*

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Gamut compression

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

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White Point/Black Point

- ICC Specification hasn’t been clear
- Change ICC model
  - *To be more like PostScript*

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Bad arithmetic

- Don’t do it
- Get help

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Interpolation errors

- Adjust table size for more accuracy
- Tables need fractional values
  - ***Get ICC to change***

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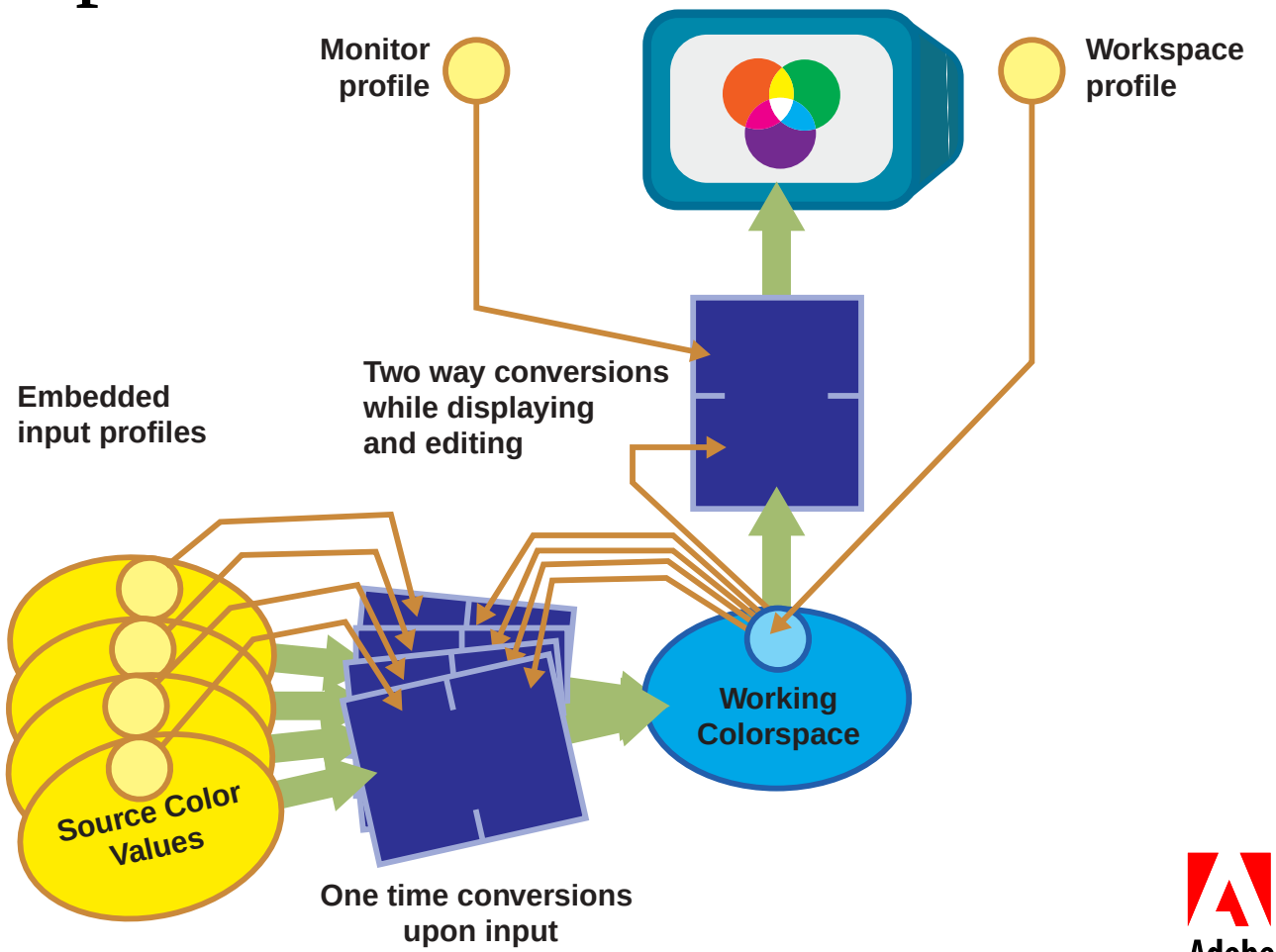
Compound Documents

It gets complicated!

Compound Documents
(more than one colorspace)

- Photoshop



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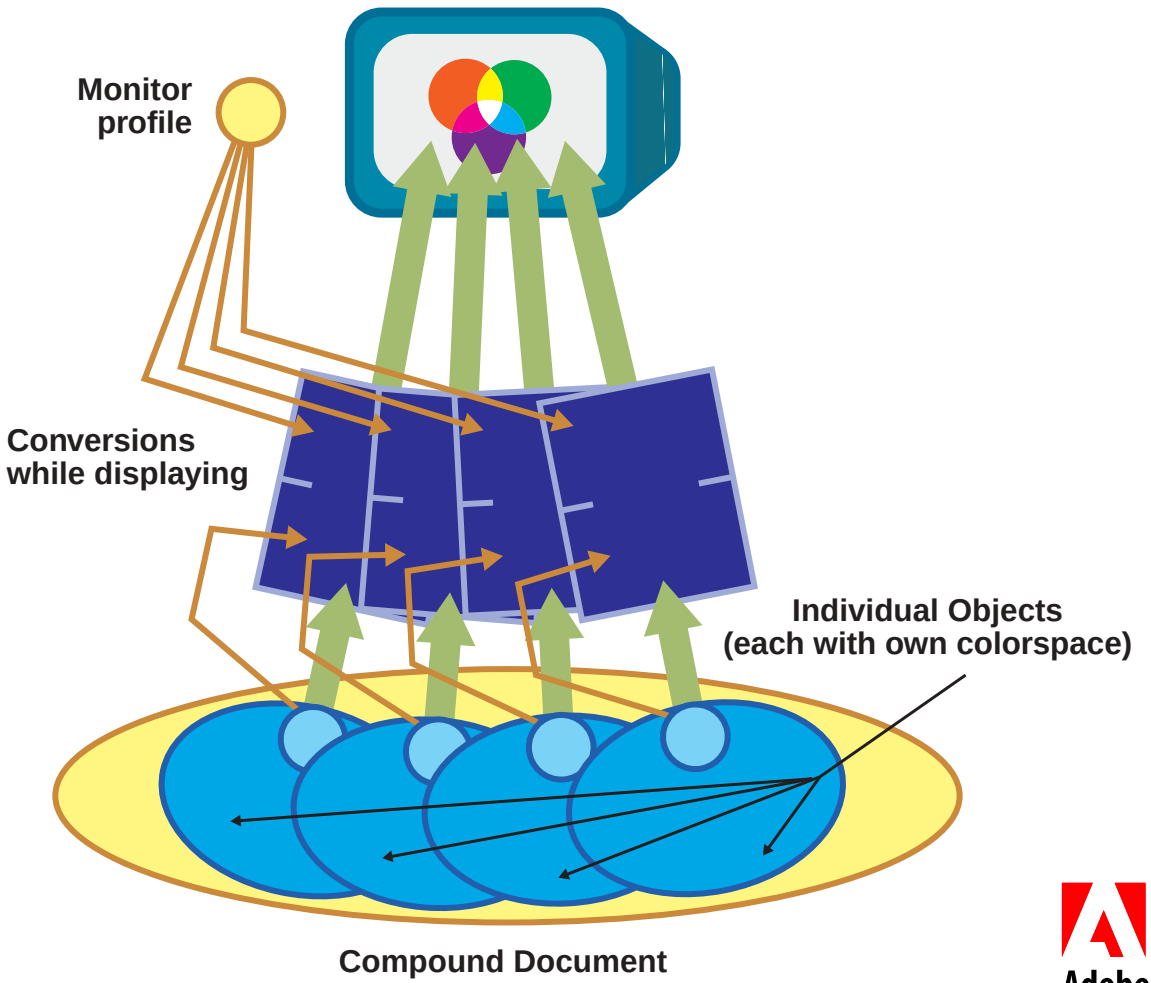
Compound Documents
(more than one colorspace)

- PageMaker



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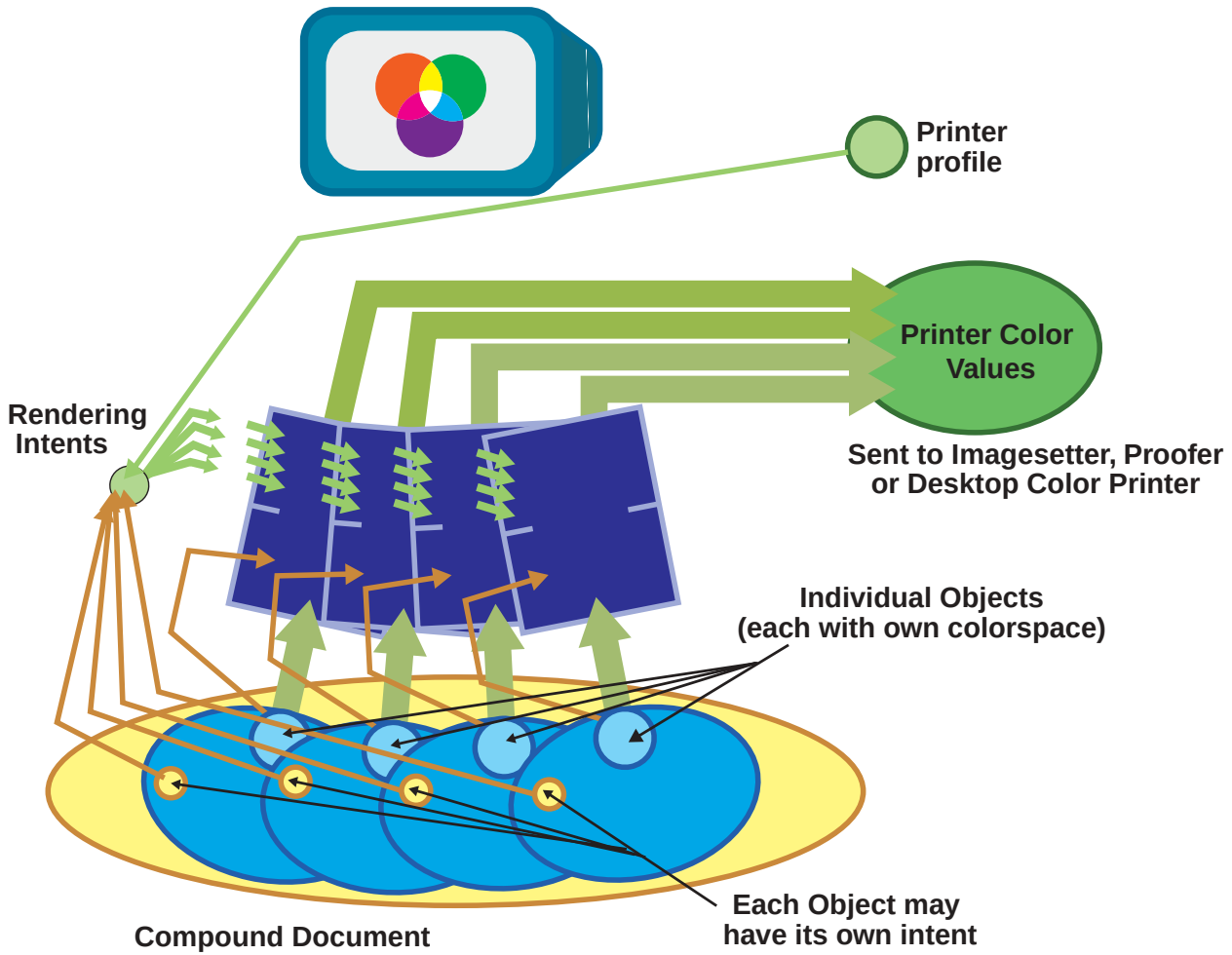
Compound Documents
(more than one colorspace)

- PageMaker or In the RIP



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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

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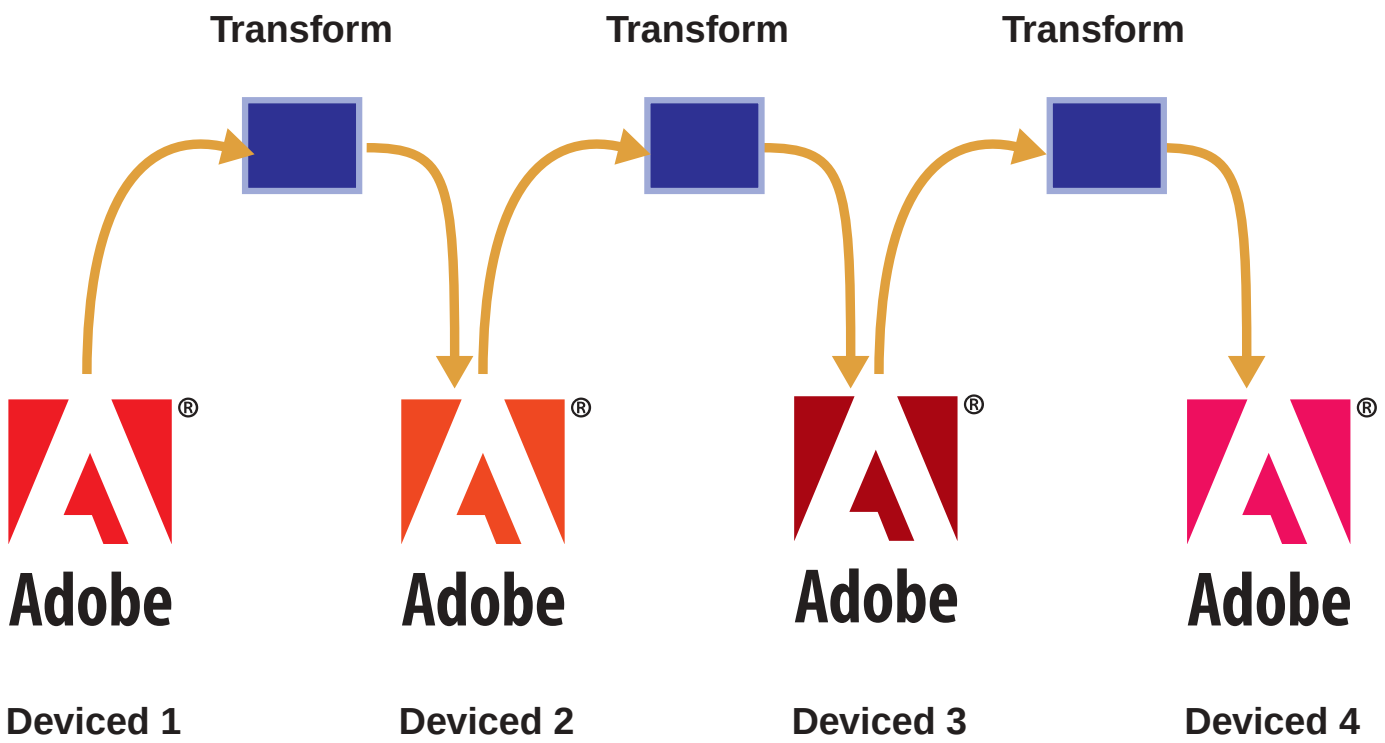
Now is Device Centric

- We move colors through device colorspaces



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We have it backwards!

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

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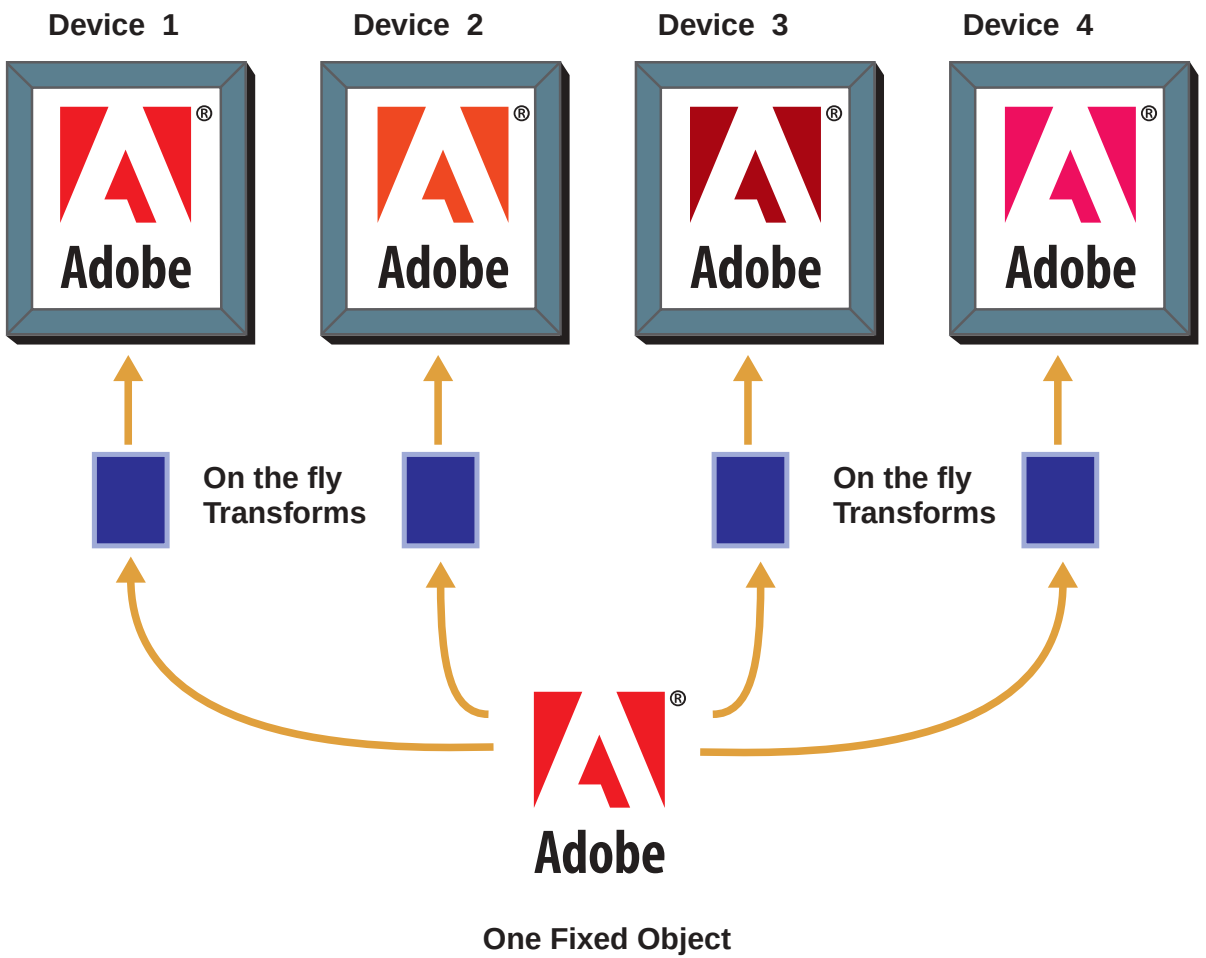
Fixed Colored Data

Just have Windows onto it

- Only Change the view of it



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Fixed Colored Data

- A universal colorspace
  - *Extend the idea of workspace*
- All colors visible by humans
- Enough bits to allow flexibility
  - *Precision*
  - *Range*

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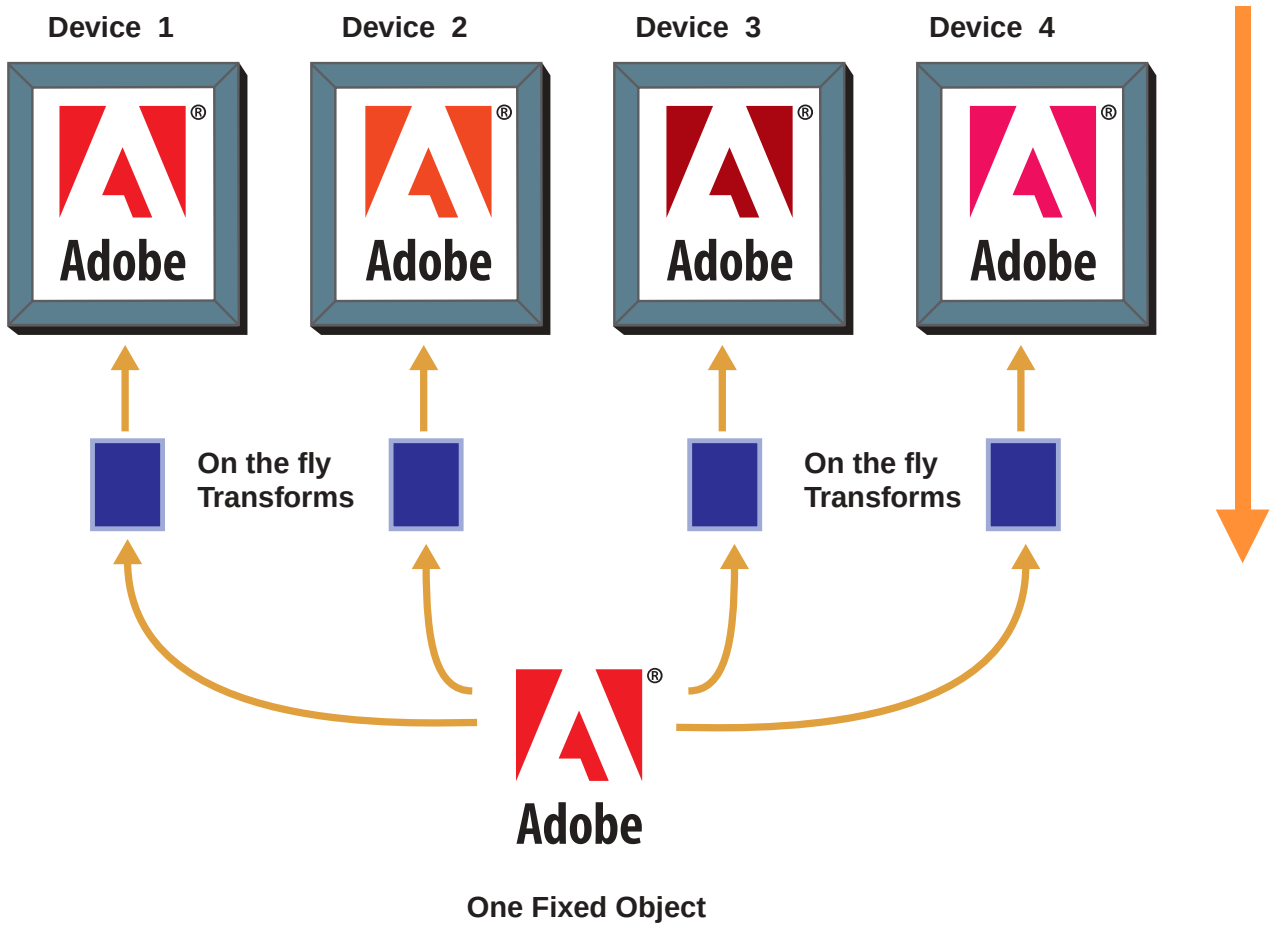
Homework

- How do you edit using this model?



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