Hybrid Printer Output Profiles

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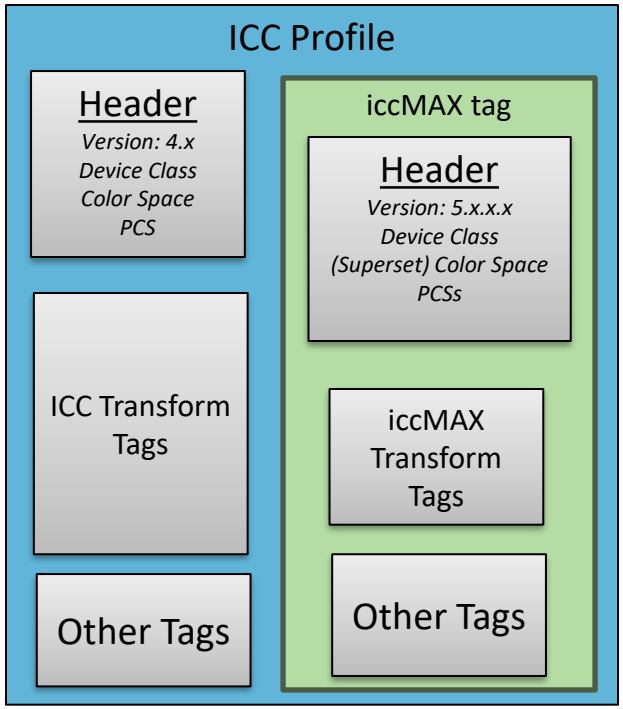
Why Hybrid Profiles?

- **An ICC profile is useful to perform color management in various workflows**
- **Adding an iccMAX profile inside a tag in an ICC profile enables additional extended color management workflows using:**
  - New ways to communicate about color
    - Spectrally based, different observers/lighting, using viewing/illumination angles, and/or selective channel connection
  - Utilization of extra channels (not managed by base ICC profile)
  - More robust transform definition with extended processing elements
- **Provides new (optional) functionality without breaking existing workflows**
  - Existing software just ignores the extension tag as a private tag in terms of applying color management but carries it along because it is part of the ICC profile
  - New software can be configured to enable/use new workflows

Hybrid ICC/iccMAX Profile Overview

Hybrid ICC/iccMAX profile



- **An iccMAX tag provides extensions to device color space, connection spaces, and/or transform encoding**
- **Legacy ICC systems ignore the iccMAX tag**
- **Device class of extension profile should be same as containing profile**
- **An *Interoperability Conformance Specification* (ICS) is associated with iccMAX tag sub-class and sub-class version defines encoding and usage scenarios**
- **Redundant tags are not needed in an iccMAX tag that are in the containing profile**
- **Extension profile should contain all tags that are required for application of the iccMAX Transform Tags**
- **Use of iccMAX tag is determined by CMM control option of an iccMAX capable system**

Hybrid Spectral Reflectance Output Profiles

Motivation for spectral reproduction

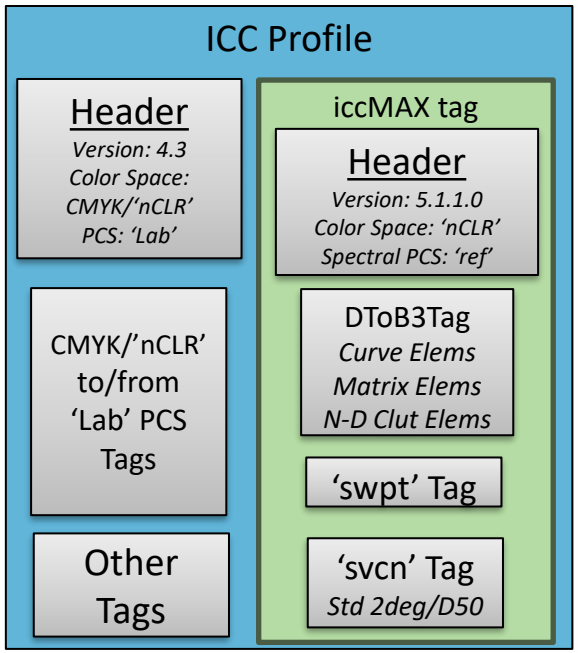
- **Matching spot colors is critically important in textile printing and packaging**
  - Unable to control lighting conditions where printed results are viewed
- **Spectral matches will match regardless of lighting conditions**
- **Ink formulation is one approach for spectral matching**
  - Using ICC profile colorimetric color management for determining spot color replacements are only good for one viewing condition
- **Spectral matching with using device ink replacements requires a spectral understanding of device color and method to find spectral matches**

Spectral printer color management – Hybrid N-Color Printer Profile

- (Base) profile provides colorimetric transforms
- (iccMAX) Tag provides spectral characterization

Level 1 requirements minimize implementation overhead

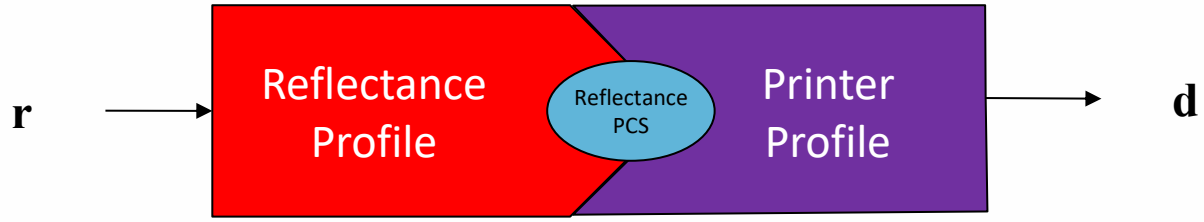
Hybrid printer profile



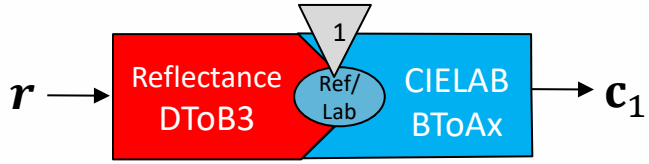
Level 1 sub-class

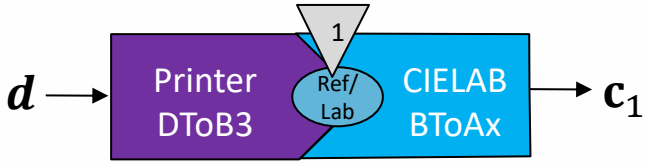
- Presently working on a hybrid spectral printer profile ICS document
- Connection scenarios include:
  - (Base) Std Colorimetric to Print
    - Printing
  - (Base) Print to Std Colorimetry
    - Proofing
  - (iccMAX) Print to Custom Colorimetry
    - Proofing with different observing conditions
  - (iccMAX) Print to Reflectance
  - (iccMAX) Reflectance to Print
    - Spectral Reproduction

Conceptual Spectral Reproduction

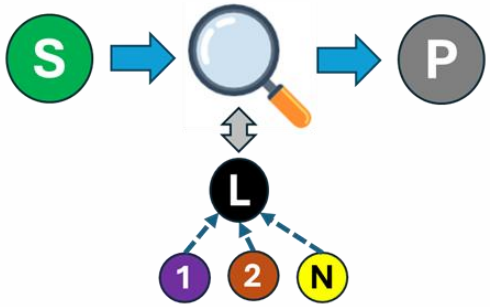


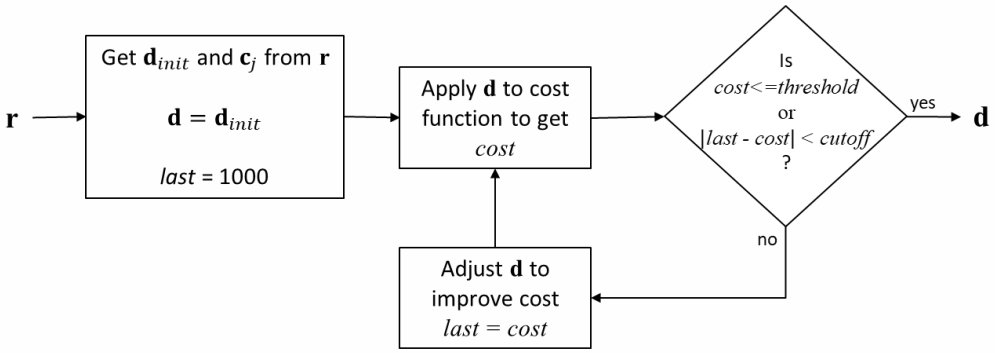
- **This has an implied printer reflectance PCS transform (B2DxTag) which has challenges**
  - High dimensionality
  - Interpolation error
  - Very complex
- **This can be implemented in terms of a search using the printer profile's forward reflectance transform (D2BxTag) with multiple Profile Connection Conditions profiles**
  - Creation of a D2BxTag is easy if spectral data is available as part of printer profile creation





Spectral reproduction using search



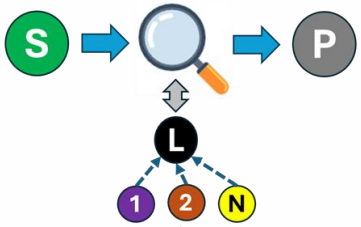


- **Target colorimetry for different viewing conditions is determined for target spectral reflectance using reflectance profile and profiles for each viewing condition**
- **Device values are applied to printer profile to get spectral reflectance which is converted to colorimetry for same viewing conditions and finally compared to target colorimetry for viewing conditions to determine cost (index of metamerism)**
- **Device values are adjusted to minimize cost until either reaches a minimum threshold or change in cost become minimal**
- **This is now implemented in iccDEV project with the CIccCmmSearch class in IccProfLib, and as the command line tool iccApplySearchCmm**

Example: Round trip through Reflectance

iccApplyNamedCmm

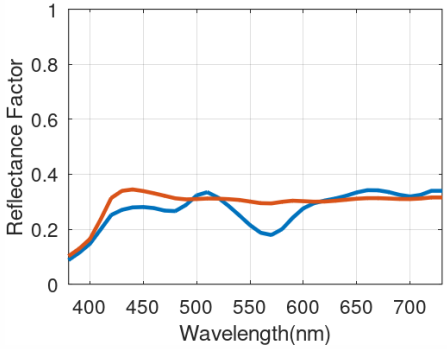
iccApplySearch



Starting CMYK

Patch	C	M	Y	K
1	50	40	40	0
2	0	0	0	50

Spectral Reflectance Results



CMYK Results

Patch	C	M	Y	K
1	49.28	39.34	39.40	1.31
2	0.16	0.13	0.20	49.87

Blue – Patch 1 reflectance

Red – Patch 2 reflectance

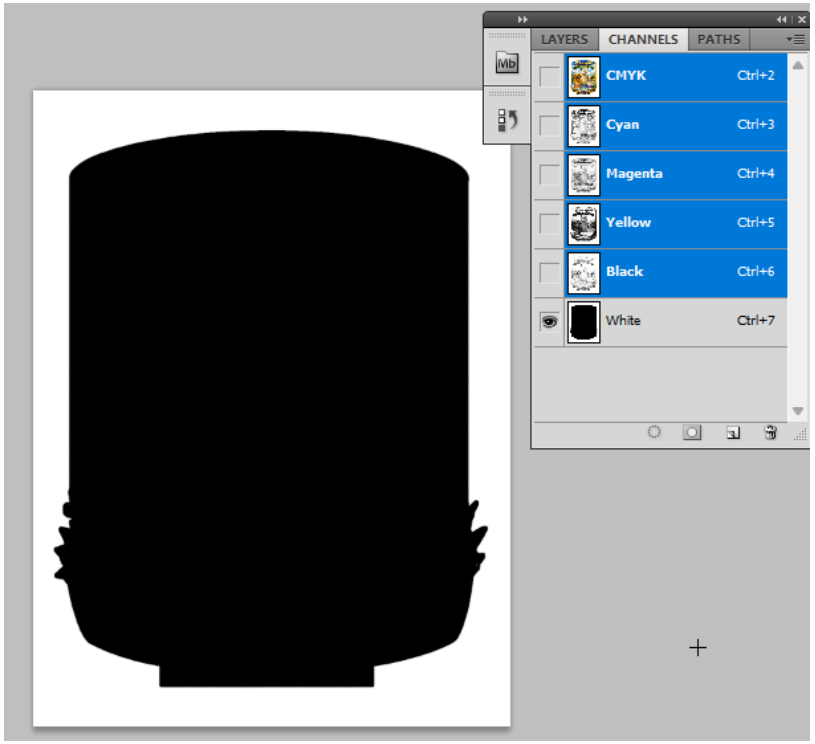
Use Case: Spot Replacement using Spectral Reproduction

- **Spot color replacement values can be extracted before processing PDF file to determine device values to use as replacements for spot colors**
  1. Use known reflectances or extract spectral reflectances for spot colors from PDF document's CxF information
  2. Use CIccSearchCMM to get output device values for spot color reflectances
  3. Use resulting device values as spot color replacements for processing PDF file
- **Results in replacements that have minimal color difference under different illuminants with reflectances for spot colors**
- **Note: This spectral reproduction approach can use a different CMM than used for image/document color management**

Hybrid Overprint Simulation Output Profiles

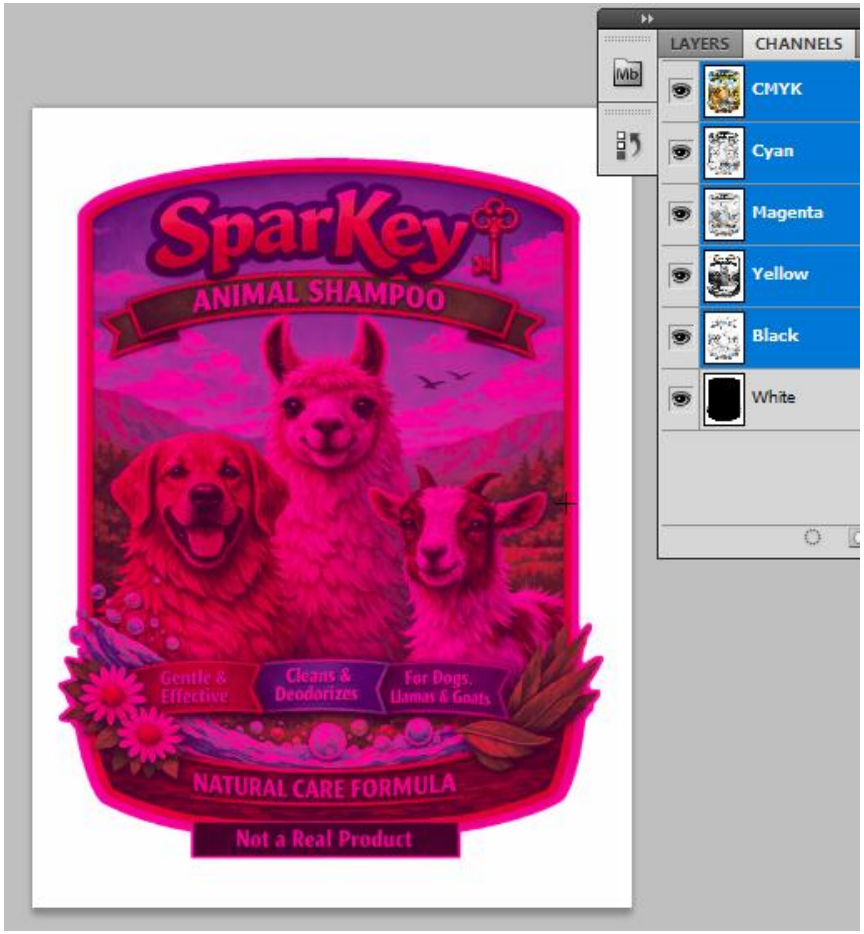
Motivation for Overprint Simulation (Part 1)

Some channels are managed by ICC profile (process colors)



Some channels are not managed by ICC profile (spot colors)

Motivation for Overprint Simulation (Part 2)



- **The combined channels are printed, and preview doesn't match printed output**
- **Overprint simulation varies by implementer**
- **Additional information possibly needed/desired**
  - Print order
  - Spectral measurement of spots for ink formulation
- **No convenient way to communicate overprint simulation that can be used throughout color workflows**
- **Should work for both raster and vector**

Hybrid Output Profile with Overprint Simulation

Base ICC Profile Contents

- **CMYK color space**
- **Transform(s) from CMYK to PCS**
  - For preview of process color data
- **Transform(s) from PCS to CMYK**
  - For printing/creating process color data
- **Required metadata**

iccMAX Sub-tag Contents

- **Color space with ALL channels**
- **Transform(s) from ALL channels to PCS**
  - Overprint simulation transform
  - May consider background
  - May consider viewing/lighting angles
  - May be spectrally based
- **Optionally include**
  - Print Order
  - Spectral measurements of tints over white (and black)
  - Selective channel usage (using MCS)

Example Overprint Transform Creation

- **Overprint modeling provided by AToBxTag using MultiProcessingElementsType with calc element**
- **Demonstration based on SCOP modeling of Kiran Deshpande**
  - K. Deshpande, “N-colour separation methods for accurate reproduction of spot colours,” Ph.D. dissertation, University of the Arts London, May 2015.
  - https://www.researchgate.net/profile/Kiran Deshpande4/publication/279286487 N-colour separation methods for accurate reproduction of spot colours/links/5591685a08ae47a34910a278.pdf

SCOP models

- **Linear**

$$X_r = j_x(X_b X_f) + k_x$$
$$Y_r = j_y(Y_b Y_f) + k_y$$
$$Z_r = j_z(Z_b Z_f) + k_z$$

Substitute :

$$j_{f,x} = j_x X_f$$
$$j_{f,y} = j_y Y_f$$
$$j_{f,z} = j_z Z_f$$

Resulting in :

$$X_r = j_{f,x} X_b + k_x$$
$$Y_r = j_{f,y} Y_b + k_y$$
$$Z_r = j_{f,z} Z_b + k_z$$

Scale XYZ $j_{f,x}, j_{f,x}, j_{f,x}$

Offset XYZ k_x, k_y, k_z

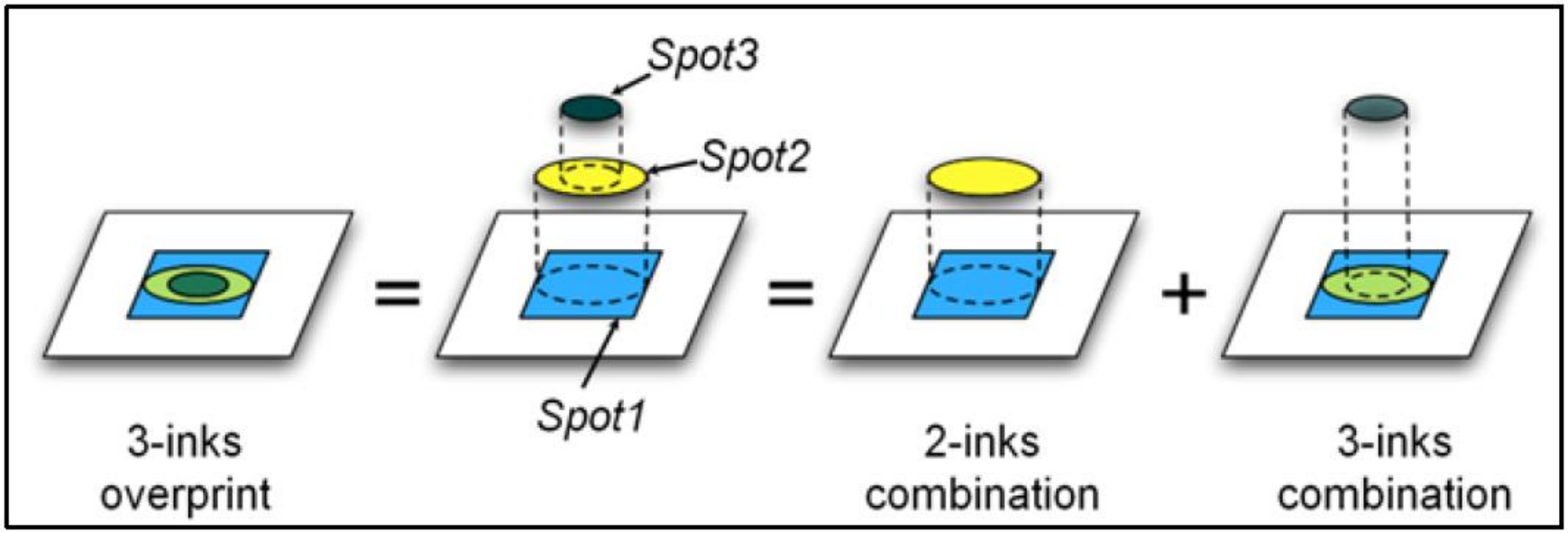
- **Power**

$$X_r = j_x(X_b X_f)^{k_x}$$
$$Y_r = j_y(Y_b Y_f)^{k_y}$$
$$Z_r = j_z(Z_b Z_f)^{k_z}$$

or

$$\ln(X_r) = \ln(j_x) + k_x \ln(X_b X_f)$$
$$\ln(Y_r) = \ln(j_y) + k_y \ln(Y_b Y_f)$$
$$\ln(Z_r) = \ln(j_z) + k_z \ln(Z_b Z_f)$$

Repeated SCOP to for N-Color



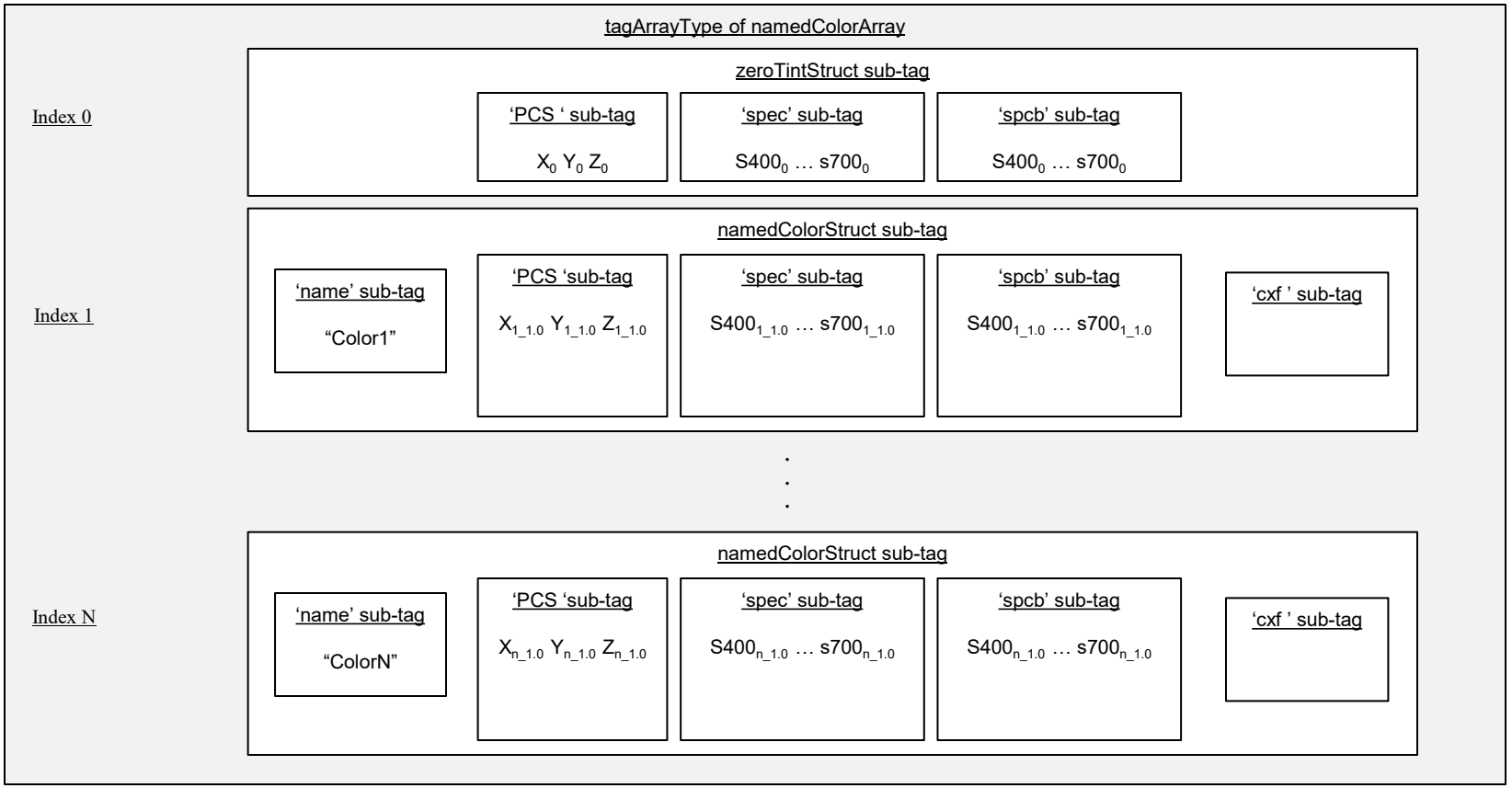
SCOP A2BxTag Creation & Implementation

- **Measure CMYK combinations over media, grey and black**
- **Create shaper curves**
- **Pre-compute scalars $j_{x,y,z}$ and $k_{x,y,z}$ for CMYK combinations and store in CLUT**
- **Measure tints of Spots over media, grey and black**
- **Pre-compute scalars $j_{x,y,z}$ and $k_{x,y,z}$ for tint values**
  - Use interpolation to determine intermediate measurements
- **Create tint tables for spot scalars**

- **Within Calc Element**
  - Start with initial background XYZ (possibly based on CMM environment variables bkgX, bkgY, and bkgZ) and set as current XYZ
  - For each background spot color in overprint order
    - Apply SCOP model with tint based scalars (using tables) to update current XYZ
  - Apply shaper curves for CMYK
  - Apply SCOP model with CMYK tint based scalars (using CLUT) to update current XYZ
  - For each spot color in overprint order
    - Apply SCOP model with tint based scalars (using tables) to update current XYZ
  - Output resulting XYZ

Spectral information for ink formulation

- **Optional namedColorTag in iccMAX sub-tag can provide channel specific measurement information for ink formulation**



Demonstration

T-Shirt Overprint Simulation

Printing on colored fabric over/under white/silver spot

T-Shirt print simulation: Profile Creation

1. **Use measurement of tint over white/grey/black to determine tint scale and offset XYZ values for white/silver**

2. **Use measurement of CMYK over white/grey/black to determine tone curves and tint scale and offset XYZ tables**

3. **Use iccToXml to convert CMYK profile to XML**

4. **Add iccEmbeddedV5Tag entry to XML**
   - Encoding overprint simulation model

1. **Use iccFromXML to convert XML to CMYK_W_Overprint.icc**

iccMAX SubTag contents

- **Header**
  - Data colorspace is ‘nc0005’
  - PCS is XYZ
  - DeviceSubClass is ‘osim’
  - MCS is ‘mc0005’
- **Tags**
  - profileDescriptionTag, copyrightTag
  - colorantTableTag, colorantOrderTag
  - multiplexTypeArrayTag, multiplexDefaultValuesTag
  - Shared transform between AToB1Tag and MToB0Tag
    - multiProcessElementsTag with calc element used to encode an overprint simulation model

Overprint model in calc processing element

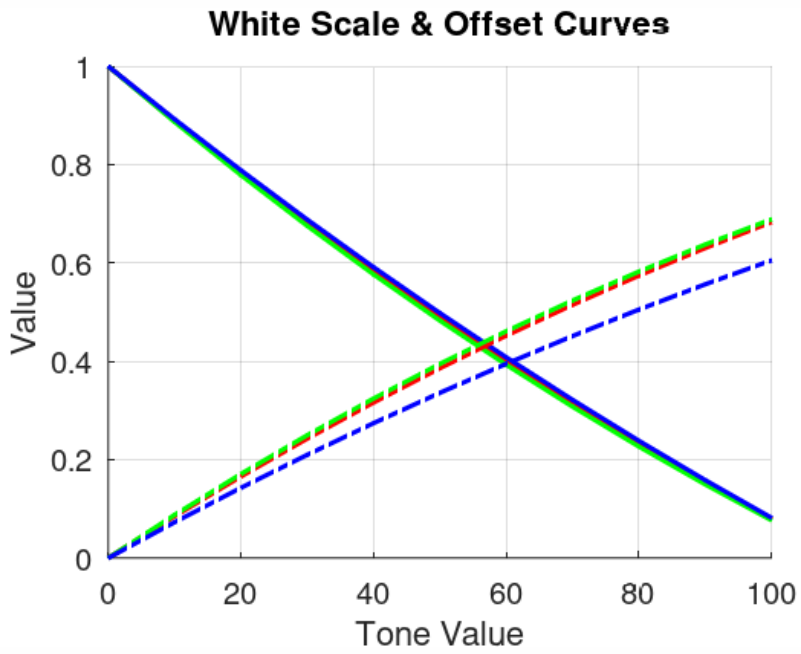
- **SubElements**
  - WhiteScaleXYZ, WhiteOffsetXYZ tintElements
  - Cyan, Magenta, Yellow and Black shaper curves in curveSetElement
  - CmykScaleXYZ and CmykOffsetXYZ extendedCLutElements

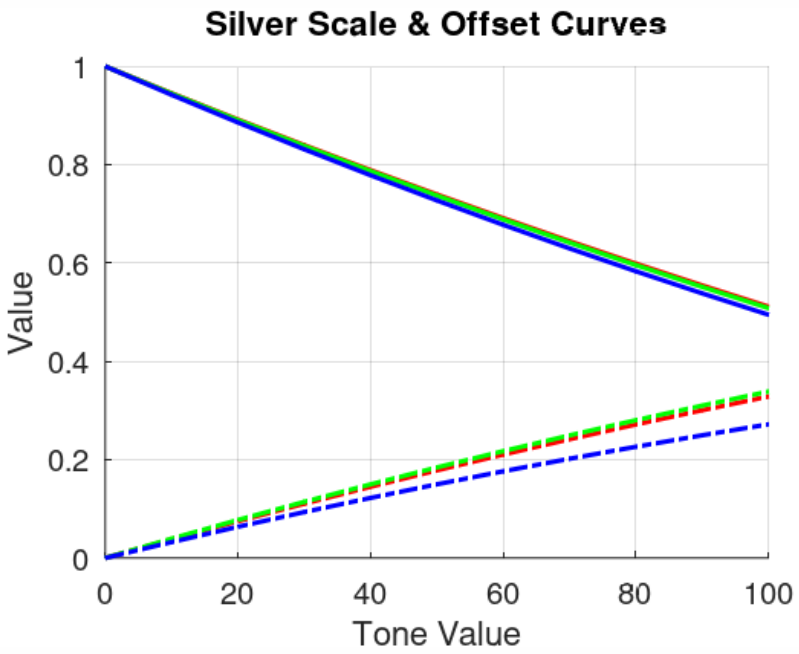
- **Main Function**

```
;default background XYZ is D50 for relative white point
env(bkgX) not if {pop 0.9642}
env(bkgY) not if {pop 1.000000}
env(bkgZ) not if {pop 0.8249}

1 in{White} sub tput{InvWhite} ;photoshop inverts spots
tget{InvWhite} 0 gt if {
      tget{InvWhite} tint{WhiteScaleXYZ} mul(3)
      tget{InvWhite} tint{WhiteOffsetXYZ} add(3)
}

in{ProcessCyan,4}
curv{CmykShaper} copy(4) tput{ShapedCMYK}

clut{CmykScaleXYZ} mul(3)
tget{ShapedCMYK}
clut{CmykOffsetXYZ} add(3)

out(0,3) ; store XYZ results
```

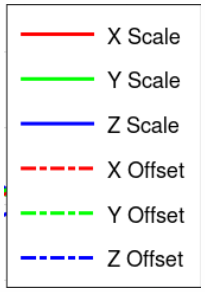
Note: Also created profile with CMYK over silver and profile with Silver over CMYK

Comparison of Scale and Offset Curves





White is about 90% opaque and reflects 60% of illumination



Silver is only 50% opaque and reflects 30% of illumination

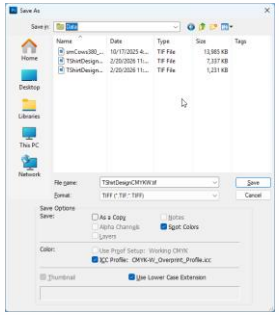
T-Shirt print simulation: Image Creation

1. Created an RGB image logo using AI

2. Used Photoshop to create a spot channel for the white ink background

3. Used Convert to Profile to convert RGB+Spot to CMYK+Spot (associated with hybrid CMYK_W_Overprint profile)

4. Saved Image as TIFF image with embedded hybrid overprint profile



Dump of TShirtDesginCMYKW.tif

Overprint Preview over black

---------->Tiff Image Dump<----------

Filename: TShirtDesignCMYKW.tif
Size: (1080 x 1440) pixels, (15.00" x 20.00")
Planar: Interleaved samples
BitsPerSample: 8
SamplesPerPixel: 5
ExtraSamples: 1
Photometric: Min Is White
BytesPerLine: 5400
Resolution: (72.000000 x 72.000000) pixels per/inch
Compression: LZW
Profile: Embedded
Version: 4.30
Color Space: CmykData
Colorimetric PCS: LabData
Description: CMYK-W_Overprint_Profile.icc
Sub-Profile: Embedded
Version: 5.00
Color Space: 0x0005ChannelData
Colorimetric PCS: XYZData
Description: CMYK over White Overprint Visualization

Applying Overprint Simulation with iccApplyProfiles

```
{
 "imageFiles": {
  "dstCompression": true,
  "dstEmbedIcc": false,
  "dstImgFile": "Results\\TShirtDesignPrevUW-G.tif",
  "dstPlanar": false,
  "srcImgFile": "Data\\TShirtDesignCMYKW.tif"
 },

 "profileSequence": [
  {
   "iccEnvVars": [
    {"name": "bkgX", "value": 0.0985},
    {"name": "bkgY", "value": 0.159},
    {"name": "bkgZ", "value": 0.122}
   ],
   "iccProfile": null,
   "intent": "relative",
   "interpolation": "linear",
   "transform": "default",
   "useV5SubProfile": true
  },

  {
   "iccProfile": "..\\sRGB_v4_ICC_preference.icc",
   "intent": "relative",
   "interpolation": "linear",
   "transform": "default"
  }
 ]
}
```

Embedded (null), Over Silver, and Under Silver profiles were used

Background XYZ values for white (default), red, black, blue and green were used

Apply overprint config

T-Shirt Overprint Simulations

White Under (embedded)

Silver Under

Silver Over

- Same Source Image
- Columns: Different bkgXYZ values for shirt color
- Rows: Different overprint profiles

Hybrid Overprint Simulation Profiles - Summary

- **The overprint model is in the profile**
  - Resulting in consistent preview of overprint simulation by various implementers
  - Can be used throughout workflows
- **Additional information included**
  - Print order is conveyed
  - Spectral measurement of spots for ink formulation
- **Works with both raster and PDF**
  - Embedded as profile in raster
  - Can be used as output intent profile in PDF
- **Hybrid Overprint Simulation profiles package together relevant aspects of working with spot colors**
  - It’s an extension of printer output profiles

In Conclusion

- **Hybrid printer profiles are created by embedding an iccMAX sub-profile that supports additional workflows**
  - A spectral reflectance sub-profile allows for (limited) spectral reproduction to be implemented
    - Spectral reproduction of spot colors using color management
  - An overprint simulation sub-profile allows for preview of spot colors (not color managed by base profile)
    - Carries useful information about spot colors and overprints
- **Hybrid printer profiles are valid ICC printer profiles and can be used wherever printer profiles are used**
  - Legacy systems will ignore the hybrid extension
  - Extended systems can utilize sub-profiles for extended color management workflows
- **ICS documents specify requirements for creating and applying hybrid profiles**