So You Think You Want a 2 ΔE?

David Hunter

COLOR20

get the answers here

SGIA

Advancing Graphic Communications

PRINTING INDUSTRIES OF AMERICA

Audience Roles

What is your Primary Role

- Brand Manager
- Creative
- Print Buyer
- Prepress
- Printer Operator
- Manufacturer
- Other?

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Audience Expertise

3 Questions- Heard of it, Understand it, Teach it

Raise Hand for each definition, and keep raised

- Delta E 2000
- Different Delta E formulas
- CIE Lab color space
- Spectral color space
- Traditional Score Card App (ColorCert/PressSign)
- G7 Methodology
- Understand Standards only take us so far…

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Agenda

Stack of Tolerances

- What reference? Aim point:
- Delta What? Δ **?**
- Print Device capabilities
- Reference disagreements
- Substrate disagreements
- Measurement disagreements
- Light booth disagreements
- Rules of Engagement

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Print Manufacturing Road Map

Maturity of Print Service Providers

GRAPHIC ARTS — PRINT MANUFACTURING

SUBJECTIVE PERSONAL-BASED JUDGMENT — METRIC-BASED JUDGMENT SCIENTIFIC

VISUAL ASSESSMENT • COMPARATIVE COLOR MEASUREMENT • ADVANCED COLOR CONFORMANCE

VISUAL

Personal perception-based comparision to physical standard

- no knowledge required
- expensive and time-consuming personal supervision
- dependent on the person
- lighting conditions related
- uncontrolled metamerism

BASIC INSTRUMENTAL

Instrument-based comparision to physical standard

- numerically expressed color differences
- expensive and time-consuming personal supervision
- uncontrolled metamerism
- initial swatch-book inaccuracy

COLORIMETRIC AIM

Instrument-based comparision to colorimetric standard

- numerically expressed color differences
- stable color definition
- exchangable color definition
- the possibility of remote control

SPECTRAL AIM

Instrument-based comparision to spectral standard

- numerically expressed color differences
- spot colors, SCTV, CxF/X-4 compliant
- exchangable color definition
- lighting condition

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Covering Eight Device Tolerances

Four levels Color Control Maturity

- Don’t have the time to Cover the first three level
- They are in PDF of this presentation

- *We are covering the most mature color control option*
- *Only way to hope to achieve a 2 ΔE tolerance*

- *Reference hand outs to provide road map to 2 ΔE*

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Defining Color Salability (Acceptability):

Depends on:

- Print buyer's *expectations*
  - *Spot/brand color match*
  - *Image/page color match*
- Print device's *production capability*

- Important related variables (instrument/lighting/substrate)
- All of which affect print devices production capabilities

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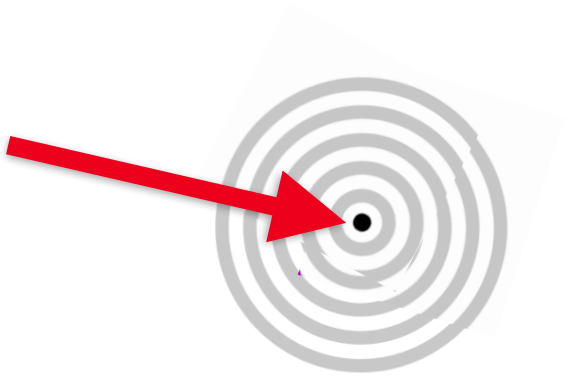
Requirements to Define Color Match

Requires:

- Defining **Reference** to Match:
  - *Spot/brand color match*
  - *Image/page color match*
- Allowable **Tolerance (Δ):**
  - Dependent on variables
  - *Printing process, device, consumables, measurement, light booth,*



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How Different is Too Different?

Which one is Correct? Which is the Reference?

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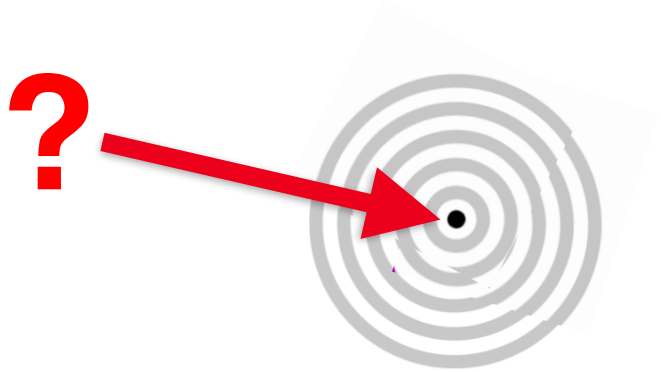
1a. Defining Print Reference (a la GRACoL)

Options for defining reference

- Physical Print
- Industry References (7 CRPCs)
- SCCA Adjusted to CRPC
- Actual Print Condition
  - Create custom ICC Profile



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Limitations of Print Sample to Match to …

No idea how it was printed

- Is it reproducible?
- Standard colorants, and densities for CMYK primaries?
- Dot gain, gray balance and overprints?
- Will require a lot of trial and error, and may never match

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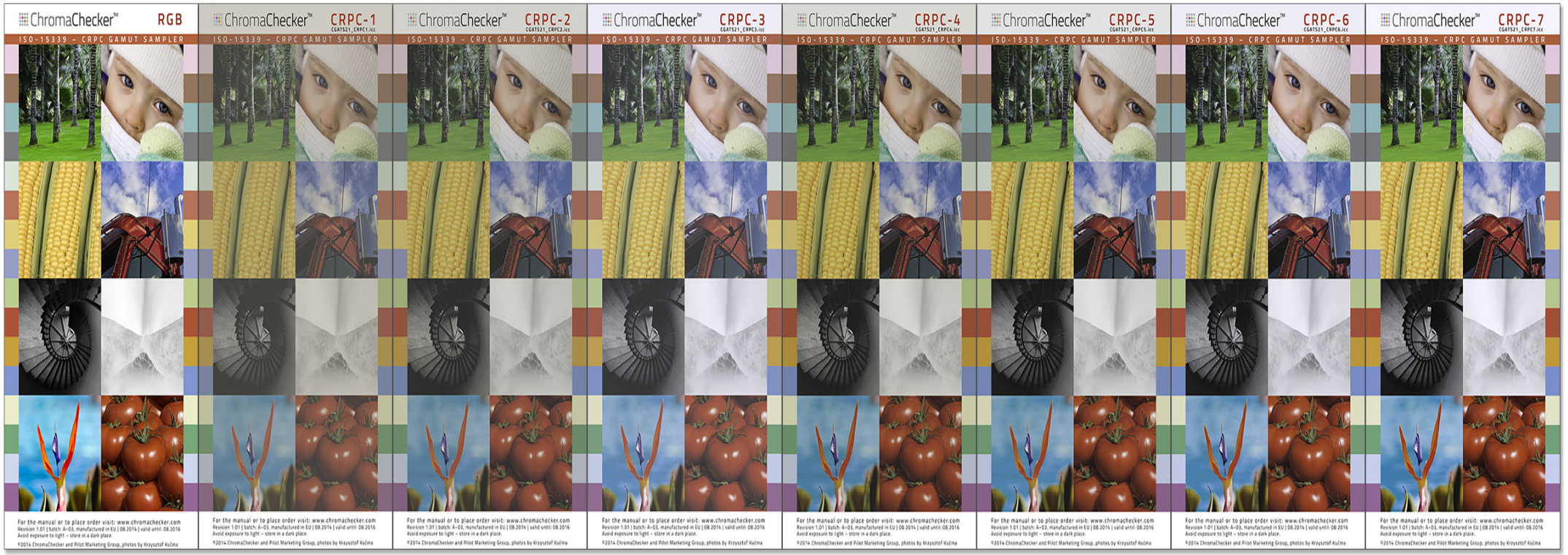
Characterized Reference Printing Conditions

Representing 7 different conditions/substrates

- 4 Coated stocks, 3 Uncoated stocks, ISO 15339 Part 2



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SCCA Adjusted CRPC to accommodate paper

Works well if substrate is Lab=95,1,-4 (M1)

- But not many substrates match this value which requires:
  - Suppliers to apply SCCA to their process to match
  - Suppliers use M1 measurement devices
- If substrate is close (within 4 ΔE) then use SCCA

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Limitations of Reference Print Conditions match

Works well if substrate is within 2ΔE (00)

- But not many substrates match this value which requires:
  - Suppliers to apply SCCA to their process to match
  - Suppliers use M1 measurement devices
- If substrate is close (within 4 ΔE) than use SCCA to define a new Reference Print Condition
- If substrate is greater than 4 ΔE, suggest creating Custom Profile (Actual print condition)

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Actual Print Condition

Need to run on multiple printer runs

- Provides most accurate rendition of Print Condition
- Requires fairly small target (no dedicated press runs)
  - Spectral prediction software
  - Ready for ICC Max (next generation profiling)
- Use one master instrument that can be adjusted for
- Takes extra time and money, but much more accurate

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Reference Options for Process Color

Road Map to Analytic Based Print Manufacturing

GRAPHIC ARTS — PRINT MANUFACTURING

SUBJECTIVE PERSONAL-BASED JUDGMENT — METRIC-BASED JUDGMENT SCIENTIFIC

VISUAL ASSESSMENT • COMPARATIVE COLOR MEASUREMENT • ADVANCED COLOR CONFORMANCE

VISUAL
Personal perception-based comparision to physical standard

Physical Print Sample

BASIC INSTRUMENTAL
Instrument-based comparision to physical standard

CRPC (Lab)

COLORIMETRIC AIM
Instrument-based comparision to colorimetric standard

CRPC (SCCA)

SPECTRAL AIM
Instrument-based comparision to spectral standard

Actual Print Condition

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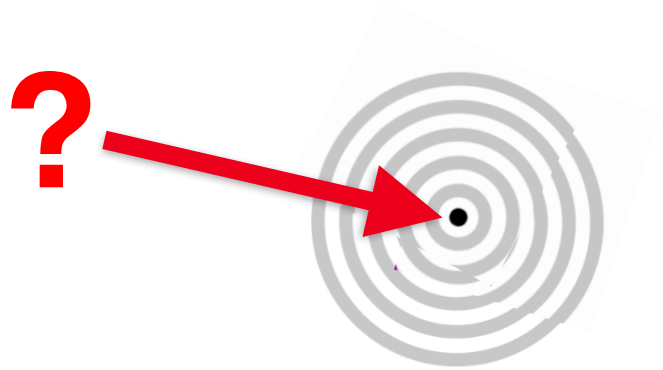
1b. Defining Brand/Spot References

Options for defining reference

- Master Library and palettes for different substrates
- PMS book (coated/uncoated/other)
  - Age of book, batch number
  - Physical sample
- Numeric value based on CIE-Lab (illuminant dependent)
- Numeric value based on Spectral (illuminant independent)



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Options for Defining Brand Color References

Pros and Cons

- PMS Number (PMS 185) and the chip book
  - Visual only, every chip book is different
- Printed Color with CIE Lab values (GMI)
  - Every print is slightly different and ages differently
  - Lab values are not Illuminant independent, No tints
- PMS Number and digital value in CxF format
  - Which PMS Library? M0, M1, RIPs have M2 but you want M0, easy 5 ΔE difference accidental substitutions

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Reference Disagreements- PMS Guides

ΔE=

ΔE 2000	Pantone Guides PMS Book 1987	Pantone Guides PMS Book 1992	Pantone Guides PMS Book 1995	Pantone Guides PMS Book 2005	Pantone Guides PMS Book 2008km	Pantone Guides PMS Book 2013_Plus	Pantone Guides PMS Book 2017_Plus1
PMS Book 1987 Pantone Guides		PANTONE 100 C 1.5 PANTONE Blue 072 C 5.2 PANTONE Green C 0.7 PANTONE Red 032 C 5.9	PANTONE 100 C 1.6 PANTONE Blue 072 C 5.4 PANTONE Green C 0.5 PANTONE Red 032 C 6.2	PANTONE 100 C 1.9 PANTONE Blue 072 C 4.2 PANTONE Green C 0.4 PANTONE Red 032 C 10.4	PANTONE 100 C 2.2 PANTONE Blue 072 C 3.5 PANTONE Green C 0.5 PANTONE Red 032 C 5.2	PANTONE 100 C 4.5 PANTONE Blue 072 C 3.6 PANTONE Green C 0.9 PANTONE Red 032 C 8.6	PANTONE 100 C 5.2 PANTONE Blue 072 C 4.2 PANTONE Green C 1.0 PANTONE Red 032 C 7.4
PMS Book 1992 Pantone Guides	PANTONE 100 C 1.5 PANTONE Blue 072 C 5.2 PANTONE Green C 0.7 PANTONE Red 032 C 5.9		PANTONE 100 C 1.4 PANTONE Blue 072 C 0.4 PANTONE Green C 1.0 PANTONE Red 032 C 0.3	PANTONE 100 C 0.4 PANTONE Blue 072 C 3.2 PANTONE Green C 1.0 PANTONE Red 032 C 4.5	PANTONE 100 C 0.9 PANTONE Blue 072 C 2.8 PANTONE Green C 0.9 PANTONE Red 032 C 0.7	PANTONE 100 C 4.9 PANTONE Blue 072 C 2.9 PANTONE Green C 1.5 PANTONE Red 032 C 2.9	PANTONE 100 C 5.5 PANTONE Blue 072 C 3.5 PANTONE Green C 1.6 PANTONE Red 032 C 2.0
PMS Book 1995 Pantone Guides	PANTONE 100 C 1.6 PANTONE Blue 072 C 5.4 PANTONE Green C 0.5 PANTONE Red 032 C 6.2	PANTONE 100 C 1.4 PANTONE Blue 072 C 0.4 PANTONE Green C 1.0 PANTONE Red 032 C 0.3		PANTONE 100 C 1.8 PANTONE Blue 072 C 3.3 PANTONE Green C 0.7 PANTONE Red 032 C 4.2	PANTONE 100 C 2.3 PANTONE Blue 072 C 3.0 PANTONE Green C 0.2 PANTONE Red 032 C 1.0	PANTONE 100 C 3.5 PANTONE Blue 072 C 3.0 PANTONE Green C 1.0 PANTONE Red 032 C 2.6	PANTONE 100 C 4.1 PANTONE Blue 072 C 3.5 PANTONE Green C 0.8 PANTONE Red 032 C 1.9
PMS Book 2005 Pantone Guides	PANTONE 100 C 1.9 PANTONE Blue 072 C 4.2 PANTONE Green C 0.4 PANTONE Red 032 C 10.4	PANTONE 100 C 0.4 PANTONE Blue 072 C 3.2 PANTONE Green C 1.0 PANTONE Red 032 C 4.5	PANTONE 100 C 1.8 PANTONE Blue 072 C 3.3 PANTONE Green C 0.7 PANTONE Red 032 C 4.2		PANTONE 100 C 0.5 PANTONE Blue 072 C 1.0 PANTONE Green C 0.8 PANTONE Red 032 C 5.2	PANTONE 100 C 5.2 PANTONE Blue 072 C 0.9 PANTONE Green C 0.5 PANTONE Red 032 C 2.1	PANTONE 100 C 5.8 PANTONE Blue 072 C 0.7 PANTONE Green C 0.8 PANTONE Red 032 C 3.6
PMS Book 2008km Pantone Guides	PANTONE 100 C 2.2 PANTONE Blue 072 C 3.5 PANTONE Green C 0.5 PANTONE Red 032 C 5.2	PANTONE 100 C 0.9 PANTONE Blue 072 C 2.8 PANTONE Green C 0.9 PANTONE Red 032 C 0.7	PANTONE 100 C 2.3 PANTONE Blue 072 C 3.0 PANTONE Green C 0.2 PANTONE Red 032 C 1.0	PANTONE 100 C 0.5 PANTONE Blue 072 C 1.0 PANTONE Green C 0.8 PANTONE Red 032 C 5.2		PANTONE 100 C 5.7 PANTONE Blue 072 C 0.6 PANTONE Green C 1.1 PANTONE Red 032 C 3.5	PANTONE 100 C 6.2 PANTONE Blue 072 C 1.4 PANTONE Green C 1.0 PANTONE Red 032 C 2.5

PMS Books compared over 30 years (perfect condition)

Limitations of PMS/Printed Samples-30 year

ΔE 2000	Pantone Guides PMS Book 1987	Pantone Guides PMS Book 1992	Pantone Guides PMS Book 1995	Pantone Guides PMS Book 2005	Pantone Guides PMS Book 2008km	Pantone Guides PMS Book 2013_Plus	Pantone Guides PMS Book 2017_Plus1
PMS Book 1987 Pantone Guides		PANTONE 100 C 1.5 PANTONE Blue 072 C 5.2 PANTONE Green C 0.7 PANTONE Red 032 C 5.9	PANTONE 100 C 1.6 PANTONE Blue 072 C 5.4 PANTONE Green C 0.5 PANTONE Red 032 C 6.2	PANTONE 100 C 1.9 PANTONE Blue 072 C 4.2 PANTONE Green C 0.4 PANTONE Red 032 C 10.4	PANTONE 100 C 2.2 PANTONE Blue 072 C 3.5 PANTONE Green C 0.5 PANTONE Red 032 C 5.2	PANTONE 100 C 4.5 PANTONE Blue 072 C 3.6 PANTONE Green C 0.9 PANTONE Red 032 C 8.6	PANTONE 100 C 5.2 PANTONE Blue 072 C 4.2 PANTONE Green C 1.0 PANTONE Red 032 C 7.4
PMS Book 1992 Pantone Guides	PANTONE 100 C 1.5 PANTONE Blue 072 C 5.2 PANTONE Green C 0.7 PANTONE Red 032 C 5.9		PANTONE 100 C 1.4 PANTONE Blue 072 C 0.4 PANTONE Green C 1.0 PANTONE Red 032 C 0.3	PANTONE 100 C 0.4 PANTONE Blue 072 C 3.2 PANTONE Green C 1.0 PANTONE Red 032 C 4.5	PANTONE 100 C 0.9 PANTONE Blue 072 C 2.8 PANTONE Green C 0.9 PANTONE Red 032 C 0.7	PANTONE 100 C 4.9 PANTONE Blue 072 C 2.9 PANTONE Green C 1.5 PANTONE Red 032 C 2.9	PANTONE 100 C 5.5 PANTONE Blue 072 C 3.5 PANTONE Green C 1.6 PANTONE Red 032 C 2.0
PMS Book 1995 Pantone Guides	PANTONE 100 C 1.6 PANTONE Blue 072 C 5.4 PANTONE Green C 0.5 PANTONE Red 032 C 6.2	PANTONE 100 C 1.4 PANTONE Blue 072 C 0.4 PANTONE Green C 1.0 PANTONE Red 032 C 0.3		PANTONE 100 C 1.8 PANTONE Blue 072 C 3.3 PANTONE Green C 0.7 PANTONE Red 032 C 4.2	PANTONE 100 C 2.3 PANTONE Blue 072 C 3.0 PANTONE Green C 0.2 PANTONE Red 032 C 1.0	PANTONE 100 C 3.5 PANTONE Blue 072 C 3.0 PANTONE Green C 1.0 PANTONE Red 032 C 2.6	PANTONE 100 C 4.1 PANTONE Blue 072 C 3.5 PANTONE Green C 0.8 PANTONE Red 032 C 1.9
PMS Book 2005 Pantone Guides	PANTONE 100 C 1.9 PANTONE Blue 072 C 4.2 PANTONE Green C 0.4 PANTONE Red 032 C 10.4	PANTONE 100 C 0.4 PANTONE Blue 072 C 3.2 PANTONE Green C 1.0 PANTONE Red 032 C 4.5	PANTONE 100 C 1.8 PANTONE Blue 072 C 3.3 PANTONE Green C 0.7 PANTONE Red 032 C 4.2		PANTONE 100 C 0.5 PANTONE Blue 072 C 1.0 PANTONE Green C 0.8 PANTONE Red 032 C 5.2	PANTONE 100 C 5.2 PANTONE Blue 072 C 0.9 PANTONE Green C 0.5 PANTONE Red 032 C 2.1	PANTONE 100 C 5.8 PANTONE Blue 072 C 0.7 PANTONE Green C 0.8 PANTONE Red 032 C 3.6
PMS Book 2008km Pantone Guides	PANTONE 100 C 2.2 PANTONE Blue 072 C 3.5 PANTONE Green C 0.5 PANTONE Red 032 C 5.2	PANTONE 100 C 0.9 PANTONE Blue 072 C 2.8 PANTONE Green C 0.9 PANTONE Red 032 C 0.7	PANTONE 100 C 2.3 PANTONE Blue 072 C 3.0 PANTONE Green C 0.2 PANTONE Red 032 C 1.0	PANTONE 100 C 0.5 PANTONE Blue 072 C 1.0 PANTONE Green C 0.8 PANTONE Red 032 C 5.2		PANTONE 100 C 5.7 PANTONE Blue 072 C 0.6 PANTONE Green C 1.1 PANTONE Red 032 C 3.5	PANTONE 100 C 6.2 PANTONE Blue 072 C 1.4 PANTONE Green C 1.0 PANTONE Red 032 C 2.5

PMS Books compared over 30 years (perfect condition)

Limitations of PMS/Printed Samples- Same Yr

Actual Comparison:

- Printer: Formulation Guide
- Customers- PMS Bridge
- Differences w/in <1ΔE
- Between 1-5 ΔE?????

Primaries and Spots

ΔE 2000	Pantone Guides PMS Book 2017_Plus1	Pantone Guides PMS Book 2017_Plus2	Pantone Guides PMS Book 2017_Plus3	Pantone Guides PMS Book 2017_Plus4
PMS Book 2017_Formula Guide1 Pantone Guides	PANTONE 100 C 5.1 PANTONE Blue 072 C 2.2 PANTONE Green C 0.2 PANTONE Red 032 C 1.1	PANTONE 100 C 4.4 PANTONE Blue 072 C 1.9 PANTONE Green C 0.4 PANTONE Red 032 C 1.5	PANTONE 100 C 4.2 PANTONE Blue 072 C 1.9 PANTONE Green C 0.4 PANTONE Red 032 C 1.5	PANTONE 100 C 4.8 PANTONE Blue 072 C 2.2 PANTONE Green C 0.6 PANTONE Red 032 C 1.1
PMS Book 2017_Plus1 Pantone Guides		PANTONE 100 C 0.7 PANTONE Blue 072 C 0.5 PANTONE Green C 0.5 PANTONE Red 032 C 0.5	PANTONE 100 C 0.9 PANTONE Blue 072 C 0.4 PANTONE Green C 0.5 PANTONE Red 032 C 0.5	PANTONE 100 C 0.4 PANTONE Blue 072 C 0.4 PANTONE Green C 0.6 PANTONE Red 032 C 0.3
PMS Book 2017_Plus2 Pantone Guides			PANTONE 100 C 0.2 PANTONE Blue 072 C 0.1 PANTONE Green C 0.0 PANTONE Red 032 C 0.2	PANTONE 100 C 0.5 PANTONE Blue 072 C 0.4 PANTONE Green C 0.2 PANTONE Red 032 C 0.5
PMS Book 2017_Plus3 Pantone Guides				PANTONE 100 C 0.6 PANTONE Blue 072 C 0.3 PANTONE Green C 0.2 PANTONE Red 032 C 0.4

PMS Books compared same batch, 2018, brand new

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Limitation with Library in CIE Lab Space

Effect of Illumination Not Quantifiable

- Color Inconstancy: Lighting illuminates colors differently

M1

	A	B	C	D50	D55	D60	D65	D75	E	F2	F7	F11	R-12- Smart_Led	MB_Led
L	41.30	45.63	47.32	45.99	46.54	47.01	47.40	48.03	46.23	41.54	46.48	42.62	41.44	46.29
a	-35.26	-26.04	-19.31	-27.43	-25.25	-23.34	-21.68	-19.00	-22.96	-20.67	-21.88	-25.97	-18.53	-7.00
b	-44.66	-37.28	-34.32	-36.63	-35.59	-34.70	-33.95	-32.74	-35.47	-44.80	-36.17	-43.55	-44.71	-38.55
sRGB														
Ref.														
CII	8.06	2.63	1.20	2.81	1.77	0.83	0.00	1.39	1.34	6.95	1.25	5.72	7.32	8.50

- Assess affect of suppliers light booth on brand colors

Lighting E-Factor

	Brand Color Palette			
	ΔE2000	ΔE_{ab}	ΔC	ΔH
FACTOR	5.48			
Max	5.48	6.22	5.59	6.12
95%	5.48	6.22	5.59	6.12
Mean	2.58	3.01	2.18	3.59
Std. dev.	2.00	2.48	2.32	2.26

	Capture - X-Rite i1 Pro 2 sn. 1000307 - 2019-08-28 10:27			D50			ΔE_{ab}	ΔE_{00}
	L*	a*	b*	L*	a*	b*		
	42.63	67.97	45.34	47.30	69.09	53.36	6.22	5.48
	39.56	-34.57	25.56	38.57	-35.50	24.11	1.40	1.25
	76.05	60.81	103.81	79.58	57.18	109.89	5.16	3.86
	94.64	-17.63	118.31	94.94	-14.85	119.34	1.29	1.30
	75.80	-1.90	62.63	76.38	-0.55	63.71	0.99	1.00

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Benefits of Library in CxF X4 Complete

Accurate Simulation:

- Visual and numeric value for all tints
- Visual and numeric value for all spot overprints
- Visual and numeric value for effect of lighting on color

Lighting E-Factor

	WideGamutAudit			
	ΔE2000	ΔE_{ab}	ΔC	ΔH
E-FACTOR	6.86			
Max	7.25	6.49	13.18	10.65
95%	6.86	5.84	9.85	10.22

	Area 5			D50			ΔE_{ab}	ΔE_{00}
	L*	a*	b*	L*	a*	b*		
	17.25	58.97	-80.83	17.71	44.32	-77.81	5.84	6.49
	54.84	73.82	51.22	57.36	72.85	58.09	4.45	3.88
	21.12	42.31	-71.76	21.34	30.31	-70.12	5.48	6.86

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How to Make CxF/X4 Brand Library

Use CxF/X4 Template with your Suppliers

- Spectral solid value using CxF format
  - No ability define tints or overprinting with another color
- Spectral solid and tints values using CxF/X4 format
  - Accurate definition of solids, tint, and overprint value with another spot or process color
  - This is the optimum format for Brand Color Definitions

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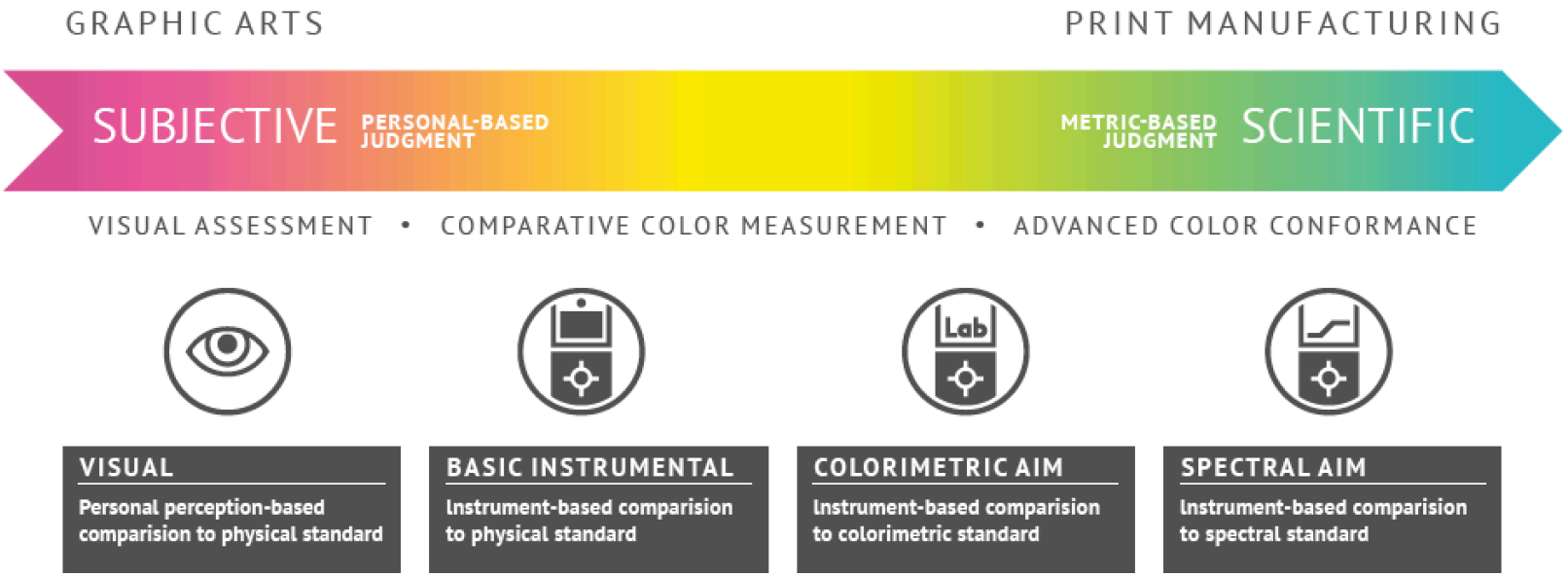
Options for Spot/Brand Color Reference

Road Map to Analytic Based Print Manufacturing



PMS Chip Print Sample | **PMS Name (Lab/CxF)** | **Custom Name (Lab/CxF)** | **Custom Name Spectral/Tints CxF/X4**

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2. Delta What??? (Δ)

How to Define Color Difference

- Know the Reference- How close is close enough?
- 2 Rings, 4 Rings, 6 Rings?
- More Rings, bigger difference

- How to Quantify with Numbers?

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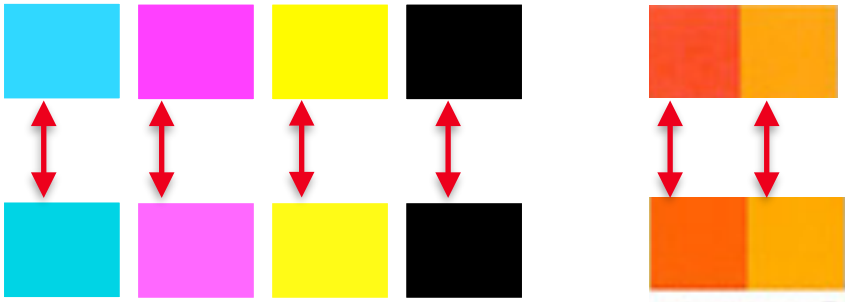
2. Delta What??? (Δ)

What Type of Color Match?

- Match specific colors: Spot, brand colors



- Match between pages and or images: Process Color

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How Close is Close Enough- to Sell Print?

How different is too different for Customer?

- Actual printed sample from multiple suppliers…

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How to Quantify Color Differences

What Type of Color Match?

- Match for individual colors: Brand/Spot Color
  - **ΔE (delta E**) quantifies single color differences
  - Bigger the number, bigger the difference

- Match between pages or images: Many Colors, Pages
  - **E-Factor** (EF)- quantifies process color differences
  - Type of ΔE (CRF at 95th percentile)
  - Think ΔE for process colors, same relative difference

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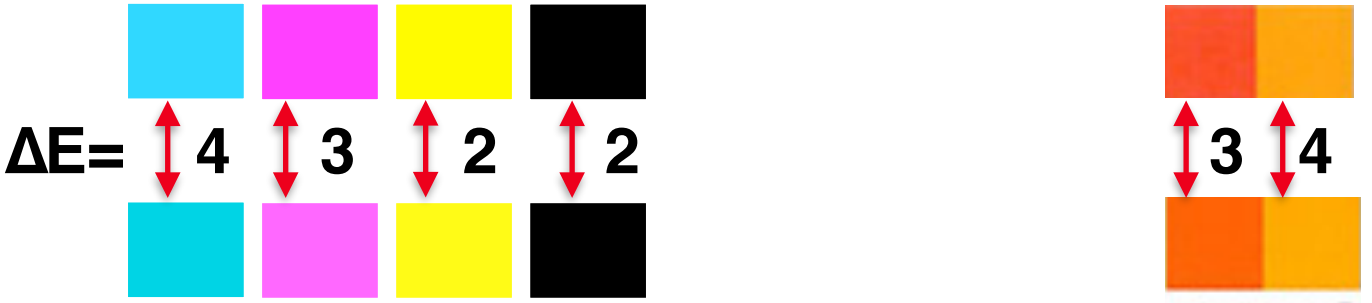
Quantify Color Differences

What Type of Color Match?

- Match specific colors: Process Control (C,M,Y,K), Spot



- Match between pages and or images: Process Color

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What is E-Factor: ΔE00 CRF at 95th Percentile

Compare Measurements from 2 Prints

- Example with Idealliance Control Wedge ISO12647-7 (2013)

Color Aim/Reference: GRACoL2013

Actual Printing Condition: “Large Format”

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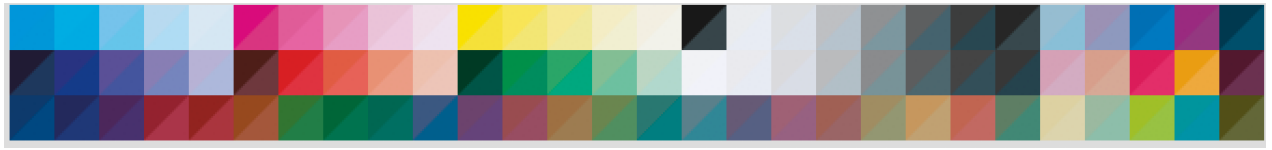
What is E-Factor

Many software programs support today…

1. Calculate **ΔE00** difference for each patch



GRACoL2013 vs "Large Format"

2. Reorder patches from the smallest to largest ΔE

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Metric required for G7 Color Space

95% Chance of Colors being within Expectations

3. Calculate 95th percentile (95% worst match of patches)

95% of reordered patches are below the ΔE value (12.5ΔE00)

GRACoL2013 vs "Large Format"
(ΔE reordered)

Last 5% of reordered patches have larger ΔE values (12.5ΔE00) - outliers

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Defining Color Salability (Acceptability):

Research Shows

- ΔE and E-Factor 2-3 almost universally **accepted**
  - *Spot/brand color match*
  - *Image/page color match*
- ΔE and E-Factor 8+ almost universally **unacceptable**

- ΔE and E-Factor between 3-8- ***depends on person***

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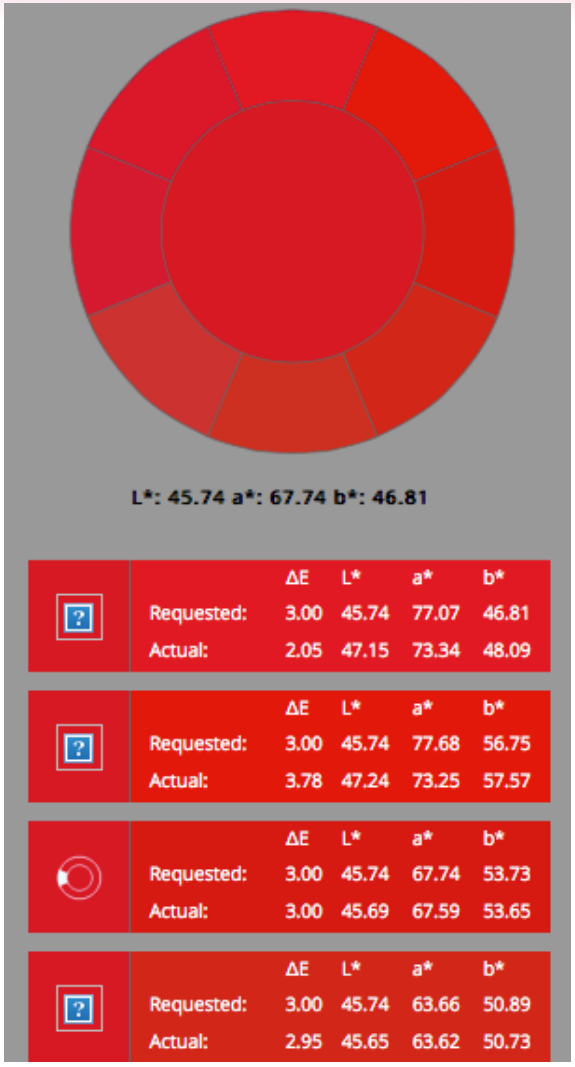
Enter Actual Lab values for your Colors

Preview actual differences

- 3M Red- Entered Lab values
- Spot Color Exercise
- Choose Different delta E formulas
- Compare across hue angles
- Use to determine Acceptability
- Show numbers show the Δa and Δb and ΔE



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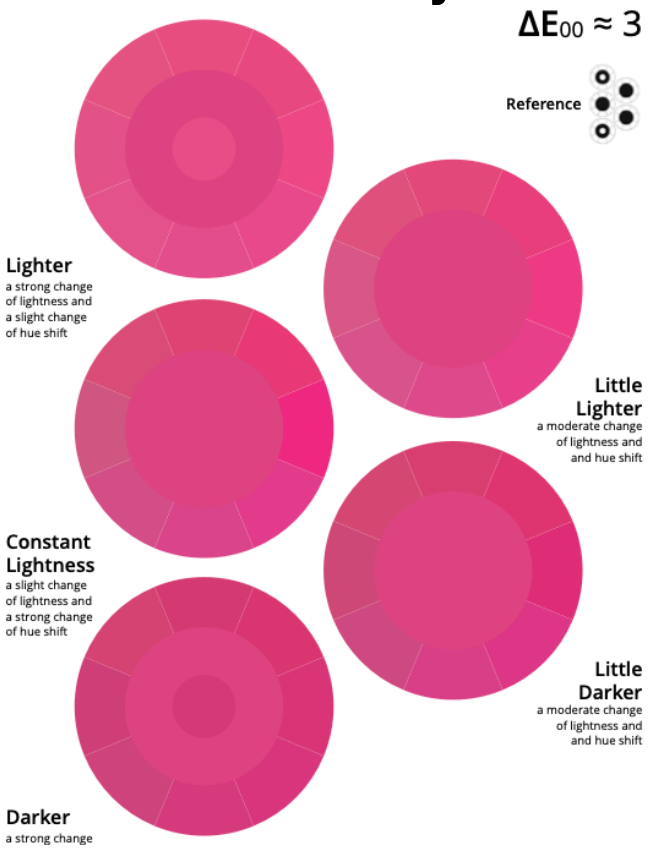
Visualize All ΔE variations: Seeing Believing

Use Variator to See Result for each Color

- Shows all variations of any ΔE in every direction



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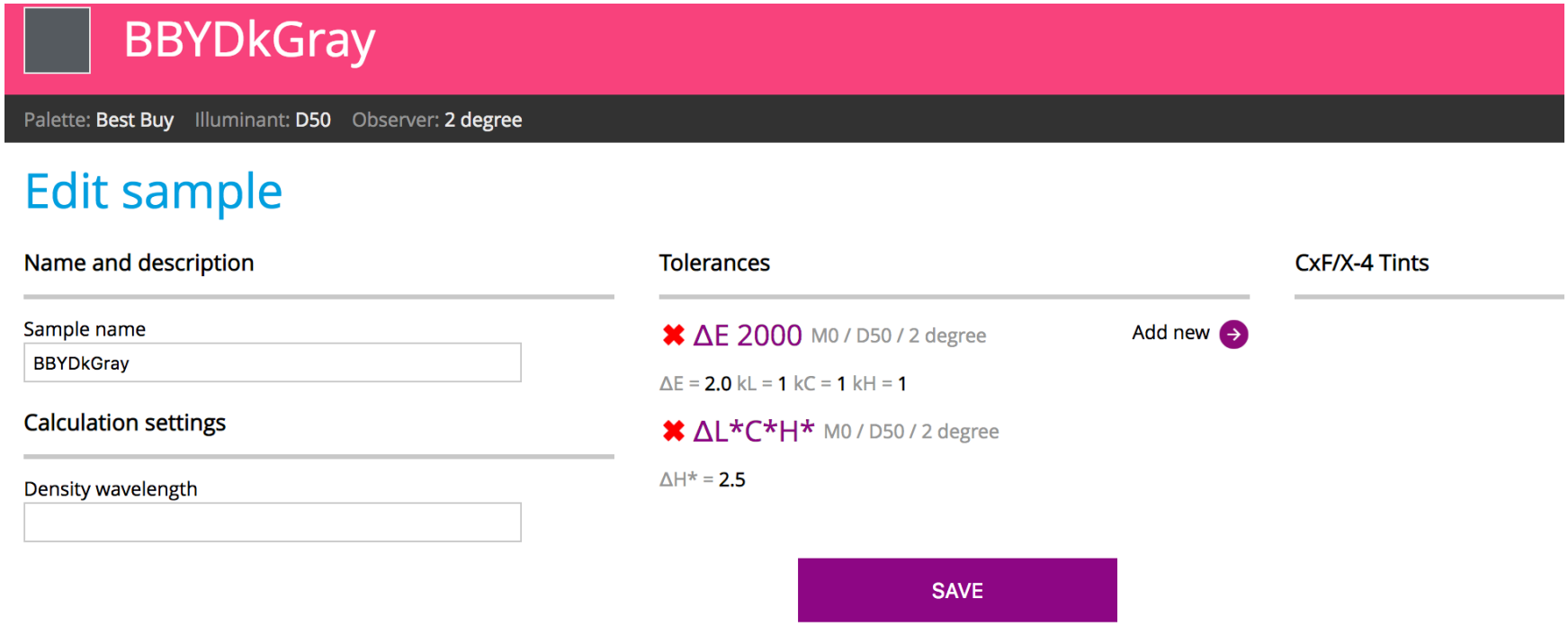
Customize Tolerance add additional metrics

Customize Tolerance

- Use ΔE and add Δh maximum
- Every color can have different metrics



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Customize Tolerance Visually, Define digitally

ΔE (00) differences are non uniform

- Different colors render differently in different hue angles
- Visually use ΔL, Δa and Δb to change relative difference
- Document the delta differences
- Addresses the non linearity of ΔE as tolerance metric

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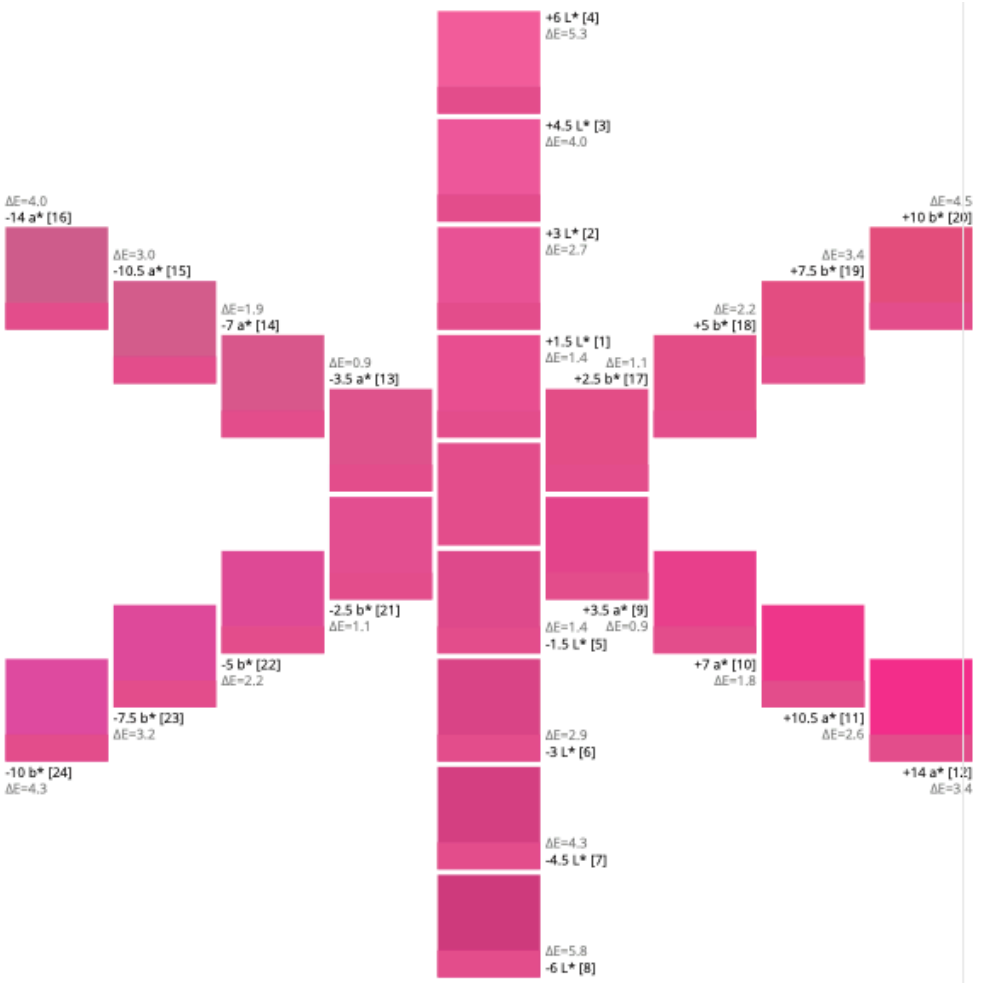
Customize Tolerances based Visual Acceptance

Snowflake determine Acceptable Tolerances

- Compare ΔL, Δa, Δb



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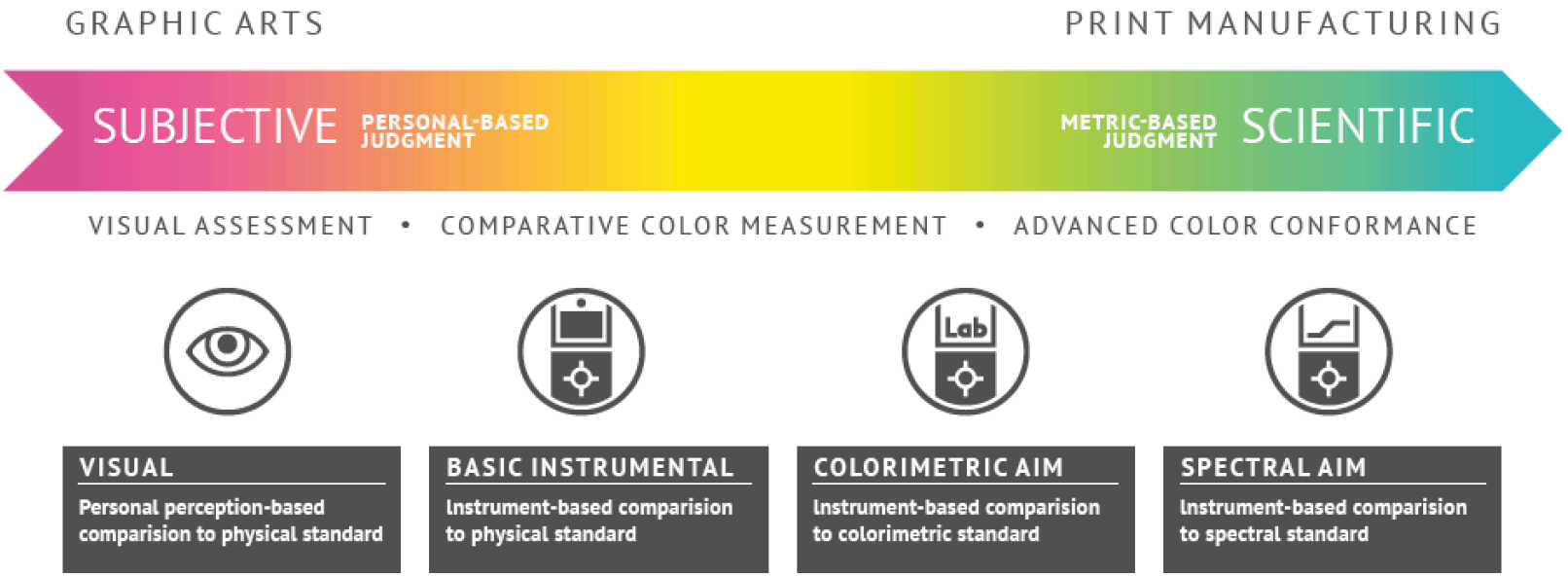
Specification for Brand/Spot Tolerancing

Road Map to Analytic Based Print Manufacturing



Visual Review

Delta E (00)

Delta E (00) + Δh, or additional

+-L,+-a,+-b

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Page (Process) Color Differences…

Which one is the Most Correct- Closest?

- Actual printed sample from multiple suppliers…

GRACoL

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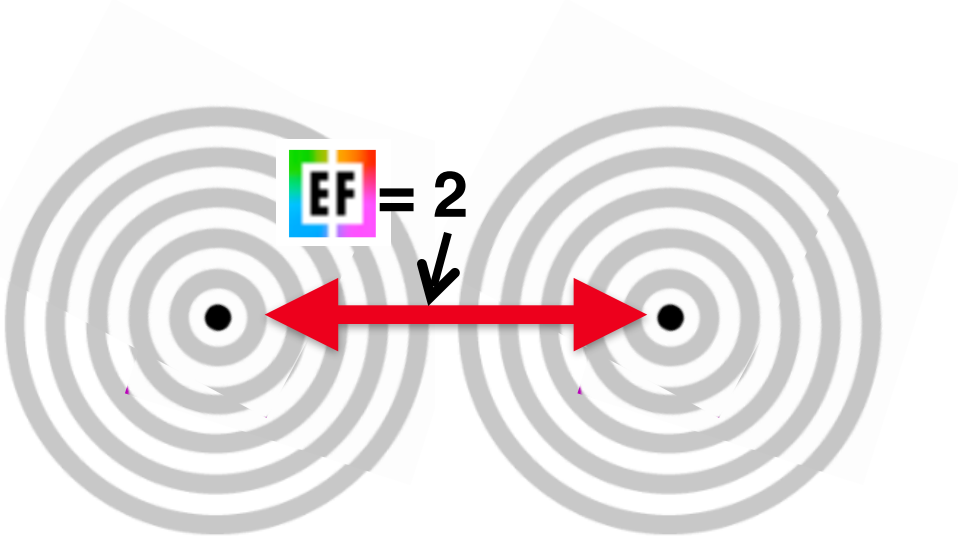
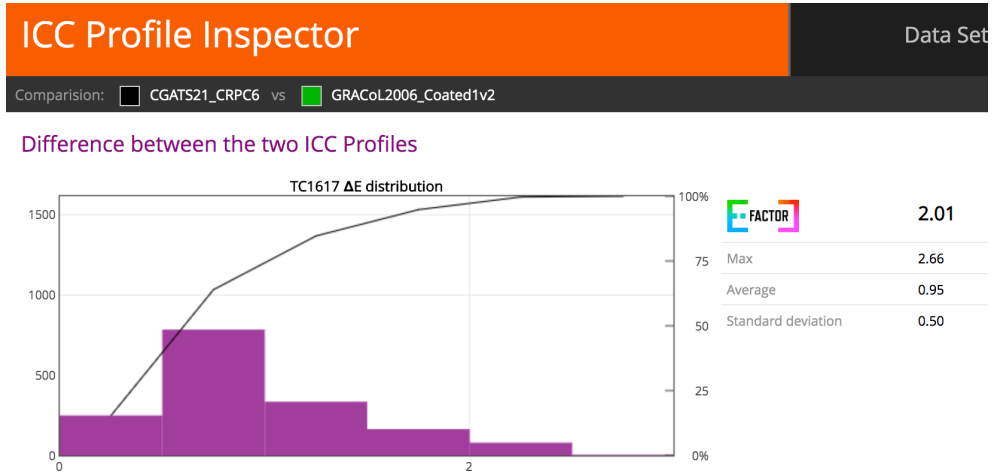
Which GRACoL2006 or 2013?

Visual Difference Between the Two…

- They are Different…



GRACoL2006 **GRACoL2013**



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How Close is Close Enough- to Sell Print?

How different is too different for Customer?

- How different from the Reference (GRACoL)?

GRACoL

EF = 6

EF = 12

EF = 3

GRACoL

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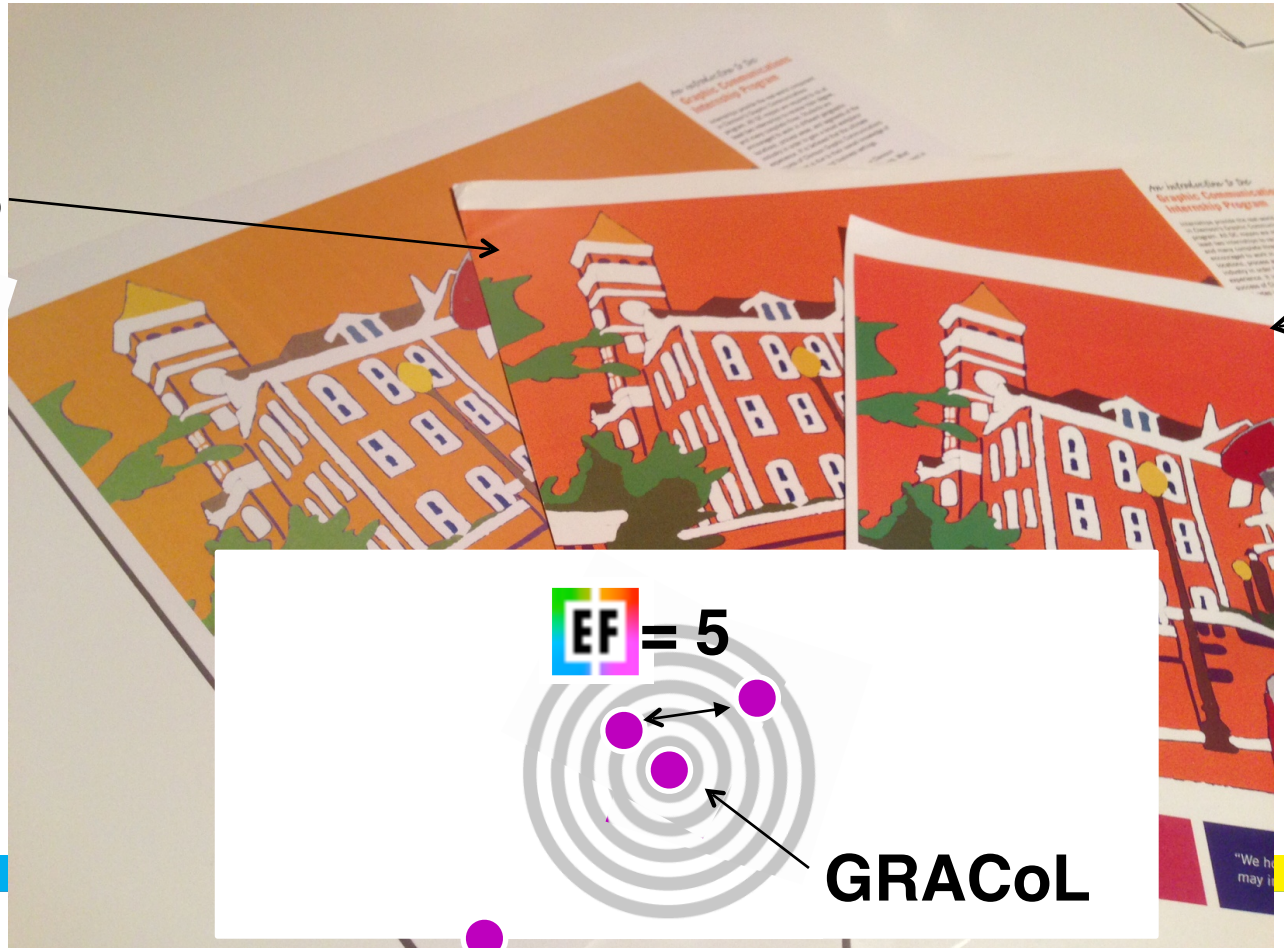
How Close is Close Enough- to Sell Print?

How different is too different for Customer?

- How different from the Reference (GRACoL)?



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How Close is Close Enough- to Sell Print?

How different is too different for Customer?

- Actual printed sample from multiple suppliers…

EF = 5 ✓

EF =10 ✗

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How Close is Close Enough- to Sell Print?

How different is too different for Customer?

- Score Cards do not communicate Visual Difference well

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What about Score Carding Programs

Purpose of Score:

- Assess print is within customer expectations
- Assess how close printer is to reference
- Assess how close printer is to itself over time
- Assess how close two different printers are to one another

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What about Score Carding Programs

Purpose of Score:

PC Score Card

- Assess print is within customer expectations
- Assess how close printer is to reference
- Assess how close printer is to itself over time
- Assess how close two different printers are to one another

Process Control Score Cards- Old Way-

- Score doesn't relate to Customer Expectations
  - 85% Score doesn't relate to Expectations…
- Score doesn't relate to how close two prints are to one another
  - Week to week from same vendor, or between two vendors

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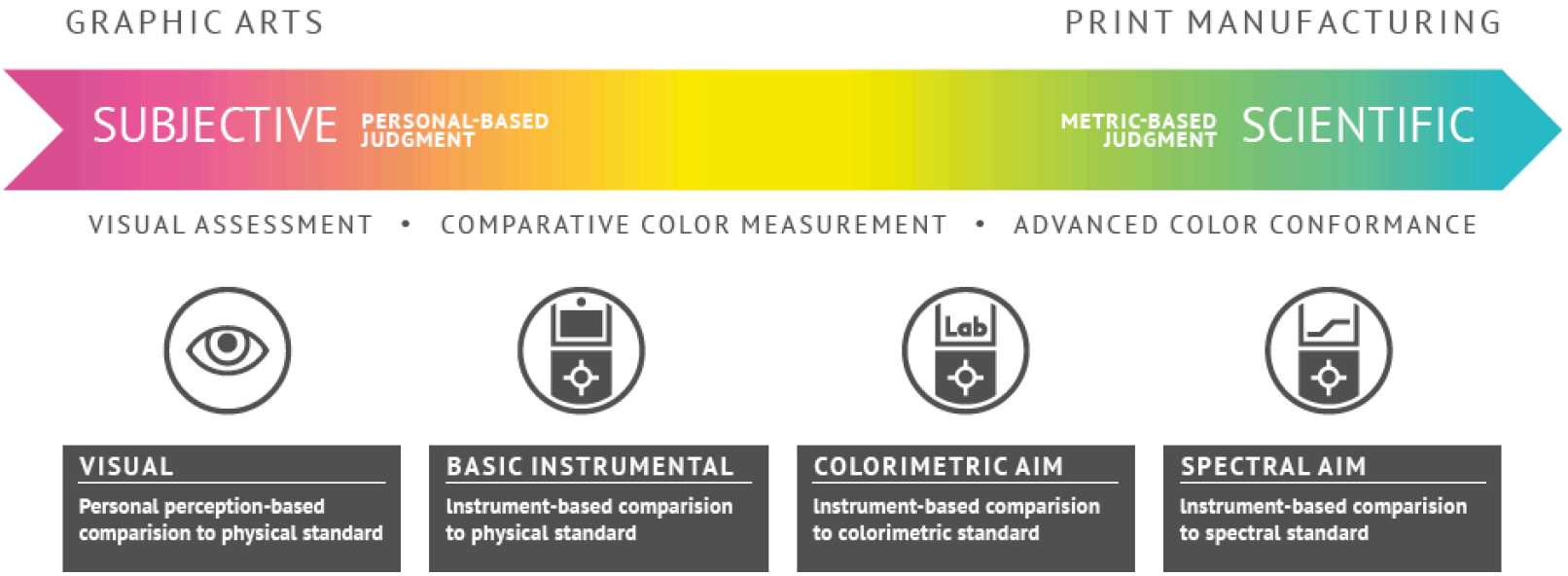
Specification for Image/Page Tolerancing

Road Map to Analytic Based Print Manufacturing



Visual Review

Score Card ColorCert/ Bodoni

G7 ColorSpace

CRF 95th Percentile

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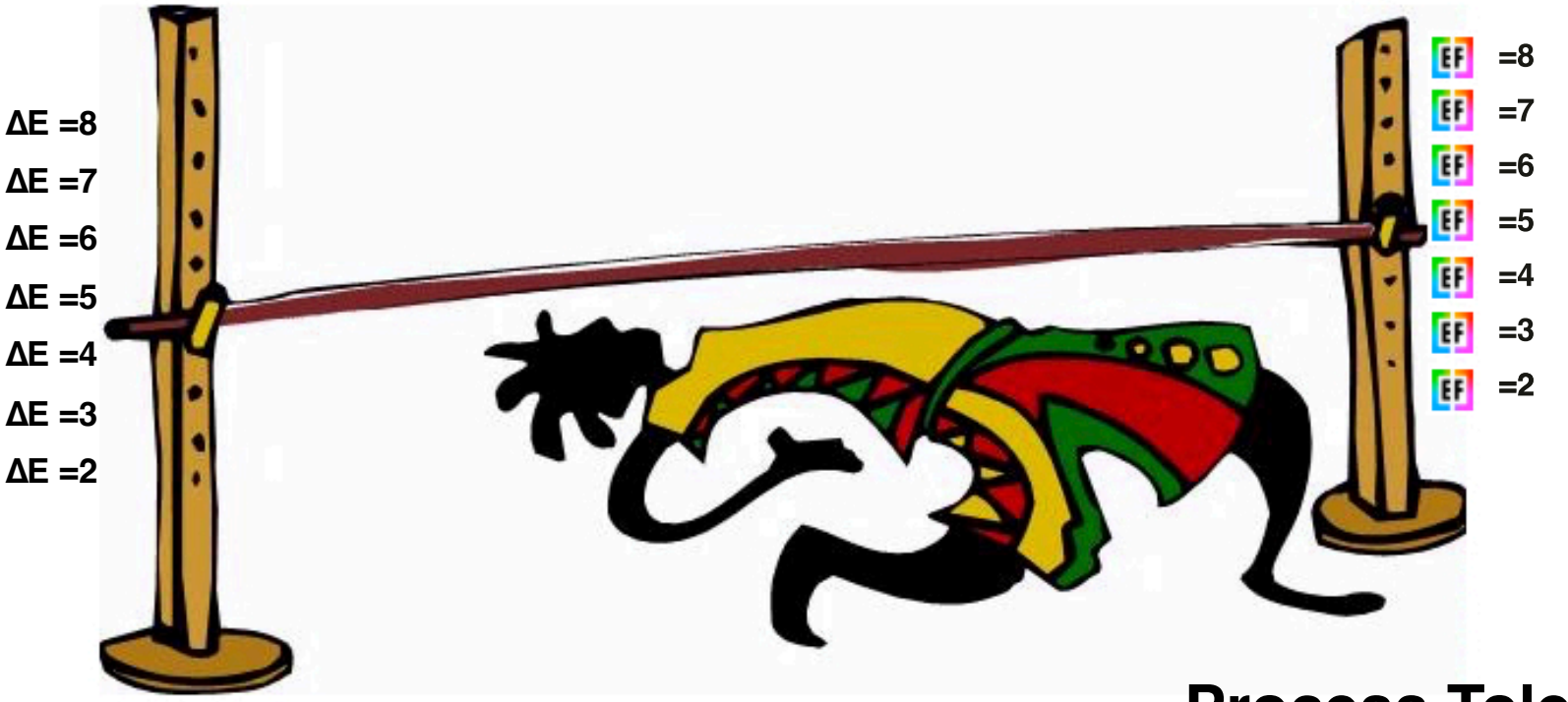
Understand… Tighter the Tolerance- Harder

Exponentially Harder to Achieve- More $$$



Process Tolerances

Spot Tolerances

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3. Output Device Capabilities?

Print Device Production Capabilities

- Not just process control (ensuring CMYK and G7 gray is OK)
- Sum of all variables: print device, consumables, operator
- Manufacturer's don't publish this number (mileage varies)

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Defining Method to Characterize Output

Depending upon Process, and Reference

- Create Tone Curve to accommodate device condition
  - E-Factor= 5-6
- Create an ICC Profile to accommodate device condition
  - E-Factor= 3-5
- ICC Device links with ink savings
  - E-Factor= 2-4

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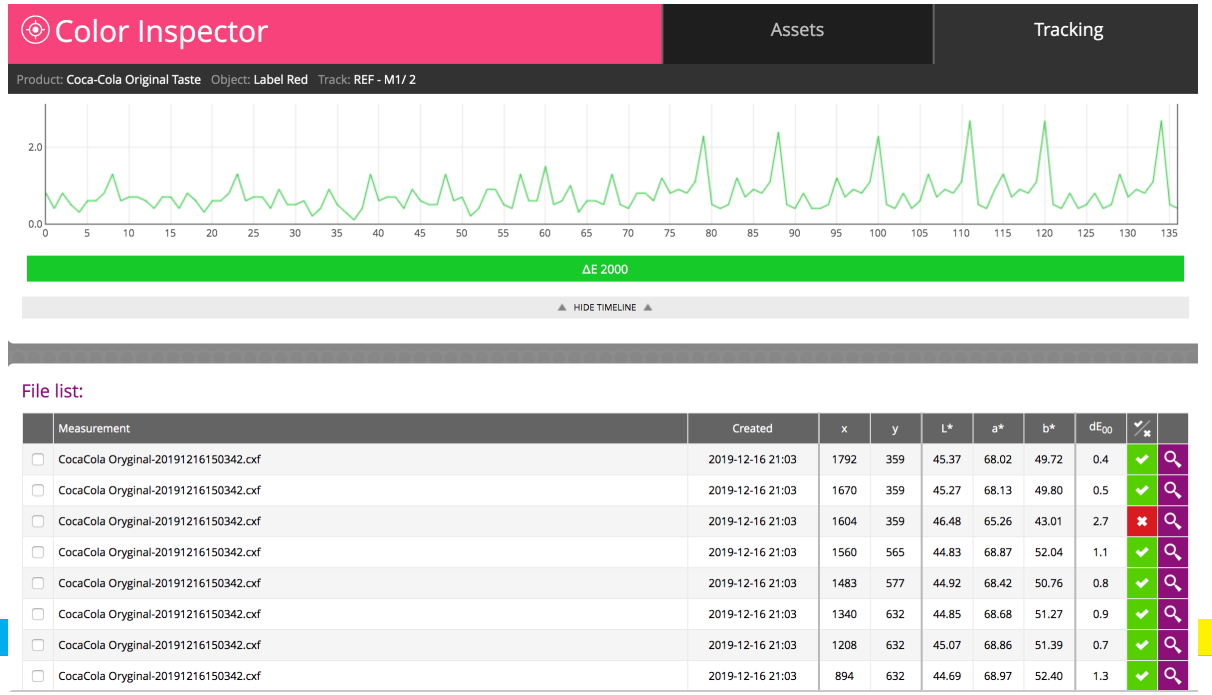
Then Determine if Tolerance is Possible…

Depending upon process, may not maintain

- True spot color with custom ink formulation for substrate
- Spot color simulation on digital device
  - Using CMYK builds to simulate the desired color



	Measurement	Created	x	y	L*	a*	b*	dE_{00}		
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	1792	359	45.37	68.02	49.72	0.4	✔	🔍
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	1670	359	45.27	68.13	49.80	0.5	✔	🔍
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	1604	359	46.48	65.26	43.01	2.7	✖	🔍
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	1560	565	44.83	68.87	52.04	1.1	✔	🔍
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	1483	577	44.92	68.42	50.76	0.8	✔	🔍
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	1340	632	44.85	68.68	51.27	0.9	✔	🔍
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	1208	632	45.07	68.86	51.39	0.7	✔	🔍
☐	CocaCola Oryginal-20191216150342.cxf	2019-12-16 21:03	894	632	44.69	68.97	52.40	1.3	✔	🔍

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Benchmarking Printing Devices

Over 1 Million measurements- published report

- Benchmark procedures to audit your devices- free software
- Digital press, large format, flexo, offset
  - Gamut Size, Consistency, Accuracy, Resolution

Benchmark #1 Gamut Size: Results

Fuji J-Press*	558,700	75%
Kodak Prosper	515,200	74%
KM1 Press*	513,900	76%
Konica Minolta KM1	512,900	76%
Digital Press NEE	504,100	71%
Digital Press NI	459,400	70%
Indigo 10000*	451,100	66%
Indigo 12000*	450,500	66%
Digital Press O	445,300	68%
Indigo WS6600*	420,900	63%
Igen 6 Press*	401,300	65%
Digital Press N	351,900	57%
Kodak Nexpress*	350,700	57%

Benchmark #2 Variation: Results

Printer	With/in		Between		E-Factor M
Indigo 12000*	1.0	P	1.0	P	1.1
Domino press	1.0	P	1.0	P	1.1
Fuji J-Press*	1.2	P	1.1	P	1.1
KM1 Press*	1.3	P	2.0	P	1.6
Kodak Nexpress*	1.2	P	1.8	F	2.9
Konica Minolta KM1	1.4	P	1.2	F	1.1
Digital Press O	2.3	F	3.2	F	2.2
Igen 6 Press*	2.5	P	2.2	P	2.8
Kodak Prosper	3.0	F	1.4	F	3.6
Digital Press N	5.1	F	5.5	F	4.7
Indigo 6600 *	.9	P	Incomplete		3.0
Indigo 6000 *	1.8	F			

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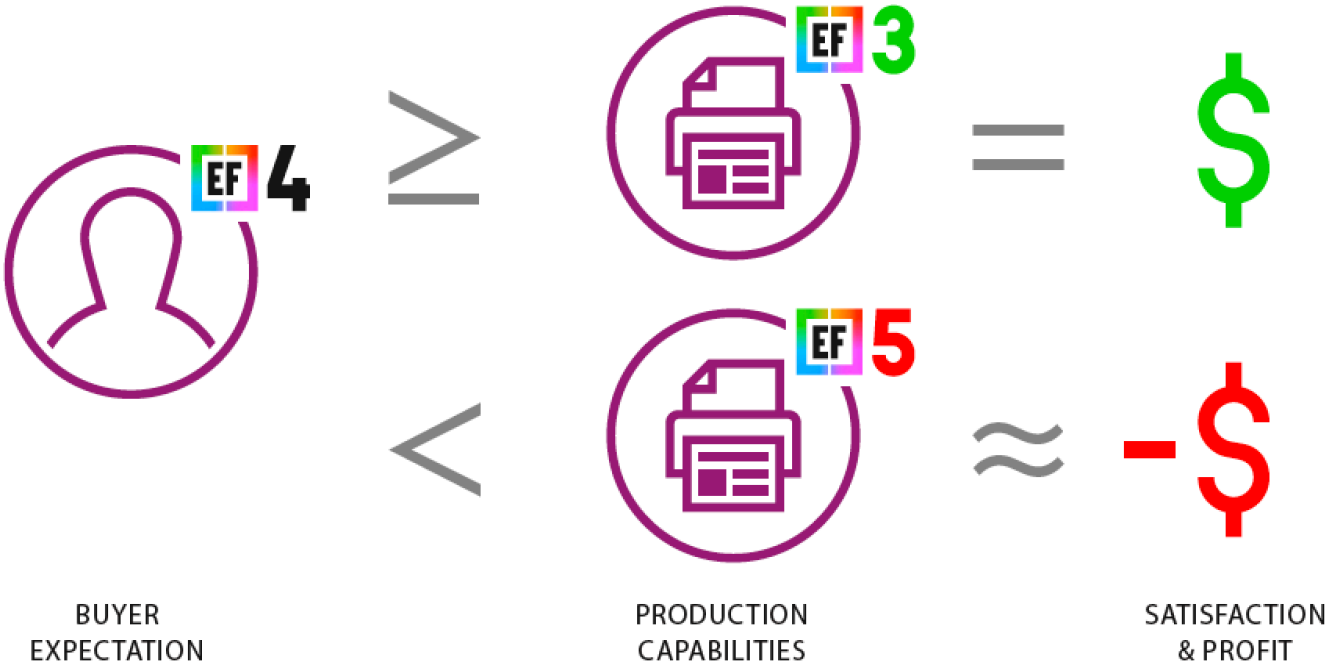
Color Conformance-More than Process Control

Is Color Close Enough?

- Define Production Capability of all Devices
- Define if devices are within Customer Expectations



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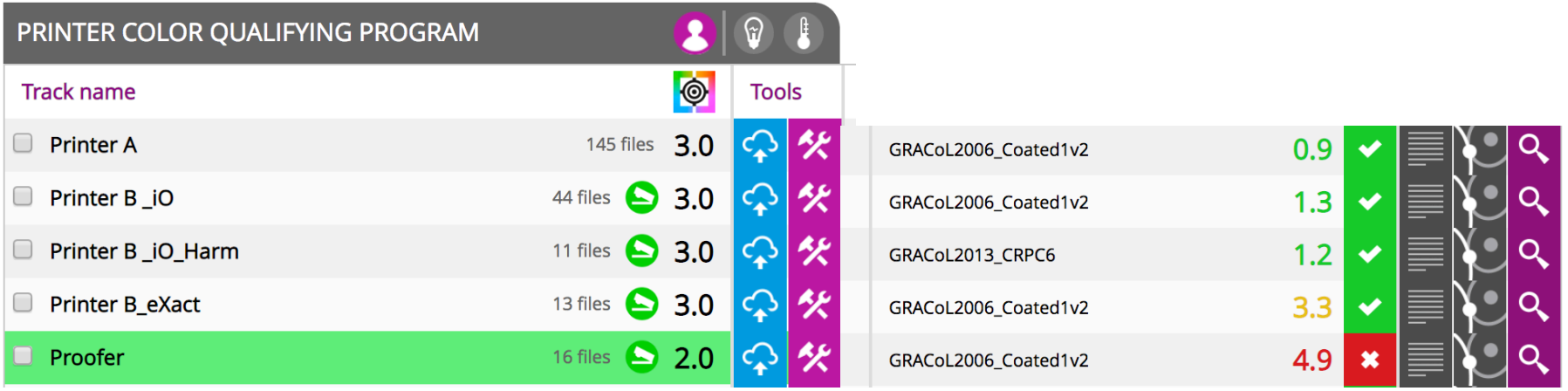
Assessing all Output Devices

- Centralized, Accountable Color Control
- Allows Each Operator to be Responsible
- Notifications sent if Device not maintained

System Overview



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4. What Variables affect assessment

All variables have a cumulative affect

- Difference in paper manufacturing
- Difference between measurement backing
- Differences between measurement devices
- Differences between lighting

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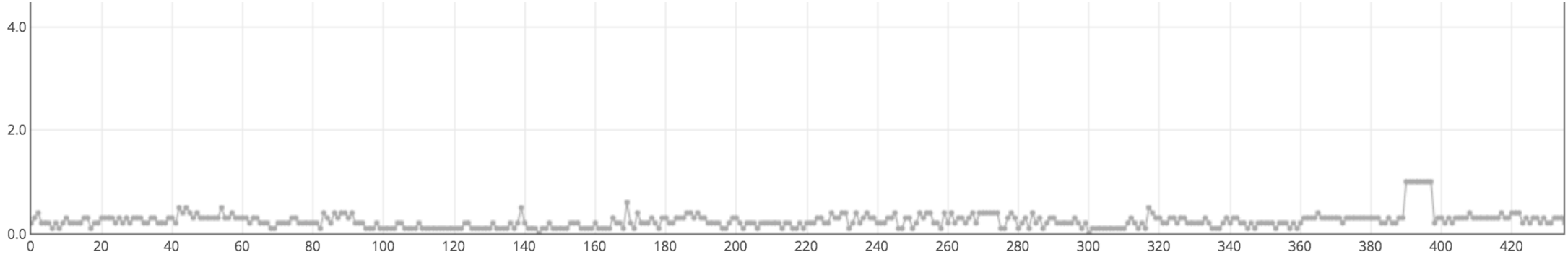
Paper Manufacturing

Many Variables, OBA, Water, Fiber

- Paper variation in manufacturing- Oregon vs. Wisconsin
- Proofing Paper tolerances- Max 1Δ in L* or a* or b*
- Photo Paper tolerances- Max 2Δ in L* or a* or b*
- Track Paper independent of Ink



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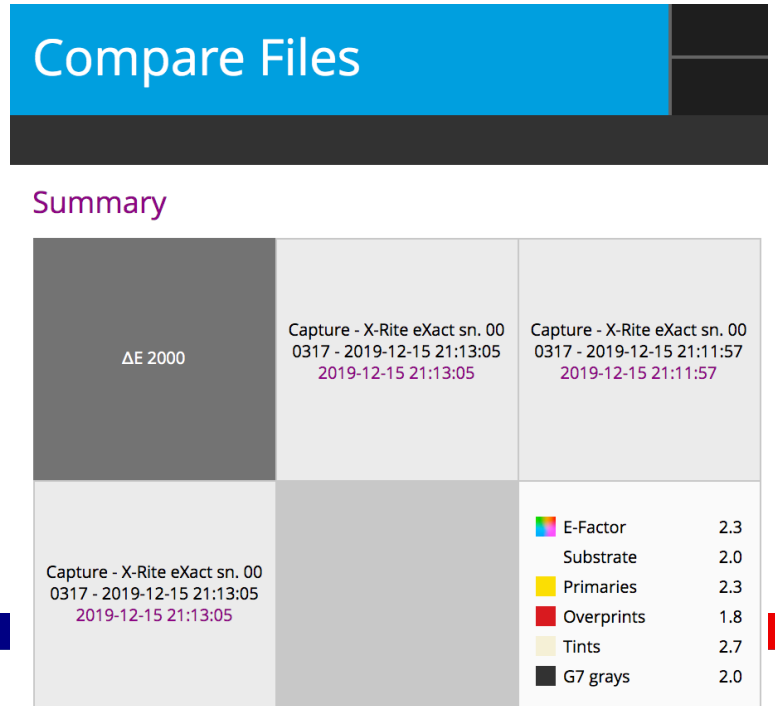
Measurement Backing Differences

Actual Data- Changing backing behind measure

- Measuring same target with same accurate instrument
- Measure on ISO White, ISO Black, and actual paper
- Differences are greater than 2 E-Factor…

Press Side
Measurement= Black

Proofing
Measurement= White



ISO 13655
L* = 95
a* = .9
b* = 1.3

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Measurement Device Differences: Six Sigma

Instrument Gauge Factor

- Every Manufacturing Industry using this metric, except
- Defines what percentage of Production tolerance can be used up due to instrument disagreement (20%-33%)
- Means, if tolerance is 2ΔE, need to give up .4-.66ΔE to within instrument variation
- Delta E stacks on top, two or more instruments total difference be within .4ΔE (stay within 20% of 2ΔE)

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How Measurement Device Influences Result

No two measurement devices measure same…

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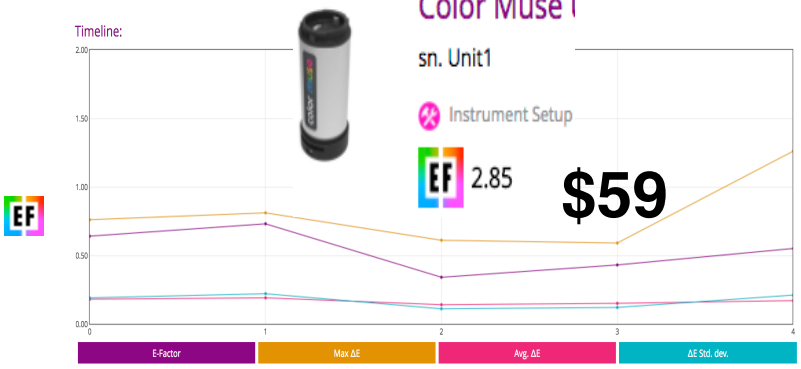
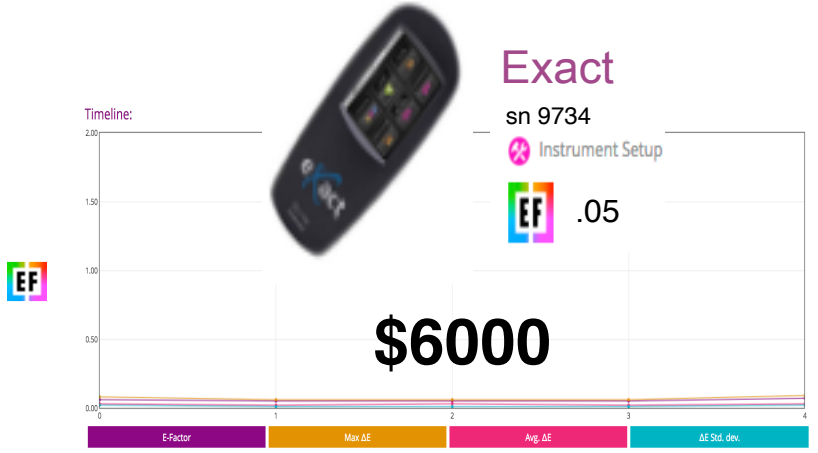
How Measurement Device Influences Result

No two measurement devices measure same…





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Instrument Needs to be Considered!

Different Instruments Measuring Same Colors:

- Same Brand Color bar measured with i1, Exact, SpectroDens

Primaries and Spots

ΔE 2000	Capture - X-Rite i1 Pro 2 sn. 1000307 - 2019-04-09 12:05:08 2019-04-09 12:05:08	Capture - Techkon SpectroDens Premium sn. B408573 - 2019-04-03 10:50:07 2019-04-03 10:50:07	Capture - MSP X-Rite eXact sn. 032095 - 2019-04-03 10:48:23 2019-04-03 10:48:23
2019-04-09 12:05:08 Capture - X-Rite i1 Pro 2 sn. 1000307 - 2019-04-09 12:05:08		BBY_PacSalesBlue 1.7 BBY_PacSalesRed 1.2 BBY_GC_CoolGray9 4.1 BBY_GC_CoolGray6 3.4 BBY_GC_CoolGray3 2.8 BBY_GS_Orange 2.1 BBYValueRed 1.6 BBYDkGray 2.6 BBY_MagnoliaRed 0.6 BBY_MyBBYBlue 1.5 BBYDkBlue 0.6 BBYLtBlue 0.5 BBYDkYellow 1.7 BBYLtGray 2.2 BBYTechWhite 3.5 BBYTechBlack 1.7 BBYTechYellow 1.6 BBYHumanBlue 1.5	BBY_PacSalesBlue 1.9 BBY_PacSalesRed 1.3 BBY_GC_CoolGray9 4.1 BBY_GC_CoolGray6 3.0 BBY_GC_CoolGray3 3.4 BBY_GS_Orange 2.0 BBYValueRed 1.2 BBYDkGray 3.1 BBY_MagnoliaRed 1.2 BBY_MyBBYBlue 1.7 BBYDkBlue 0.5 BBYLtBlue 0.4 BBYDkYellow 1.6 BBYLtGray 4.6 BBYTechWhite 6.4 BBYTechBlack 2.3 BBYTechYellow 1.6 BBYHumanBlue 1.5

ΔE Values- only difference is the instrument…

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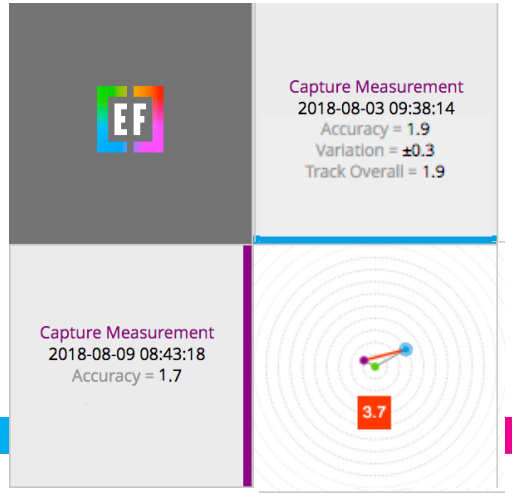
Understand Supplier Differences

Different Printers attempting to Print desired colors

- Each Printer could be within 2ΔE of Reference
- But be up to 4ΔE to each other- different inks/toners
- Realistic Tolerances



Primaries and Spots

ΔE 2000	Capture - X-Rite i1 Pro 2 sn. 1000307 - 2019-04-09 12:05:08 2019-04-09 12:05:08
2019-04-03 10:50:07 Capture - Techkon SpectroDens Premium sn. B408573 - 2019-04-03 10:50:07	BBY_PacSalesBlue 1.7 BBY_PacSalesRed 1.2 BBY_GC_CoolGray9 4.1 BBY_GC_CoolGray6 3.4 BBY_GC_CoolGray3 2.8 BBY_GS_Orange 2.1 BBYValueRed 1.6 BBYDkGray 2.6 BBY_MagnoliaRed 0.6 BBY_MyBBYBlue 1.5 BBYDkBlue 0.6 BBYLtBlue 0.5 BBYDkYellow 1.7 BBYLtGray 2.2 BBYTechWhite 3.5 BBYTechBlack 1.7 BBYTechYellow 1.6 BBYHumanBlue 1.5

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Understand Instrument Differences

Same Color bar measured with 3 instruments

- Comparison between 3 measurement devices
- X-Rite Exact vs i1; Peak ΔE= 6.4: White
- Tolerance is 2ΔE?
- Fails due to Instrument Differences

Primaries and Spots

ΔE 2000	Capture - X-Rite i1 Pro 2 sn. 1000307 - 2019-04-09 12:05:08 2019-04-09 12:05:08
2019-04-03 10:48:23 Capture - MSP X-Rite eXact sn. 032095 - 2019-04-03 10:48:23	BBY_PacSalesBlue 1.9 BBY_PacSalesRed 1.3 BBY_GC_CoolGray9 4.1 BBY_GC_CoolGray6 3.0 BBY_GC_CoolGray3 3.4 BBY_GS_Orange 2.0 BBYValueRed 1.2 BBYDkGray 3.1 BBY_MagnoliaRed 1.2 BBY_MyBBYBlue 1.7 BBYDkBlue 0.5 BBYLtBlue 0.4 BBYDkYellow 1.6 BBYLtGray 4.6 BBYTechWhite 6.4 BBYTechBlack 2.3 BBYTechYellow 1.6 BBYHumanBlue 1.5

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Two Instrument Strategies: Process vs Spot

Process Color Instrument Strategy

- Harmonize Instruments to one another- Compensate on fly
- Build profiles for each instrument, compensate measurements

	X-Rite i1 iSis 2 XL ISIS_M0	X-Rite i1 Pro 1 Autogenerated baseline 2018-03-01 09:06:44	X-Rite i1 Pro 2 I1_SN307_M0	X-Rite SN317 eXact Exact_SN317_M0
X-Rite i1 iSis 2 XL ISIS_M0		Workflow = 6.20 H = 1.50 Instrument = 1.24 H = 0.30 Harmonizer = 313% Max = 1.29 Avg. = 0.67	Workflow = 6.25 H = 1.35 Instrument = 1.25 H = 0.27 Harmonizer = 363% Max = 1.41 Avg. = 0.70	Workflow = 5.60 H = 1.85 Instrument = 1.12 H = 0.37 Harmonizer = 203% Max = 1.26 Avg. = 0.64

- Without Harmonization- Mix instruments require E-Factor= 6
- With Harmonization- Mix instruments enables E-Factor= 1.8

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Two Instrument Strategies: Process vs Spot

Spot/Brand Color Instrument Strategy

- Resign that every instrument is different
- Track same color product with different instruments/conditions

Gatorade Frost		Reference Value	Last Measurement		
▶ Label Transparent	60	L=92 a=0 b=3	2019-09-30 16:28	1.5	✓
▶ Orange overprinted on Red	24	L=51 a=64 b=64	2019-09-30 16:28	0.8	✓
▶ Printed Black	41				✗
▼ Printed Cyan	22	L=68 a=-31 b=-31	2019-09-30 16:28	1.1	✓
REF - M1/ 2	9	L=68 a=-31 b=-31	2019-09-30 16:28	1.1	✓
TR - M1/ 2	13	L=63 a=-16 b=-18	2019-09-30 15:09	1.4	✓

- Accommodates mixing Spherical measurements and 45/0
- Communicate references to supply chain

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Instrument Tracking and Compensation

Road Map to Analytics Based Print Manufacturing

GRAPHIC ARTS — PRINT MANUFACTURING

SUBJECTIVE PERSONAL-BASED JUDGMENT — METRIC-BASED JUDGMENT SCIENTIFIC

VISUAL ASSESSMENT • COMPARATIVE COLOR MEASUREMENT • ADVANCED COLOR CONFORMANCE

VISUAL

Personal perception-based comparision to physical standard

- no knowledge required
- expensive and time-consuming personal supervision
- dependent on the person
- lighting conditions related
- uncontrolled metamerism

Visual Review

BASIC INSTRUMENTAL

Instrument-based comparision to physical standard

- numerically expressed color differences
- expensive and time-consuming personal supervision
- uncontrolled metamerism
- initial swatch-book inaccuracy

Send to Factory

COLORIMETRIC AIM

Instrument-based comparision to colorimetric standard

- numerically expressed color differences
- stable color definition
- exchangable color definition
- the possibility of remote control

Vendor tools

SPECTRAL AIM

Instrument-based comparision to spectral standard

- numerically expressed color differences
- spot colors, SCTV, CxF/X-4 compliant
- exchangable color definition
- lighting condition

Harmonize to Master

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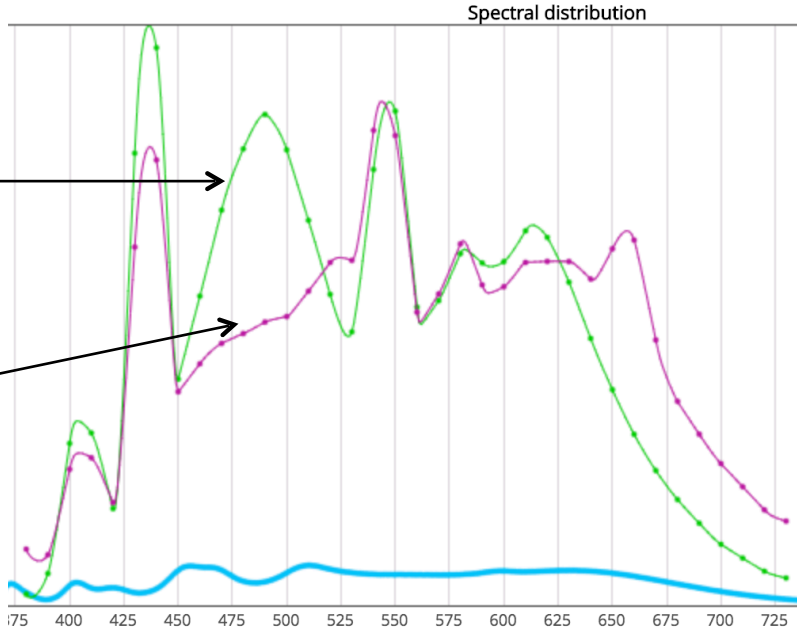
Light Booth Differences

Two most used light booths on market

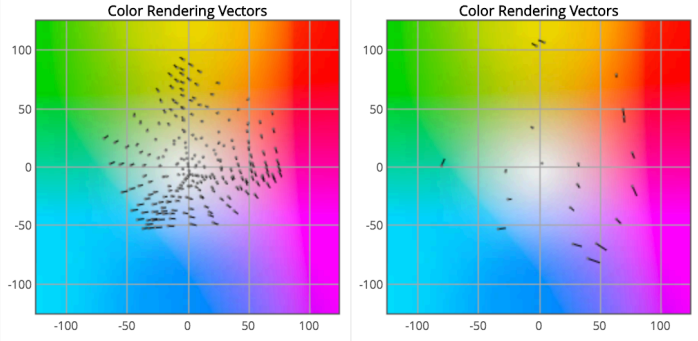
- Press has one, Prepress has other- Mismatches

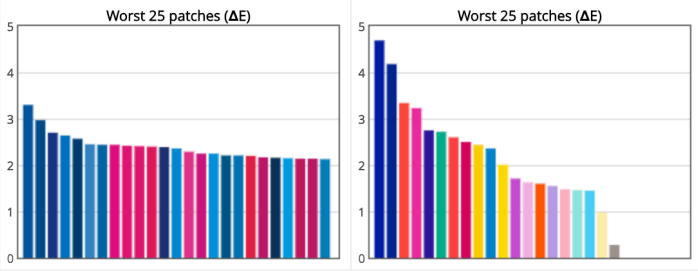


Brand Colors React differently to different lighting (LED)…

Just Normlicht LED vs GTI Proofing

	CMYK				Spots			
	ΔE2000	ΔE_{ab}	ΔC	ΔH	ΔE2000	ΔE_{ab}	ΔC	ΔH
FACTOR	2.36				4.15			
Max	3.27	3.21	4.84	4.98	4.66	4.81	9.42	7.12
95%	2.36	2.60	3.52	4.14	4.15	4.07	8.03	6.88
Mean	1.40	1.59	1.53	1.86	2.22	2.44	3.10	3.47
Std. dev.	0.54	0.60	1.07	1.24	1.06	1.12	2.46	2.14



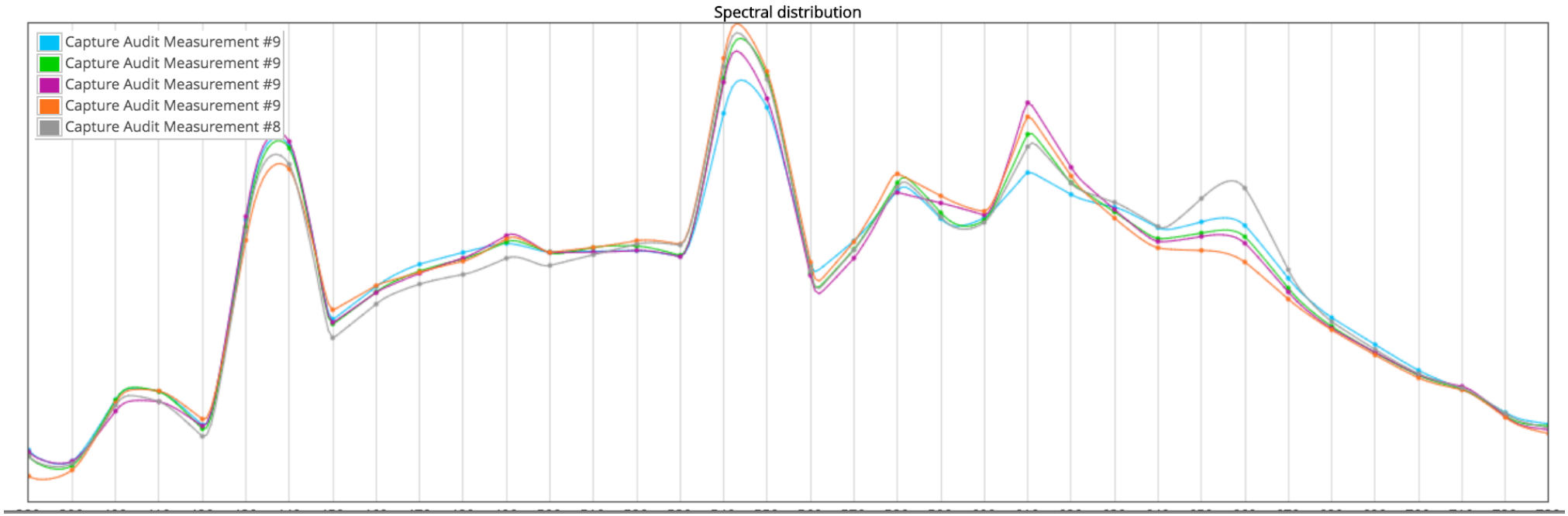


Light Booths- Flourescent bulbs change

Quantify How Close to One Another

- Multiple Light Booths, normal variations

Spectral comparision



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Light Booths

Quantify How Close to D50, and to One Another

- Two light booths that pass ISO doesn't guarantee match
- Never mind two different vendors- same vendor!!!
  - T8 Bulbs versus T12 bulbs- and different ages > 2
- Trying to match E-9900/Gracol06 with 9000/Gracol2013
- Color server, manual corrections: very close- customer rejected- Due to Light booth!!!
- Changed ballast to support same tube, bought same batch, set schedule for change out

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Light Booth Tracking and Compensation

Road Map to Analytics Based Print Manufacturing

GRAPHIC ARTS — PRINT MANUFACTURING

SUBJECTIVE (PERSONAL-BASED JUDGMENT) → (METRIC-BASED JUDGMENT) SCIENTIFIC

VISUAL ASSESSMENT • COMPARATIVE COLOR MEASUREMENT • ADVANCED COLOR CONFORMANCE

VISUAL

Personal perception-based comparision to physical standard

- no knowledge required
- expensive and time-consuming personal supervision
- dependent on the person
- lighting conditions related
- uncontrolled metamerism

Visual Review

BASIC INSTRUMENTAL

Instrument-based comparision to physical standard

- numerically expressed color differences
- expensive and time-consuming personal supervision
- uncontrolled metamerism
- initial swatch-book inaccuracy

Once year Audit

COLORIMETRIC AIM

Instrument-based comparision to colorimetric standard

- numerically expressed color differences
- stable color definition
- exchangable color definition
- the possibility of remote control

Measure Monthly

SPECTRAL AIM

Instrument-based comparision to spectral standard

- numerically expressed color differences
- spot colors, SCTV, CxF/X-4 compliant
- exchangable color definition
- lighting condition

Same Batch, Manufacturer

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Rules For Engagement

Understand the Ramification of Every Variable

- Need to be Advanced in Every Category
  - Defining References
  - Defining Tolerances
  - Defining Backing
  - Defining Instrumentation- and Harmonization
  - Defining Lighting

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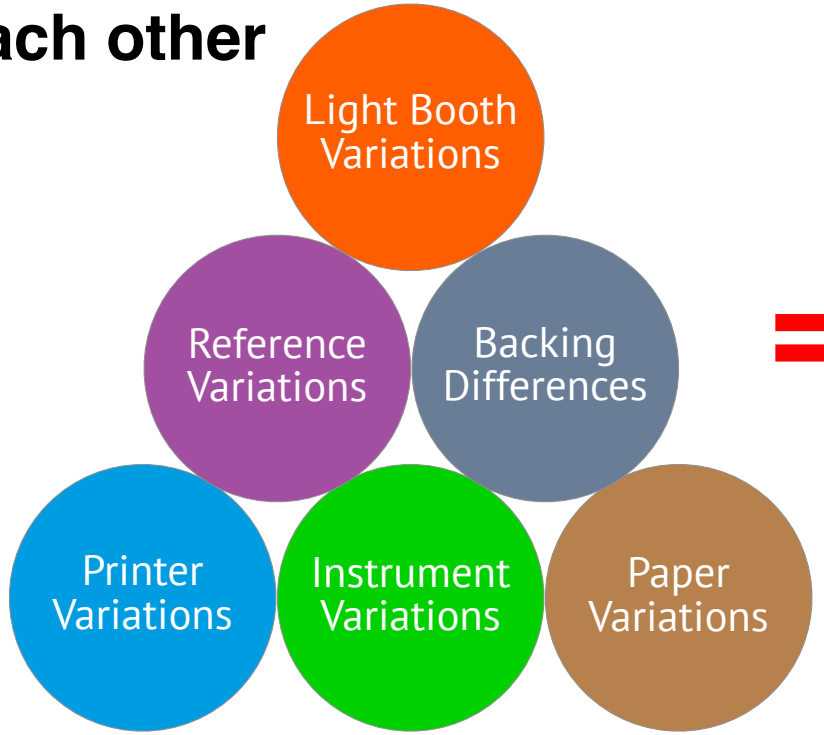
Each Variable Stacks on Top of Each Other

Cumulative Process:

- Each Workflow Component is tracked using **ΔE** or **E-Factor**
- **They all stack on each other**



or 12 EF

= 8 EF

or 5 EF

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Print Manufacturing Salable Number

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SUBJECTIVE PERSONAL-BASED JUDGMENT — METRIC-BASED JUDGMENT SCIENTIFIC

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VISUAL

Personal perception-based comparision to physical standard

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EF = 9+

BASIC INSTRUMENTAL

Instrument-based comparision to physical standard

- numerically expressed color differences
- expensive and time-consuming personal supervision
- uncontrolled metamerism
- initial swatch-book inaccuracy

EF = 6-8

COLORIMETRIC AIM

Instrument-based comparision to colorimetric standard

- numerically expressed color differences
- stable color definition
- exchangable color definition
- the possibility of remote control

EF = 4-5

SPECTRAL AIM

Instrument-based comparision to spectral standard

- numerically expressed color differences
- spot colors, SCTV, CxF/X-4 compliant
- exchangable color definition
- lighting condition

EF = 2-3

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Color Conformance vs. Process Control

Defined tolerances in ΔE, E-Factor will determine:

- What type of process control for given manufacturing
- How often process control is performed
- How tight the process control metrics are
- How tight raw materials have to accountable to
- Proactively assessing all variables, all time
  - Not sending instrument back to factory once/year
- Communicating to Operators, Management, Sales etc.

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If You Want any Chance for 2 ΔE/E-Factor

Need to be maximum maturity for every category

- Defining and Communicating Digital References
- Defining and Communicating Intelligent Tolerances
- Defining Print Manufacturing Capability (E-Factor)
- Defining Substrates, and allowing SCCA
- Defining Instrument Backing (ISO 13655-2017)
- Harmonizing Instruments (Compensate for differences)
- Using same light booth/bulbs, tracking bulb age
- Real time tracking and assessment

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Thank you for attending!

COLOR20

get the answers here

SGIA

Advancing Graphic Communications

PRINTING INDUSTRIES OF AMERICA