Process Control, ISO 12647-2 & ISO 15339

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Process control is to achieve accurate and consistent color reproduction. Standards provide aims and tolerances.

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- Printing process control
- ISO 12647-2
  - Process dependent aims & tolerances for offset printing
- ISO 15339
  - Process independent aims for analog and digital printing
- ISO/TS 10128 for in-gamut color adjustments
- ISO 12647-2 vs. ISO 15339

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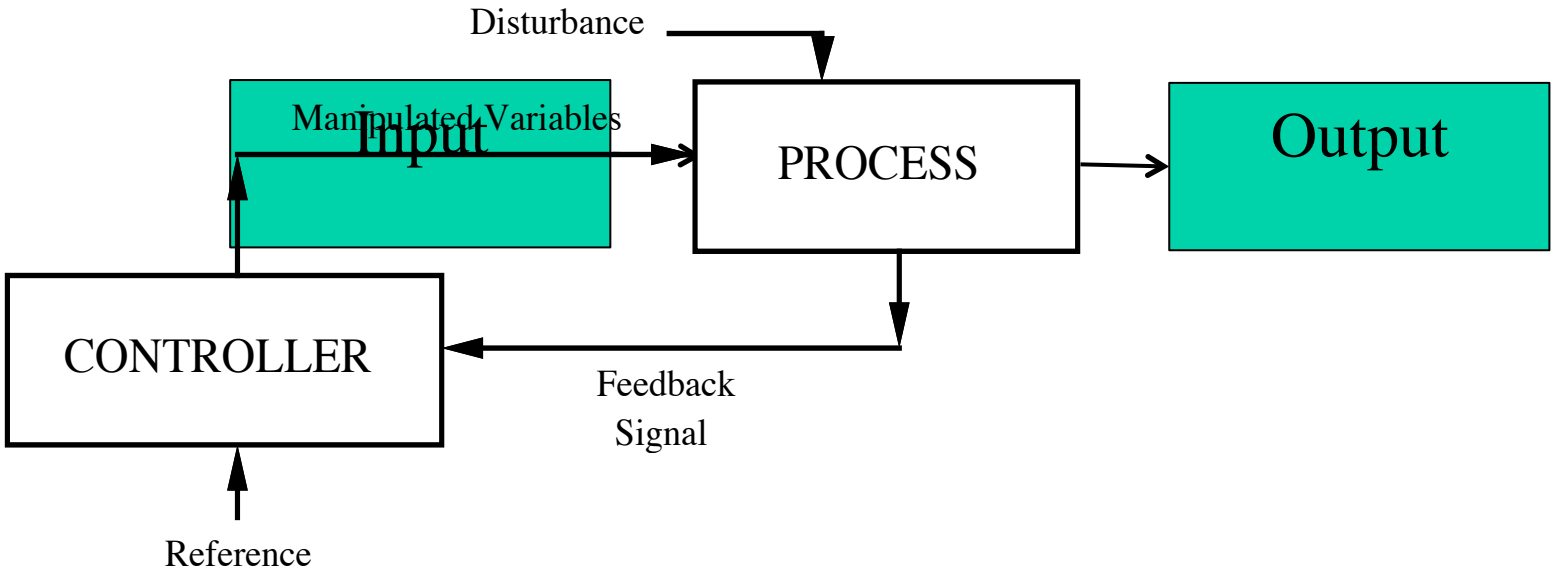
What is Printing Process Control?

- Monitoring and correcting a color printing device by
  - Defining process control aims and tolerances
  - Using test targets and measurement device to adjust the device to produce conforming products



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Why Printing Process Control?

- Verify stability of the device
  - Demonstrate process conformance
- Detect device drifts and make necessary adjustments
  - Achieve quick press make-ready
  - Reduce pressroom waste
  - Ensure consistency of product quality
- Make color management system work.
  - Matching color by “printing by numbers”

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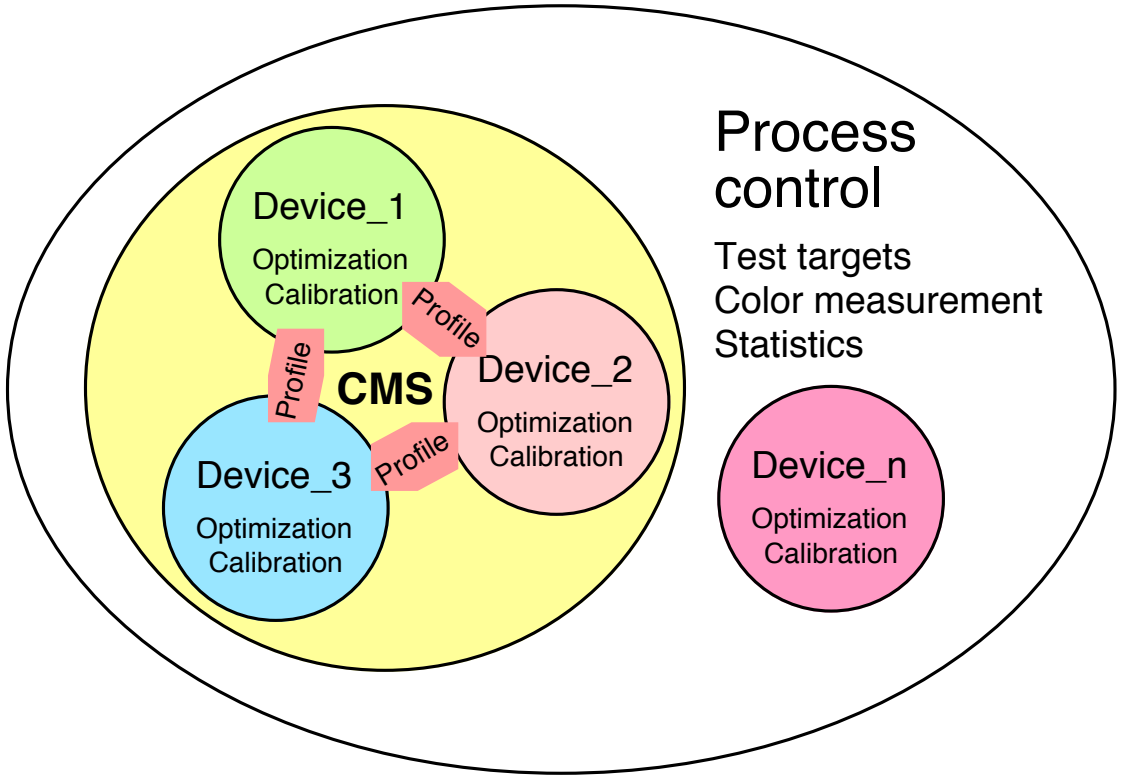
Printing Process Control

- The BIG Picture – To enable color management
  - Proof-to-print
  - Within-run
  - Run-to-run



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Printing Process Control

- Test target & color measurement are common to process control and color management.
  - Provide data for calibration
  - Provide data for profiling
  - Provide data for statistical process control
    - To correct for the device drifts
- Repeatable color can be achieved through
  - Device optimization
    - Optimization often means promising of substrate-colorants-screening-printer interactions
  - Device calibration

Device Optimization

- Hardware, software, and consumable are comparable.
  - RIP, colorants, substrate, printer
- Device performance
  - Spatial uniformity
    - Side-to-side
    - Head-to-tail
    - Front-to-back
  - Temporal consistency
    - From beginning to the end of the print production
  - Run-to-run repeatability

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Device Calibration

- Adjusting a device's behavior to achieve desired outcome, e.g.,
  - %dot (in) equals %plate dot (out) in a CTP operation
    - Also known as device linearization
    - Adjust CTP gradation to achieve gray balance
  - Solid coloration and %dot are vs. TVI (tonal value increase) curve conform to an industry standard, e.g.,
    - ISO 12647-2
    - SWOP or GRACoL
  - Color gamut of a printer conforms to a reference printing condition.
    - CRPC (Characterized Reference Printing Condition)

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Calibration vs. Profiling

- Calibration and profiling are separate processes with different goals.
  - A device is calibrated or adjusted by taking colorant-substrate-plate-printer into consideration.
  - A device is profiled by taking a snapshot of the device-to-color relationship.
- Device calibration precedes ICC profiling.
  - If a printer is uniquely calibrated, it requires profiling in order to perform digital color exchange from design to the printer space.
  - If a printer has been calibrated to a specified CRPC, it can use the standard ICC profile to perform color exchange from design to print in prepress workflow.

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Printer Calibration & Profiling

- A printer is calibrated to known solid ink density, dot gain, or gray balance conditions.
  - Inking adjustments are made on conventional presses.
  - Transfer curves are applied to CTP devices or digital printers.
- A printer is profiled with the use of a profiling target with known CMYK digital values.
  - Printed patches are measured colorimetrically.
  - Printer (CMYK) values and colorimetric data are encoded into a profile.

Implementing Process Control

- Identify key control parameters.
- Implement real-time measurements and corrective actions.
- Conform to aim points.
- Use structured problem solving techniques to remove root causes.

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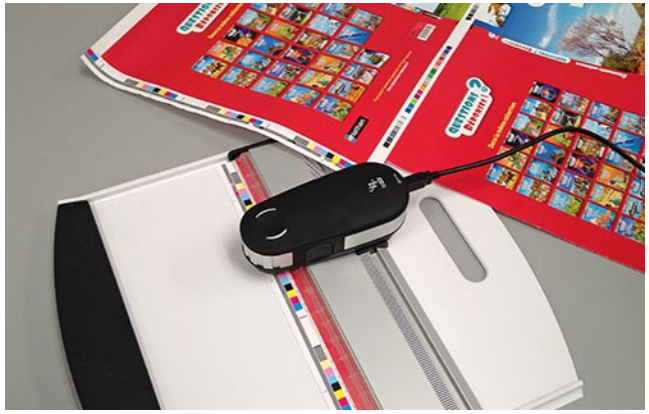
Process Control Tools

- IT8.7/4 (ISO 12641)
  - Useful target for printer profiling
    - CMYK data
    - Large footprint (1,617 patches)
- Color control bar
  - Useful for process control
    - Long and narrow
    - Positioned across the width of paper



Process Control Tools

- Pictorial reference images
  - ISO 12640 Standard Color Image Data (SCID)
    - CMYK data
    - Memory colors of familiar objects
      - Skin tone
      - Highlights or pastels
      - Metallic surfaces
    - Large neutral background
    - High frequency contents

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Process Control Tools

- Open-loop control
  - Feedback is often in the form of graphical displays.
    - Operators decide what to do with the visual information.

Heidelberg

Heidelberg Harris M1000B

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Process Control Tools

- Closed-loop control
  - Automatic adjustments without operator intervention
    - Artificial intelligence
    - Operators over-ride machine decisions.

MAN Roland web offset press

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Calibration vs. Process Control

- **Curling** as an analogy
  - Curling is a game played on ice, in which two four-member teams slide heavy, oblate stones towards a fixed mark in the center of a circle at either end.

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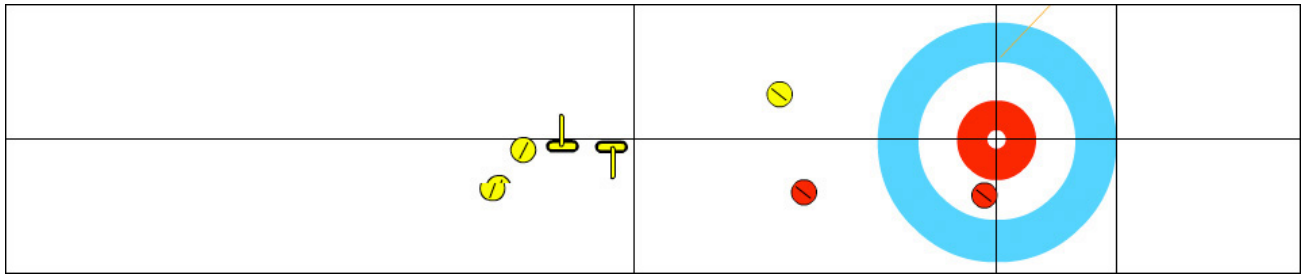
Calibration vs. Process Control

- Calibration is like **launching** the stone, it focuses on the initial aiming of its target.
- Process control is like **sweeping**, it focuses on the efforts of guiding and correcting the process.



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Where are Printing Aims From?

- From color separation films
  - Color separation and color proofing are standardized.
  - Printing is to match the color proof.
  - ISO 12647-2 defines solid coloration, TVI, and midtone spread.
  - ISO 12647-2 does not specify CRPC.
- From CRPC
  - Printing or proofing conformance is about adjusting process control parameters, including color management, so that print or proof conforms to CRPC.
  - ISO 15339 specifies CRPC.

ISO 12647-2 Process Control Aims

- Graphic technology - Process control for the manufacture of half-tone colour separations, proof and production prints
  - Started in ISO TC130 in 1991
  - ISO 12647-1 was published in 1996
  - Initially based on film workflow, now include digital data
  - ISO 12647-2 was revised in 2007 and 2013.

ISO 12647-2 Process Control Aims

- Print substrates (PS1~PS4) specifications, 2013

Characteristic	Paper type and surface											
	PS1			PS2			PS3			PS4		
Type of surface	Premium coated			Improved coated			Standard glossy coated			Standard matte coated		
Mass-per-area [a] g/m²	80 to 250 (115)			51 to 80 (70)			48 to 70 (51)			51 to 65 (54)		
CIE Whiteness [b]	105 to 135			90 to105			60 to 90			75 to 90		
Gloss [c]	10 to 80			25 to 65			60 to 80			7 to 35		
Colour [d]	Coordinates			Coordinates			Coordinates			Coordinates		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
White backing	95	1	−4	93	0	−1	90	0	1	91	0	1
Black backing	93	1	−5	90	0	−2	87	0	0	88	0	−1
Tolerance	±3	±2	±4	±3	±2	±2	±3	±2	±2	±3	±2	±2
Fluorescence [e]	moderate			low			low			low		

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ISO 12647-2 Process Control Aims

- Print substrates (PS5~PS8) specifications, 2013

Characteristic	Paper type and surface											
	PS5			PS6			PS7			PS8		
Type of surface	Wood-free uncoated			Super calendered uncoated			Improved uncoated			Standard uncoated		
Mass-per-area [a] g/m²	70 to 250 (120)			38 to 60 (56)			40 to 56 (49)			40 to 52 (45)		
CIE Whiteness [b]	140 to 175			45 to 85			40 to 80			35 to 60		
Gloss [c]	5 to 15			30 to 55			10 to 35			5 to 10		
Colour [d]	Coordinates			Coordinates			Coordinates			Coordinates		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
White backing	95	1	−4	90	0	3	89	0	3	85	1	5
Black backing	92	1	−5	87	0	2	86	−1	2	82	0	3
Tolerance	±3	±2	±2	±3	±2	±2	±3	±2	±2	±3	±2	±2
Fluorescence [e]	high			low			faint			faint		

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ISO 12647-2 Process Control Aims

- Coloration description (CD1~CD4), 2013

Characteristic		Colorant description											
		CD1 Premium coated			CD2 Improved coated			CD3 Standard coated glossy			CD4 Standard coated matte		
Colour		Coordinates			Coordinates			Coordinates			Coordinates		
		L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Black	WB	16	0	0	20	1	2	20	1	2	24	1	2
	BB	16	0	0	20	1	2	19	1	2	23	1	2
Cyan	WB	56	-36	-51	58	-37	-46	55	-36	-43	56	-33	-42
	BB	55	-35	-51	56	-36	-45	53	-35	-42	54	-32	-42
Magenta	WB	48	75	-4	48	73	-6	46	70	-3	48	68	-1
	BB	47	73	-4	47	71	-7	45	68	-4	46	65	-2
Yellow	WB	89	-4	93	87	-3	90	84	-2	89	85	-2	83
	BB	87	-4	91	84	-3	87	81	-2	86	82	-2	80
Red	WB	48	68	47	48	66	45	47	64	45	47	63	41
	BB	46	67	45	47	64	43	45	62	43	46	61	39
Green	WB	50	-65	26	51	-59	27	49	-56	28	50	-53	26
	BB	49	-63	25	49	-57	26	48	-54	27	49	-51	24
Blue	WB	25	20	-46	28	16	-46	27	15	-42	28	16	-38
	BB	24	20	-45	27	15	-45	26	14	-41	27	15	-38
Overprint CMY_{100}	WB	23	0	-1	28	-4	-1	27	-3	0	27	0	-2
	BB	23	0	-1	27	-4	-1	26	-3	0	26	0	-2

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ISO 12647-2 Process Control Aims

- Coloration description (CD5~CD8), 2013

Characteristic		Colorant Description											
		CD5 Wood-free uncoated			CD6 Super calendered			CD7 Improved uncoated			CD8 Standard uncoated		
Colour		Coordinates			Coordinates			Coordinates			Coordinates		
		L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Black	WB	33	1	1	23	1	2	32	1	3	30	1	2
	BB	32	1	1	22	1	2	31	1	3	28	1	2
Cyan	WB	60	-25	-44	56	-36	-40	59	-29	-35	54	-26	-31
	BB	58	-24	-44	54	-35	-40	57	-29	-35	52	-26	-31
Magenta	WB	55	60	-2	48	67	-4	53	59	-1	51	55	1
	BB	53	58	-3	46	65	-4	51	56	-2	50	52	-1
Yellow	WB	89	-3	76	84	0	86	83	-1	73	79	0	70
	BB	86	-3	73	81	0	83	80	-2	70	76	0	67
Red	WB	53	56	27	47	63	40	51	57	31	48	53	31
	BB	51	55	25	46	61	38	49	54	29	47	51	29
Green	WB	53	-43	14	49	-53	25	53	-43	18	47	-38	20
	BB	52	-41	13	48	-52	24	51	-43	17	46	-37	18
Blue	WB	39	9	-30	28	13	-41	37	8	-31	36	9	-25
	BB	37	9	-30	27	12	-40	36	7	-30	34	9	-26
Overprint CMY_{100}	WB	35	0	-3	27	-1	-3	34	-3	-5	33	-1	0
	BB	34	0	-3	26	-1	-4	33	-3	-5	31	-2	0

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ISO 12647-2 Process Control Aims

- Printing conditions (PC) specifications, 2013

Printing Condition (PC)	Print Substrate (PS)	Colorant Description (CD)	Screening Description			
			Periodic		Non-periodic	
			TVI Curve	Frequency in cm^{-1}	TVI Curve	Spot size in µm
PC1	PS1	CD1	A	60-80	E	20(25)
PC2	PS2	CD2	B	48-70	E	25
PC3	PS3	CD3	B	48-60	E	30
PC4	PS4	CD4	B	48-60	E	30
PC5	PS5	CD5	C	52-70	E	30(35)
PC6	PS6	CD6	B	48-60	E	35
PC7	PS7	CD7	C	48-60	E	35
PC8	PS8	CD8	C	48-60	E	35

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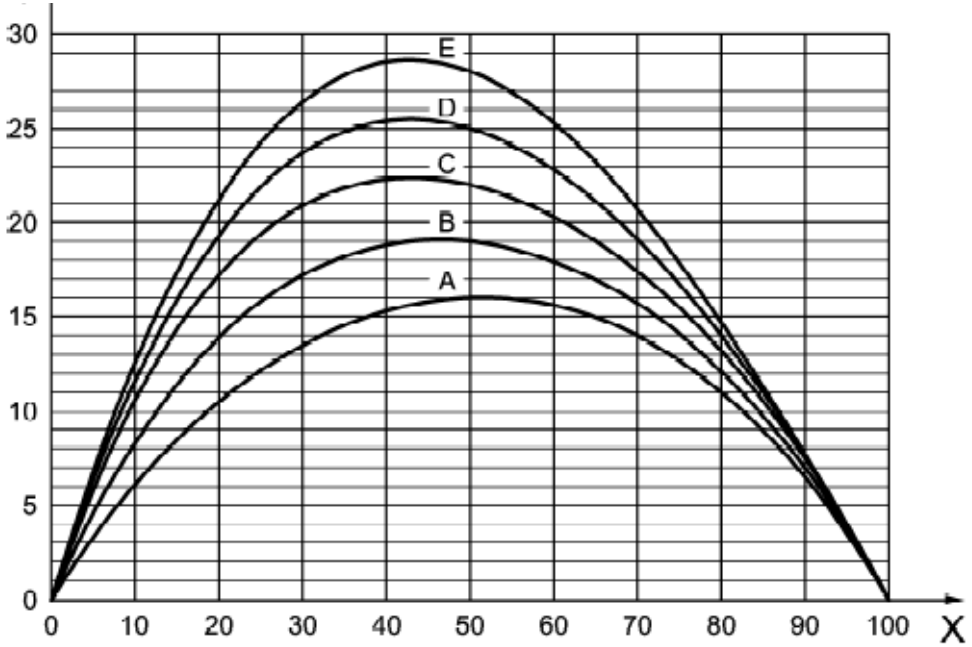
ISO 12647-2 Process Control Aims

- Tonal value increase (TVI), 2013

Printing condition	Periodic screens			
	40	50	75	80
PC1	15	16	13	11
PC2, PC3, PC4	19	19	14	12
PC5, PC6, PC7, PC8	22	22	15	13



ISO 12647-2 Process Control Aims

- Colorimetric tolerances of process color solids
  - Deviation tolerances of the OK print
  - Variation tolerances of production samples

Process colour	Deviation tolerance		Variation tolerance		
	OK print		Production print		
	ΔEab	*ΔEoo* [a]	*ΔEab*	*ΔEoo* [a]	*ΔH*
Black	5	5	4	4	-
Cyan	5	3,5	4	2,8	3
Magenta	5	3,5	4	2,8	3
Yellow	5	3,5	5	3,5	3

[a] Tolerance values for DE2000 are given for information only

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ISO 12647-2 Workflow

- How is it used?
  - Designer/client picks printing condition from ISO 12647-2 based on paper and process to be used.
  - ECI publishes the Fogra datasets and ICC profiles for digital data exchange.
  - Proofs based on aims of ISO 12647-7 as interpreted by non-standardized characterization data from various trade groups.
  - Printer calibrates his press to achieve deviation conformity, i.e., solids and TVI for printing condition of ISO 12647-2.
  - Produce OK print to match the proof.
  - Control the print run to achieve production conformity (solids and TVI).

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ISO/PAS 15339 Printing Aims

- March/April 1999 issue of IPA Prepress Bulletin
  - "Reference Printing Conditions - What Are They & Why Are They Important?"
- Promises of the "Reference Printing Conditions"
  - Printing process agnostic
  - Simplify the interface between prepress and printing
  - Standardize characterization data, NOT process control data
  - Provide consistent tone reproduction and gray balance aims across data sets
  - Provide some mechanism to "adjust" CRPC for modest paper changes, including OBA.

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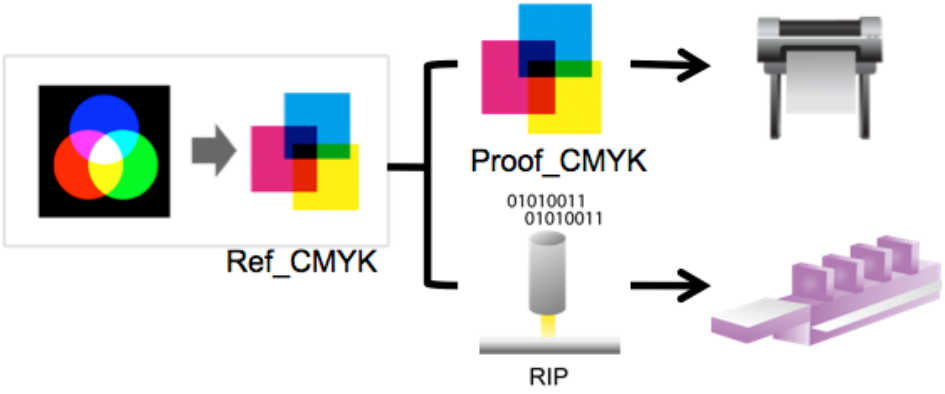
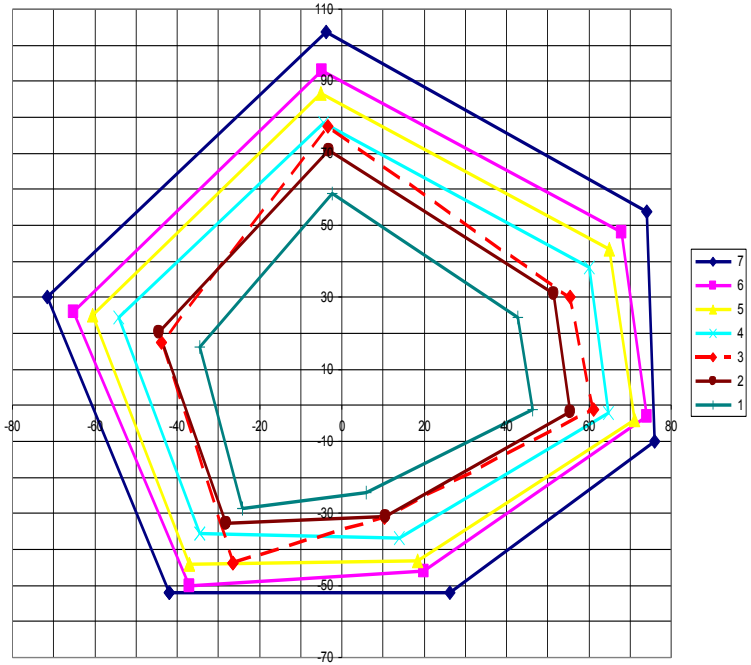
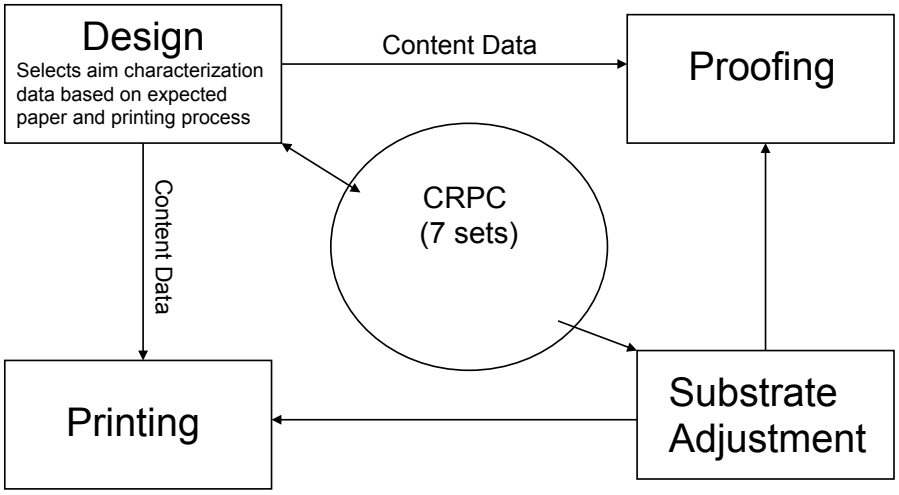
ISO/PAS 15339 Workflow

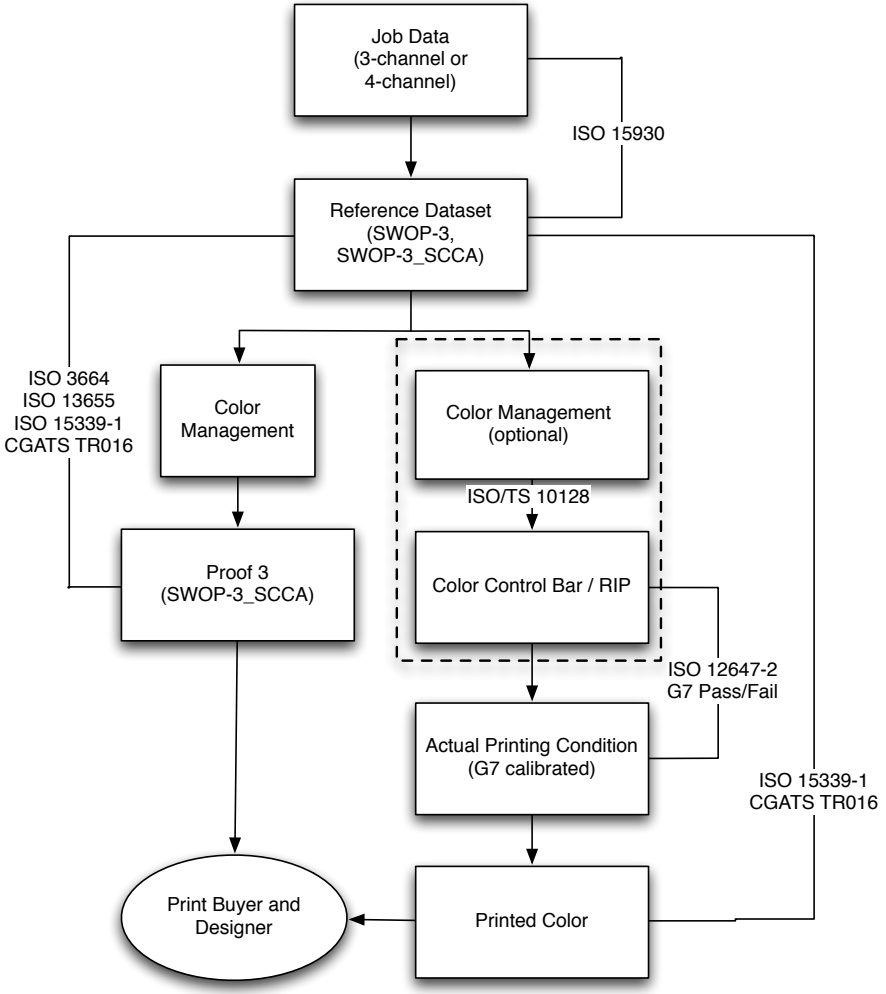






ISO/PAS 15339 Workflow

- A new approach to printing aims
  - Using reference color characterization data as printing aims
  - Process independent
  - Providing data adjustment for variations in paper color
  - Process control is the responsibility of the printer.



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ISO/PAS 15339 CRPCs

- CRPC conformity ≠ process control conformity
  - Dataset is the whole.
  - Process control parameters are the parts.
- Have a limited set of CRPCs that differ in gamut to serve as common threads between design, prepress, proofing, and printing.
- Provide a mechanism to “adjust” CRPC for paper color changes.

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ISO/PAS 15339 CRPCs

- CRPC is the relationship between input CMYK (or virtual CMYK) data and the color on the printed sheet.
  - Color gamut is defined in terms of 1,617 patches of ISO 12642-2 (IT8.7/4) target.
  - Gamut color is determined by paper, ink, process capability.
  - In-gamut color is adjustable using 4-D LUT or 1-D transfer curves, (ISO TS 10128).

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ISO/PAS 15339 CRPCs

- CRPCs are independent of printing process (agnostic).
  - Since its creation in 1995, TR001 (SWOP) has applied to both offset and gravure publications.
  - All proofing (regardless of proofing process) is based on matching characterization data.
  - Packaging matches color across printing processes and multiple substrates.

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ISO/PAS 15339 Substrate Adjustment

- Tristimulus correction method (SCCA)
  - Uses CIE XYZ values of new substrate to adjust CIE XYZ values of reference characterization data to predict what same printing would be on the new substrate.
  - SCCA method works equally well for changes in substrate resulting from a basic shade change or change in OBA level.
  - Provides new aims for all CMYK data points, including solids and neutrals.
    - TVIs aims are not affected.

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ISO/PAS 15339 In-gamut Adjustment

- ISO/TS 10128 Graphic technology — Methods of adjustment of the colour reproduction of a printing system to match a set of characterization data
  - Assumes outer gamuts are correct.
  - Adjusts within-gamut data by one of three methods:
    1) Matching of tone value curves to develop 4 1-D transforms
    2) Use of near-neutral scales to develop 4 1-D transforms
    3) Use of CMYK to CMYK multi-dimensional transforms (colour management device link transform)
  - Can be used to support printing based on either ISO 15339 or ISO 12647.

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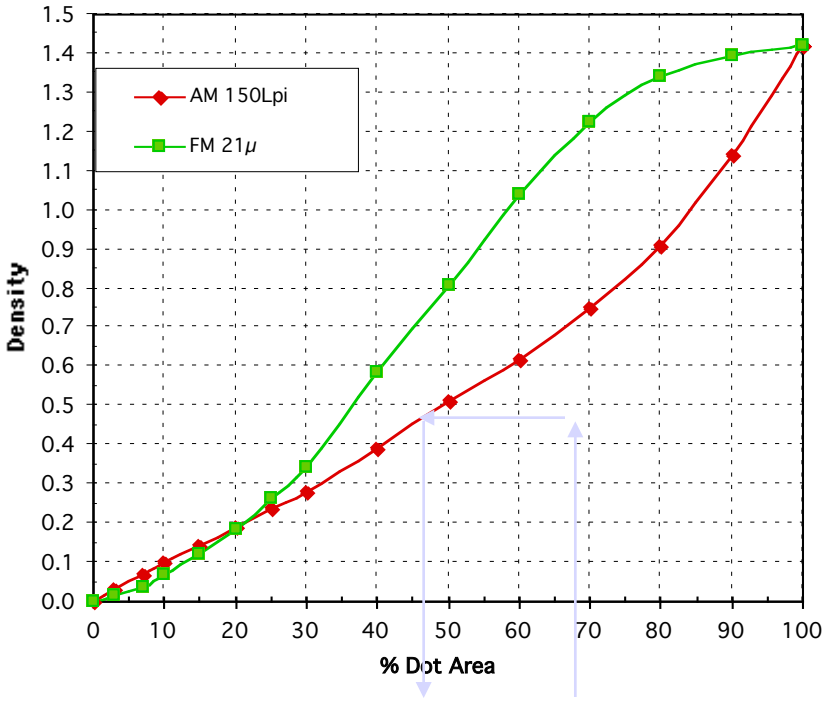
Four 1-D TVI Transform

- Enter two tone value curves, i.e., reference & sample, for each channel.

  1) Find %tone value pairs yield equal density.

	%	AM 150Lpi	FM 21μ
1	0	0.000	0.000
2	3	0.030	0.018
3	7	0.070	0.039
4	10	0.100	0.070
5	15	0.145	0.123
6	20	0.190	0.184
7	25	0.240	0.263
8	30	0.280	0.342
9	40	0.390	0.587
10	50	0.510	0.806
11	60	0.620	1.043
12	70	0.750	1.227
13	80	0.910	1.341
14	90	1.140	1.394
15	100	1.420	1.420



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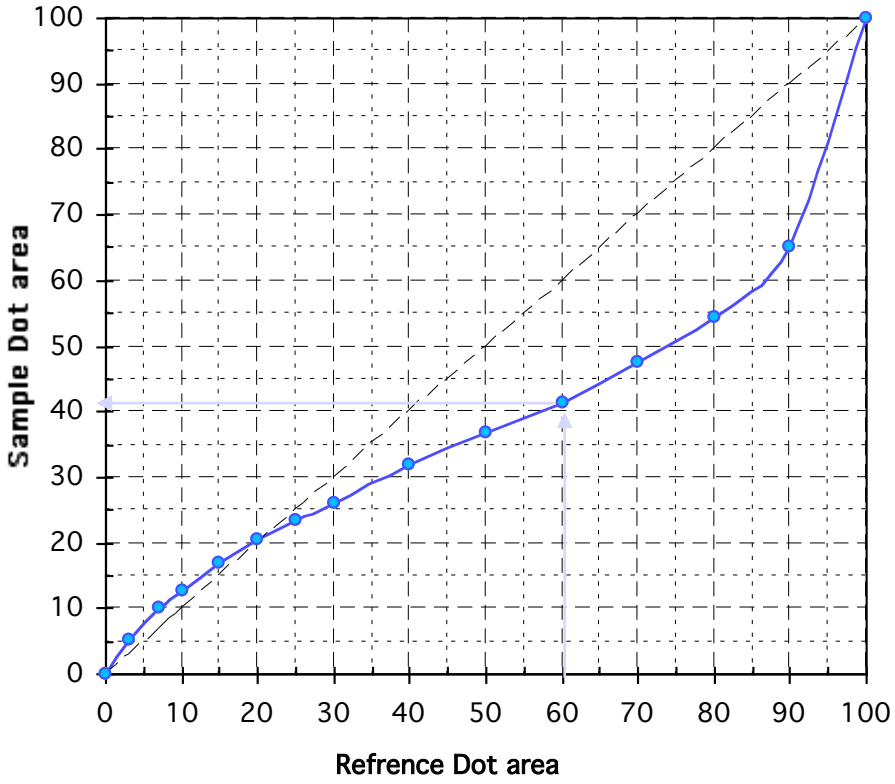
Four 1-D TVI Transform

2) Send transfer curve (%TV_in vs. %TV_out) to RIP to alter the device values for each channel during the CTP operation.

Transfer curve		
	AM 150Lpi	FM 21μ
1	0	0.0
2	3	5.3
3	7	10.0
4	10	12.8
5	15	16.8
6	20	20.4
7	25	23.5
8	30	26.1
9	40	32.0
10	50	36.9
11	60	41.5
12	70	47.4
13	80	54.4
14	90	65.3
15	100	100.0



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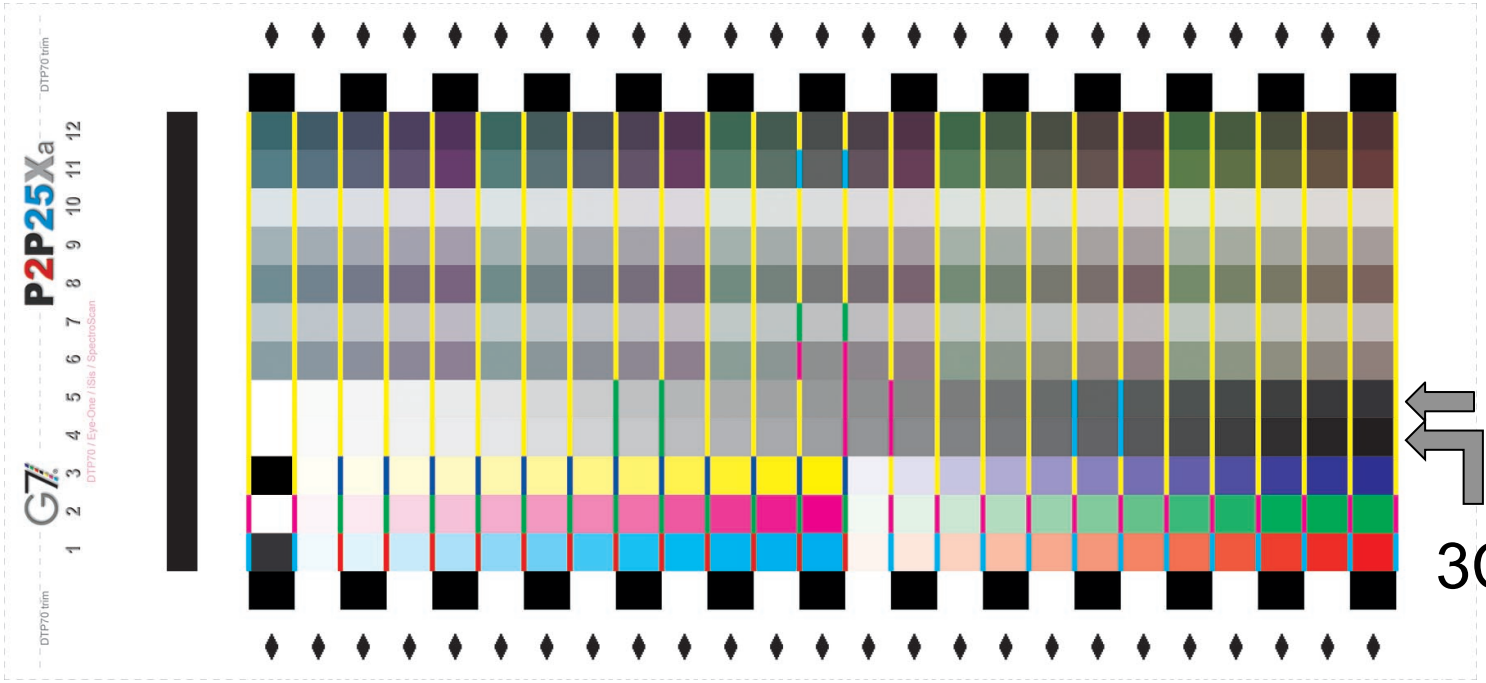
Four 1-D Gray Transform

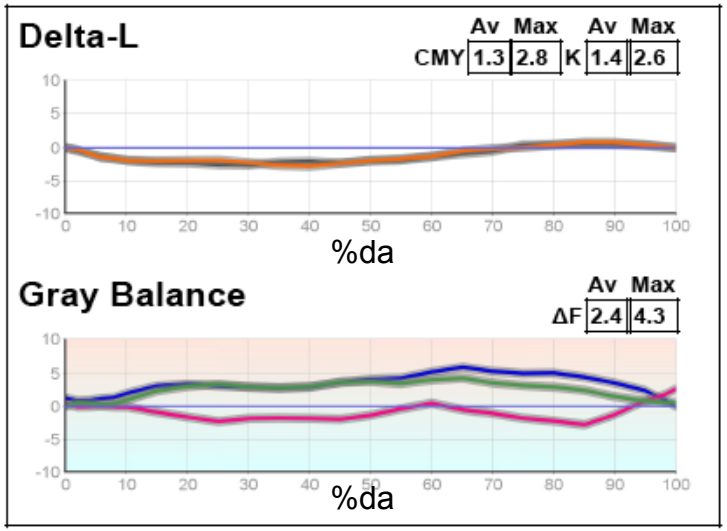
1) Print and measure the pre-defined triplets and a K-only ramp (P2P target).



Four 1-D Gray Transform

2) Assess tone reproduction and gray balance of the initial printing condition using Curve2 s/w.

ΔL* for cmy (orange), ΔL* for k (gray)



Δa* (red), Δb* (blue), ΔC_h (green)

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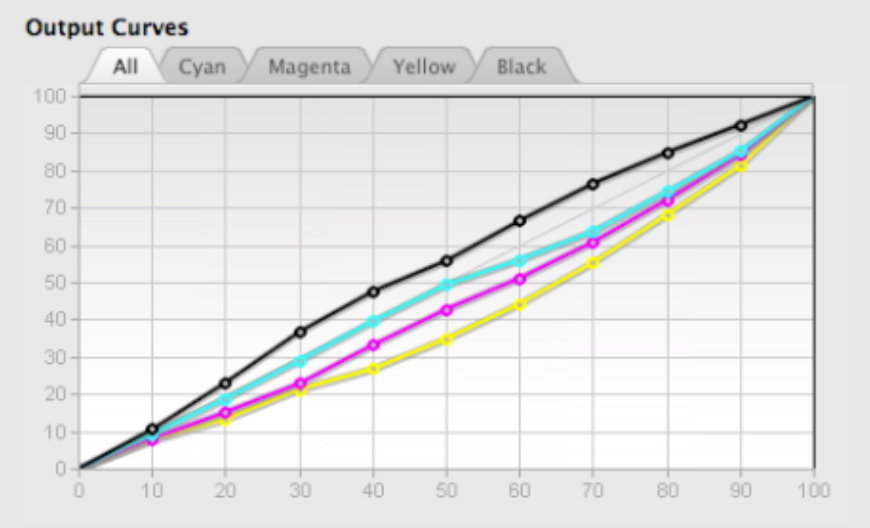
Four 1-D Gray Transform

3) Determine gray balance and tone reproduction requirements based on paper white and neutral print density.

4) Derive transfer curves for each channel via Curve2 s/w.



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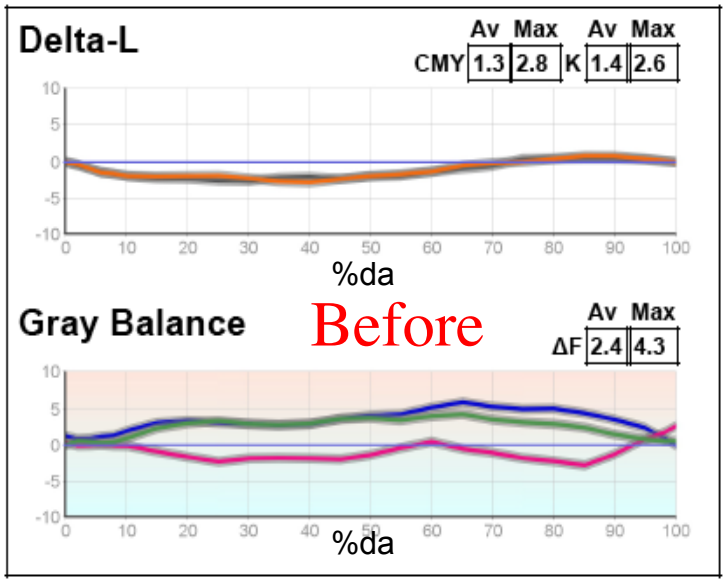
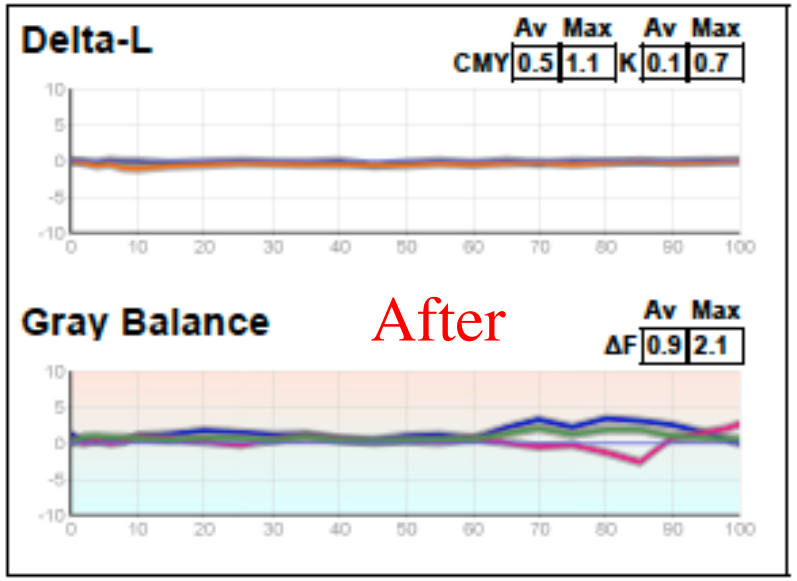
Four 1-D Gray Transform

5) Assess gray balance and tone reproduction of the G7 calibrated printing condition.

ΔL* for cmy (orange), ΔL* for k (gray)





Δa* (red), Δb* (blue), ΔC_h (green)

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Multi-dimensional Transform

- Four 1-D transfer curves assume similar color and transparency of the inks between the reference printing condition and the initial printing condition.
  - Applicable to conventional printing where CTP is used.
- The above assumption is not required when ICC device-link profiles are used to implement CMYK-to-CMYK transforms between the reference printing condition and the initial printing condition.
  - Applicable to digital printing

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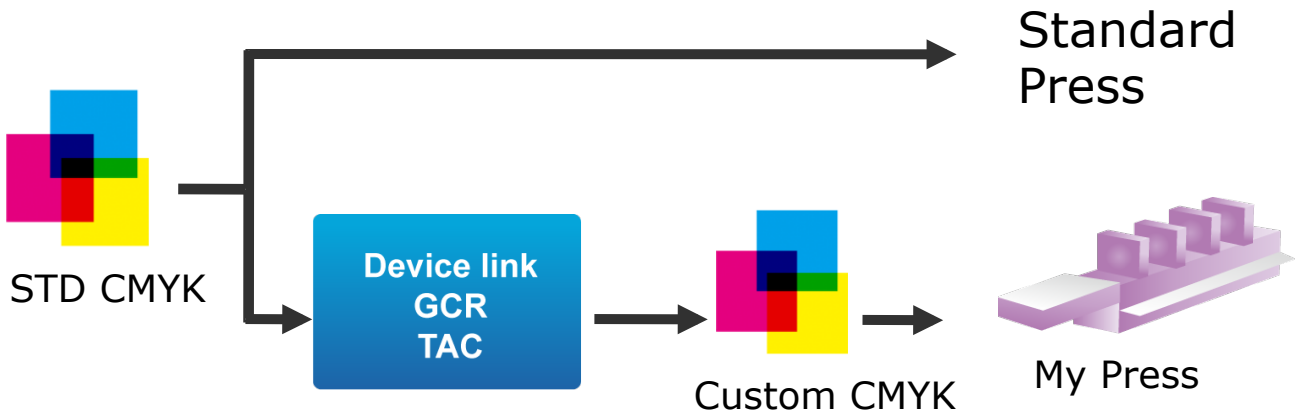
Multi-dimensional Transform

- Device link uses a pre-defined four-dimensional transform to convert CMYK data of the reference space to the sample space while preserving the integrity of single channel data.



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ISO 12647-2 vs. ISO 15339

	ISO 12647-2	ISO 15339
Printing mechanism	Real ink-paper-press (process dependent)	Virtual CMYK (a family of 7 CRPCs)
Aims and tolerances	Process dependent; substrate dependent	process independent; substrate corrected
Process control	ISO/TS 10128 - TVI	ISO/TS 10128 (printer's responsibility)
Conformance	Match solid, TVI, and midtone spread	Match selected CRPC

- A key performance difference is the print-to-proof match under the influence of OBA.

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ISO 12647-2 vs. ISO 15339

- CRPC derived solid coloration and TVI are not identical (but in tolerance) to the ISO 12647-2 aims.
  - ISO 15339 uses equal neutrality and tone reproduction as the design criteria for all CRPCs.
  - ISO 12647-2 uses equal TVI as the design criteria for all process control aims.
- Different printing certification schemes will evolve. The market will decide if they fit.

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Summary

- Process control is aimed at achieving accurate and consistent color.
  - Standards provide aims and tolerances.
  - Test targets and color measurement devices are tools to make it happen.
- Process control is the routine efforts in keeping the device stay calibrated.
  - It requires real-time measurement and corrective actions in order to achieve device consistency in a print production workflow.

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References

- ISO 12647-2 (2013) Graphic technology — Process control for the production of halftone colour separations, proof and production prints — Part 2: Offset lithographic processes

- ISO/PAS 15339 (2014) Graphic technology — Printing from digital data across multiple technologies — Part 1: Principles

- McDowell, David, “Reference Printing Conditions - What Are They & Why Are They Important?” IPA Prepress Bulletin, March/April 1999

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Thank you.

Q/A

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