# Intro to Color Control

Presented by: David Hunter

Color Conference

# Part 1: Demystifying Color

## Agenda

- Color Fundamentals
- Terms and Definitions
- Overview of 5 C's of Color Management
- Covering the 1st C- Capturing your Data
- Demonstration and Trial that you can do…

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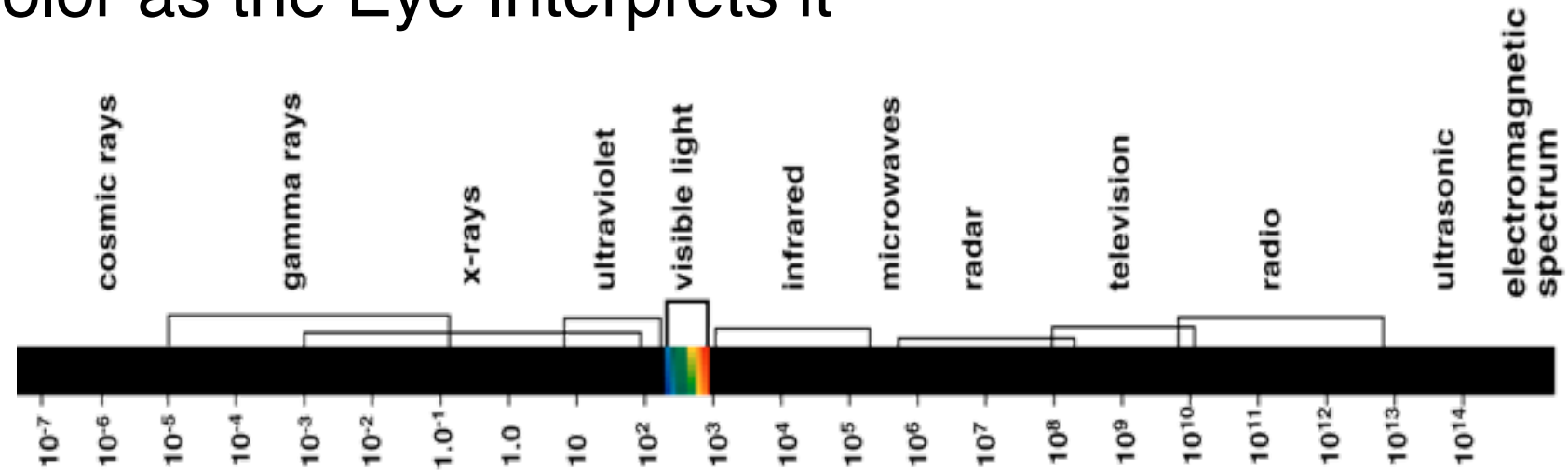
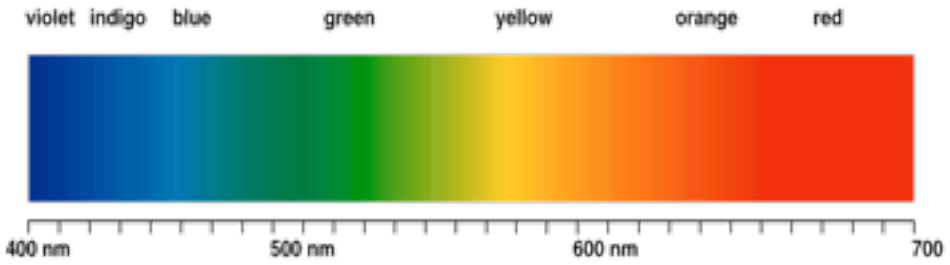
# Quantifying Color

## Electromagnetic Spectrum

- Color as the Eye Interprets it




R•O•Y•G•B•I•V

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# No Light

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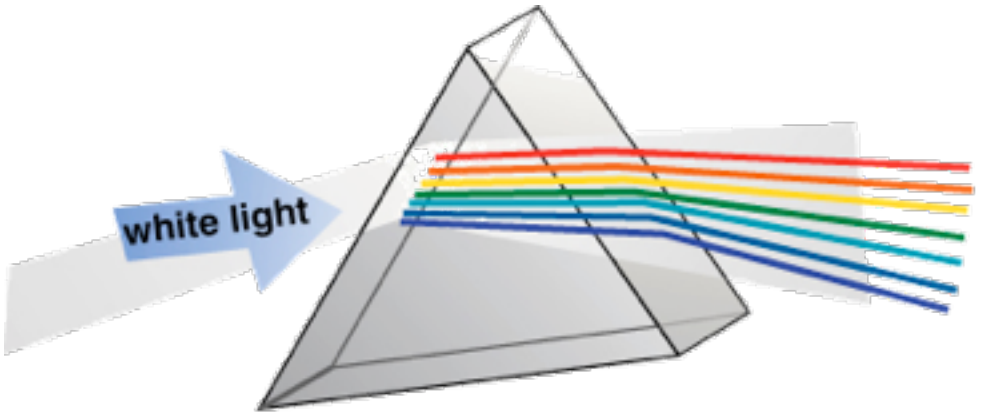
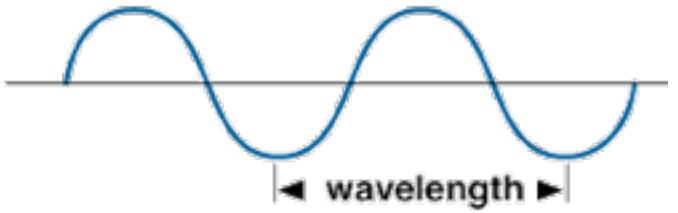
# Need Light Source (Illuminant)

## Prism

- White Light- Composed of all colors of spectrum
- Black Light?

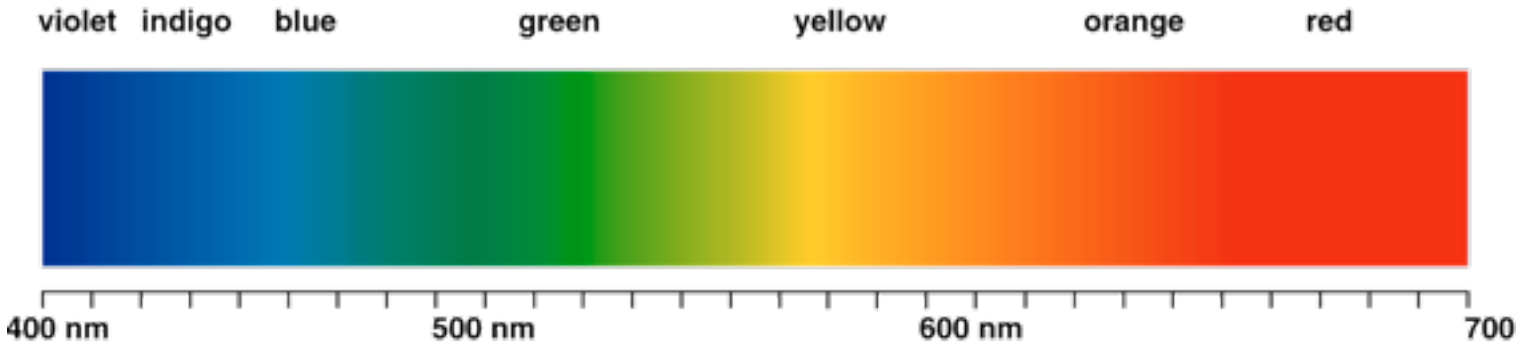


# Spectral Definition

## One Color

- 380-720 NM
- 10 NM increments
- 32 numbers represent one color
- Can predict result of new light source
- Easily Convert to CIE-Lab

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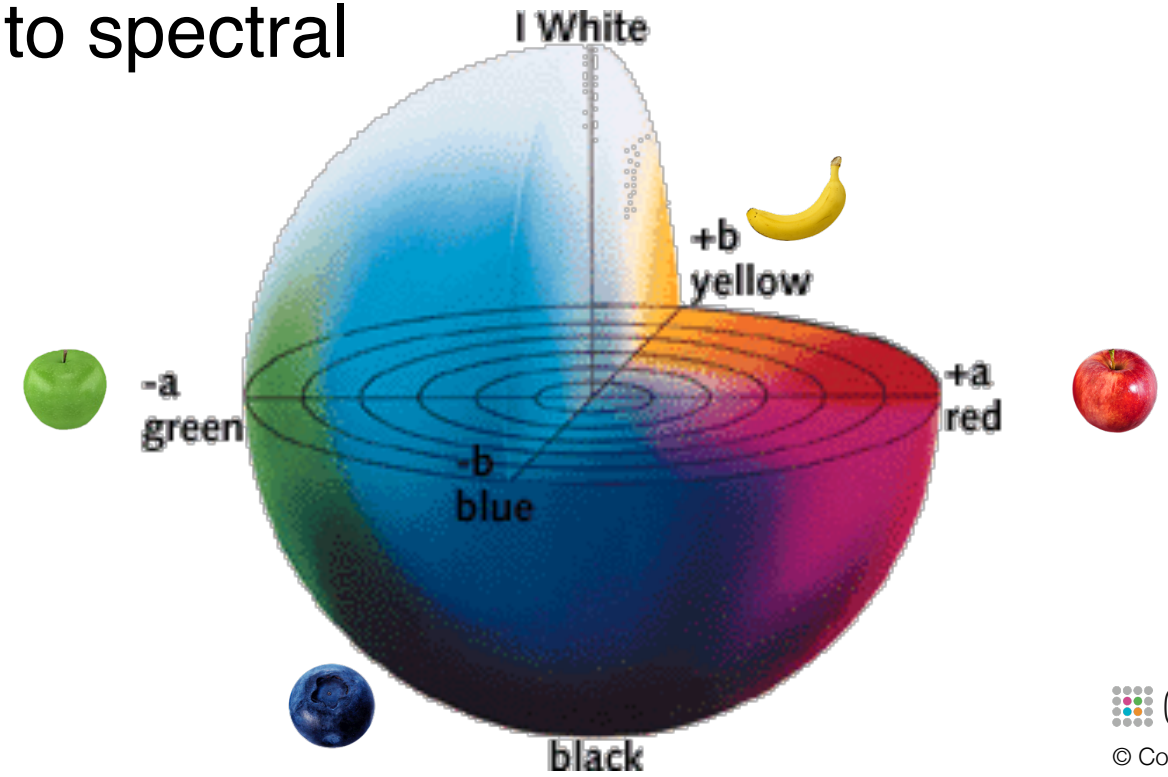
# CIE-Lab Definition

## One Color

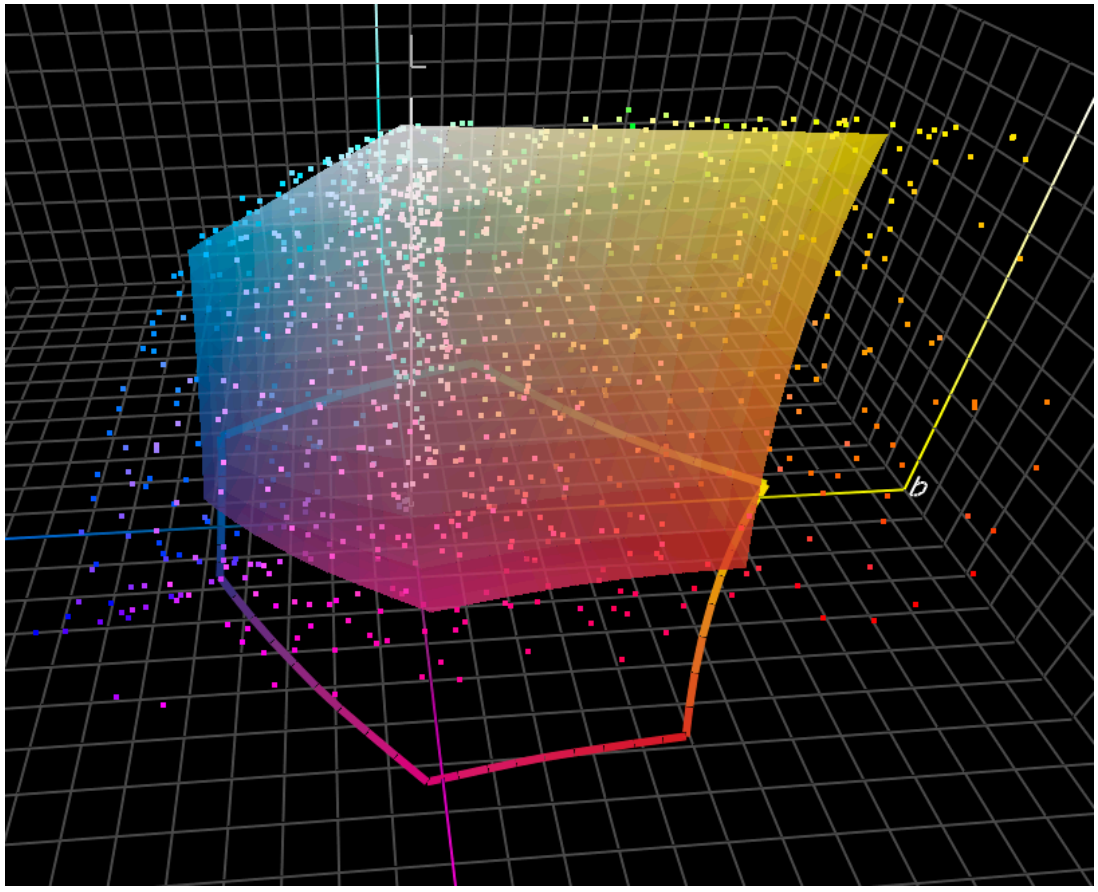
- 3 numbers, L* lightness, a* red/green axis, b* yellow/blue
- Illuminant dependent- Only good for 1 Light source
- Can't convert to spectral



# Define Printing Gamut and Measured Colors

## GRACoL Print Gamut and PMS Colors

- 58% of colors within 2ΔE(00)

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# Quantifying Color Differences: Numerically

## *What type of Color Match*

- Match specific brand colors: Spot colors

- Match between pages or presses : Process colors


G7


G7


G7 ChromaChecker

# Quantifying Color Differences: Numerically

## *What type of Color Match*

- Match specific brand colors: Spot colors
  - ΔE (delta E) quantifies spot differences: two colors to one another
  - Bigger the number, bigger the difference, 1 is unrealistic

- Match between pages or presses : Process colors
  - E-Factor EF Quantifies process color differences
  - Bigger the number, bigger the difference, 1 is unrealistic
  - Think ΔE for process colors- same relative differences

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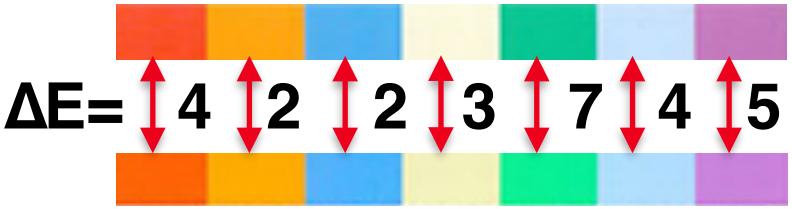
# Quantifying Color Differences: Numerically

## *What type of Color Match*

- Match specific brand colors: Spot colors




- Match between pages or presses : Process colors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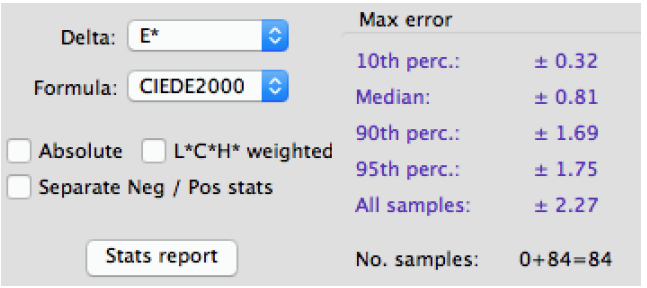
# Technical Definition: EF =95th Percentile ΔE

***95% of colors are within that ΔE, 5% are more***

- Used to quantify all colors on page, and images
- First defines in TAGA Paper 2001: author: Robert Chung et al
- Compares patch differences and sorts highest ΔE to lowest
  - CRF at 95th percentile ΔE (00)
  - Key metric in G7 Color Space, Fogra PSD (human expectations)

**GRACoL2013 vs "Large Format"**




- Requires at least 60 different patch values

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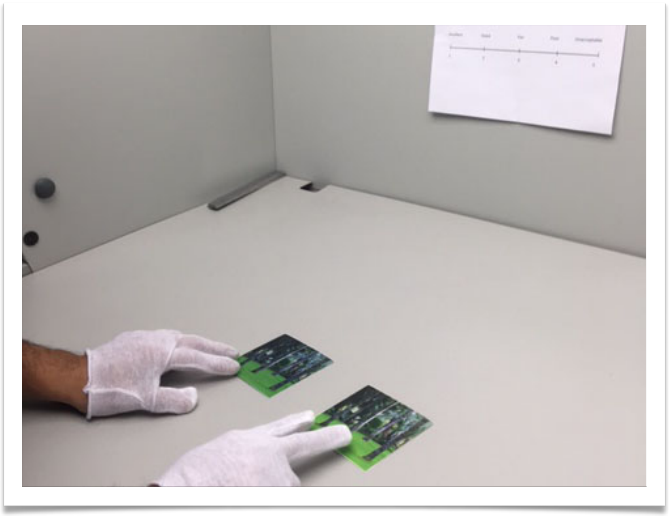
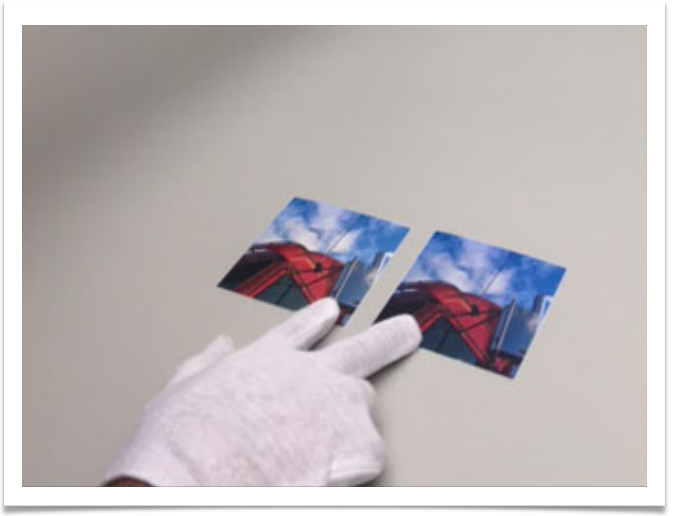
# But what are Customer Expectations?

## *Industry Survey (TAGA 2017 Research Results)*

- 200+ Industry personnel surveyed their expectations
- 80 random paired comparisons with different E-Factors, D50 light
- Grade the matches: Excellent, Good, Fair, Poor, Unacceptable





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# But what are Customer Expectations?

## *Industry Survey (TAGA 2017 Research Results)*

- Defined Expectations of Industry:

  - *E-Factor: 1-3 = Good or Excellent Match by vast majority*
  - *E-Factor: 3-8 = Disagreement on Acceptability*
  - *E-Factor: 8+ =* ***Unacceptable by vast majority***

**Published TAGA 2017, Chung, Federovski, Urbain, Hunter**

***Elena Federovski after tabulating ANOVA Statistics: "In my 30 years researching color, I have never seen a metric so closely co-relate human color expectations!"***

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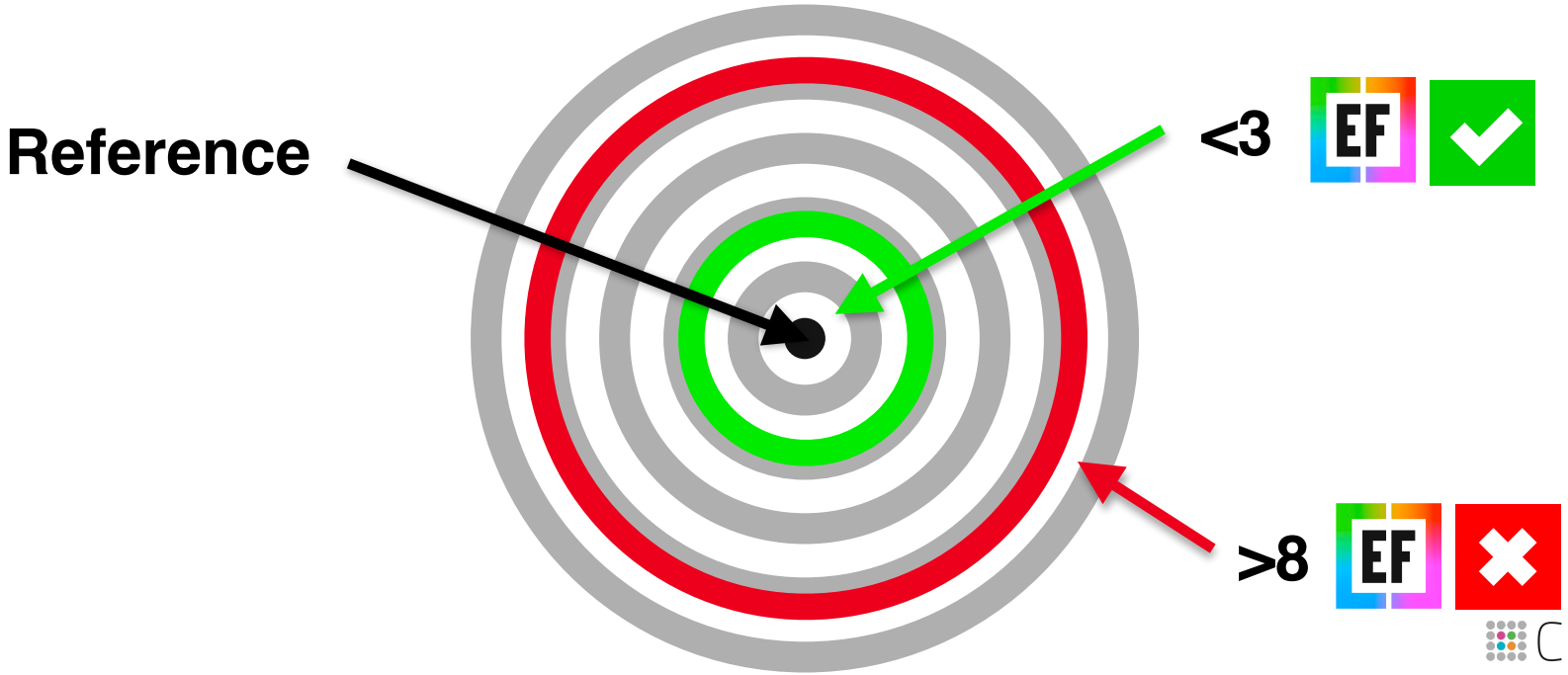
# Range of Acceptability

## *Industry Survey (TAGA 2017 Research Results)*

- Defined Expectations of Industry:
  - *85%+ Print Buyers accept <3*
  - *95%+ Print Buyers will not accept >8*

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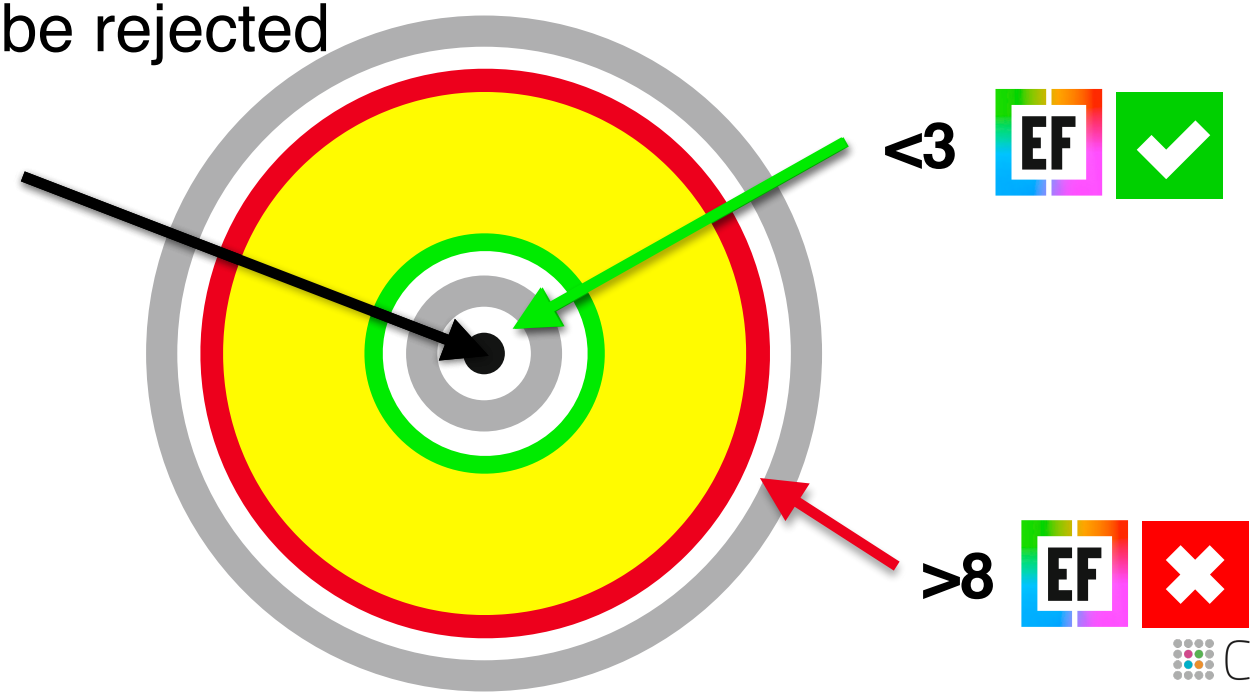
# Interpretation

## *First time can use one number to determine Waste*

- If EF >8 = Waste
- Danger Zone- Between 3 and 8 EF
- Most Printers today manufacture between 3 and 8 EF
- Any print could be rejected

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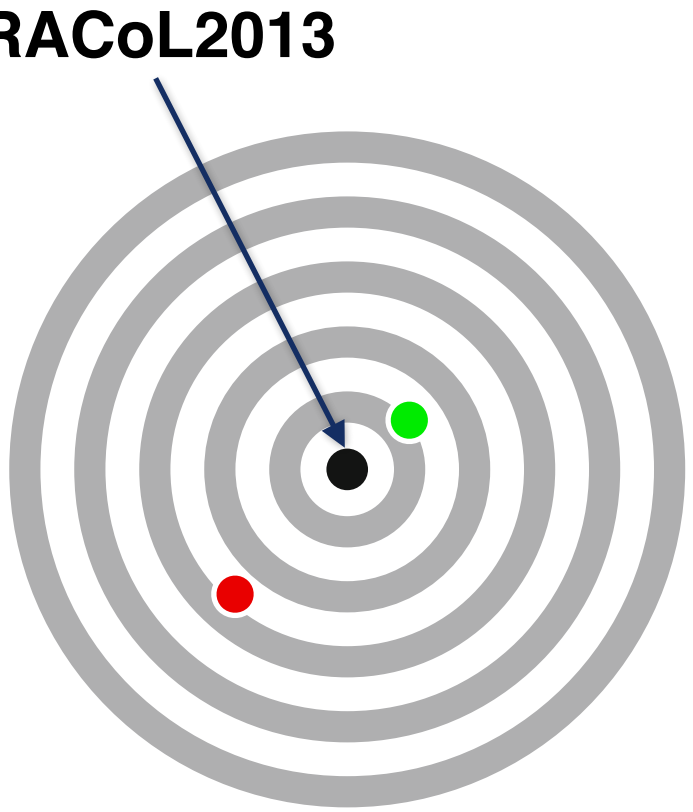
# How Close are Printers Matching GRACoL?

## *Just because they are G7, doesn't tell us how close*

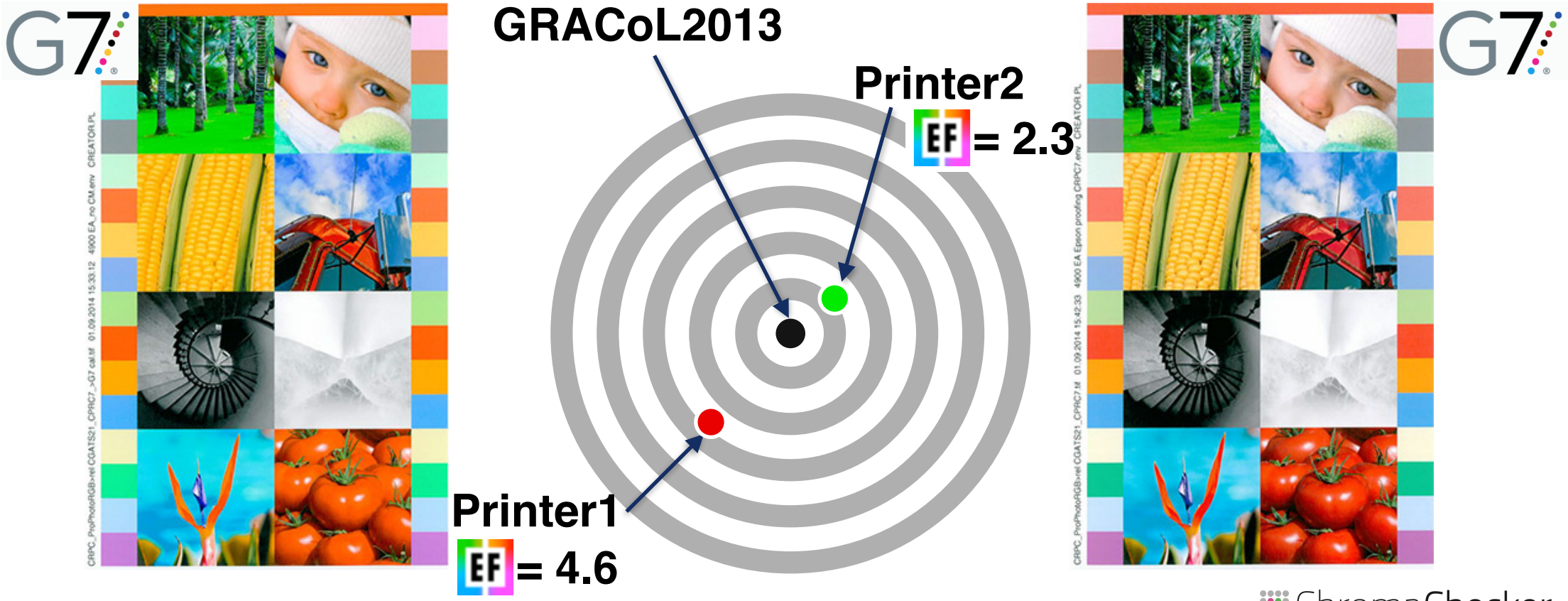
- Doesn't even tell us which one is better (**closer**)…




# How Close are Printers Matching GRACoL?

## *E-Factor Defines how close each are to GRACoL*

- G7 compliance is not a reasonable production standard

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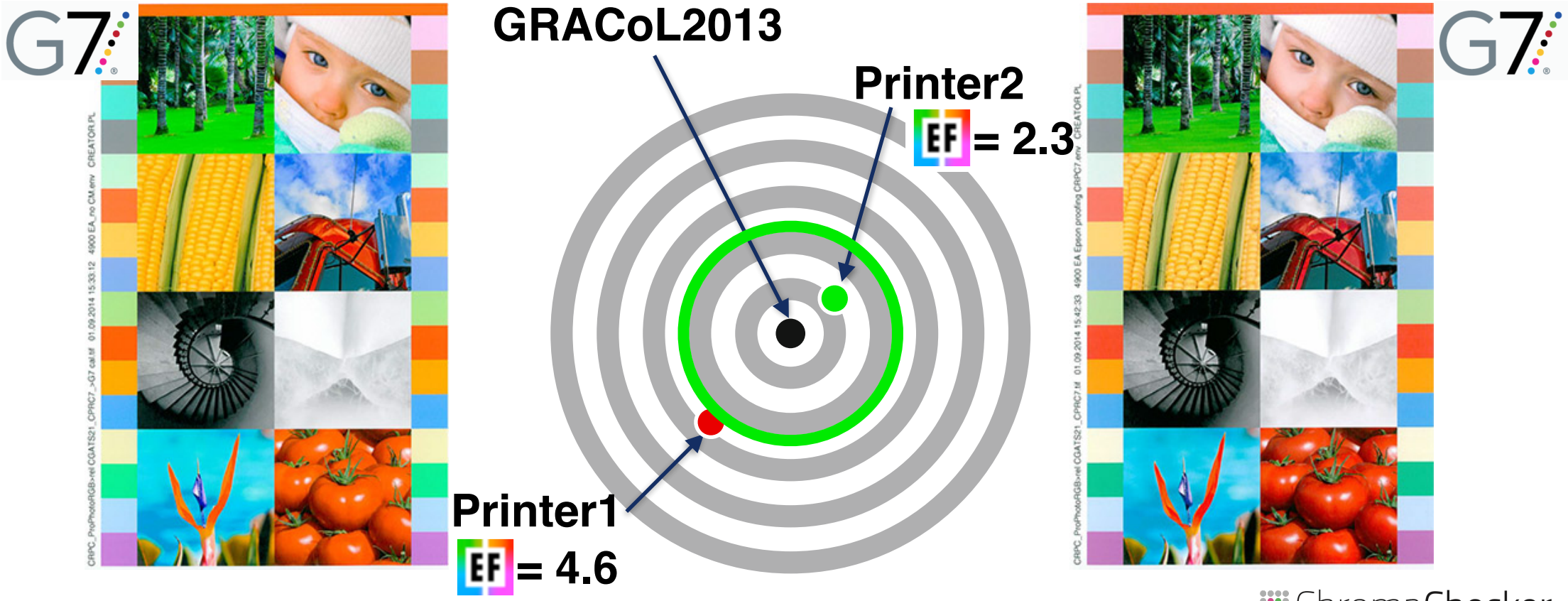
# How Close are Printers Matching GRACoL?

## *E-Factor Allows For Production Standard*

- Determine which printers are manufacturing salable goods vs waste

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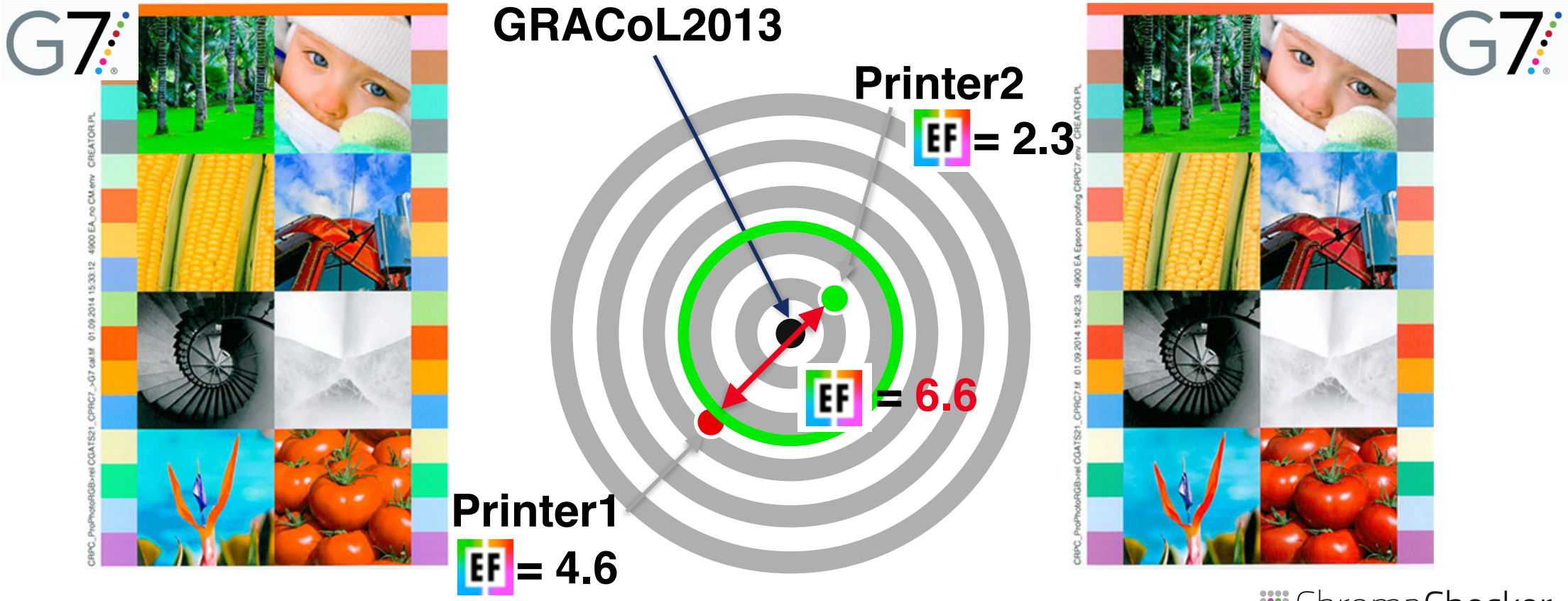
# How Close Printers Matching Each Other?

## *E-Factor Allows For Production Standard*

- Determine which printers are manufacturing salable goods vs waste

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# Rethink Approach to Print Production

## *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
- no repeatability
- initial swatch-book inaccuracy
- instability of color samples (aging, dirt)

### BASIC INSTRUMENTAL

**Instrument-based comparision to physical standard**

- numerically expressed color differences
- expensive and time-consuming personal supervision
- uncontrolled metamerism
- initial swatch-book inaccuracy
- instability of color samples (aging, dirt)
- different substrates / OBAs
- unpredictable issues of

### COLORIMETRIC AIM

**Instrument-based comparision to colorimetric standard**

- numerically expressed color differences
- stable color definition
- exchangable color definition
- the possibility of remote control
- limited color definition
- only one lighting condition specified
- uncontrolled metamerism

### SPECTRAL AIM

**Instrument-based comparision to spectral standard**

- numerically expressed color differences
- spot colors, SCTV, CxF/X-4 compliant
- exchangable color definition
- lighting condition independent
- controlled metamerism
- the possibility of remote control


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EF = 8+

### BASIC INSTRUMENTAL

**Instrument-based comparision to physical standard**

- numerically expressed color differences
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- initial swatch-book inaccuracy
- instability of color samples (aging, dirt)
- different substrates / OBAs
- unpredictable issues of

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
- limited color definition
- only one lighting condition specified
- uncontrolled metamerism

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 independent
- controlled metamerism
- the possibility of remote control

EF = 3-4


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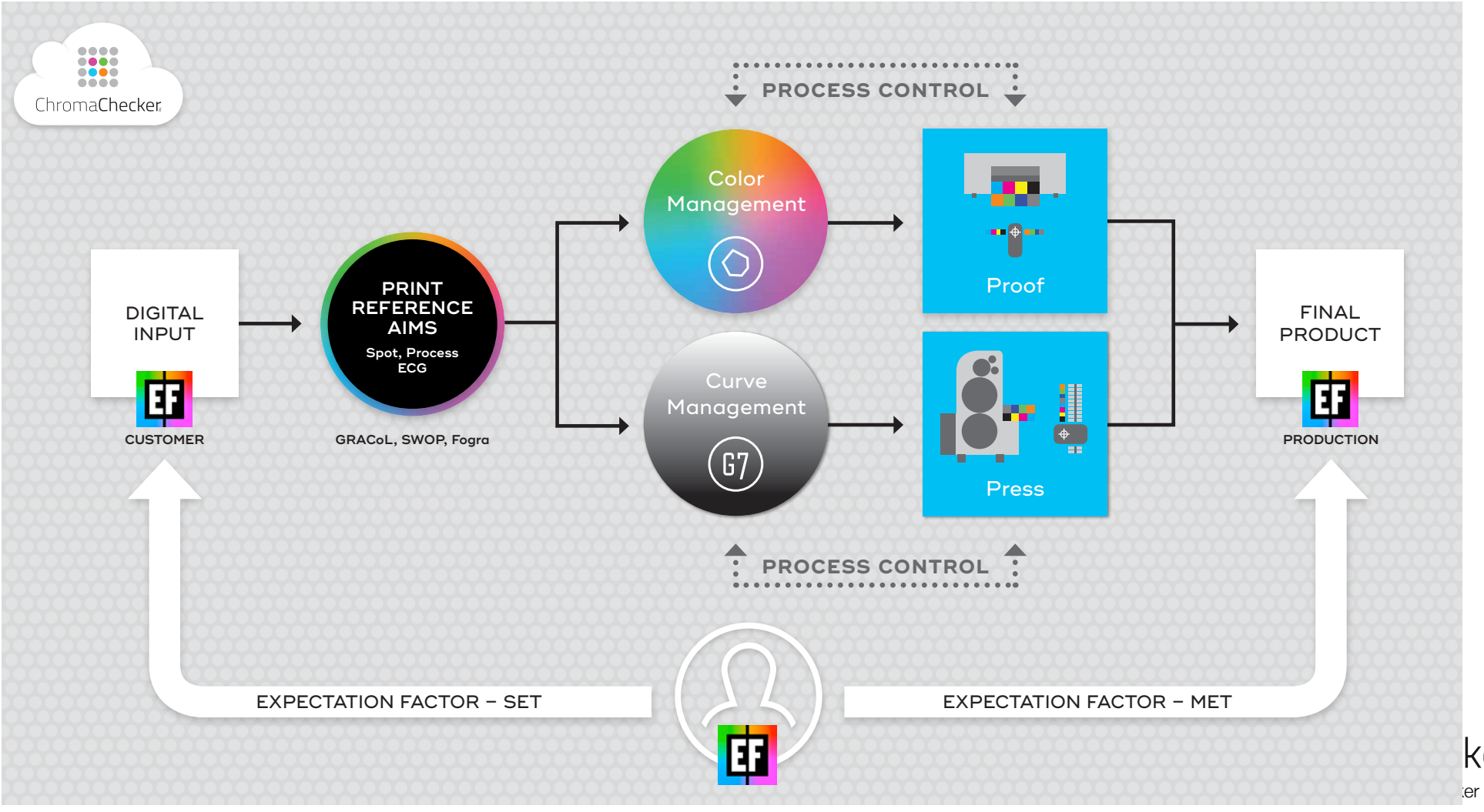
# Color Conformance Platform

## *Defines type, level, routine for process control*



# Summary

## Light Affects Color

- Spectral definition is more desired for defining colors
- CIE-Lab is still valuable for editing, correcting colors
- Spectral Prediction for Spots/Tints/Profiles is future
- Quantifying how different pages are using E-Factor
- Quantifying how different single colors are using ΔE
- Defining your shops tolerance is key to determine Waste

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## Color Control Fundamentals

# 5 C's Color Control

# Assess What is Salable for Printing Devices

**Where are your Printers? Salable? Every time?**

- Do they have shared appearance?
- Do they match your reference or each other?
- Do they render salable spot color matches?

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# Assess What is Normal for Printing Devices

**Where are your Printers? Salable? Every time?**

- Do they have shared appearance?
- Do they match your reference or one another?
- Do they render salable spot color matches?

**Do You Even Know???**

- Use Conformance Software to tell you
- Then determine what needs to be improved…

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# Use Conformance Software to Report

## Choose Printer

- Print this target on all printers
- Measure the color bar
- Document
  - E-Factor
  - Date
  - Printer Device/Substrate


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# Visually Compare the Different Prints

## Review Differences


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# Color Expectations: Define Conformance

**How Close is Close Enough?**

- How to Quantify what constitutes a Color Match
  - Brand Colors
  - Images and Page Comparisons
- Learning customer expectations requires Tribal knowledge
  - Direct experience customer learning their expectations
- Industry Expectations- Scientific published research- 2017
  - Based on Visual Color Matching using E-Factor metric

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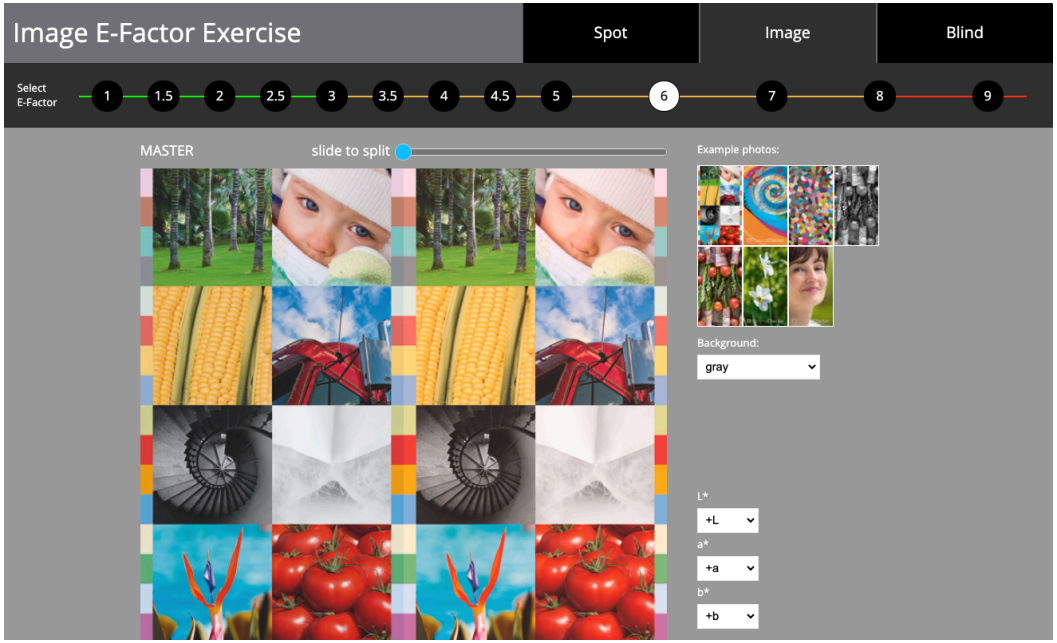
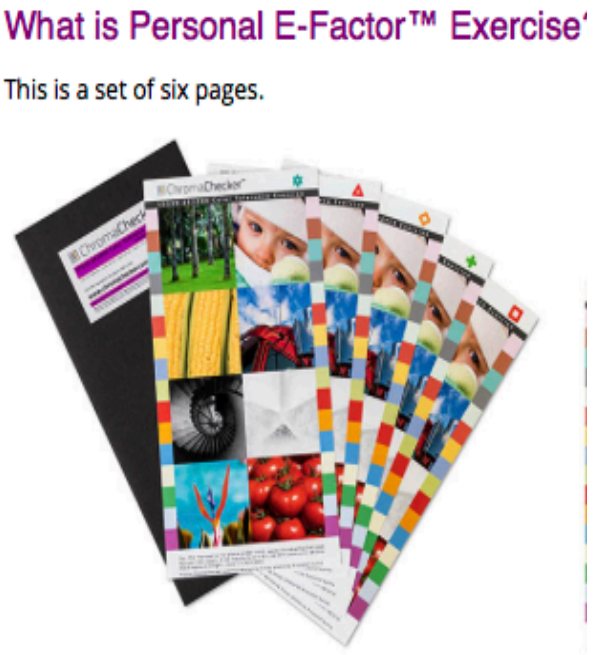
# Quantify Expectations!

## E-Factor Exercise- Connect Customer with Production

- Web site, or Hard Copy Version

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# Link Color Expectations to Print Capabilities

## *E-Factor defines if Printer can deliver salable color*

- Production Standard for Operator, Managers, Customers


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# Determine Printers with highest E-Factors

**Then Determine on what needs to be fixed**

- Conformance Software can guide you…
- But problems can exist for many reasons:
  - Not consistent
  - Not accurate

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# Printing Devices Not Meeting Expectations

## How to go about fixing problems

- Conformance Software can guide you…
- But problems can exist for many reasons:
  - Not consistent
    - Requires Capture Instrument & Calibration and Process control (routine checks)
  - Not accurate
    - Requires Characterization & Conversion

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# Printing Devices Not Meeting Expectations

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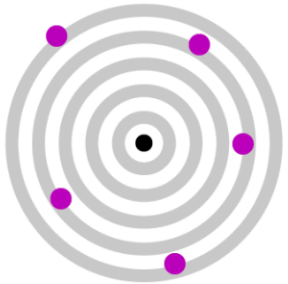
# Definitions/Vocabulary

## *Device Consistency*

- Precision
- Process Control- G7
- Shared Visual Appearance
- Delta E metrics for CMYK solids

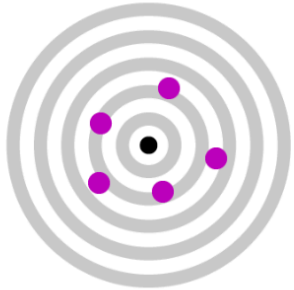
## *Device Matching*

- Accuracy
- Color Conformance- EF
- Color Match
- E-Factor metrics for pages



NO ACCURACY
NO PRECISION

LOW ACCURANCY
HIGH PRECISION



HIGH ACCURANCY
LOW PRECISION

HIGH ACCURANCY
HIGH PRECISION

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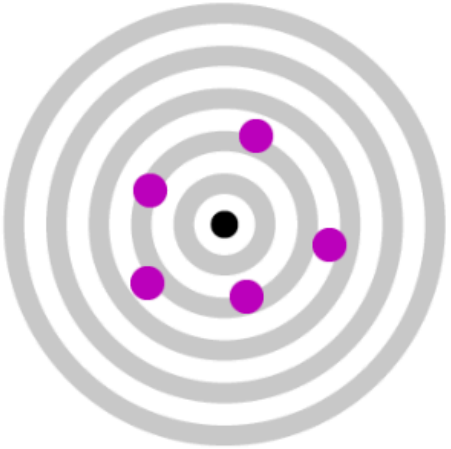
# 5 C's determine Quality of Color Match

**Need Good Components for all 5 C's to have best color**

- Precision and Accuracy achieved with all 5
- Might not need all 5 C's depending on your Expectations

**No C's Color Control**

**Capture & Calibration**



**+ G7 Curve Calibration**

**+Characterization & Conversion**

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# 5 C's determine Quality of Color Match

**Need Good Components for all 5 C's to have best color**

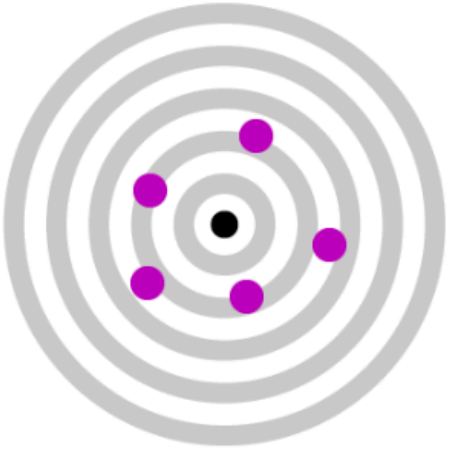
- Precision and Accuracy achieved with all 5
- Might not need all 5 C's depending on your Expectations

**No Color Control**

**=9+**

**Capture & Calibration**

**=7**



**+ G7 Curve**

**=5**

**+Characterization & Conversion**

**=3**

# 5 C's of Color Control

**Capture** — collect device (printer, instrument, lighting) capabilities

**Calibration** — make device consistent to itself & over time

**Characterization** — define device gamut and create profile

**Conversion** — map one gamut to another in the workflow

**Conformance** — verify new results and meet expectations

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# Capture

## 1st C

# First of the 5 C's of Color Control

## **Capture data** - measure, collect data all devices

**Calibration** — make device consistent to itself & over time

**Characterization** — define device gamut and create profile

**Conversion** — map one gamut to another in the workflow

**Conformance** — verify results and meet expectations

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# Capture Data with Measurement Instruments

## *Quantify color with multiple capabilities*




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# Capture- Selecting a Measurement Device

## Factors to Consider

- Ease of use- measuring single color? More?
- Level of automation (auto patch/ bar code)
- Substrate material thickness/transparency
- Aperture Size per printed line screen
- Textured material
- Other measurement devices to match
- Price and Accuracy/Precision

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# Capture with Manual Measurements

***Manually measure one color at a time***




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# Capture with Single Strip Measurements

***Measure color bar, patch size dependent on instrument***

- Calibration (process control) and Conformance applications



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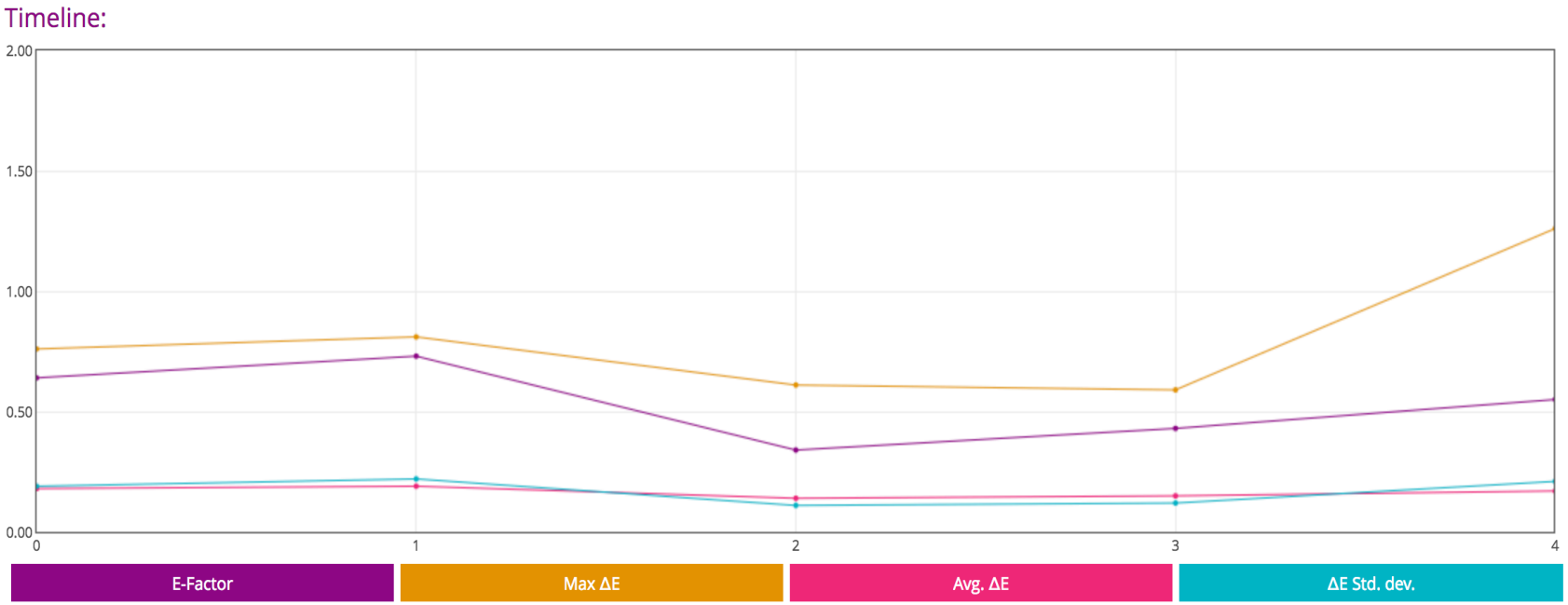
# Capture- How Precise is an Instrument?

## Data from measuring 42 patch target multiple times

- Exposes state of “exactness” and “repeatability”




**Average: .57**


**ColorMuse**

**$50**

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# Capture- How Precise is an Instrument?

## Data from measuring 42 patch target 12 times

- Exposes state of “exactness” and “repeatability”

**Average: .37**

**i1Pro1**

**Discontinued**




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# Capture- How Precise is an Instrument?

## Data from measuring 42 patch target multiple times

- Exposes state of “exactness” and “repeatability”

**Average: .14**

**i1Pro2**

**$500 refurbished**




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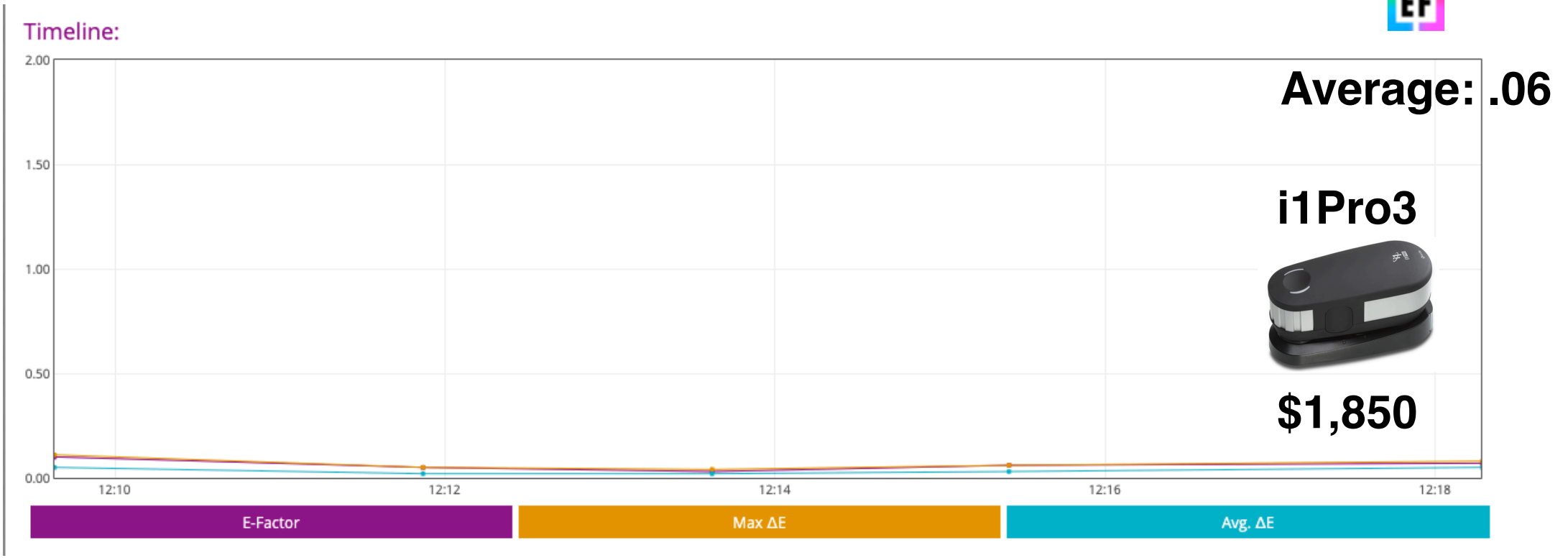
# Capture- How Precise is an Instrument?

## Data from measuring 42 patch target multiple times

- Exposes state of “exactness” and “repeatability”

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# Capture- How Precise is an Instrument?

## Data from measuring 42 patch target multiple times

- Exposes state of “exactness” and “repeatability”

**Average: .05**

**eXact**

**$7500**




File list:

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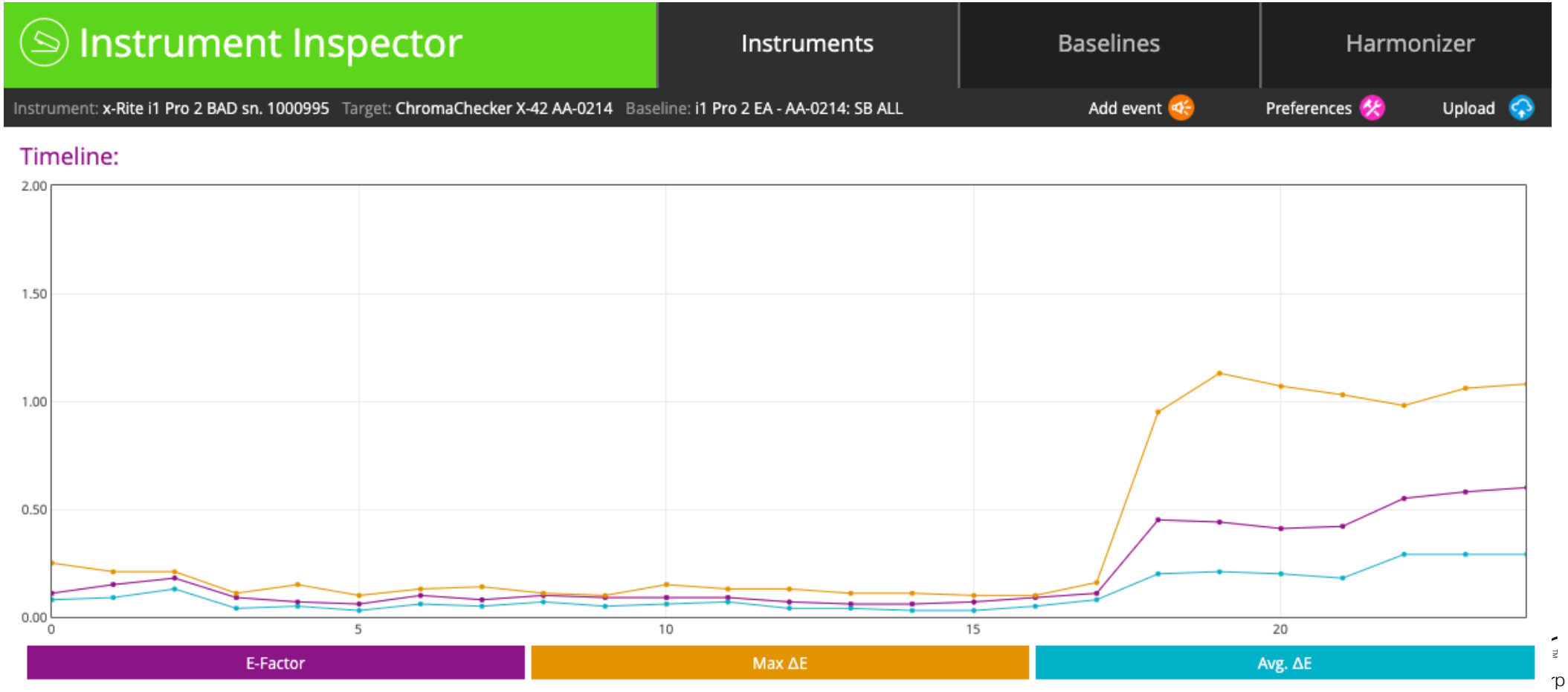
# Capture- How Precise is an Instrument?

## Data from measuring 42 patch target multiple times

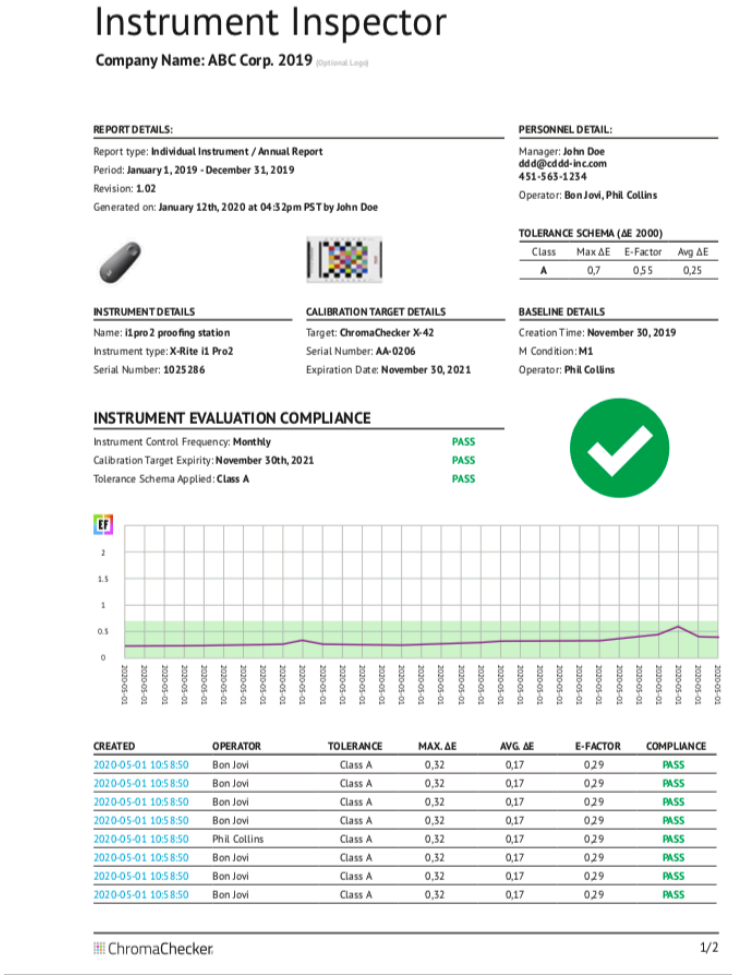
- Exposes state of “accuracy” and “repeatability”



# Eliminate Sending Instruments Back Annually?

## Prove ISO Compliance and never send back again

- Prove Accuracy of instrument
- Save a lot of money, $750 for i1/yr, +$1000 for Exact/Techkon, more ITX
- Being without instrument for approximately 2 weeks
- No shipping/insurance fees



Instrument Inspector

Company Name: ABC Corp. 2019 (Optional Logo)

**REPORT DETAILS:**

Report type: **Individual Instrument / Annual Report**
Period: **January 1, 2019 - December 31, 2019**
Revision: **1.02**
Generated on: **January 12th, 2020 at 04:32pm PST by John Doe**

**PERSONNEL DETAIL:**

Manager: **John Doe**
**ddd@cddd-inc.com**
**451-563-1234**
Operator: **Bon Jovi, Phil Collins**

**TOLERANCE SCHEMA (ΔE 2000)**

| Class | Max ΔE | E-Factor | Avg ΔE |
|---|---|---|---|
| A | 0,7 | 0,55 | 0,25 |

**INSTRUMENT DETAILS**

Name: **i1pro2 proofing station**
Instrument type: **X-Rite i1 Pro2**
Serial Number: **1025286**

**CALIBRATION TARGET DETAILS**

Target: **ChromaChecker X-42**
Serial Number: **AA-0206**
Expiration Date: **November 30, 2021**

**BASELINE DETAILS**

Creation Time: **November 30, 2019**
M Condition: **M1**
Operator: **Phil Collins**

**INSTRUMENT EVALUATION COMPLIANCE**

| | |
|---|---|
| Instrument Control Frequency: **Monthly** | PASS |
| Calibration Target Expirity: **November 30th, 2021** | PASS |
| Tolerance Schema Applied: **Class A** | PASS |

| CREATED | OPERATOR | TOLERANCE | MAX. ΔE | AVG. ΔE | E-FACTOR | COMPLIANCE |
|---|---|---|---|---|---|---|
| 2020-05-01 10:58:50 | Bon Jovi | Class A | 0,32 | 0,17 | 0,29 | PASS |
| 2020-05-01 10:58:50 | Bon Jovi | Class A | 0,32 | 0,17 | 0,29 | PASS |
| 2020-05-01 10:58:50 | Bon Jovi | Class A | 0,32 | 0,17 | 0,29 | PASS |
| 2020-05-01 10:58:50 | Bon Jovi | Class A | 0,32 | 0,17 | 0,29 | PASS |
| 2020-05-01 10:58:50 | Phil Collins | Class A | 0,32 | 0,17 | 0,29 | PASS |
| 2020-05-01 10:58:50 | Bon Jovi | Class A | 0,32 | 0,17 | 0,29 | PASS |
| 2020-05-01 10:58:50 | Bon Jovi | Class A | 0,32 | 0,17 | 0,29 | PASS |
| 2020-05-01 10:58:50 | Bon Jovi | Class A | 0,32 | 0,17 | 0,29 | PASS |

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# Capture- Understand Measurement Devices

## Next Measure Production Printers, any color bar

- Proofer

- Conventional Press


- Digital


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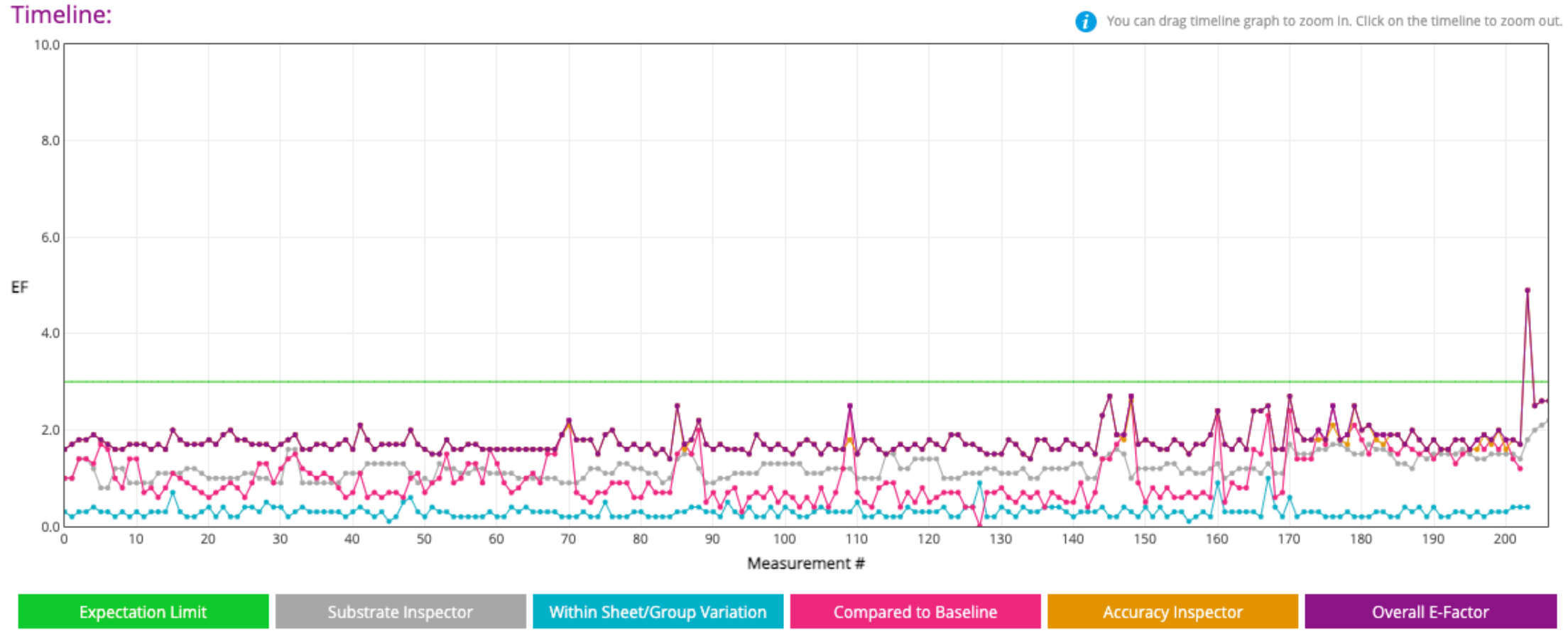
# Capture- Baseline Production Printing Device

## Any Color Bar, formatted for Instrument

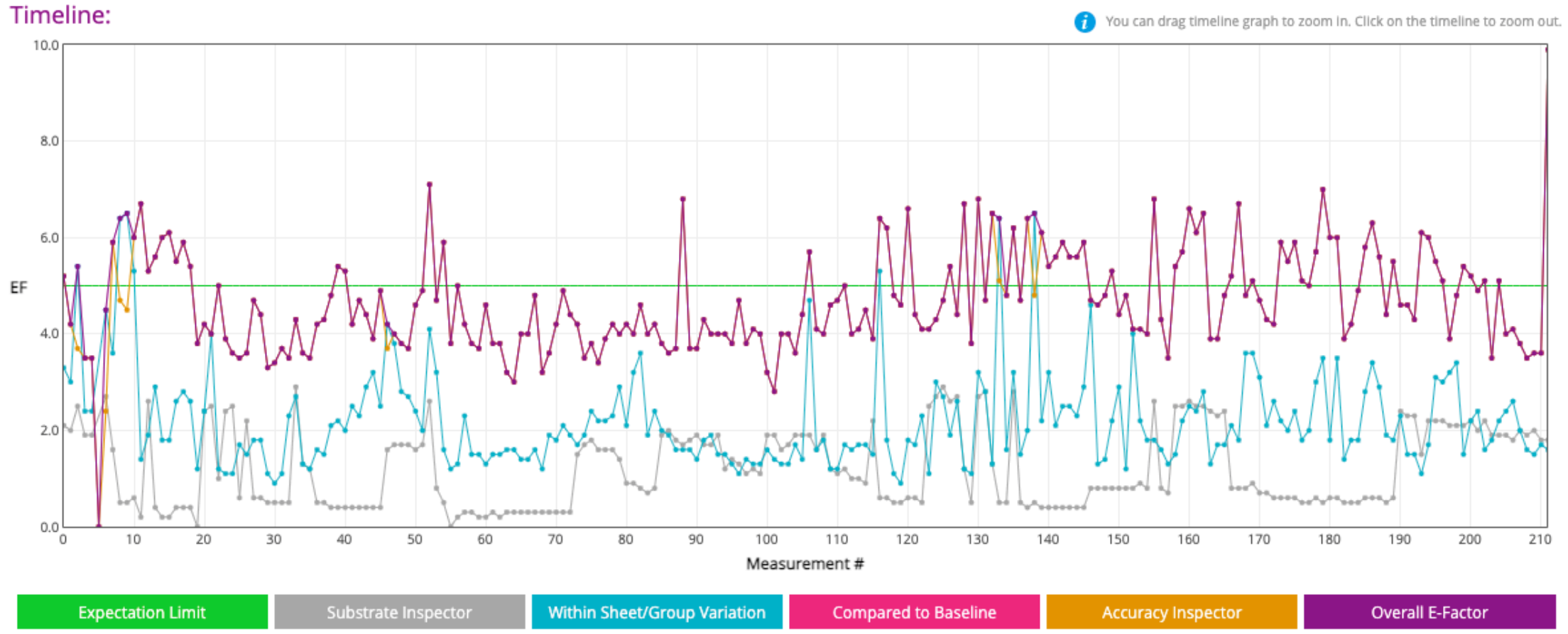
- Exposes state of “accuracy” and “repeatability” of printer



# Capture- Baseline Production Printing Device

## Any Color Bar, formatted for Instrument

- Exposes state of “accuracy” and “repeatability” of printer



# Call to action: Download- Print- Measure

## Baseline Your Printing devices

- Production Printing Devices
- Assess against GRACoL
- Assess G7 Compliance
- Assess printer to printer match


For step by step instruction scan QR code or visit:

**https://chromachecker.com/trial**

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# Capture- Summary: 1st C of the 5 Cs

**Capture Data and Conformance (verification)**

- Determining Production Standards, Tolerances
- Capturing data allows for baselining devices
  - Instruments, Printers, Light booths and more
- Calibration
- Characterization
- Conversion
- Conformance

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# Capture- Determining Which Device is Required

**Considerations based on E-Factor**

- Tighter the expectations the more critical the accuracy
- Precision- repeatability/consistency
- Accuracy- in relation to “Master” instrument
- Not always directly related to price

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# Capture- Is Instrument Precise Enough?

## E-Factor- Expectations

- Instrument Gauge Factor
- Every Manufacturing Industry has IGF
- ChromaChecker introduces to Print Industry
- Workflow Tolerance:
  - % of precision + cross instrument variation
  - allocate down to 20% to instrument variation

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# Capture- Interpreting the Data

**“Stacking” Effect of Multiple Devices**

- Multiple instruments measuring same color: Deviation
- Instrument use different technology, lighting, math
- With two Instruments double numbers, three= triple…
- Interpretation of data reveals:
  - (2) i1Pro1 = .74, then workflow = 3.7
  - (2) i1Pro2 = .28, then workflow = 1.40
  - (2) eXact = .10, then workflow = 0.50

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# Capture with Automated Target Measurements

***Automated x, y measuring large targets***

- Characterization (ICC Profile) targets
- Predefined locations with i1iO
- Bar code incorporated with target for automatic routing

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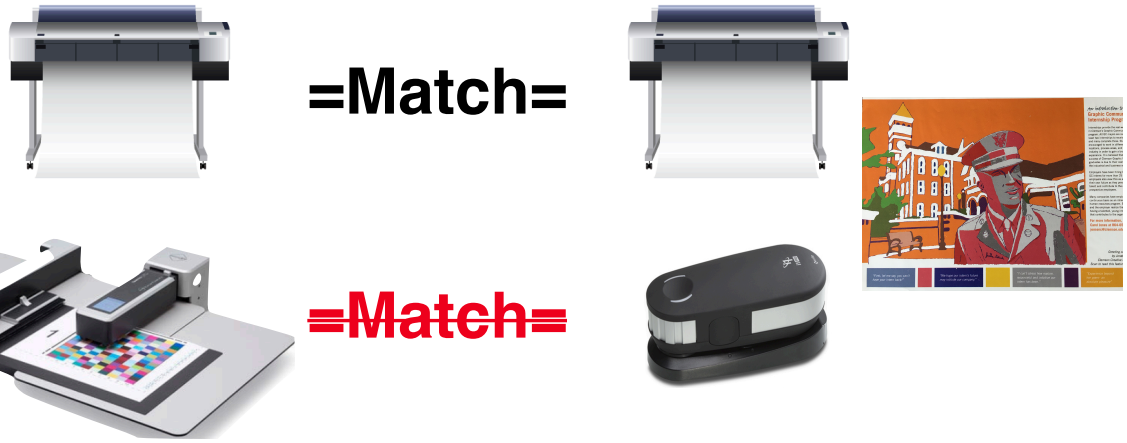
# Capture- Interpreting the Data

## “Stacking” Effect of Multiple Instruments

- Measuring same color differently results in Deviation
- FAIL customer tolerance before print page 1




**Create Profile Instrument A**

**Verify Profile Instrument B** **Fails!**

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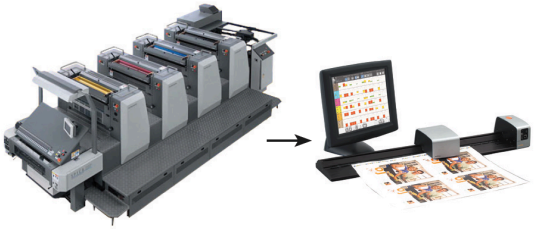
# Capture- Interpreting the Data

## “Stacking” Effect of Multiple Instruments

- Measuring same color differently results in Deviation
- FAIL customer tolerance before print page 1

=Match=

~~=Match=~~



**Compare to Press?**
**Instrument C**

**Fails ALSO!**

**Create Profile**
**Instrument A**

**Verify Profile**
**Instrument B**

**Fails!**

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# Capture- How Accurate is an Instrument?

## Comparing how different devices measure color

- Exposes state of “correctness” and closeness to “bullseye”


| | X-Rite i1 Pro 2<br>I1_SN307_M0 | X-Rite SN317 eXact<br>Exact_SN317_M0 |
|---|---|---|
| X-Rite i1 Pro 1<br>Autogenerated baseline 2018-03-01 09:06:44 | Workflow = 2.65 H = 1.20<br>Instrument = 0.53 H = 0.24<br>Harmonizer = 121%<br>Max = 0.54<br>Avg. = 0.29 | Workflow = 4.85 H = 1.20<br>Instrument = 0.97 H = 0.24<br>Harmonizer = 304%<br>Max = 1.17<br>Avg. = 0.62 |
| X-Rite i1 Pro 2<br>I1_SN307_M0 | | Workflow = 3.60 H = 0.95<br>Instrument = 0.72 H = 0.19<br>Harmonizer = 279%<br>Max = 0.76<br>Avg. = 0.42 |

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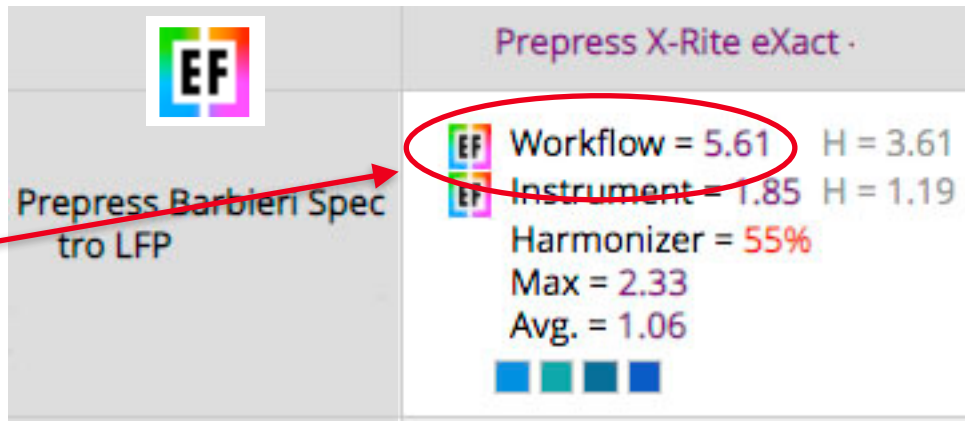
# Capture- How Accurate is an Instrument?

## Comparing how different devices measure color

- Exposes state of “correctness” and closeness to “bullseye


If E-Factor Workflow > Tolerance= **PROBLEM**

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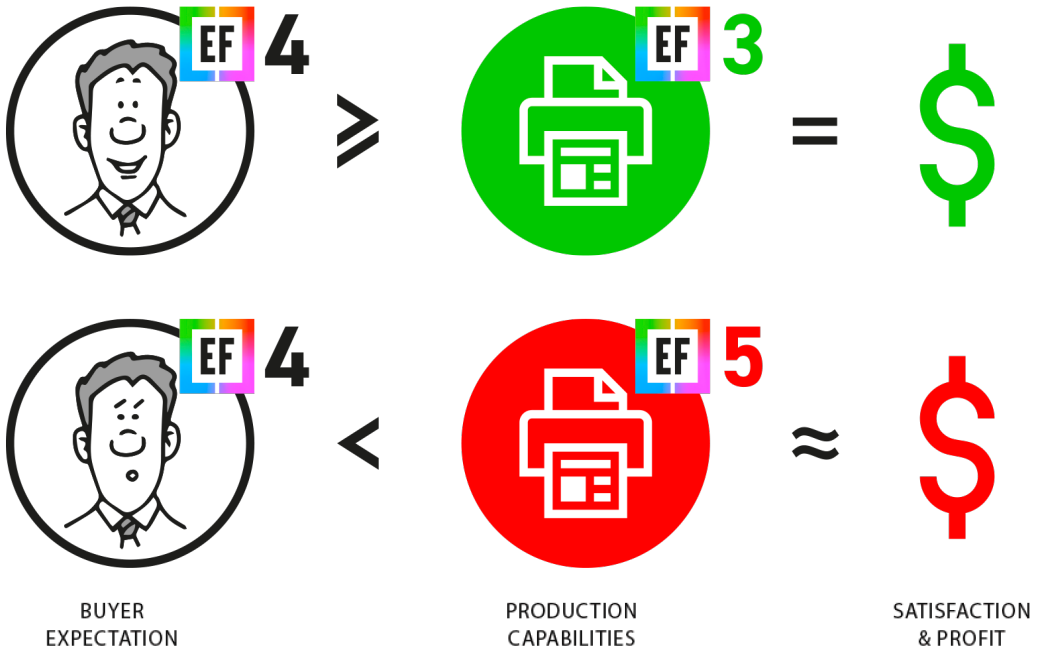
# Capture- Instrument Differences affect Printer E-Factor

## *If Instrument differences > Tolerance*

- Cause the Printer E-Factor to appear to FAIL
- Problem is Instrumentation Differences
- ChromaChecker can minimize this difference: Harmonization

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# Summary: Capture Instrument

## Application and Use Cases

- Multiple instruments measuring same color
- Understand: Capture instruments are different
  - *Even two units one serial number apart…*
- ChromaChecker Instrument Inspector
  - *Assess precision/accuracy each instrument*
  - *Warn when exceeds Tolerance Expectations*
  - *Can Harmonize to minimize differences*

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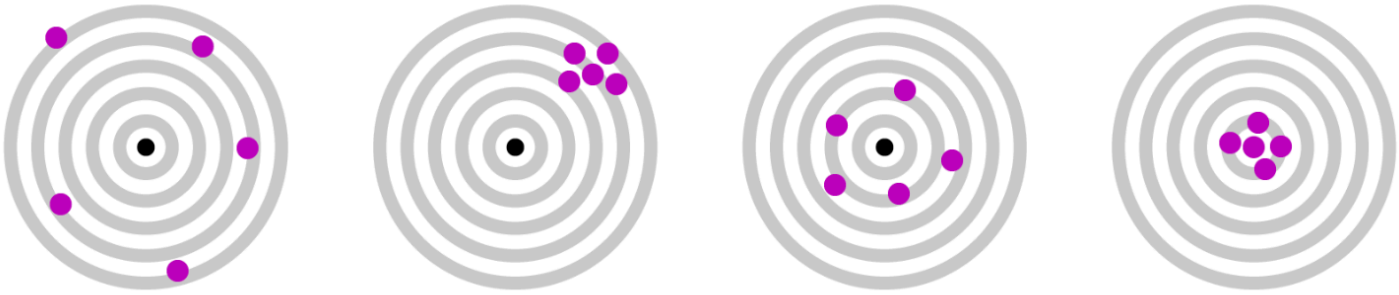
# Transition from Graphic Arts to Manufacturing

## *Taking Raw Materials & Creating Products that Consistently Meet Customer Expectations*

- **Maximum Color Match Requires**- Optimum process control, tighter metrics, optimum color conformance, lower EF




EF =9+ EF =7 EF =5 EF =3

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