# THE SECOND C:
## The Ninth Sphere of Paradise—Primum Mobile, Part 1

By Keith Hoover, with contributing author, Russ Merritt

***"And as their vision is sublime, so far they gain their purpose."***

*—Dante Alighieri, Divine Comedy, Paradiso, Canto XXVIII*

In the first installment of "The Second C," I stated that the purpose of a color department was to "assure that the product ends up in the right color." Specifically, it executes a risk management process implemented to provide some level of assurance that the products in the store will appear the same color as specified by the designer. To achieve that end, we have discussed color inspirations versus standards, color replication, digital color models, color difference equations, and acceptability tolerances. Color management in our industry currently involves "lab dipping," a process that sets aside time in the product development calendar to negotiate color acceptability by sending fabric swatches on trips around the world. [1] It is a fool's errand. In this installment, we will look at a better way to assure "the right color."

## LAB DIPPING—THE ORIGINAL SIN

First, let's consider a best-case version of the lab dipping process—one that uses feasible digital color standards, spectrophotometers, color QC software, relevant illuminants, and proper tolerances.

Lab dipping is a negotiating process between a brand color office and its suppliers/mills involving a series of iterative tasks. Designers identify color standards and communicate requests to match those color standards on fabrics from various mills. Mills, in turn, petition the brand color office for approval by sending dyed swatches intended to match the color standards specified by the designers. These mill color samples are measured with spectrophotometers and the data defining color are captured with each measurement and stored with each record. Once an acceptable swatch is received and evaluated by the color office, it is approved. Mills are required to resubmit samples until they receive a color approval.

As typically executed in the industry today, color approval occurs at two static points in the product life cycle: product development (lab dipping) and first of production (bulk). This approach assumes that 1) first of production fabric will look like the approved lab dip and 2) all of production will look like the approved first of production fabric.

### Measuring The Efficiency of Futility

Key Performance Indicators (KPIs) and metrics are gleaned from this collection of color data to grade mill color performance, including:

- **First submit approval rate**: For all submits, the percentage approved on the first round (not the percentage of all approvals that were marked "round 1")
- **Average number of submits for approval**: For all approvals, the average of all submit round numbers including approval exceptions
- **Approval exceptions**: Best Can Dos (BCDs) and technical passes as a percentage of all approvals [2]

While these metrics define the efficiency of the approval process, they do not address the quality of mill performance. Note also that two of the three KPIs involve time, as such targeting the color approval process as an area of interest within a brand's initiative to shorten their development cycle.

The lab dipping process is flawed for two reasons. First, there is no basis in fact or observation to assume that all of production looks like the approved first bulk. No data, KPIs, or metrics support that assumption. In fact, the process has not included methodology to characterize color accuracy or precision over the course of the mills' production (typically, several lots of fabric are dyed for each order). Second, the color approval process is slow and ill-suited to achieve the desired outcome. Therefore, approval processes, by their very nature, require considerable time to execute. Additionally, KPIs and metrics are associated with the end of the process instead of the beginning and success is negotiated while the process is in progress.

Finally, the lab dipping process cannot adequately manage risk. It has neither a dynamic view of color quality over the course of production nor the means to determine a mill's ability to produce color accurately and consistently. Instead, it is a static, time-consuming process that leaves product quality at considerable risk.

## MAKING ALL THINGS NEW

A specification/compliance model is a better tool for risk management than lab dipping, since it defines success up front instead of negotiating it over the course of the process. For that to happen, there must be a way to 1) objectively establish each mill's competency and 2) access mill production color difference data to confirm ongoing compliance. There are some prerequisites for this new process.

**Brands**

- Define and communicate feasible digital colors as specifications to mills
- Set fixed approval tolerances for acceptability

**Mills**

- Use formulation software to match each color specification within pre-defined tolerances.
- Execute an internal QC process using spectrophotometers to measure production lots
- Share those measurements with the brand

### No Lab Dips—Trust & Verify

In 2007, a novel "Color Accreditation Program" (CAP) was developed for a major US retailer using this new specification/compliance approach. As a result, the conventional lab dipping process was *eliminated* and the color quality of all production lots could be monitored —not just silly lab dips or first of production samples. The CAP includes two major components, the first one predictive, and the second results-oriented. Each is described below.

## TRUST

At the core of the CAP is the predictive **Color Capability Maturity Model (C2M2)**. It forms the framework of an in-depth audit to define a mill's initial process capability and predict its risk level.

Conceptually, C2M2 is based on root cause analysis and the premise that the drivers of shade variability

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can be defined, measured, and managed to improve mill performance. It is illustrated as a fishbone diagram (Figure 1), based on a series of about 350 questions in seven categories. [3] The spine, or problem to be solved, is Color Quality; the combination of accuracy and precision necessary to consistently provide onshade production runs. Major bones correspond to Assessment Areas within the C2M2 and minor bones match C2M2 Criteria. Not shown, and at a lower level of detail, are the Key Performance Indicators (KPIs) for all Criteria and their associated metrics. It is these metrics upon which the questions in C2M2 are built.

For example, the Materials assessment area is at the tail of the fish. Within this area, there are three criteria: Raw (Materials), Chemicals, and Water Quality. Within the "Raw" criteria, there is a KPI for Greige Goods. Associated with this KPI are several metrics, one of which is: "Are greige goods inspected for pH?" Table 1 shows the relationship between metrics (specific questions), KPIs, Criteria, and an Assessment Area (a major bone of the fish).

## The C2M2 Audit

The C2M2 audit is straightforward, consisting of only three elements: a mill self-assessment, an independent on-site assessment in which answers are determined for each metric, and a series of on-site exercises. The Assessment Areas, Criteria, Key Performance Indicators (KPIs), and metrics are the same for both the self- and independent on-site assessments and come directly from the C2M2. Self-assessments are conducted and reported by mill personnel. On-site assessments are conducted by an experienced, independent firm with relevant subject matter expertise. [4] The only difference is that the on-site team administers three tests to assess accuracy and precision in the lab and production.

### Test1: Observation of an Exercise in Lab Color Matching

It is important to understand a mill's approach to color matching, not just gather numbers. So, four QTX files are given to the staff in the color lab to match under specific illuminants within a given tolerance resulting in a sample that passes required performance tests. The lab

| Assessment Area | Criteria | KPI | Metric ID | Metric |
|---|---|---|---|---|
| Materials | Raw | Greige Goods | 6.1.1.1 | Are greige goods inspected for wettability? |
| | | | 6.1.1.2 | Are greige goods inspected for extractables? |
| | | | 6.1.1.3 | Are greige goods inspected for pH? |

*Table 1: Example of the C2M2 hierarchy.*

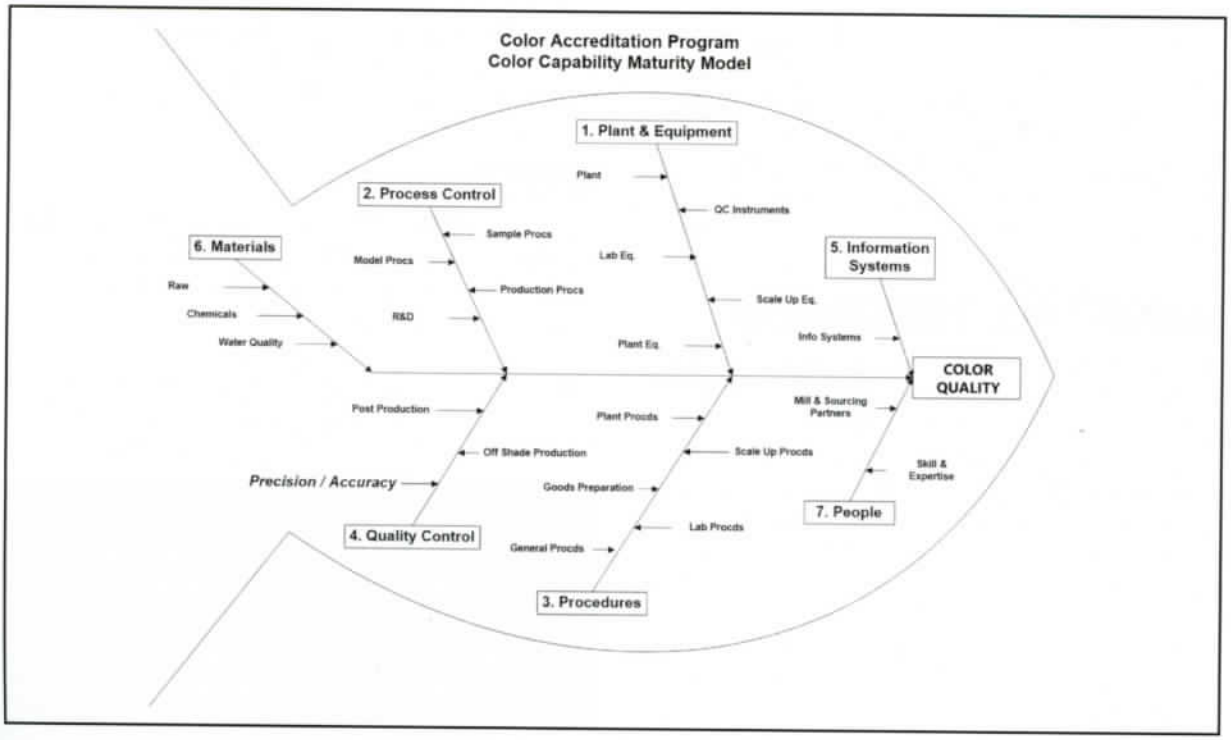



*Figure 1: Drivers of shade variability.*

staff then walk through their matching process, explaining their dye and procedure selection. Actual matching takes place and continues until a sample for each color matches the standard in each illuminant within tolerances. These samples are then sent for performance testing. [5] The predicted match data are documented along with the number of rounds to match each color and the colorimetric data for each round. Finally, the test results are recorded for each sample.

**Test 2: Measurement and Analysis of Existing Production Runcards**

There is a distinct bias toward accuracy and precision within the CAP. *Accuracy* is defined as how closely lab dyeings, scale-up models, and production runs match the standard. *Precision* is defined as how closely lab dyeings, scale-up models, and production runs are clustered about their own arithmetic mean, that is, how closely they match each other.

In this exercise, runcards containing 15 to 30 consecutive production runs for four colors are retrieved and measured on a spectrophotometer. The resulting data are compared to the original color standards under the specified illuminants. The average color difference for all batches is calculated for each color to determine Accuracy.

A new spectral data batch (called "[standard name] Precision") is then created by averaging all the production lots for each color together to define the arithmetic mean. This new batch is then set as the standard and all production lots are compared to it to determine Precision.

The Accuracy and Precision metrics are documented for each color. While valuable, average values can be misleading (the average age of a diaper-wearer is about 40 since users range from infants to the elderly). So, an additional metric called Process Score is required.

A *Process Score* is defined as the average color difference plus three times the standard deviation of all batches. Process Scores are calculated for all production batches compared to both the original standard (for Accuracy) and the "[standard name] Precision" standard (for

Precision) to determine the reliability of that dye recipe/procedure. A Process Score of 1.00 or below indicates reliability. Just as the average color difference for Precision is usually lower than the average color difference for Accuracy, the Process Score for Precision is usually lower than the Process Score for Accuracy. The best case is when Accuracy and Precision Process Score values are nearly the same and <0.50.

**Test 3: Calculation of Reverse Correlation (Bulk-to-Lab)**

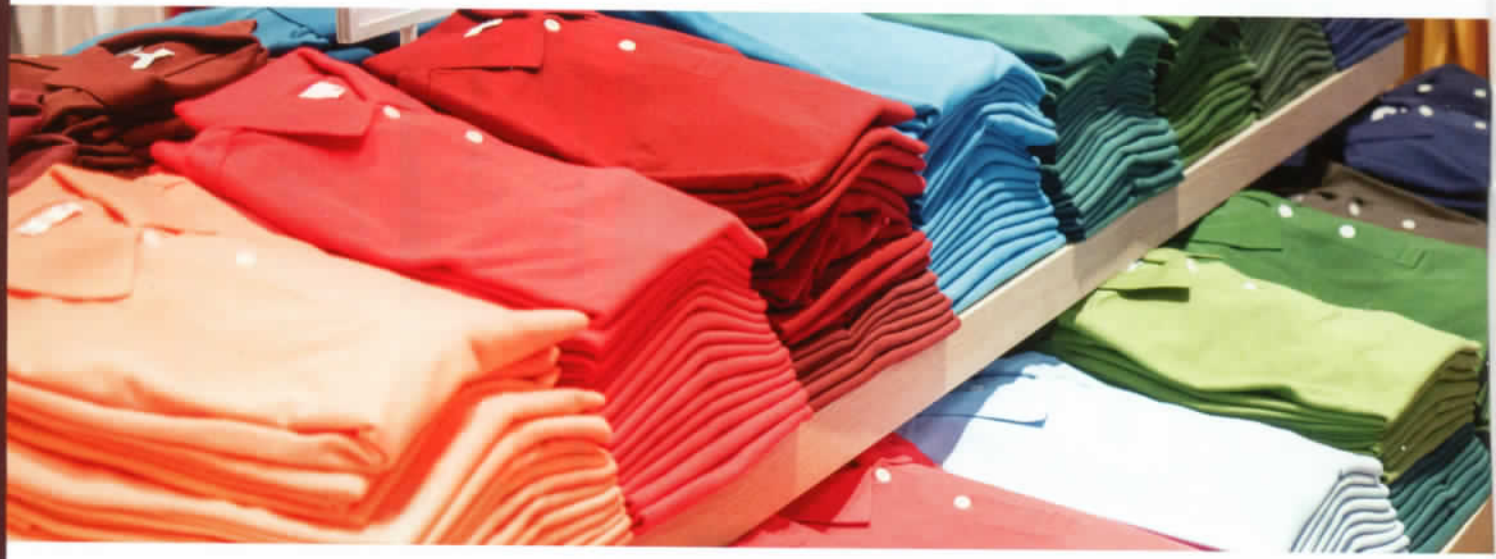
In "The Second C: From Inspiration to Replication," we saw the importance of lab-to-bulk correlation – "…a given dye recipe must produce the same shade on a 20g swatch as it does on a 400kg production dye lot." So, this exercise addresses that correlation in reverse. Instead of spending resources to scale up the colors matched in Test 1 to production, this test involves six colors running in production at the time of the C2M2 audit. Someone in the color lab identifies the production dye recipes and fabrics for each of those production runs and dyes them in the lab.

When the production runs and lab dyeings are complete, all samples are compared to the correct color standards. Then the lab dyeings for each color are compared to their production counterparts. Low color difference metrics are desirable in both sets of comparisons.

## How Much Do I Trust You?

Once the C2M2 on-site audit has been completed, the on-site team finishes its documentation and evaluates the results, comparing them to the minimum performance profiles established for each maturity level. Maturity levels (Figure 2) are milestones along the continuum of color capability maturity demarcated by clear performance boundaries.

- **Level 1—Assessed**: Mills that have completed the C2M2 audit but must complete significant Get Well Soon plans identified in the audit. No self-approval privileges are granted at this level.
- **Level 2—Remedial**: Mills with the ability to generate digital production records, but without the ability to execute production runs within Accuracy and Precision tolerances for Level 3 or higher. No lab dip brand approvals are required, but a physical first-of-production sample must be sent and approved by the brand. Level 2 is also set aside when CAP mills produce and ship fabric above the required color difference tolerances. This level is transitory in that a mill may only remain there temporarily.
- **Level 3—Almost There**: This level is aimed at mills that match a brand's color standard and then run all production <1.00 $DE_{CMC}$ compared to that approved lab dip (instead of the standard). This is also a transitional level in which mills work diligently to improve their Accuracy and Precision.
- **Level 4—Competent**: This is the place to be—every lot of production measures under 1.00 $DE_{CMC}$. While all lots are acceptable, Level 4 mills continue to improve their Accuracy and Precision.
- **Level 5—Critical Match**: Bragging rights—every lot of production measures under 0.60 $DE_{CMC}$. Every last one. Level 5 mills have proven Accuracy and Precision because their processes are under control.



## VERIFY

Verification is the results-oriented part of the CAP. The key to verification is access to reliable data.

All mills inspect finished goods before they are released. This involves several QC steps including spectrophotometric shade assessment. Linking to data at the point of capture not only simplifies access but increases data integrity since those data are a part of a mill's business systems. Setting up additional processes to capture data for a certification process (especially through outside systems) increases the likelihood that the data will either be incomplete or false. Frankly, it is easier to cheat an outside system than one used to drive the business.

So, ongoing performance verification is accomplished by making a connection to primary source data. When the CAP is set up, a utility is installed on the color lab computer that transmits spectral data for all brand-related production QC measurements to an online data warehouse accessible by the brand and the mill. In essence, it allows the brand to peek over the shoulder of the QC technician. This transparency satisfactorily solves the verification issue.

When the CAP was launched, we found that CAP mills were looking at their own data in the online data warehouse more than we were. The user interface for that data was designed to tell them everything they need to know about the efficiency and quality of their operation.

## UPWARD MOBILITY

Upon completion of the C2M2 audit, the independent team writes an exhaustive report of their findings along with the initial CAP maturity level rating and recommended action plans to improve performance (usually about 50 pages). In my experience, with over 100 CAP mills since 2007, 99% were rated at Level 4—Competent after the C2M2 audit, and all but one maintained that level or above continuously. Notably, during my time at one major retailer, Masood Textiles in Faisalabad, Pakistan, went months at a time at Level 5—Critical Match—reflecting their relentless control of every production variable.

As mills progress through the levels, they realize greater opportunity for time and cost savings (see Figure 3). At the highest levels, mills become increasingly attractive as partners since their documented objective performance sets them apart from their competitors.

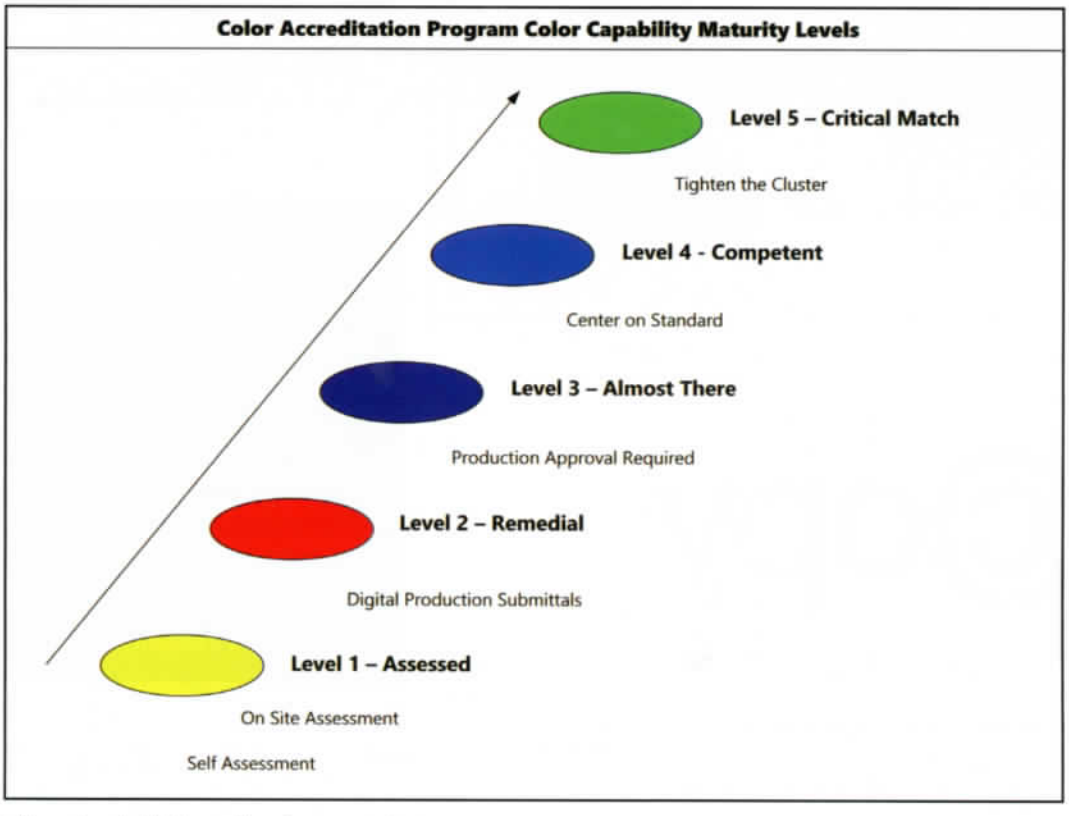



*Figure 2: Unlike rock and roll, it's actually a short way to the top.*

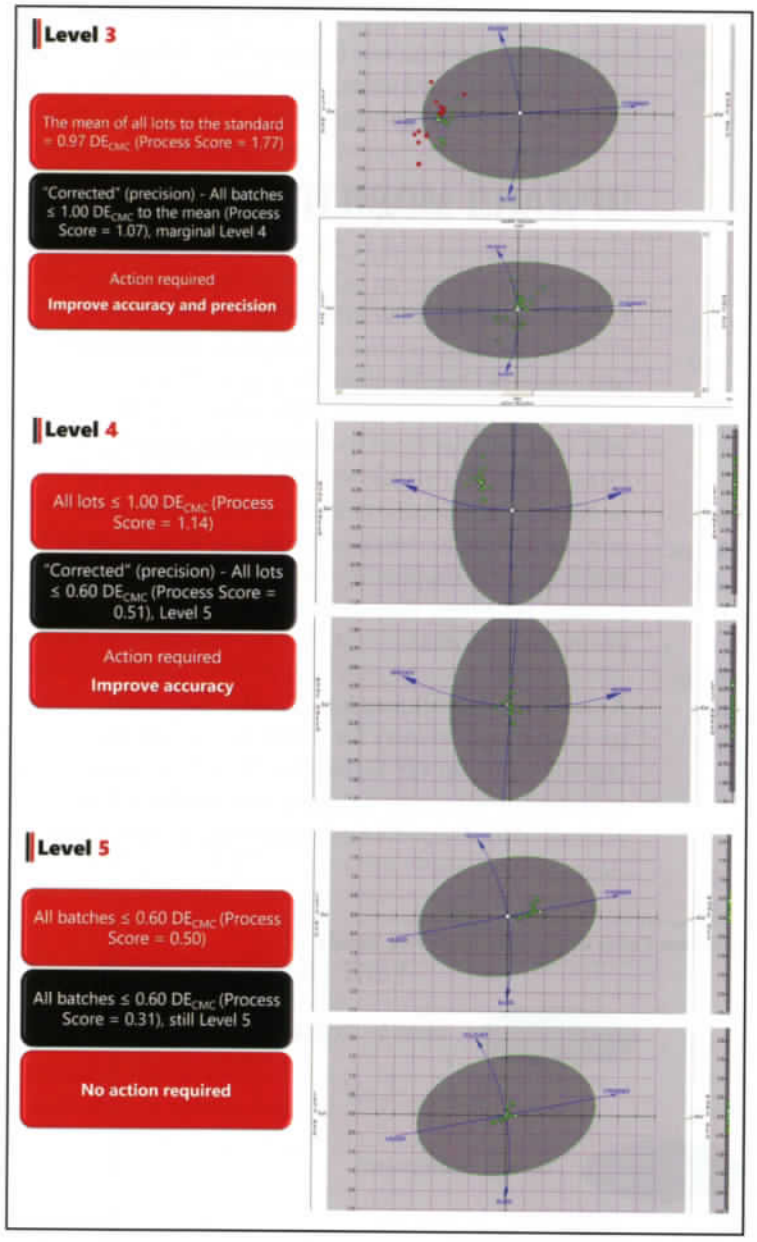



*Figure 3: CAP maturity levels and actions required for improvement.*

## YOUR WORKS, YOUR TOIL, AND YOUR PATIENT ENDURANCE

While the C2M2 audit proved instructive for mills to find the root causes of quality issues, the data played a much greater role in qualifying a mill's ability to consistently deliver the "right color." In the next installment, we will look at some examples of the data along with some case studies in how the CAP provides brands with more sourcing flexibility without added risk.

### Notes

1. As a reminder, the lab dipping process is different from an actual lab dyeing, that is, a precise color dyed on a specific fabric at the mill to assure that the first lot of production is on-shade. The lab dyeing sample is subsequently sent to the brand as a part of its lab dip process. See "The Second C: From Inspiration to Replication," p30, *AATCC Review*, Volume 22, No. 2, March/April 2022.
2. Approval exceptions: A BCD is an approval given to an offshade submit where color standard feasibility information and/or other submits for the same color/fabric indicate that a match is possible. A BCD is the mill's fault. A Technical Pass is an approval given to an offshade submit where color standard feasibility information and/or other submits for the same color/fabric indicate that a match is not possible. A Technical Pass is the brand's fault.
3. C2M2 was based on work done at North Carolina State University in the late 1900s.
4. Natific currently supports the CAP industry-wide. **https://natific.com/**
5. Correlation between performance testing of lab samples versus production samples will be addressed in a future installment.

**Keith Hoover, President of Black Swan Textiles, implements manufacturing-centric digital processes for color and fabric development. He has implemented digital color management programs for Ralph Lauren, Target, Lands' End, JCPenney, and Under Armour, ultimately leading to a process that eliminated lab dips altogether. At Under Armour, Hoover championed the UA Lighthouse, driving digitalization and advanced manufacturing processes to explore local-for-local sourcing. He has worked hands-on in mills worldwide and is a frequent AATCC presenter.**