Chris Travis – Director of Technology

Ink on Substrate
New printing processes and applications that *are* and *can* expand the positioning of today’s printer
Learning from others
Learning from others

McDonald's

Hamburgers

We have sold over 1 million

McCafe
Learning from others
Printers offer all types of services that are not directly print related
New Ideas

Printers offer all types of services that are not directly print related.
Printers offer all types of services that are not directly print related

- Design Services
- Marketing Services
- Web/Internet Services
- Data Management Services
- Fulfillment and Warehousing
- Photography and Video Production
- Mailing Services
- CD/DVD/USB Replication Services
2011 Split of Print and Non-Print Revenue
U.S. and Canada
$ billion

Total Industry Revenue $156.5 billion

- Print Revenue $135.3 billion 86.5%
- Non-Print Revenue $21.2 billion 13.5%

Non-Print Revenue

2011 Non-Print Revenue by Service

<table>
<thead>
<tr>
<th>Service</th>
<th>Revenue (billion)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Services</td>
<td>$5.70</td>
<td>27%</td>
</tr>
<tr>
<td>Marketing Services</td>
<td>$1.35</td>
<td>6%</td>
</tr>
<tr>
<td>Fulfillment and Warehousing Services</td>
<td>$6.09</td>
<td>29%</td>
</tr>
<tr>
<td>Design Services</td>
<td>$5.29</td>
<td>25%</td>
</tr>
<tr>
<td>Web/Internet Services</td>
<td>$0.81</td>
<td>4%</td>
</tr>
<tr>
<td>Photography and Video Services</td>
<td>$0.35</td>
<td>1%</td>
</tr>
<tr>
<td>CD/DVD/USB Replication Services</td>
<td>$0.37</td>
<td>2%</td>
</tr>
<tr>
<td>Data Mgmt Services</td>
<td>$1.29</td>
<td>6%</td>
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</tbody>
</table>

2011 Non-Print Revenue $21.2 billion

<table>
<thead>
<tr>
<th>Market Segment</th>
<th>2011</th>
<th>2016</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Print Revenue</td>
<td>$21.23</td>
<td>$33.24</td>
<td>56.5%</td>
</tr>
<tr>
<td>Commercial Printers</td>
<td>$11.24</td>
<td>$19.37</td>
<td>72%</td>
</tr>
<tr>
<td>Digital Imaging Service Firms</td>
<td>$1.64</td>
<td>$2.53</td>
<td>54%</td>
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<tr>
<td>Direct Mail Printers</td>
<td>$2.95</td>
<td>$3.40</td>
<td>15%</td>
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<tr>
<td>Transactional Printers</td>
<td>$0.57</td>
<td>$0.72</td>
<td>27%</td>
</tr>
<tr>
<td>Specialty Printing</td>
<td>$2.03</td>
<td>$3.45</td>
<td>70%</td>
</tr>
<tr>
<td>Package Printers</td>
<td>$2.80</td>
<td>$3.76</td>
<td>34%</td>
</tr>
<tr>
<td>Total</td>
<td>$21.23</td>
<td>$33.24</td>
<td>57%</td>
</tr>
</tbody>
</table>

*Printing Industries of America (PIA) estimate
2008 – 2013 No real growth

The recovery has been a marathon not a sprint.

Printing industry is predicted to grow 2-3% over the next year

Bumping up to 2.5%-3.5% next year

Our industry is *finally* growing again.
We will be printing stuff in the future things that we have never printed in the past

In order to prepare for these innovations -

Add new technology that will open your business to new applications and opportunities

Strengthen the overall company positioning
From 2013-2014 an increase of 40% in mergers and acquisitions

Paper, Commercial, Packaging, Consumables are all merging

Dedicated business specifically for print related merges and acquisitions.

Most often they are acquiring the sales.....some cases the assets
Mergers, Acquisitions and Restructuring

- RockTenn
- MWV
- RR Donnelley
- CGX
- Multi Packaging Solutions
- ASG
- Menasha
- Strine
New Technologies – Press Configurations

6 Color + Coater
New Technologies – Press Configurations

- Double Coaters – inline enhancements
  - Spot UV
  - Spot Matte
  - Special Effect Coatings
New Technologies – Press Configurations

- Double Coaters with Printing Units - inline enhancements
  - Spot Matte
  - Special Effects
  - Micro Embossing
• Coating Units down first
  • Whites
  • Foils
  • Sizing
New Technologies – Press Configurations

- Long Perfecting
  - Double Capacity
  - One pass
  - LED UV
New Technologies – Press Configurations

- Long Perfecting
  - Double Capacity
  - One pass
  - Coat both sides
New Technologies – Press Configurations

- Multiple printing units – vibrant PMS colors
New Technologies – Press Configurations

- Size – 81” sheet
Equipment Sales

Total Printing Equipment Purchases 2012 – 2017

Total Equipment Sales: $16.1 billion in 2017
*CAGR 2012-2017

- Sheetfed offset -0.5%
- Coldset web offset -1.3%
- Heatset web offset -0.3%
- Gravure -2.1%
- Flexographic 2.1%
- Inkjet 1.7%
- Electrophotographic 1.1%

Source: NPES 2013 study “World-wide Market for Print: Identifying Global Opportunities for the Print Industry” by Economist Intelligence Unit

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Sheetfed offset litho equipment</td>
<td>6,177.5</td>
<td>5,452.6</td>
<td>3,630.7</td>
<td>3,905.7</td>
<td>4,030.1</td>
<td>3,648.2</td>
<td>3,512.0</td>
<td>3,518.8</td>
<td>3,555.7</td>
<td>3,526.6</td>
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<tr>
<td>Flexographic equipment</td>
<td>2,796.3</td>
<td>2,661.7</td>
<td>2,081.6</td>
<td>2,149.7</td>
<td>2,219.9</td>
<td>2,146.2</td>
<td>2,216.8</td>
<td>2,273.5</td>
<td>2,348.7</td>
<td>2,308.8</td>
<td>2,386.1</td>
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<tr>
<td>Inkjet equipment</td>
<td>1,378.4</td>
<td>1,725.8</td>
<td>1,387.8</td>
<td>1,382.1</td>
<td>2,002.7</td>
<td>1,955.7</td>
<td>1,992.6</td>
<td>2,037.8</td>
<td>2,104.8</td>
<td>2,069.0</td>
<td>2,131.6</td>
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<td>Electrophotographic equipment</td>
<td>1,376.2</td>
<td>1,343.0</td>
<td>866.4</td>
<td>982.2</td>
<td>1,099.0</td>
<td>1,116.6</td>
<td>1,139.2</td>
<td>1,153.7</td>
<td>1,146.1</td>
<td>1,159.2</td>
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<tr>
<td>Coldset web offset litho equipment</td>
<td>1,553.1</td>
<td>1,268.2</td>
<td>993.7</td>
<td>1,001.1</td>
<td>849.2</td>
<td>771.0</td>
<td>756.2</td>
<td>748.2</td>
<td>732.1</td>
<td>738.8</td>
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<td>Platesetters</td>
<td>1,523.8</td>
<td>1,470.3</td>
<td>650.3</td>
<td>676.5</td>
<td>667.5</td>
<td>610.8</td>
<td>601.8</td>
<td>604.1</td>
<td>612.9</td>
<td>607.2</td>
<td>616.2</td>
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<td>Screen equipment</td>
<td>1,153.4</td>
<td>1,130.6</td>
<td>710.5</td>
<td>807.1</td>
<td>807.0</td>
<td>584.2</td>
<td>579.2</td>
<td>585.2</td>
<td>593.6</td>
<td>588.8</td>
<td>597.1</td>
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<tr>
<td>Heatset web offset litho equipment</td>
<td>1,424.5</td>
<td>1,311.8</td>
<td>765.3</td>
<td>708.2</td>
<td>638.9</td>
<td>604.6</td>
<td>599.7</td>
<td>602.3</td>
<td>598.7</td>
<td>600.0</td>
<td>595.4</td>
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<tr>
<td>Letterpress equipment</td>
<td>554.2</td>
<td>642.9</td>
<td>452.6</td>
<td>522.6</td>
<td>553.8</td>
<td>501.0</td>
<td>513.1</td>
<td>527.4</td>
<td>553.3</td>
<td>540.8</td>
<td>565.3</td>
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<tr>
<td>Gravure equipment</td>
<td>47.8</td>
<td>98.2</td>
<td>62.8</td>
<td>54.1</td>
<td>168.0</td>
<td>144.5</td>
<td>127.4</td>
<td>127.7</td>
<td>131.7</td>
<td>129.5</td>
<td>130.2</td>
</tr>
</tbody>
</table>

Source: NPES 2013 study “World-wide Market for Print: Identifying Global Opportunities for the Print Industry” by Economist Intelligence Unit

Source: NPES/PRIMIR
Innovative Substrates

- Plastic Packages
  - Rigid plastics – PP, PE, PET, PVC….

- Flute packages
  - Micro, E, S, B, C, EB Flutes….

- Board packages
  - Foil, SBS, CC, CCNB, Recycled board….

- Specialty substrates
  - Pre Treated, Black, Viner, Security

Last 4 years a reported growth of 3.22%, with an expected growth of 5.81% in the next 4 years
New Processes – Energy Curable Inks

- Traditional UV
  - Mercury Vapor Lamp
- Optimized UV
  - Iron Doped Mercury Vapor lamp
- LED UV – the future of energy curable inks and coatings
New Processes – Energy Curing

- **Traditional UV** – Mercury Vapor Lamp
- **Optimized UV** – Iron Doped MV lamp
- **LED UV** – the future of energy curable inks and coatings

---

### UV radiation spectrum

- **Vacuum UV**
- **UV-C**
- **UV-B**
- **UV-A**

### Reactive ranges:

- **Traditional UV**
  - Reactive range of UV inks

- **Optimized UV**
  - Reactive range of HR-UV inks

- **LED-UV**
  - Reactive range of LED-UV inks

---

Highest radiation intensity of the individual UV lamp type.
New Processes – Energy Curable Inks

LED UV – The Future of drying

4/4

4/4+L

- LED Stick
- EOP UV
- EOP IR
- EOP HA
- LED Stick
New Processes

- Inline Cold Foil – foil application before printing
New Processes

- Inline Cold Foil – foil application before printing
New Processes

• Inert UV – food grade coatings
New Processes

1. Coater (Aqueous / UV)
2. Dryer units (IR/ TL / UV)
3. 10 printing units
4. Coater (Aqueous / UV)
5. Dryer units (IR/ TL / UV)
6. Coater (Aqueous / UV)
7. UV-Inert dryer units
8. AirTronic delivery (IR / TL / UV)
Implemention of new processes
Largest print markets, 2017
(US$ bn)

- China: 154.0
- US: 141.8
- Japan: 48.0
- Germany: 38.8
- UK: 35.6
- France: 29.4
- India: 29.3
- Brazil: 20.0
- Italy: 19.0
- Spain: 15.0
- Mexico: 14.6
- Canada: 9.2
- Indonesia: 9.1
- Netherlands: 8.6
- Australia: 7.5
- Belgium: 7.4
- Russia: 7.3
- South Korea: 7.0
- Argentina: 5.5
- Switzerland: 5.2
- Others: 56.4

Global market size in 2017: US$668.6 bn

Source: NPES 2013 study "World-wide Market for Print: Identifying Global Opportunities for the Print Industry" by Economist Intelligence Unit
Markets Trends

- Packaging
  - Craft Beers
  - Marijuana
  - Ammunition
- Medical/Pharma
- Boutique
- Food
- Flexible
- Labels
Markets Trends

- Bio-gradable packaging
  - Using new substrates and coatings

- Die Sublimation
  - Old process new tricks
Markets Trends

- Printed Electronics
  - The ability to print a wire
    - Lighting
    - Power
    - Sensors
    - Display
    - Logic and Control
By breaking out of the boundaries we have placed upon “printing”, we once again open “printing” to limitless possibilities.
LIFE BEGINS AT THE END OF YOUR COMFORT ZONE
Science and Technological for a Secure Country

Patrick Younk, Staff Scientist
Los Alamos National Laboratory

TAGA 67th Annual Technical Conference

March 2015
Outline

- Overview of the Lab
- Research at Los Alamos in more depth:
  - The HAWC Gamma-ray Observatory
  - Ultra-fast Optical Ranging
- Final thoughts
Overview of Los Alamos National Lab
The role of Los Alamos for DOE and NNSA

1 / 17 – DOE Laboratory System
1 / 08 – NNSA Nuclear Security Enterprise

Office of Science Laboratories
1. Ames Laboratory
   Ames, Iowa
2. Argonne National Laboratory
   Argonne, Illinois
3. Brookhaven National Laboratory
   Upton, New York
4. Fermi National Accelerator Laboratory
   Batavia, Illinois
5. Lawrence Berkeley National Laboratory
   Berkeley, California
6. Oak Ridge National Laboratory
   Oak Ridge, Tennessee
7. Pacific Northwest National Laboratory
   Richland, Washington
8. Princeton Plasma Physics Laboratory
   Princeton, New Jersey
9. SLAC National Accelerator Laboratory
   Menlo Park, California
10. Thomas Jefferson National Accelerator Facility
    Newport News, Virginia

Other DOE Laboratories
1. Idaho National Laboratory
   Idaho Falls, Idaho
2. National Energy Technology Laboratory
   Morgantown, West Virginia
   Pittsburgh, Pennsylvania
   Albany, Oregon
3. National Renewable Energy Laboratory
   Golden, Colorado
4. Savannah River National Laboratory
   Aiken, South Carolina

NNSA Laboratories
1. Lawrence Livermore National Laboratory
   Livermore, California
2. Los Alamos National Laboratory
   Los Alamos, New Mexico
3. Sandia National Laboratory
   Albuquerque, New Mexico
   Livermore, California

Kansas City Plant
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
Nevada National Security Site
Pantex Plant
Sandia National Laboratories
Savannah River Site
Y-12 National Security Complex
LANL started as “Project Y” in WWII

- LANL has a long history of conducting world class science.

Hans Bethe, Nobel Prize 1967

Enrico Fermi, Nobel Prize 1938
LANL: Then and Now

Theoretical Division Offices, 1947

Same view, July 2014
LANL is a Federally Funded Research and Development Center (FFRDC)

Managed and operated by the University of California
1943 to 2006

Now managed by Los Alamos National Security (LANS), LLC
2006 to present
Located in Northern New Mexico

Omega Bridge, the slopes of the Jemez mountains in the background
Senior Executive Team

Directors Office
Charlie McMillan, Director
Paul Henry, Acting Deputy Director
Rich Marquez, Executive Director
Ted Sherry, Associate Deputy Director

Principal Associate Directors (PADS)
Alan Bishop
Craig Leasure (acting)
Terry Wallace
Carl Beard
Paul Henry

Quick Facts
• ~10,000 Employees
• ~2 billion Annual Budget
• 36 square miles of DOE property
• 47 technical areas
• 1,280 buildings
• 11 nuclear facilities

Science, Technology, and Engineering
Weapons Programs
Global Security
Operations and Business
Capital Projects

TA-3 Campus
Strategic Plan: Deliver on policy shaped by the President

“I state clearly and with conviction America's commitment to seek the peace and security of a world without nuclear weapons…”

“Make no mistake: As long as these weapons exist, the United States will maintain a safe, secure and effective arsenal to deter any adversary.”

--President Barack Obama
April 9, 2009
Prague
Los Alamos Strategic Plan is aligned with DOE and NNSA

DOE mission areas:
1. National Security
2. Science
3. Energy
4. Environmental Management

The role of National Labs:
- DOE is a powerhouse of science and technology for the nation
- National labs are principal agents of execution on missions of national importance
- All of this is done in public service

NNSA Commitments:
1. Sustain the nuclear weapons stockpile
2. Conduct leading-edge scientific research
3. Help prevent nuclear materials from falling into the hands of terrorists
4. Support the Navy’s nuclear reactor program
5. Repair and modernize our aging infrastructure
6. Protect the safety and security of our sites, our employees, and the public

Ernest Moniz
Secretary of Energy

Frank G. Klotz,
NNSA Administrator
We anticipate, innovate, and deliver solutions

Our solutions result in:
- 126 R&D 100 Awards since 1978
- 32 E. O. Lawrence Awards
- The Seaborg Medal
- The Edward Teller Medal
- The Nobel Prize in Physics

A proud history; Solving today’s challenges; Basic research with a vision for the future

Trinity device before testing
Dual Axis Hydrodynamic Radiography Test Facility
How an exascale computer might model a shock wave
Our core mission is to ensure the U.S. nuclear deterrent

- Ensure safety, reliability and performance of stockpile
- Design agency for four out of seven warhead systems constituting nation’s deterrent

Confidence without nuclear testing requires a fundamental understanding of science and engineering

- Modeling, simulation, radiography, and non-nuclear testing provide assurance
How could you ensure this worked, *without starting the engine*?

Our stockpile is as unique in manufacturing as the engine of this sports car.

High performance race cars are made up of 80,000 components, if they were assembled 99.9% correctly; they would still start the race with 80 things wrong.

The United States faces a much more complex challenge in caring for its nuclear stockpile.
Threat Reduction

- Safeguard and detect radiological material
- Train inspectors for the International Atomic Energy Agency
- Counterterrorism
- Disaster response

We work on reducing threats to the nation and the world
Pursuing energy security breakthroughs

- Hydrogen fuel cells & Algal biofuels
- Impacts of growth in energy demand
- Safer nuclear reactors
- Energy infrastructure analysis

In a world with limited resources, energy security *is* national security
Support for Curiosity Rover

- Power Source
- ChemCam: Laser Induced Breakdown Spectroscopy (LIBS)
- LIBS Technology applicable to IAES work…

Backpack unit for the IAEA
The Lab is involved in research that is of critical interest to the people of the United States

- The Lab is a national resource and a vital part of our nation’s intellectual infrastructure.
- ~2000 scientists and engineers with terminal degrees.
Science and the capability for basic and applied research is a key part of the infrastructure for a civilized and peaceful world.
In More Depth:
The HAWC Gamma-ray Observatory (NEW!)
The HAWC Instrument in the state of Puebla, Mexico

High Altitude Water Cherenkov Gamma ray Observatory
A New, State-of-the-art Gamma-ray Observatory

- LANL has taken a leading role in the construction and operation of the HAWC instrument.

HAWC Group at LANL
Gamma rays?

The spectrum of cosmic messenger particles

<table>
<thead>
<tr>
<th>Wavelength (m)</th>
<th>Photon energy (eV)</th>
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</thead>
<tbody>
<tr>
<td>$10^{-9}$</td>
<td>$10^9$</td>
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<tr>
<td>$10^{-6}$</td>
<td>$10^6$</td>
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<tr>
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<td>$10^3$</td>
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<td>$10^6$</td>
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<tr>
<td>$10^9$</td>
<td>$10^9$</td>
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</tbody>
</table>

Gamma rays?

very high energy (VHE) gamma rays

Mosquito push-up
Where do VHE Gamma-rays come from?

- VHE Gamma-rays (non-thermal) are messenger particles from the most luminous objects and violent environments in the universe!

Enrico Fermi

Tycho Supernova Explosion

Cygnus A – Jets from supermassive black hole

Gamma ray burst (drawing)
How do we see VHE gamma rays?

- **Low flux:**
  - Brightest VHE source: 1 particle / m² / day.
  - Need BIG detector, necessarily built on the ground.

- **Gamma rays interact in atmosphere**
  - Cannot measure VHE gamma rays directly
  - Can only measure the air shower.
Design Concepts for HAWC

- HAWC is a Detector Array.
- **High Altitude** (13,500') so we see more shower particles.
- **Water-Cherenkov** is the detector technology.

- Angle of primary is determined from timing.
- Energy of primary is determined from energy in detector.
HAWC Design

300 close packed water tanks (50,000 gallons), each with four photomultiplier tubes at the bottom.
Nearly Ideal Site

- 4100 meters (13,500 ft)
- Between the mountains Pico Orizaba and Sierra Negra in Mexico
Preliminary HAWC Data...
The VHE sky is dynamic!

These are the first ever VHE flares detected by a ground array!

Mrk 505 Flare

Mrk 421 Flare
HAWC is a new set of eyes for observing the cosmos

The HAWC Observatory was officially inaugurated March 19, 2015.
HAWC enhances the science capabilities of the Lab

- HAWC’s broad science goals and its hardware/software development are relevant to the Lab’s national security mission.

- Three HAWC (or former HAWC) scientists currently work on projects directly related to national security.
In More Depth: Ultra-fast Optical Ranging
Do these things have anything in common?

- The answer may surprise you...

![Nuclear Bomb](image1)

![Printing Press](image2)
Do these things have anything in common?

- Both are high-speed, high-precision assembly machines.

Nuclear Bomb

Printing Press
Synergy

- Insuring the performance, reliability, and safety of our nuclear deterrent in the absence of live tests necessarily requires measurement systems on the cutting edge of technology.

- To maintain a competitive advantages in **Printing** and the **Graphic Arts**, we also must have measurement systems on the cutting-edge of technology.

- Ultra-fast Optical Ranging is one example of synergistic, cutting-edge technology....
Ultra-high Speed Optical Ranging

- Noncontact position measurement (Doppler insensitive) at a rate of \(~100\,\text{MHz}\) and \(~1\,\text{micron}\) accuracy.

Many possible applications….

Ultra-precision, Dynamic Runout

Dynamic surface roughness

Film Thickness and registration

Senses multiple layers or a cloud of particles
Descriptions of the fundamentals of the method are in the open literature

- Accurately measure the time-of-flight difference between the Reference and Object Legs.

Mode-locked, femto-second Laser, 1560 nm center

Laser → Splitter → Optical Circulator → Collimating Probe → Object Leg

Spool of Fiber to chromatically disperse the pulse → Splitter

Ref. Leg

Photodetector → O-scope

Object-of-Interest


Connector Legend
- SMF-28 Optical Fiber
- Open Beam
- Electrical
How the time-of-flight is accurately measured...

- The frequency $f$ is proportional to time-of-flight difference $t$; Doppler insensitive.
- Freq. measurement is inherently immune to signal level fluctuations – allows for the detection of multiple surfaces.

Pulses dispersed by several km of fiber

Pulses are now chromatically dispersed and several nm long

Pulses are made to interfere with each other creating a tone pulse in a detector.
Simple demo: A spinning square

- Note: Doppler Velocimetry does not measure surface approach due to transverse motion.
- Thus OR (which is Doppler insensitive) is complementary to Doppler Velocimetry.
Ultra-high Speed OR may have interesting applications

Measuring thin films… Can measure the position of two surfaces simultaneously.

These are things that a Doppler-based system cannot do.
Ultra-high Speed OR may have interesting applications

- R&D at LANL will lead to contributions to the scientific literature – our colleagues at STL have already published an OR paper.
- In turn, this will fuel new industrial applications.
- Optical Diagnostics is just one example of possible synergy between LANL and industry…
Collaborations with industry may be facilitated by **The New Mexico Consortium**

- “The New Mexico Consortium (NMC) is an innovative effort to engage universities and industry in scientific research in the nation's interest and to increase the role of Los Alamos National Laboratory (LANL) in science, education and economic development.”
- Please visit: http://newmexicoconsortium.org/
Final Thoughts

- LANL is a Science and R&D Power-house.
- While our primary mission is insuring our nuclear deterrent, our capabilities confront a broad scope of problems in both basic and applied research.
- Our basic research insures we continue to be at the cutting edge of science and technology.
- Our applied research has applicability to industry and the graphic arts.
- LANL is an important part of your national infrastructure – LANL is YOUR Lab.
Using data and a print-centric strategy to manage relevant, timely omni-channel marketing
What the heck is omni-channel?

- Multi-channel is not omni-channel
- Omni-channel defined
Why print as the primary driver?

- It works!
- You control the display
- You control the content and the context
- It plays well with other channels
- It's trackable
So let’s talk about data

- Customer data
- Mailing data
- Data about the data
Customer data

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<td>ALBERT SUCHOSKI</td>
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</tr>
</tbody>
</table>
Mail delivery data
Data about data

- Transactional data
- Propensity scoring
- Response Analysis
Detour into Big Data
When smaller is better
Data versus instinct

• Create a balance of the two
• Use the data to remove as much indecision as you can
• Use your intuition to test the data
• Use the data to train your intuition
What do I use data for (and when)?

- For developing your strategy (before)
- For executing your strategy (during)
- For measuring your results (after)
Data for developing your strategy

<table>
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<tr>
<th>Source Group Description</th>
<th>Source Code</th>
<th>Source Code Description</th>
<th>Circulation Qty</th>
<th>Responder Qty</th>
<th>Response Qty</th>
<th>Revenue</th>
<th>Response Rate</th>
<th>Average Revenue</th>
<th>Gross $ Per Piece</th>
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<tbody>
<tr>
<td>House</td>
<td>10A03501</td>
<td>0-6 Mo. Recency Buyers</td>
<td>26,928</td>
<td>857</td>
<td>1,040</td>
<td>$167,678.16</td>
<td>3.86%</td>
<td>$180.46</td>
<td>$6.97</td>
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<td>House</td>
<td>10A03502</td>
<td>7-12 Mo. Recency Buyers</td>
<td>22,635</td>
<td>568</td>
<td>664</td>
<td>$126,843.53</td>
<td>2.93%</td>
<td>$191.03</td>
<td>$5.60</td>
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<td>House</td>
<td>10A03503</td>
<td>13-24 Mo. Recency Buyers</td>
<td>52,496</td>
<td>315</td>
<td>466</td>
<td>$52,007.71</td>
<td>0.89%</td>
<td>$111.60</td>
<td>$0.99</td>
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<td>House</td>
<td>10A03504</td>
<td>25-36 Mo. Recency Buyers</td>
<td>32,973</td>
<td>272</td>
<td>304</td>
<td>$46,408.33</td>
<td>0.92%</td>
<td>$152.66</td>
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<td>House</td>
<td>10A03505</td>
<td>37-48 Mo. Recency Buyers</td>
<td>19,270</td>
<td>62</td>
<td>79</td>
<td>$9,880.33</td>
<td>0.41%</td>
<td>$125.07</td>
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<td>House</td>
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<td>Requestors/Inquiries</td>
<td>1,211</td>
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<td>21</td>
<td>$4,296.51</td>
<td>1.73%</td>
<td>$204.60</td>
<td>$3.55</td>
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Drop 1: Spring Preview Postcard Total: 155,513 2,093 2,574 $427,114.58 1.88% $165.93 $2.75

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<thead>
<tr>
<th>Source Group Description</th>
<th>Source Code</th>
<th>Source Code Description</th>
<th>Circulation Qty</th>
<th>Responder Qty</th>
<th>Response Qty</th>
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<td>164</td>
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<td>$21,454.63</td>
<td>1.07%</td>
<td>$133.26</td>
<td>$1.43</td>
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Drop 2: Spring Catalog Total: 317,987 3,372 5,689 $582,795.29 1.15% $158.84 $1.83

Allocated Totals: 473,500 5,463 6,243 $1,008,909.87 1.32% $161.77 $2.13
Data for executing the strategy

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<th>ADDRESS</th>
<th>CITY</th>
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<td>253 WILBRAHAM ST</td>
<td>PALMER</td>
<td>MA</td>
<td>01069</td>
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</tbody>
</table>
Data for measurement

- DMTC - delivery data
- Transactional data
- Response analysis; ROI analysis
The data cycle
How do I get started?

- Inkjet personalization
- Personalized message
- Versioning and/or demographic binding
- Variable data
- Completely variable digital piece
Inkjet personalization
Variable laser imaging
Color inkjet on versioned pieces
Four color inkjet personalization
Fully variable digital print
Highly targeted VDP with PURLs
Driving from print to other channels

- Interactive print
- Content management platform
- Data onboarding
Interactive Print
Launch the Atrable app and "scan" the QR code above to open an auto filled form.
Variable QR

Check out your very own Personalized offer page!

Check out your very own Personalized offer page!
Image Recognition

Launch the Actable app and "scan" the jacket image to see more information and buy online.

Launch the Actable app and "scan" the ad for a related video.
Augmented Reality
Near Field Communications
Content management systems
Data onboarding

- Connecting your customer data to all your marketing platforms
- Measurement
- Targeting
- Leveraging your CMS
Customers say:

• I want to buy what I want, where I want, when I want
• If you won’t let me, someone else will
• I’m more connected than you think
• I value good use of my time
• I like to be educated
• I will respond to a good offer if it’s relevant and takes little effort
• What’s in it for me?
Keep in mind…

- Print is still the major driver of sales
- Channels can’t exist in a vacuum
- You need to be where your customer is (or will be)
- Personalization and targeting increase sales
- You need data to drive your marketing
Keep in mind…

• More is not always better
• Know your data to know your customer
• Build your contact strategy with print in sync with digital channels
• Test, test, test
Media Solutions – IPS & Digital Editions

IPS - Image Recognition & Augmented Reality

Social Media

Personalized eMails

PURL Landing pages

iOS & Android tablet editions and applications

iOS & Android mobile editions and applications
Printed Electronics
Salvation or Snake-oil?

Bruce E. Kahn
Printed Electronics Consulting
265 Viennawood Dr.
Rochester, NY 14618
bkahn@ElectronicsPrinting.com
http://www.ElectronicsPrinting.com/

Clemson University
Graphic Communications
Sonoco Institute
Clemson, SC 29634
bkahn@Clemson.edu
sonocoinstitute.com
US Printing Industry Shipments and Profits

WhatTheyThink
Strategies for Management, Inc.
Printing vs. Manufacturing

Profit Margins: US Printing vs. US Manufacturing, 2001-2013

http://haroldkyle.com/ink-on-paper/printing-profit-margins/
US Printing Industry
Shipments and Employment

© Bruce E. Kahn      TAGA 2015      Albuquerque, NM      March 22, 2015
Options

• Stop Printing!
• Fight!
• Find new markets and opportunities
• Rethink Printing
  – High throughput, multilayer, deposition tool
  – Functional not/(in addition to) visual
Why Functional Printing?

• Large area
• High throughput (volume)
• Flexible substrates
• Additive
How to pattern a layer

Silicon Process

Printing

Xia Yu, RIT, (Polyera)
Why Functional Printing?

- Large area
- High throughput (volume)
- Flexible substrates
- Additive
- Low cost
- Manufacturing
- Robust
False Hopes

• Nanotechnology
  – “A trillion dollar industry by 2015”
    (M. Roco, NSF, 2001)

• RFID
  – “Trillions of devices per year”
    (~ 2003)!

– 250 M$ in 2007 (Roco)
– 26 M$ in 2014 (BCC Res.)
– Enabled?
– NOT
– 6.9 B tags, 8.89 B$ in 2014 (IDTechEx)
More Market Inflation

• “The market for printable electronics will generate estimated revenues of over $7 billion (U.S.) in 2010”
  – Nanomarkets, 9/6/2005

• 3D Printing
  – The relative factor

  – Actual ~ $2 B
  – Manufacturable?
  – Low volume
3D Printing Headlines

- The Economist: Special report: Manufacturing and innovation, A third industrial revolution
  
- Los Angeles Times: 3-D food 'printer' aims to end world hunger, starting with pizza
  
- Science World at Telus World of Science: 3D Printing: The Answer to a Shortage of Human Organs?
  
- Wired: 3D printing 'bigger than internet'

Jon Harrop & Wendy Kneissl
IDTechEx PE USA 2013
Lao Tzu (c. 604 - 531 B.C.)

• Those who have knowledge, don’t predict
• Those who predict, don’t have knowledge
Forecasting

• Never make predictions, especially about the future. Casey Stengel

“... so it turns out it wasn’t opportunity knocking, it was false hope.”
“Killer” apps? (IDTechEx data)

• Billion dollar industries
  – OLED Displays 15.7 (not printed)
  – Sensors 6.42
    • Glucose > 6
  – Conductive inks 2.2
  – Electrophoretic Displays (E-ink) Sales peaked in 2011
### Current Status (IDTechEx)

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<th>Below $50 Mn</th>
<th>$50Mn to $1Bn</th>
<th>&gt; $1 Bn</th>
<th>2014 total: $24.6Bn</th>
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<tr>
<td>OLED Lighting</td>
<td>$18Mn</td>
<td>E-paper displays</td>
<td>$160Mn</td>
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<tr>
<td>Electrochromic Displays</td>
<td>&lt;$1Mn</td>
<td>AC EL displays</td>
<td>$80Mn</td>
</tr>
<tr>
<td>Logic &amp; memory</td>
<td>$3Mn</td>
<td>Sensors</td>
<td>3%</td>
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<tr>
<td>OPV, DSSC</td>
<td>&lt;$1Mn</td>
<td>Printed/thin film batteries</td>
<td>&lt;$5Mn</td>
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Printed: $8.84Bn (going to $14.97Bn in 2024)

Use flexible substrates: $6.41Bn (going to $23.5Bn in 2024)

% CAGR 2015-2020

Displays and Lighting: System Components: Power supply

Printed, Organic, Flexible Electronics 2015-2025, IDTechEx.com
# Current Technologies & Profitability (IDTechEx)

<table>
<thead>
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<th>Component Type</th>
<th>Technology</th>
<th>Technology status 2014</th>
<th>Profitable? (IDTechEx Comment)</th>
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<td>OLED displays</td>
<td>Not printed</td>
<td>Yes (with rapid growth)</td>
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<td></td>
<td>Electrophoretic</td>
<td>Printing like</td>
<td>Borderline (but market is in decline)</td>
</tr>
<tr>
<td></td>
<td>Electroluminescent</td>
<td>Printed</td>
<td>Yes (but market is in decline)</td>
</tr>
<tr>
<td></td>
<td>Electrochromic</td>
<td>Printed</td>
<td>No</td>
</tr>
<tr>
<td>Lighting</td>
<td>OLED Lighting</td>
<td>Not printed</td>
<td>No</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>OPV, DSSC</td>
<td>Some printed</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>CIGS</td>
<td>majority not printed</td>
<td>Break-even (the entire PV industry is barely break even)</td>
</tr>
<tr>
<td>System Components</td>
<td>Logic and Memory</td>
<td>Some printed</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Thin Film Batteries</td>
<td>Some printed</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Sensors and Actuators</td>
<td>Mostly printed</td>
<td>Yes (glucose test strips)</td>
</tr>
<tr>
<td></td>
<td>Conductive ink</td>
<td>All printed</td>
<td>Yes (PV bus bars, touch screen bezels)</td>
</tr>
</tbody>
</table>
OLED Lighting (not Displays)

• The US has invested $17.5 Billion in incentives/loans:
  • 4.1 GW of capacity
  • 0.4% penetration

IDTechEx/Jed Dorscheiner (2012)
Largest reported carrier mobility


Klauk, CSR, 2010, 2643
Annual Trade Balance in Goods with Advanced Technology Products

Billion $

Year

US Census Department

© Bruce E. Kahn      TAGA 2015      Albuquerque, NM      March 22, 2015
Annual Trade in Goods
with Advanced Technology Products

Billion $


Year

US Census Department

Exports
Imports
Balance
The Administration’s Early Focus on the U.S. Manufacturing Sector...

“I want us all to think about new and creative ways to engage young people in science and engineering ... encourage young people to create, build, and invent to be makers of things, not just consumers of things"

President Obama - 2009 National Academy of Sciences Annual Meeting
The report details the strengths of the basic research being conducted in Europe and the vitality of the close partnerships between university groups, basic research laboratories, industry, and innovation centers, sustained by sizeable research grants that specifically promote such interactions and efficiently support development.
The Flexible Electronics Opportunity (1/2015)

A. The United States should increase funding of basic research related to flexible electronics and augment support for university-based consortia to develop prototypes, manufacturing processes, and products in close collaboration with contributing industrial partners.

B. Consortia, bringing together industry, universities, and various levels of government, should be used as a means of fostering precompetitive applied research in flexible electronics.

C. The United States should establish and support a network of user facilities dedicated to flexible electronics.

D. Where possible, federal efforts to support the growth of competitive flexible electronics industries should leverage state and regional developmental efforts, with the objective of establishing co-located local supply chains and capturing the associated cluster synergies.

E. Agency mission needs should help drive demand for flexible electronics technologies, while lowering costs, improving capabilities, and contributing to the development of a skilled workforce.
The future is promising if you look in the right places
I’m from the government and I’m here to help you!
Manufacturing Innovation Institutes

- America Makes (The National Additive Manufacturing Innovation Institute), August 2012
- **Power** America (Next Generation Power Electronics Manufacturing Innovation Institute), January 2014
- Institute for Advanced Composites Manufacturing Innovation (IACMI), January 2014
- **Digital Manufacturing** & Design Innovation Institute (DMDII), February 2014
- Lightweight Innovations for Tomorrow (LIFT, Lightweight Modern Metals Manufacturing Institute), February 2014
• He *really* means Flexible Hybrid Electronics
• Sensors can be printed too!
• (Including these two)
• Energy
• Workers
• Innovation
Flexible Hybrid Electronics MII

The Department of Defense will lead a competition for a new public-private manufacturing innovation institute in flexible hybrid electronics, combining $75 million of federal investment with $75 million or more of private investment. The modern world is filled with electronics: computers, cell phones, sensors, and literally trillions of small devices that make American lives better, if somewhat busier. The vast majority of these electronic devices are made up of boxy, rigid circuit boards. But in the world around us, most things are not flat or boxy; our bodies, the environment, the vehicles that transport us all tend to reflect an organically derived shape with plenty of curves and flexibility. Flexible hybrid electronics combine advanced materials that flex with thinned silicon chips to produce the next generation of electronic products seamlessly integrated into the things around us. These include items as diverse as comfortable, wireless medical monitors, stretchable electronics for robotics and vehicles, and smart bridges capable of alerting engineers at the first signs of trouble. For the nation’s warfighters, these new technologies will make lifesaving advances and improve mission effectiveness. For example, intelligent bandages and smart clothing will alert soldiers to first signs of injury or exhaustion; structural integrity sensors will offer real-time damage assessment for helicopters or aircraft after engagement; and small, unattended sensors will give soldiers greater situational awareness.
DoD Institute #5
Flexible Hybrid Electronics
Manufacturing Innovation Institute

Flexible Hybrid Electronics
Highly tailor able devices on flexible, stretchable substrates that combine thinned CMOS components with components that are added via “printing” processes. This technology is identified as flexible-hybrid due to integration of flexible components such as circuits, communications, sensors, and power with more sophisticated Silicon based processors.

<table>
<thead>
<tr>
<th>Commercial</th>
<th>DOD Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearable Technologies</td>
<td>Warfighter information devices and sensors</td>
</tr>
<tr>
<td>Internet of Things</td>
<td>Unattended sensors, vehicle borne sensors</td>
</tr>
<tr>
<td>Medical prosthetics, medical sensing</td>
<td>Warfighter Training and performance monitoring, Soldier medical care</td>
</tr>
</tbody>
</table>

POTUS Announcement– December 12, 2014
Government Subject Matter Expert Team
160 Industry, Non-profit, and Academic Responses

Dept of Defense (OSD Manufacturing Technology)
Lab Physical Sciences
DoD Lab

Dept Army  Dept AF  Dept Navy
Defense MicroElectronics Activity
Office Sec Defense
DTRA  SOCOM

Dept Energy
NIST
NASA
NIH
National Institute of Biomedical Imaging and Bioengineering

Dept Education

25 RFI Written Responses representing 40 organizations
10 Letters of Endorsement
102+ participants Webinar (NIST AMTECH Grant)
12 Industry one-on-one dialogue with OSD
Global Challenges

- Air
- Water
- Food
- “Green”

- Energy
  - Storage
  - Production/Harvesting/Transduction
  - More efficient Devices
Global Challenges (PE Contributions)

- **Air**
  - Sensors

- **Water**
  - Sensors
  - Filtration/Purification

- **Food**
  - Sensors

- **“Green”**
  - Additive Deposition
  - Additive Manufacturing

- **Energy**
  - **Storage**
    - Batteries
    - Supercapacitors
  - **Production/Harvesting/Transduction**
    - Solar
    - Vibration
    - RF
  - **More efficient Devices**
    - OLED Displays
    - LED Lighting
Ambient RF energy harvesting using printed metamaterials

Bruce E. Kahn
Clemson University
And now, for something completely different
This Project

- Energy Harvesting
- Meta-materials
- Printed Electronics
- Flexible Hybrid Electronics
- Si Electronics
Energy Harvesting (Scavenging)

- Means of powering electronic devices by scavenging many low-grade ambient, or "wasted" energy sources such as environmental vibrations, human power, thermal gradients, or pressure gradients, and their conversion into useable electrical energy.

- Potentially attractive as replacements for primary batteries in low power applications.
Ambient Power Density
(before Conversion)

Boisseau & Despesse, EE Times, 2/27/2012
Number of Publications (SciFinder)

- Photovoltaic: 14,000
- Piezoelectric: 12,000
- Vibration: 800
- Thermal: 400
- Chemical: 200
- RF: 0

© Bruce E. Kahn      TAGA 2015      Albuquerque, NM      March 22, 2015
Ambient RF sources

- TV
- Radio
- Cellphone
- Wi-Fi networks
- Base stations
- Routers
- Communications devices
Why Harvest RF?

- Can reuse broadcast RF
  - 1 uW is a fraction of 10 mW Zigbee (Bluetooth, WiFi)
- Ubiquitous in urban environments
  - Day and night
  - Inside and out
  - Stationary or mobile
- No added energy cost
- Industrial design
  - RF goes through most materials
  - Can reuse antennas
Computing Energy Efficiency

Gollakota et. al., Computer, 32, 1/2014
Cell Phone Statistics

• More people around the world have cell phones than ever had land-lines

• There are nearly as many mobile subscriptions as there are people on earth
Trends

• Power efficiency
• RF availability
• RF → DC efficiency
• RF energy harvesting
RF Power Spectrum at City Location

Nasab, et. al., Active and Passive Electronic Components, 2010
RF Power Density (London)

Piñuela et. al., ITMTT, 2013, 2715
## Frequency Bands

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>DTV</td>
</tr>
<tr>
<td>850/900</td>
<td>GSM (US/Europe)</td>
</tr>
<tr>
<td>1800/1900</td>
<td>GSM (US/Europe)</td>
</tr>
<tr>
<td>2100</td>
<td>3G</td>
</tr>
<tr>
<td>2400</td>
<td>WiFi, Bluetooth</td>
</tr>
<tr>
<td>5000</td>
<td>WiFi</td>
</tr>
</tbody>
</table>
AM (MW) Radio Transmitters

http://fmscan.org/coverage.php?band=mw
Metamaterials

• “Artificially” engineered structures that exhibit properties not found in naturally occurring materials.

• Assemblies of multiple individual elements fashioned from conventional materials, but the materials are usually constructed into repeating patterns, often with microscopic structures.

• Properties are derived not from the compositional properties of the base materials, but from their structures.
Inspired by Nature
Properties of metamaterials are mostly dependent on their geometry.
Metamaterial Applications

• Negative refractive index
  – Bend light “backwards”
• Invisibility cloak
  – Make things “disappear”
• Flat lenses
• Superlenses
  – Resolution beyond diffraction limit
Metamaterial Advantages for RF EHA’s

• Wide bandwidth
• Multiband absorption
• Electrically small (can be 10X smaller than conventional)
• Could absorb > 3X more energy than similar size rectenna
Multiple Frequency Absorption
Examples
Why Print RF metamaterials

• Critical dimensions  
  – sub mm
• Large area
• Easy to control spacings

• Flexible
• Thin
• Lightweight  
  – Rollable, stowable, foldable
# Available Power Density

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Mobile Phone</th>
<th>WiFi router</th>
<th>GSM Base Station</th>
<th>AM Radio Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>800-900</td>
<td>2400, 5000</td>
<td>850, 1900</td>
<td></td>
<td>0.535-1.605</td>
</tr>
<tr>
<td>Transmitted Power (W)</td>
<td>0.5</td>
<td>1</td>
<td>100</td>
<td>50,000</td>
</tr>
<tr>
<td>Distance (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>40,000</td>
<td>80,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1,600</td>
<td>3,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>400</td>
<td>800</td>
<td>80,000</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>8</td>
<td>800</td>
<td>400,000</td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td>16,000</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>5000</td>
<td></td>
<td></td>
<td></td>
<td>160</td>
</tr>
<tr>
<td>10000</td>
<td></td>
<td></td>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

**Needs**

- Large Area
- High Efficiency
Ambient Power and Device Consumption

Typical sensitivity range of cellphones: $10^{-8} \sim 10^{-3} \mu W$

Cellular: $5 \mu W@100 \text{ m distance using Eq. (1) with } \lambda/2 \text{ dipole antenna}$

Measured WiFi power density ($1\text{nW} \sim 1\mu W$) in IST Build., PSU, PA, USA

RFID: $45 \mu W/4.5 \text{ mW@10/1.0 m distance using Eq. (1) with } \lambda/2 \text{ dipole antenna}$

[A] A 12-bit 250 S/s A/D converter in 65nm CMOS
[B] A biomedical sensor interface
[C] A glucose sensor
[D] A temperature sensor
[E] A biomedical transmitter
[F] A neural/multimedia transmitter
[G] A UWB transceiver
[H] A wireless transceiver and 16-bit MCU: PIC24F
[I] A 4.0 W 2.4 GHz WiFi or 915 MHz RFID reader

Li, INEWCAS, 2014, 73
Recently Reported RF Powered Systems

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>System function</td>
<td>Glucose sensor</td>
<td>Battery charging</td>
<td>Temperature sensor</td>
<td>Biomedical transmitter</td>
<td>Neural/EMG telemetry</td>
<td>Wireless transceiver</td>
<td>Audio/Image transmission</td>
<td>Wireless transceiver</td>
</tr>
<tr>
<td>RF signal sensitivity</td>
<td>15cm @ 10W EIRP</td>
<td>/</td>
<td>-12 dBm</td>
<td>-6 dBm @ 918 MHz</td>
<td>1.5 m @ 4W EIRP</td>
<td>-17.1 dBm</td>
<td>4 m @ 4 W EIRP</td>
<td>14 dBm @ 900 MHz</td>
</tr>
<tr>
<td>Carrier frequency</td>
<td>1.8 GHz</td>
<td>950 MHz</td>
<td>900 MHz</td>
<td>918 MHz, 306 MHz</td>
<td>915 MHz</td>
<td>915 MHz, 2.45 GHz</td>
<td>915 MHz</td>
<td>7.9 GHz</td>
</tr>
<tr>
<td>Modulation scheme</td>
<td>FM-LSK</td>
<td>/</td>
<td>EPC</td>
<td>OOK</td>
<td>BPSK</td>
<td>FSK/OOK</td>
<td>BPSK</td>
<td>UWB</td>
</tr>
<tr>
<td>Process</td>
<td>0.13 μm CMOS</td>
<td>0.18 μm CMOS</td>
<td>0.13 μm CMOS</td>
<td>0.13 μm CMOS</td>
<td>0.35 μm CMOS</td>
<td>90 nm CMOS</td>
<td>PCB</td>
<td>0.13 μm CMOS</td>
</tr>
<tr>
<td>Power consumption</td>
<td>3 μW</td>
<td>/</td>
<td>16 - 33 μW</td>
<td>50.6 μW</td>
<td>1.23 mW</td>
<td>0.85 mW</td>
<td>1.23 mW</td>
<td>10.9 mW</td>
</tr>
<tr>
<td>Energy harvesting efficiency</td>
<td>20% (peak)</td>
<td>40% @ -11 dBm input</td>
<td>36.6%</td>
<td>20-30%</td>
<td>20.6%</td>
<td>/</td>
<td>20.6%</td>
<td>/</td>
</tr>
<tr>
<td>Data rate</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>4 Mbps</td>
<td>5 Mbps</td>
<td>5 Mbps</td>
<td>5 Mbps</td>
<td>112 Mbps</td>
</tr>
</tbody>
</table>

Li, INEWCAS, 2014, 73
Dragonfly Biotelemetry

- Battery free < 36 mg
- Data rate 5-96 Mbps
- Tx 4W ISM 902-928 MHz
- “Backpack”
  - 2.36 x 1.88 mm die
  - 4.6 x 6.8 mm flex circuit
  - 1.31 mW
  - 1.5 m range

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Gollakota et. al., Computer, 32, 1/2014
Potential Applications

- Low power devices
  - Microcontrollers, displays (e.g. E-ink), RF transceivers, and others
- Charge batteries
  - Smartphones, bluetooth devices, and other portable devices
- Battery-free wireless network sensor applications
  - Unattended ground sensors (UGS), environmental monitoring and building automation (e.g. temperature sensor)
- Military applications
  - UAV recharging, powering wearable tracking devices, and covert surveillance sensors.
- Internet of Things (IoT)
  - Untethered, autonomous, self-powered machine to machine (M2M) devices.
“PARC Paperclip” Design Concepts

- Coupled Split-Ring Resonator
- The metamaterial elements (2 split-ring resonators) are connected (coupled) in a racetrack configuration.
- Inductance
  - The size of SRR’s
- Capacitance
  - The azimuthal gap of the SRR’s
- Impedance
  - Antenna gap
“PARC Paperclip” Advantages

• High efficiency
• Wide bandwidth
• High gain
• Nearly isotropic
Wide Bandwidth

![Graph showing VSWR vs Frequency (MHz)]
This is NOT Inductive Coupling!
Antenna + Coplanar Waveguide (1x3 Array)
Hybrid Energy Harvester

Inductors
Capacitor
Diodes
Capacitor

Capacitor Bank
Demonstration 1: Continuous Discharge

- LED
- 2-3 mW
- ≥ 1.7 V
Demonstration 2: Energy Storage

- Energy is stored in capacitors
- Energy is discharged through LED when button is pressed
Skin Depth

Antenna Thickness (µm)

% RF Absorbed

AM 0.535-1.605 MHz
ISM 13.56 MHz
Phone 800-900 MHz
GSM 850 MHz
GSM 1900 MHz
WiFi 2400 MHz
WiFi 5000 MHz

% RF Absorbed

Antenna Thickness (µm)
The Team

Clemson
• Liam O’Hara
• Chip Tonkin

Tampere UT (Finland)
• Don Lupo
• Miao Li

PARC
• Printed Electronics
  – Greg Whiting
  – Ping Mei
• Metamaterials
  – Bernard Casse
  – Armin Völkel
  – George Daniel
  – Victor Liu
Sponsors

FlexTech Alliance

DuPont Teijin Films
• “Most people make the mistake of thinking design is what it looks like. People think it’s this veneer – that the designers are handed this box and told, ‘Make it look good!’ That’s not what we think design is. It’s not just what it looks like and feels like. Design is how it works.” – Steve Jobs, 2003

• Don’t make fashion, make function!
Editors
B. Kahn  Patternning processes for flexible electronics
N. Morrison  An Overview of Process & Product Requirements for Next Generation Thin Film Electronics, Advanced Touch Panel Devices and Ultra High Barriers
J. MacKenzie  Perspectives on Energy Storage for Flexible Electronic Systems
V. Subramanian  High-speed printing of transistors: From Inks to Devices
G. Cho  Key issues with printed flexible thin film transistors and their application in disposable RF-sensors
J. Hester  Additively Manufactured Nanotechnology and Origami-enabled Flexible Microwave Electronics
J. Veres  From printed transistors to printed smart systems
J. He  Inorganic Materials and Assembly Techniques for Flexible and Stretchable Electronics
D. Hackler  Enabling Electronics with Physically Flexible ICs and Hybrid Manufacturing
S. Lee  Transparent Semiconducting Oxide Technology for Touch Free Interactive Flexible Displays
V. Misra  Flexible Technologies for Self-Powered Wearable Health and Environmental Sensing
R. Ghaffari  Catheter-Based Systems with Integrated Stretchable Sensors and Conductors in Cardiac Electrophysiology
N. Verma  Enabling Scalable Hybrid Systems: architectures for exploiting large-area electronics in applications
The Rules

1. Silicon
   - Sheats’ Rule (Jim Sheats, NanoSolar)
     - If it can be done with Si, it will be!
   - Bob’s Rule (Bob Reuss, DARPA)
     - Don’t mess with Texas Silicon
       - Corollary: You better have a darned good rule not to use Si!

2. Ink-jet Ink
   - Hakola’s Rule (VTT, Finland)
     - If it is easy to formulate, it doesn’t perform well, and vice versa.
   - Joe’s 1st Rule (Steve Jones, Printed Electronics, Ltd., UK)
     - An ink’s functionality is inversely proportional to its jettability.
   - Goldberg’s Corollary
     - No pain, no gain!

3. Kahn’s Rules
   - High volume and low cost (particularly over large areas) can not be achieved a drop at a time.
   - Nature abhor’s a vacuum – and so do I!
     - Vacuum’s Suck!
References


References


• International Telecommunication Union, ICT Data and Statistics

• Societal Implications of Nanoscience and Nanotechnology
  – National Science Foundation, 2001

• https://www.whitehouse.gov/photos-and-video/video/2014/12/11/president-obama-meets-export-council

• https://www.census.gov/foreign-trade/balance/c0007.html
Achieving the Newest Generation of Flexo Plate Capabilities and Its Implementation

Dr. John Anderson
WW Business Development Packaging
Eastman Kodak
Introduction

- Introduction
- Issues Faced By Flexo In 2007
- Foundations Of Flexcel NX
- Continued Challenges In Flexo
- Next Generational Solutions
- The Future Opportunities With Flexo
- Conclusions
The Issues Faced In 2007 By Flexo

- Flexo in 2007 faced many challenges and issues to continue its growth in the global market place:
  - *Inconsistency was the normal*
    - Round top dots were sensitive to operator impression changes and wear
    - Heavy ink usage but still poor solid ink densities caused “muddy” colors
  - *Increased costs for digital plates*
    - Insufficient plate life, long setup times, and on press inconsistency
  - *One dominant imaging technology in LAMS (Laser Ablative Mask System) for all digital plates – “good enough” limited innovation*
    - Carbon layer or black polymer mask layer with high power lasers
  - *Lack of innovation drove brands to relook at offset and rotogravure*
    - Supported by innovation in offset plus gravure imaging and costs
Foundations Of Flexcel NX

- IN 2008 Kodak commercialized the Flexcel NX system
- New Flexo plate system that introduced digital flat top dots to the mass flexo market
- It had 5 unique initial foundations
- DigiCap NX was introduced in 2010 to address the solid ink densities
Core Technologies For Flexcel NX In 2008

- SQUAREspot imaging is foundation of offset printing, 16,000 CTP in the market, up to 450 LPI AM & FM
- TIL - Thermal dye based multi-layer ablative film, capable of 800 lpi
- One NXH plate for all applications (except corrugated post-print) specified at 300 LPI, 0.4-99.6%
- Combined in one optimized solution

Albuquerque, NM 2015
SQUAREspot Technology

Gaussian Laser

Other imaging (thermal & visible) ~15 microns

laser spot from CTP

halftone dot on plate (50%)

2400 dpi grid

SQUAREspot Laser

SQUAREspot imaging

10.6 microns

2.5 microns

2400 dpi grid

SQUAREspot Laser

2,400 dpi

10,000 dpi (4x4)

Albuquerque, NM 2015
Core Technologies For Flexcel NX In 2008

- Once the TIL is imaged, need to transfer image to NXH plate
- Simple flat bed lamination
- Results in digital flat top dot
- Exclusively produces Pixel-For-Pixel imaging from digital file to plate
- Utilizes offset dither technologies
  - “Camouflage for transitions”
- Simplifies proofing and color matching
- Predictability and consistency addressed!
Exclusive Pixel For Pixel Reproduction

- Unmatched exclusive imaging technology

File Bitmap | Imaged TIL | Flexcel NXH Plate
---|---|---
![File Bitmap](image1.png) | ![Imaged TIL](image2.png) | ![Flexcel NXH Plate](image3.png)

67th Annual Technical Conference
tagaatc.printing.org
Digicap NX - Using The Imaging Technology

- Pin-holing and solid ink density remained a major limitation for all Flexo
- Plate transfers the pattern from the anilox roll to the substrate
  - *Cell and Cell Wall cause voids or pin-holes*
- DigiCap NX breaks up the cell pattern on the plate surface, to stop its transfer

Using 5x10 Micron Elements

Albuquerque, NM 2015
DigiCap NX

No surface texturization

Kodak DigiCap NX Screening Applied

Traditional plate cell patterning applied

Albuquerque, NM 2015

67th Annual Technical Conference
tagaatc.printing.org
Plate Innovation Alone Is Not Enough – Implementation Is A Team Activity!

- Despite any leap forward in one component or technology, in printing and particularly Flexo it is not until the rest catch up that the true benefits are seem!
  - *Flexo is a system, press, ink, anilox, metering, tape, plate, substrate, drying and the press operators*
  - *Prepress required higher resolution images, for file preparation*
  - *Brands need education on what Flexo is now capable of*
  - *The whole industry is in catch up mode after a major innovation*

- Brands and end customers only see the main stream implementation 2-5 years later
  - *Was the same with 60° anilox rolls, LAMS digital plates, quick change sleeves, gearless presses*
Continued Challenges In Flexo In 2014

- **Color & Color Fidelity**
  - Pin-holing with heavy anilox volumes – whites, coatings
  - Color tonal range – spot or four color vs expanded color gamut pros & cons
  - Cleanliness of colors – relates to white base and process builds

- **Print Details**
  - Fades to zero without grainy hybrid screens
  - Keeping reverses open and clean with heavy anilox volumes
  - Dirty print and its effect on process productivity

- **Economics & Competition**
  - Relatively heavy ink deposits & effect on costs or productivity
  - Cost control for brands, looking for more for less
  - Competitive demands to increase resolution – match the 175 LPI used in Rotogravure to enable greater conversion
The Importance Of Pin Holes To Color

- White inks are applied using high volume anilox rolls
- Very high ink volumes are used to avoid pin holes and achieve opacity
- White is the base for other colors
- Pin holes cause darkening of print, and color shift
- TAGA members spend a lot of time measuring color, but how much of a $\Delta E$ is caused by the white issues?

Albuquerque, NM 2015
Pinholes Relate To The Color, Color Cleanliness And Final Tonal Range

- Image shows 2 white ink images, magnified 200X pictured over a black background, one with pinholes, one without
- Color overlay with 50% transparency illustrates the effect caused by pinholes
Next Generational Solutions

- Address white ink transfer as the base for colors
- Address highlight structure:
  - Smoother hybrid screens minimizing graininess for high resolution flexo
  - Isolated dot robustness with modern platemaking
Addressing High Volume Anilox Rolls

- The range of anilox rolls used in Flexo is huge:
  - Very low volumes for UV and process inks
  - Very heavy volumes for white and coatings
- Achieve the improved ink laydown and minimal pin holes without increasing ink usage
  - No single patterns fits all applications, but needs simple selection & implementation
  - Anilox volume is a critical parameter
- Tuesday paper will cover this in more details

Albuquerque, NM 2015
Addressing Highlights

- Modern Hybrid screening optimized for flexo using SQUAREspot technology
  - 85-250 LPI with smoothest results
- Improved dot robustness with modern main exposure times
  - Utilizing “Light valve” technology first patented by Kodak for LAMS plates
  - Using same 5x10 micron elements as used in DigiCap NX
Addressing Highlights - Hyperflex NX

Without Hyperflex NX

With Hyperflex NX

Albuquerque, NM 2015
The Future Opportunities Using Flexo

- Improved ink transfer with lower volume applications
- Conversion of gravure markets to flexo
  - Must match or better gravure printing
  - Addressing demands from brands for shorter runs and more frequent design updates
- Security printing to differentiate from digital and other print processes
- Printed electronics and functional printing
Conclusions

- The flexographic printing process has advanced significantly in the last decade
- Major advances in one technology, drives advances in the full system to maximize the effect
- Major improvements and enhancements are still available in imaging and application on press
- The next generation of improvements focuses on ink laydown and highlight improvements
- Much more to come for Flexo!
Any Questions?

john.anderson3@kodak.com
Especially For You Students Present

Packaging Is A Secure Job Market!

A WORLD WITHOUT PRINT

Albuquerque, NM 2015
If Paper is the 5th Color, OBA’s are the 6th and Beyond!

Don Schroeder, Director of Solutions Development
Fujifilm North America Corp
GSD
An Educational Presentation on OBA’s

A FUJIFILM Presentation

Don Schroeder, Director Solutions Development
Optical Brightening Agents...Why all the fuss

- Who has had issues with OBA’s in a job?
- When in the production cycle did it become an issue?
- How much time did it take to resolve?
- Was there a clear and definitive solution to the problem?
- Has it been resolved so it does not happen again?
What is the problem in the production stream?

- A Print specifier decides on a paper not knowing if it has OBA’s or not…and if they do know, have they communicated this to the printer? More often than not …no, but would this alone solve the problem? No…
- Most print specifiers want the best, brightest, whitest, paper they can buy at a price that is attractive to them…
- In the USA most paper manufacturers are responding with more brighteners due to the competitive nature of papers made internationally….mainly Asian Pacific Rim
- The problem of matching a color or standard now falls on the Printer!
Who’s got the ball?

- Now let’s say a Print Specifier and Agency want to make a “Marketing Campaign” Let’s say for “Don’s Dream Boats Inc”
- This means, offset printing for ad’s in trade publications, direct mail pieces from digital printing, wide format printing for poster boards and point of purchase displays, and they want all the images and corporate logos to match…and they want it all printed to GRACoL color space…sound familiar?
Who’s got the ball?

- Now what happens when the paper for offset, the paper for digital and the poster board for wide format all have different levels or some have no levels of OBA?

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<tr>
<th>SPORT SERIES</th>
<th>SLX SERIES</th>
<th>SUNDECK SERIES</th>
<th>SPORT CRUISERS</th>
<th>SPORT YACHTS/YACHTS</th>
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View prior model years
What do OBA’s look like

**OBA’s are colorless or slightly colored organic compounds**
Why OBA’s in Paper or Media?

- OBA’s are used to make paper appear more white!
- OBA’s use fluorescence to absorb invisible radiation from the UV light spectrum and re-emit the radiation as light in the visible blue range.
- The OBA’s add blue light to the reflected light
- The additional blue light offsets the yellowish tinge in the reflected light
- Thus the increase the visible brightness of the material
Principles of Optical Brightening

OBA’s absorbs ultraviolet light and re-emits most of it at between 400 and 500 nm as blue fluorescent light.
OBA’s

- Most coated papers have a b* value of -4 to -10 (The b* measurement is the blue-yellow axis of the L*A*B*)
- For uncoated papers or wide format vinyl's or boards it can be higher -14 b*
- OBA’s fade, the paper yellows over time, and have environmental issues.
- But one larger issue remains…Standards
Standards and OBA’s

- ISO and US Print standards specify paper that is a neutral white
- Years of press runs and media measurements have been made to make international data sets
- The problem is not that the paper is too white, it is that measurements might not match our perception!
- To a Spectrophotometer the brightened papers appear blue. Our eyes adapt to the paper, it appears White

Color Perception

3 factors that influence the perception color

1. Light source
2. Object being viewed
3. Observer (person)
So lets take a closer look at what we have learned to this point..

- OBA’s make the paper whiter, some more than others depending on the amount and the light spectrum..
- OBA’s shift the color appearance to the blue portion of the visible spectrum….?
- If we can see the shift to the blue…, what do you think a Spectral Device that measures color see’s?
- And if this high tech tool see this shift while making a color profile what do you think the color engine will try to do when making a profile to a standard such as GRACoL?
Answer....

- Throws more Yellow at it!
Proof to Press Match

- Modern Print Standards such as GRACOL, SWOP 3 & 5 are based on Spectrophotometric readings.
- Works well with ISO 12647-2 medias, but they are becoming harder to find.
- When paper has OBA's (Blue) the measurements are no longer accurate.
- When we calibrate using these wrong measurements we get a proof to press match that is not visibly accurate. Most often an extreme yellow cast due to the CMM information trying to add yellow as it thinks.
Let's take a look..

Papers in a normal light booth with no or minimal UV

Papers in an ISO 3664 / 2009 light booth with UV included

Papers in highly agitated UV light booth
Lighting Specifications

• ISO 3664:2009 The main difference between the old vs. new standards is that the new one closer incorporates the amount of UV energy present in D50 viewing conditions. *(This is daylight with high UV)* UV affects the way light is reflected from paper, especially if this paper has optical brighteners.

• This new standard now shows the effects of OBA’s
See how Lighting can effect change….

Epson 9800 on Epson Media M0, Epson 9900 on Epson Media M0, Epson 9900 on Oris Media M1, Sappi Opus Press Sheet, Sappi McCoy Press Sheet and NewPage Sterling Press Sheet

Albuquerque, NM 2015
See how Lighting can effect change....

UV Booth at Fujifilm Hanover Park IL

Albuquerque, NM 2015
See how Lighting can effect change....

UV Booth at Fujifilm Hanover Park IL
Other Industries with OBA’s

- Optical Brightners for Plastic
- Optical Brightners for Paper
- Optical Brightners for Fibers
- Optical Brightners for Tape
- Optical Brightners for Labels
- Optical Brightners for Adhesives

- Optical Brightners for Polymer
- Optical Brightners for Rubber
- Optical Brightners for Paint
- Optical Brightners for Coatings
- Optical Brightners for Inks
- Optical Brightners for Film

Laundry Detergent

What’s left on your clothes after washing
So where do we go from here?

- By educating everyone on the issue at hand brings “light” to how we all need to work together to understand the situation
- OBA’s have become a topic in Proof to Press match, Press to Digital match, Digital to Wide Format match and even Press to Flexo label match
- Knowing your substrate will most certainly assist in the better ability to match to a standard
The Paper is the issue but also the illumination as well...

- Spectral remissions using brighteners change with illumination!
- Without brighteners the remission curves of the same substrate are equal
- Blue paper does not mean it has brighteners in it!
- You can only detect brighteners by changing the illumination (i.e. with or without UV cut filter)
- The measurement devices do NOT give wrong measurements!
- They only use a different illumination than later for (human) observation.
- It is not an error of the measurement device, but the fact that the illumination changes the brighteners are used, and our eye interprets bright blue as white

"I see that Dufus McDufus will have a presentation on that topic later today"
The Paper is the issue but also the illumination....

- M0 / M1 (the two illumination options for graphic arts measurement using spectros) measurements identify and improve on the problem of consistent / comparable measurement data, but do not solve the issues of different measurements and viewing illumination, both don’t use true D50
- MO / M1 measurements do not use real D50/Dxx illumination, because it does not currently exist, they use models, double measurements with different illumination / assumptions of brighteners to approximate the target illumination.
- Software solution may detect brighteners (in Spectral data only) and “compensate” it very well. Compensation means either it may reduce (simulate UV-Cut only) or increase (simulate more UV) the impact of brighteners. Still the relation between UV of the measurement and the viewing illumination must be known, and this is the critical point.

Dr. TwinkleButt is going to investigate the problems with getting this to work"
What’s being done to help

- Measurement companies such as X-Rite and Konica Minolta and Techkon, Barbieri, are making devices and software to assist in knowing when these OBA’s are present and help in the proper Illumination of these OBA’s
- Industry Organizations such as PIA and IDEAlliance are actively challenging and pursuing new standards to help in this issue
- Manufacturers of Graphics Arts solutions are assisting in the education of this issue and developing Solutions and software to help this issue
- Consultants and manufacturers are actively educating buyers, users and students on this topic
Educate and understand the technical terminology

- M0: does not define UV energy, and does not completely define the illuminant condition. By definition older instruments currently in use in the graphic arts are M0. While the UV level of these instruments is typically known, they are not held to any tolerances in manufacture, and all levels of UV are considered within specs for M0.

- M1: contains a defined amount of UV energy for use with brightened stocks.

- M2: contains a specification for UV cut or UV filtered illuminant condition.

- M3: contains a specification for UV cut or UV filtered illuminant condition as well as for polarization.
Educate and understand the technical terminology

- So what does this mean to you!

  - You need to know which measurement standard is being used
  - All the new 2013 datasets are using M1 measurement
  - All of the old 2006 datasets are using M0 measurement
Educate and understand the technical terminology

- 2013/1014 Dataset and Standards using M1
  - GRACoL 2013 CRPC6, SWOP 2013 CRPC5
  - CGATS 21
  - ISO FDIS 15339:
  - ISO 12647:2013
Konica Minolta FD Series

Uniquely corresponds to Measurement Condition M1 of ISO 13655

The world's first M1 type.
Konica Minolta's original VFS (Virtual Fluorescence Standard) technology enables \( L^*a^*b^* \) measurements corresponding to ISO 13655 Measurement Condition M1 (CIE Illuminant D50).
In addition, color measurements corresponding to ISO 13655 Measurement Conditions M0 (CIE Illuminant A) and M2 (Illumination with UV-cut filter) can also be taken.

When using conventional instruments to measure materials printed on substrates containing fluorescent whitening agents (FWA), large differences between the results of measurements and visual evaluation may occur. With the new FD-7/FD-5, measurement results correspond more closely to visual evaluation results, including the effects of any FWA in the paper.
Barbieri Solutions

Find the right device for you
Use our product assistant

SpectroPad Series 2
The portable professional spectrophotometer to measure most variety of different reflective media used in professional digital printing (including large and wide format).

SpectroPad (display during measurement)

BARBIERI “qb-technology” inside

Find representative near to you

Instructions

Position and move head when ready!

Please measure Line <D>

Measuring speed indicator

Albuquerque, NM 2015
Techkon Solutions

Techkon is the largest supplier of scanning spectrophotometers for most press manufacturers. Techkon's handheld and scanning densitometers and spectrophotometers have been widely accepted tools in the commercial printing market for nearly three decades. Our SpectroDens spectrophotometer/densitometer and SpectroPlate digital microscope enable the critically accurate color measurements required in the high quality, demanding commercial print environment. The high throughput scanning capability of the SpectroDrive and the SpectroJet provides unmatched color accuracy and repeatability for every press sheet. The E55000 Inline Spectrophotometer offers similar quality color measurement for the latest high-speed digital print engines.

**SpectroDens | Spectro-Densitometer**

A fast, highly accurate handheld spectrophotometer and easy-to-use densitometer.

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**Commercial Printing**

Techkon is the largest supplier of scanning spectrophotometers for most press manufacturers. Techkon’s handheld and scanning densitometers and spectrophotometers have been widely accepted tools in the commercial printing market for nearly three decades. Our SpectroDens spectrophotometer/densitometer and SpectroPlate digital microscope enable the critically accurate color measurements required in the high quality, demanding commercial print environment. The high throughput scanning capability of the SpectroDrive and the SpectroJet provides unmatched color accuracy and repeatability for every press sheet. The E55000 Inline Spectrophotometer offers similar quality color measurement for the latest high-speed digital print engines.

**Recent Posts**

- Pre-Launch of Newest SpectroDens | Densitometer and Spectrophotometer
- How does paper color impact your G7 compliance?
- 8 Questions to Ask Before Purchasing Your Next Handheld Densitometer
- LED versus incandescent Lighting
- Accurately Communicating Color from Design to Press
X-Rite Solutions

Brochures
L7-439 Optical Brightener Compensation - What is it? 618 kb (pdf)
L7-519 H-Pro 2 Family Brochure 14.5 mb (pdf)
L7-532 Print and Packaging Training and Services 1.1 mb (pdf)
L7-533 Ink Formulation Software 1.2 mb (pdf)
The M Factor... What Does It Mean? 1.2 mb (pdf)

User Guides & Operation Manuals
NEW - i1iO Quick Start Guide 1.7 mb (pdf)

Get More Information
Sales/Support:
800-248-9748

Contact Us

Albuquerque, NM 2015

67th Annual Technical Conference
tagaaatc.printing.org
Applications and Solutions that support M1 to date
(as of 3/2015)

- FUJIFILM ColorPath Sync
- Xrite I1 Profiler
- SpotOn! Verify
- Alwan Print Standardizer
- Babel PatchTool
- Babel CT&A
- BasICColor
- Most RIPs….EFI, CGS, GMG
See how Lighting can effect change....

Same Office Furniture same carpet and wall paint...different light bulbs!

Albuquerque, NM 2015
Light Booths what can you do

1. Maintain and replace your bulbs with new ISO 3664:2009 compliant bulbs. If you need help determining if your bulbs are compliant contact your manufacturer. There is also information on ISO 3664-2009 bulbs at http://www.gracol.org. Note that it is important that everyone in your production workflow (customer and printers) use the same bulbs.

2. If you encounter problems you may choose to use a UV filtering lens in your viewing booth. Both JUST Normlicht and GTI include or make UV filtering lenses for their viewing booths. A UV filtering lens will block the UV light from passing through, and will make the new lights act like the previous bulbs, which had minimal UV content.
Light Booths what can you do continued..

- This will allow you to have the same proof to press match that was possible prior to use of the newer bulbs. If you do use a UV filtering lens it is important that everyone in your production workflows (customers and printers) also use a UV filtering lens so they have the same viewing condition.

- You can use the UV filtering lenses and still be compliant with 3664:2009. The ISO 3664:2009 standard allows for use of a custom standard (such as 3664:2009 using UV lenses, as long as it is used in the entire production workflow. UV filtering lenses also degrade over time, so if using them realize they need to be replaced periodically.
Light Booths what can you do continued..

- Watch for updates. At some future point industry color scientists and those responsible for writing the ISO 3664:2009 standard will provide working best practices for color matching with the new viewing conditions.

ISO 3664 Compliance Testing

With the new, affordable spectrometer from GL Optic you can now afford to test your print viewing areas for ISO 3664 compliance. The GL SPECTIS 1.0 offers you the ability to measure the quality of your viewing booth not only for color temperature or brightness levels but also lets you measure the color rendering index (CRI) and metamerism indices for both the visible light spectrum and the UV spectrum. Don't waste anymore time guessing on whether or not your spectrophotometer is giving you accurate results. Upgrade to something that does today. Click here for more information on this affordable device.

Albuquerque, NM 2015
Substrate Corrected Colorimetric Aims

Using Optically Brightened Papers

- Traditional printing aims are no longer valid
- Proofs no longer match prints
Substrate Corrected Colorimetric Aims

Substrate Relativity Calculator Kit 20120606

The Substrate Relativity Calculator allows advanced users the ability to recalculate industry standard or custom characterization data sets based on the CIELAB values of a given substrate. The procedure utilizes the tristimulus correction methodology defined in ISO 13655 Annex A for correcting measurements based on two backing materials. Once the data is modified relative to the new CIELAB values, the user is provided an idea on how the substrates color will affect the final printed result. The recalculated data can be used to generate profiles for more accurate proofing/converting, and the reported CMYK, RGB and Gray patches can be used for new process control aims when on press with the new substrate.

NEW 2013: There is an alternate calculator available from ANSI/CGATS that is available for free download at the NPES website on the right hand sidebar under Computational Tools:

http://www.npess.org/programs/standardsworkroom/toolsbestpractices.aspx

Albuquerque, NM 2015
Substrate Corrected Colorimetric Aims (RIT Video)

- [http://youtu.be/-Y2kwwJTal](http://youtu.be/-Y2kwwJTal)
Relative Paper Scaling!

- ColorPath Sync has this method developed into the cloud color engine!
- Caution this is not a magic fix! If you move the aims of your output you move away from the actual GRACoL aim metrics!
- Caution needs to be used when performing this method!
Substrate Correction Method a word of caution....

- But even this new paper scaling tool won’t magically match the press sheet with the proof.
- There is just no way that the specified super blue substrate is going to render color the way the neutral paper color of ISO would.
- To make it work, a new proof file should be created using this new dataset as well. It is not something desirable for every job but something that could be very important if one is printing on nonstandard substrates, custom colored paper or other situations where a precise match is expected.
- In practical terms, this could result in a printer having a traditional GRACoL C1 proof as well as one or two other proofs for nonstandard substrates such as blue/brightened or SBS. Keep in mind this challenge paper brings to our industry. Not everything will match a supplied proof, and more often than not, the problem could be the paper. Paper is the fifth color, and just ignoring it doesn’t help.
So let's go back to our Don’s Boat Campaign

- By knowing the substrates you are using will greatly enhance your ability to be successful in a color match
- By understanding the solutions and tools available to you will also enhance your success
- By understanding the viewing conditions you work in and will be analyzing your campaign in will enhance your success
- And by working with a knowledgeable Manufacturer and or Consultant you will make your Campaign as success
Thank You!

White Paper on ColorPath Sync online at:

http://www.fujifilminkjet.com/colorpath-sync-white-paper/
Inkjet for 3D Forming Applications

Mike Plier
March 23, 2015
Thermoforming and “The Imaging of Things”

A STRETCH BEYOND THE IMAGINATION
EFI: Moving beyond the document

- Founded 26 years ago
  - Originator of the Fiery digital front end to control digital copiers.
- June 2005 – entered inkjet market with VUTEk acquisition
- October 2006 – expanded ink capabilities with acquisition of Jetrion from Flint Ink
Scaled growth in ink innovation

• 2006-2014: Building innovation in ink
  – Transition from solvent to UV platforms
  – 2011: adapted Jetrion LED inkjet technology to wide-format platforms for greater versatility and low-energy consumption.
  – Consistent customer growth leads EFI to becoming the industry’s leading manufacturer of UV inkjet ink
Market development

- 2013 – research into new market applications leads to partnership with Polymeric Imaging for thermoformable inks
- EFI introduces 2m and 3m VUTEk GS Pro-TF printers and VUTEk GS-TF inks
  - SGIA 2013 Digital Ink Product of the Year
- EFI VUTEk GS Pro-TF products reflect momentum in the “Imaging of Things”
The Imaging of Things
1999 World First UV Screen Formable Ink
SCREEN PRINT MAGAZINE MARCH 1999/ Bell bicycle helmets/ Chicago, IL
Polymeric Imaging

expanding inkjet’s boundaries

• 1970s Chemist Don Sloan develops the industries 1st commercially available UV screen printing inks.
• 1993 Sloan establishes Polymeric Imaging, creating UV formulations to replace solvent-based chemistry.
• 2010 PI develops patented formulation for “deep-draw” thermoformable UV inkjet inks and coatings
• October, 2014 – EFI builds on existing licensing partnership with PI, acquiring PI’s intellectual property related to thermoformable inkjet technology.
New opportunities in “The Imaging of Things”

• Digital thermoforming technology dovetails with “IoT”: High elongation 3D graphics with vivid color and visually compelling design capabilities.

• Oct 2014 EFI acquisitions all patents and IP related to digital thermoforming technology from PI.

New Expanded opportunities and product offerings for printing companies with enhanced print capabilities to bring imaging/decoration in house.

[ EFI logo]
Thermoforming: The Digital Advantage

DISTRUPTIVE TECHNOLOGY/The UNFAIR Advantage!
Forming processes

- Thermoforming is a type of vacuum forming process requiring heat and pressure
- Standard heat is in 280-460+ degree Fahrenheit range
- Mold/Tool configuration depends on specific product or signage needs or application.
Forming processes

Illustration from Creative Form Plastics Inc., Scarborough, Ontario
www.creativeformplastics.com
Imaging of things! A closer look!
An introduction to disruptive technology! A real life story!

*It took Company X 7.5 hours of labor to produce two 13.5’ X 4’ vacuum formed signs using their current printing and painting methods  
*Using digital printed thermoforming technology they now produce 34 of the same signs in the same amount of time!

* Put another way.. What would usually would take them 3.5 weeks to produce...NOW... takes them one day!

A 93% REDUCTION OF LABOR COSTS.. A 95% INCREASE OF PRODUCTION!
Less is more: monofunctional, low-crosslinking acrylates

A Stretch Beyond the Imagination!
Monofunctional Acrylates

Original custom formulations developed in PI labs

*Enables deep draw thermoforming without cracking or mosaic fractures.
*Original formulations worked in lab tests, but required years of refinement before working in real-world production environments.

Monofunctional structure for phenoxyethyl acrylate, commonly used in energy-cured inks and coatings
Faster & harder surface but exhibits limited flexibility and adhesion ranges.
Seeing is believing! Who is Who?
Difunctional acrylates

- Most of all development of UV inkjet formulations is centered around difunctional high-crosslinking acrylates.
  - Pros: Fast Cure speeds, excellent chemical resistance & surface harness.
  - Cons: limited adhesion ranges, brittle, prone to shrinkage and edge-curl.

\[
\text{CH}_2=\text{C}-\text{C}-\text{O}-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{O}-\text{C}-\text{C}=\text{CH}_2
\]

Difunctional structure for Hexaneidiol Diacrylate (HDDA), a reactive diluent used in flexible, energy-cured inks and coatings
What Happens during forming?

- Thermoforming starts here!
  - During the heating cycle both the inks and the plastics become malleable. (Buzz words.. Thermo-sag, glass transition phase or “Bubble”)
  - The pigments or dispersions are not thermo-chromatic. They do not shift in color or hue during the heating or forming process!
  - Unlimited elongation! These systems have the ability to meet or exceed the elongation characteristics of the plastic it is printed on.
  - Extremely broad adhesion ranges with a vast application range that goes beyond vacuum forming.
Softer cure and high-heat tolerances

**signage applications**

Vending

Gaming

POS Display
Softer cure, and high-heat tolerances for functional/industrial applications

- Digitally printed hunting blind
- Custom automotive bumper
- Camo-body Polaris Utility Task Vehicle
Color Management? The Key is Profiling!

• Distortion software is often needed for proper alignment of graphic image to mold.
• In most cases with proper color profiling color hue adjustments are not needed!
  – Average draw 4 inches or less. Max Draw???
  – Print images in higher density, but at the same hue/chromatic value
“Free film” = superior color

- Successful color placement requires ink that exhibits “free film” characteristics.
- Cured film could almost stand alone as its own layer, like a sheet of cellophane
- Free film properties, combined with high density, provide consistent color during the forming process
Key attributes

- Formed parts/signage decoration with fewer steps
- Elimination of screen printing set up costs or hand painting and vinyl lettering process “Tail of the Tape”
- Superior elongation characteristics support deep draw thermoforming while maintaining opacity on various plastics, including PETG, acrylic, polycarbonate, polystyrene and PVC.
- Inks withstand heat forming and cutting without cracking, chipping or loss of adhesion.
- Water and moisture resistance enable durable, lasting images.
Taking thermoforming to its limits

- Successful applications with >24-inches of draw
- >1,000% elongation
- Aspect rations >30:1
Imaging of things! Thermoform Applications

Every single one of us comes in contact with thermoformed products all day every day of our lives!

- **Aeronautical** Interior trim, Covers & cowlings (NASA)
- **Agricultural** Trays, Tubs, Clear Growing Domes, Lawn Mower enclosures
- **Automotive** Wheel & Hub covers, Ski and storage, auto interiors, deflectors, dash clusters, Sports and outdoor vehicles cowlings
- **Marine** Boat hulls, canoes & Kayaks, hatches and dashboards
- **Electronics** Hand held, appliances, computer, instrumentation
- **Entertainment** backdrops, costumes, Animation models, Simulations
- **Medical** scanners, masks, Prosthesis parts
- **Architectural** tub & shower enclosures, Jacuzzis, custom counters
- **POP** Packaging, Blister pack, Signage, Vending, fast food
Know your plastics
The ink is only as good as the plastic it is printed on!

Plastics are comprised of two fundamental groups!

**Thermoset** (Crystalline or Rigid) & **Thermoplastic** (Amorphous or Pliable)

*Some plastics have Hydro-scopic tendencies (Ability to absorb moisture) causing pinholes or star-lighting.*

*Forming temperatures vary from plastic to plastic.*

*Select the appropriate plastic for it intended end use!*

*The right plastic for the job... Impact resistance? Weathering? Dimensional stability after forming? Resistance to solvents, chemicals or abrasion.*
Coating/protection

• Some applications require enhancement coatings or laminates.
  – Important factor in outdoor equipment, automotive, marine, and ATV applications that may require high levels of abrasion, chemical, solvent and protection from UV exposure!
  – These enhancements can be applied both pre-formed and post-formed
  – Methods of application includes screen printing, roll-coating, spray coating and lamination.
LED: a new frontier

• March 1, 2015 EFI opens new state of the art ink and coatings R&D facility in K.C., Mo.

• Future projects include leveraging EFI’s LED inkjet expertise with thermo-formable high elongation technology and enhancement coatings.

• New formulations with LED-based photo-initiators using wave-lengths of 365-400 nanometers. (Conventional UV inks being 320-365)
LED & Beyond thermoforming

• Key LED advantage:
  – Curing at 81-degees Fahrenheit works better with dimensionally unstable substrates.
  – Material stability, low distortion reduced material degradation.
  – Extended lamp life and lower cost energy costs
New packaging opportunities?

• With LED, deep-draw characteristics on a thin film could create new opportunities in vacuum-forming.

• Leverage superior flexibility and color consistency, in thin film packaging applications like direct decorating for blister pack applications.
Process simplification/cost reduction

Can Elongation Translate into stretching profits and shrink production costs?

- Potential to eliminate cardboard inserts on packages, reducing cost and time in packaging assembly process.
- Single layered 3D food packaging. No more labels?
- Variable data for 3D plastic packaging. (bar codes, Serialization, personalization)
Q&A
Thank you!

Mike Plier
Director, Ink Business Development
EFI Inkjet Solutions
michael.plier@efi.com
The Journey to Digital Flexible Packaging

2015 TAGA conference
Raia Slivniak-Zozin, PhD
March 22, 2015
Outline

- Introduction to HP Indigo
- Flexible packaging and the demand for digital printing
- Flexible packaging challenges
- HP Indigo LEP technology
- Lamination with LEP with HP
- HP Indigo 20000 Digital Press
HP Indigo product portfolio

**Existing Platform Improvements**
- HP Indigo WS6800
- HP Indigo W7250
- HP Indigo 7000
- HP Indigo 5600

**Breakthrough Next Generation**
- HP Indigo 10000
- HP Indigo 20000
- HP Indigo 30000
Digital is targeting high value pages

Digital accounts for ~41% of $52.5B graphics hardware and Ink value

2013 Graphics industry value by application ($ billions)¹

- **Flexible Packaging:** 0.7% Digital

<table>
<thead>
<tr>
<th>Application</th>
<th>Value</th>
<th>Analog Pages</th>
<th>Digital Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publishing</td>
<td>$9.2</td>
<td>86%</td>
<td>14%</td>
</tr>
<tr>
<td>Sign &amp; Display</td>
<td>$4.4</td>
<td>8%</td>
<td>92%</td>
</tr>
<tr>
<td>Design</td>
<td>$2.3</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Info Prints</td>
<td>$5.0</td>
<td>68%</td>
<td>32%</td>
</tr>
<tr>
<td>Marketing Collateral</td>
<td>$7.4</td>
<td>26%</td>
<td>74%</td>
</tr>
<tr>
<td>Labels &amp; Packaging</td>
<td>$15.6</td>
<td>10%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Source: PPS MAP 2013 Q4 application market sizing for GSB
1. Value = 2013 Hardware and ink revenues (analog and digital)
The Sheep and Flexible Packaging
Drives for digital transformation in Flexible Packaging

- SKU proliferation
- Micro-segmentation
- Faster time to market
- Supply chain efficiencies
Flexible Packaging
Technical demands

• Mid-web and wide web formats
• Regulatory
• Ability to print on challenging plastic materials
• **Complex post printing processes as lamination**
Few words about Flexible Packaging post print processes

Reverse print
Traditionally, construction components defined by the final product

Understand the final products
- Content
- Post treatment
- Storage conditions
- Shelf Life

Define media & construction
- Oxygen barrier
- Light barrier
- Look & Feel

Define Adhesives
- Solvent Based
- Solvent Less
- Water based
- ...

Define conventional ink set
- Based on the adhesives and substrates used
LEP Technology

Liquid Electro Photography (LEP)

Electro photography –
“a process in which light is used to discharge electrically charged areas and to create a latent image that can be developed by Electro Ink”.
Electro Ink

Unlike analogue inks, which can be replaced easily, HP Indigo ElectroInk is a core component which is challenging to re-design based on the media / adhesive selection.
Common lamination structure

1. **Primer** is a must to adhere ink to the relevant substrates

2. **Adhesive** has to fit HP Indigo electro ink and has to be selected carefully for laminated applications
Adhesives matrix

Technology
- Solvent Based
- Solvent Less
- Water Based

Variety of manufacturers
- Asian based
- American based
- Europeans

Performance
- General
- Medium
- High (Retort)

High
- Retort
- Microwavable
- Aqueous foods

Medium
- Meat & Cheese
- Coffee
- Snack & Confection

General
- Dry Foods
- Wrap around Labels
Validation flow

- Lamination
  - Lamination bond strength and failure mode analysis

- Folding
  - Folding stress test

- Sealing
  - Sealing stress test
    - Flat jaws + Teflon
    - Grooved jaws
    - Sealing bond strength
Major improvements using Corona treatment

**Corona Treatment – Increasing adhesion**

- Removes contamination
- Modify the polarity of surface
- Enhance chemical functionality
- Improves wetting
Mechanical Properties Evaluation

As lower the elastic modulus the better lamination performance it has with electro-ink.
Mechanism

Stress distribution

- **Rigid Adhesive**: Medium stress falls on primer-ink interface, may cause a failure.
- **Flexible Adhesive**: Large stress on primer-ink interface, leading to primer-ink failure.
- **Soft Adhesive**: Equal stress distribution → Soft Adhesive absorbed most of stress, the rest falls on ink, leading to good lamination bond strength.

**Stress [MPa]**

- **Primer**
- **Ink**
- **Adhesive**

Rigidity of adhesive
Printing HP Indigo Electro Ink on thin plastic materials is possible when using a primer which enables good adhesion of the ink to the substrate.
Achievements

- Mid-web format
- Ability to print on challenging plastic materials
- Complex post printing processes as lamination
- Regulatory
Thank you
What is digital printing?

Digital printing eliminates many analog steps associated with conventional printing

- Reducing total environmental impact
- Increases throughput speed
Digital printing time to market (TTM) Advantage

Conventional analog vs. digital

HP Indigo

- -40% set-up time

Digital Printing created a breakthrough in flexible packaging printing

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Lamination performance tree and Indigo 20000 application fit

Target up to medium level lamination performance applications.

- High
  - Retort
  - Microwavable
  - Aqueous foods

- Medium
  - Meat & Cheese
  - Coffee
  - Snack & Confection
  - Dry Foods
  - Wrap around Labels

- General

Indigo 20000

Current application fit

Solvent Based

Solvent Free

Water Based

Regulatory requirements and liability
Create new incremental business

Digital

Order From 50 bags

Order From 100 bags

Order From 500 bags
What’s Next?
Flexible packaging segment

>100 Active install base before Drupa’16

>20 FP & labels success story with major Brands

Enable High-End FP application

Introduce real disruptive E2E solution

Build facts of advantage that clearly distinguish competition

- Field proven mature product [Happy customers]
- Brand preferred product [Happy Brands]
- No limit of Application [ink is no longer weakness]
- Real disruptive E2E that opens new opportunity [beyond printing]
The Science behind TGO

- Lean redesigned for the printing and packaging industry
- Presented by Udi Arieli, EFI
The Science Behind TGO

1. About this presentation
2. Why the world needs a theory
3. An evolution of business strategies
4. The Theory of Global Optimization
5. Building Blocks of TGO
6. TGO Myths
7. TGO in Life
8. TGO Q&A
About this Presentation

This presentation summarizes the culmination of over thirty years of my research, development, and education into the Theory of Global Optimization and its application in a printing and packaging industry. Each major topic in this presentation—Workflow is taught in lectures.

As the creator of both the theory and its unique tool, PrintFlow Dynamic Scheduling, I continue in my mission in advancing intelligent automation and TGO to guide the print industry to greater profitability.
Why the world needs a theory

TGO
Changing World = Big Challenges

- Tough economic time – changing world economy
- Changing customer demand - more competition for marketing spend
- Shorter lead times
- More setups/make-readies
- Shorter runs – must manage many more jobs for the same revenue
- Lower prices, higher costs
- Increased variety and complexity of products being produced
- Continuous improvement cost
- Processes changing - analog decreasing, digital increasing
- New management challenges

Bottom line: We are challenged to maintain profitability
New Technology

- Automated equipment alone does not ensure profit growth.
- Digital processes are faster but harder to manage.
- CIM and JDF provide a strong foundation for process improvement but also introduce new (often hidden) constraints.

Albuquerque, NM 2015
The Theory of Global Optimization

Why I decided to develop TGO:

• To help the printing industry become more efficient and profitable
• Because most previous automation projects had failed
• We needed a guiding principle for software development
• The industry was ready for something new and exciting
• Other theories and practices lacked printing industry focus
• To be successful in our goal to provide the ultimate tool set for our clients, we needed to identify and attack any industry practices and myths that erode performance and profitability
Evolution of Business Strategies
Lean manufacturing theories have been around for over 200 years.

Each major leap forward was the result of an innovative thinker:

- Eli Whitney: Mechanization, Farming, Interchangeable Parts
- Henry Ford: Assembly Line, Automotive Lean
- Edward Deming: Process Control, Industry Just in Time
- Eliyahu Goldratt: Constraints, Manufacturing TOC
- Udi Arieli: Global Optimization, Printing TGO
The Theory of Global Optimization

Comparing Theories

Lean focuses on eliminating waste and reduced cycle time. TOC focuses on system constraints.

• Neither has a printing industry (job shop) focus...
• Neither focuses on the global view.
• Neither focuses on Global Optimization.
• Neither has embedded their theories in a practical, successful software product.

Albuquerque, NM 2015
The Theory of Global Optimization

The Theory of Global Optimization is the science of managing a printing or packaging operation with a global view.

TGO is not a production strategy; it is an end-to-end workflow improvement strategy that yields benefits in acquisition, administration, planning, production and delivery. When TGO is implemented with big-picture training and motivation, the culture of the company is transformed; everyone performs with the global view in mind, and everyone performs smarter.
Lean vs TGO

Lean Manufacturing
Focused on manufacturing
- Process Flow
- Process control
- Organization
- Metrics
- Logistics
- Waste Reduction

Global Optimization
Focused on total system
- Problem solving
- Optimization
- Global View
- Constraint Management
- Automation

EFI Automated, Intelligent Workflows

BASED ON THE THEORY OF GLOBAL OPTIMIZATION (TGO)
Profit Battle: Lean –vs- TGO

While many attempted to wedge Lean into the printing industry, one team recognized its limitations and shortcomings and looked for a better mousetrap.
## Comparison - Lean - TOC - TGO

<table>
<thead>
<tr>
<th>Lean</th>
<th>TOC</th>
<th>TGO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focuses on individual processes within a linear workflow.</td>
<td>TOC focuses on constrained cost centers.</td>
<td>TGO recognizes that all cost centers must be managed and optimizes.</td>
</tr>
<tr>
<td>Lean recognizes a process delay as waste in the system.</td>
<td>TOC recognizes one primary constraint that is fixed, or made permanent for a period, allowing you to place large buffers in front of it.</td>
<td>TGO recognizes that the workflow has more than one constraint and that the constraint can be constantly changing. The strategy must include a process for monitoring, identifying and addressing constraints in a fluid system.</td>
</tr>
<tr>
<td>Lean does not recognize the impact of a constraint.</td>
<td>TOC does not know the difference between a bottleneck and a constraint.</td>
<td>TGO distinguishes between a bottleneck (potentially beneficial) and a constrained cost center (causing jobs to be late).</td>
</tr>
<tr>
<td>Lean manufacturing looks at individual processes.</td>
<td>TOC utilizes Drum-Buffer-Rope (DBR) to balance the flow of the system.</td>
<td>TGO utilizes smart software with scoring algorithms to balance the flow of the system and to maximize bottom-line impact.</td>
</tr>
<tr>
<td>Lean focuses on systematic elimination of waste as its primary goal.</td>
<td>TOC only understands the primary constraints, ignoring all other goals.</td>
<td>TGO recognizes that we must find a compromise between all conflicting constraints and goals.</td>
</tr>
</tbody>
</table>
A manufacturing operation is a chain of interdependent links...
The Theory of Global Optimization

TGO

Only a few constraints control the throughput, on-time delivery, and cost of the entire printing operation.
The Theory of Global Optimization

TGO

Identify and remove the constraints, and you increase throughput and profits.
The Theory of Global Optimization

1. 2. 3.

You must have a global view in order to synchronize, optimize, identify and manage the true constraints.

By optimizing production, you produce greater throughput and profits.
What is TGO?

The Theory of Global Optimization (TGO):

The science of leveraging “smart” software to optimize workflows from acquisition through management, prep, production, delivery and analysis. TGO promotes:

- Acting according to the global view of the company.
- Change companies culture in every area
- Optimizing and synchronizing all areas of your business.
- Identifying and resolving weak links and constraints.
- Improving “real-time” communication and data sharing/analysis to address real-world challenges before they negatively impact your bottom line.

*Integration, Automation and Smart Software*
The TGO process improvement strategy identifies the constraints in a system and focuses resources on the elimination or control of the constraints to improve efficiency and throughput.

This process control is critical to the success of the end-to-end management and production workflow, allowing for the delivery of integrated, automated systems that leverage smart software for constraint management in all phases of acquisition, management and production.

By identifying the constraints up front, the impact of those constraints are minimalized, resulting in better processes, better capacity utilization, higher throughput and improved profitability.
Building Blocks of TGO
The Theory of Global Optimization

TGO Building Blocks

- Being Intentionally Proactive, Not Reactive
- Global View • Global Thinking
- Identifying and Focusing on Constraints
- Synchronization & Optimization
- Throughput • Bottleneck Management
- End-to-end Continuous Improvement
- Leveraging Objective Indicators
- Managing/maximizing Capacity /Smart Scheduling
- Teamwork
- Applying all of these Company-wide

Making TGO Part of Your Business Culture

Albuquerque, NM 2015
The Theory of Global Optimization

TGO is unique in that it is the only business development strategy supported by a foundation of smart software.
TGO Myths
The Theory of Global Optimization
Myth or Fact

The customer comes first.

There must be a realization that adjustments to accommodate one customer will almost always impact many customers and overall profit performance.

The wider perspective of the plant should prevail over the narrower focus of a single job, cost center, or customer.
Myth or Fact

Greater productivity and efficiency in a cost center equals more throughput and higher profits.

Higher efficiency or productivity in individual cost centers does not necessarily lead to higher profits.

Equipment speed only translates to profitability when the impact of its performance can be carried throughout the production process.
Myth or Fact

Bottlenecks hinder profitability, they create waste and slow down throughput.

Bottlenecks are good for your company, as long as they do not become constraints... we call them queues.

There are over 40 myths addressed by TGO. The TAGA TGO whitepaper details a number of them.
TGO in Life
Real World Success with TGO

James Pilcher
VP of Manufacturing / GM Freeport Press Inc.

David Baldree
Director of Operations
Valtim Marketing Solutions

Judi Hansen
Director of IT
J.S. McCarthy Printers
Real World Success with TGO

- I have known Udi Arieli since 2007. He has long been a proponent for both this industry and manufacturing optimization.
- We have implemented TGO throughout our operation through the use of PrintFlow.
- Our experience here at Freeport has been phenomenal. Our business continues to grow, our margins continue to increase, our productivity in our entire operation continues to improve - all this in what many consider to be some of the most challenging times in history for the printing industry.
- Thank you, Udi
Real World Success with TGO

- I preach TGO all the time
- TGO is no longer a theory but with PrintFlow has become a true scientific method.
- If you can understand TGO and deploy it, you can change any company.
- TGO has challenged me to think beyond the norm.
- Udi and TGO were probably some of the most important influences in my life
- It has allowed me to help my company grow almost forty percent in two years.
Real World Success with TGO

- J.S. McCarthy Printers: New England commercial printer focused on service, technical innovations, and superior quality of product

- “Having known Udi for more than 30 years, it still amazes me how he is always open and thinking about anything that will improve production process and has never stopped thinking outside the box!

- “While the rest of us get drawn into the day-to day-details, he is an invaluable constant presence in the printing industry, drawing us back to thinking of the global view and TGO.
Thank you

Developed by: Udi Arieli
Sr. Director of Product Management, PrintFlow, Digital Workflows EFI Productivity Software
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Albuquerque, NM 2015
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Where will JDF be 2016?

- **JDF 1.51**
  - Freeze development except for bug fixes

- **JDF 1.6**
  - No major changes
  - Business as usual
    - Add some attributes, Processes, ...

- **JDF 2.0 / XJDF**
  - Reevaluate existing XML tools and align JDF closer to mainstream XML developments
  - Simplify Interface
  - Additional Business as usual - see JDF 1.6 above
Flashback - 1999

- XML was mainstream but tools were scarce
  - Simple DOM level 1
  - Schema was virtually non-existing (we had DTD)
  - SOAP was yet another fledgling technology

- The discussion was: should we encode in COS (PDF) or XML.

- JDF design focus was to create one complete job ticket that describes an entire job including every step in the workflow and gets passed from device to device.
Ein Teil von jener Kraft,
Die stets das Böse will und stets das Gute schafft.

Was ist mit diesem Rätselwort gemeint?

Ich bin der Geist, der stets verneint!
Und das mit Recht; denn alles, was entsteht,
Ist wert, dass es zugrunde geht;
Drum besser wär’s, dass nichts entstünde.
So ist denn alles, was ihr Sünde,
Zerstörung, kurz das Böse nennt,
Mein eigentliches Element.

© Goethe
User Myths/Impressions of JDF

- JDF is too complicated
- JDF is too academic
- JDF jobs are static – changes are difficult to manage
- JDF will never work out of the box
- It is much too expensive to implement JDF
- Only the big guys will ever implement JDF
- It takes years to understand JDF
- JDF is not implemented on a large scale
Fundamental Issues with JDF

- JDF exposes too many internal implementation specific details
- Change Orders are difficult to implement
- Gang Jobs with multiple products are messy to describe
- What is the role of Intent and price negotiation in Production?
- Plug & Play is evasive.
  - Device Capabilities descriptions are very complex
- JDF has too many methods to specify similar semantics; e.g.
  - Imposition
  - Stripping
  - LayoutPreparation
XJDF interface Design Goals

• Retain the gory details that we learned in 15+ years of JDF Development

• Simplify the Interface
  – Flatten the learning curve for implementers
  – Make using JDF simple for simple applications
  – Reduce the number of methods to express similar things
  – Enable Plug&Play integration

• Separate Interface from Implementation

• Goal: It’s just <XML/>!
XJDF Xpath Compatibility

- No Inheritance
  - Flat List Structures
- Single XJDF Node
- References are limited ID-IDREF searches
  - All referenced Elements MUST have an ID
  - No Name Mangling of Links
  - Reduce use of references to the absolutely necessary
- refElements are inlined or replaced by IDRef
  - Define exactly one option allowed per individual subelement in JDF, i.e. IDREF or element.
- ICS format changes to 1 simple table:
  | XPATH | Conformance | Description |
Compatibility with modern XML tools

- Make Compatible with
  - Standard class generators
- Allow simple Mapping to databases
- Define Simple XML Schema
  - Use XML Schema to describe device constraints
- Enable simple XSLTs for legacy format translations
- Enable XSLT for display, e.g. in Browsers
- Make standard XML knowledge more applicable to JDF
JDF Process Description

- JDF describes the entire Production in one XML
  - Models Process interdependencies
    - All sub-processes are described in one single XML Job Ticket
  - May contain Manufacturing Instruction Details
  - Set of linked hierarchical JDF XML nodes
  - Devices are required to retain opaque data
Nested JDF Nodes

Resource Links define Resource Context
Node Executability

Resource

Available

Available

ResourceLink

Available

JDF Node

Executable

Resource Links
JDF Executability And Networks

Available

Waiting

Links

Not Available

Available

Not Executable

Links

Available

Available

Not Available

Available
JDF Executability And Networks

Available

Available

Available

Not Available

Available

Not Executable

Available
JDF Executability And Networks
XJDF Process Description

- XJDF assumes that the process definition is proprietary
  - Each transaction is dedicated to the recipient
  - May contain Manufacturing Instruction Details
  - Single XJDF XML node for each processor
  - No requirements to maintain opaque unknown data
Job modification and Change Orders

- Anything but updating final Amounts or Scheduling is inherently difficult – regardless of the simplicity of the interface
  - Change number or size of pages - requires new impositioning
  - Modified finishing typically ripples back to prepress
- JDF:
  - Adding process steps to JDF requires insertion of a new exchange resource that is subsequently relinked.
  - This is overkill for: “Please add varnish to this”.
- XJDF
  - All Attributes are optional in XJDF
  - Simply send a new XJDF with only modified values
Gang Jobs

- JDF
  - The Product Hierarchy is inappropriate for gang jobs with multiple customers and/or final products
    - A “Production Job” cannot be the child of multiple Customer Product elements.
  - The hierarchical structure of JDF requires complete rewriting to add a small part from an additional customer product

- XJDF
  - ProductList and Product are in a separate element
    - Modifications have no effect on the overall XJDF structure
Product Intent

• JDF
  • JDF allows for ranges in intent descriptions to support negotiation. This adds complexity in production where ranges are no longer required

• XJDF
  • XJDF assumes that all negotiation takes place in a dynamic, e.g. web to print environment
  • All intent values are simple attributes

• PrintTalk and XJDF
  • PrintTalk 2.0 simply contains XJDF elements instead of JDF
Plug & Play

- How to describe the restrictions of a real device?
- JDF
  - The flexibility of JDF and many of the non-standard XML constructs make XML schema difficult to implement
- XJDF
  - Referenced XML Schema (it’s just <XML/>...)
    - Slightly reduced functionality
      - No constraints descriptions
    ✓ Standard XML Technology
    ✓ Subset of the XJDF Schema
Partitioning (Sets of Resources)

JDF
- Hierarchical tree
- Element Inheritance
- Abstract Types

XJDF
- Linear list
- Explicit Elements

ResourceSet
- Resource
  - Part S1
- Explicit Resource e.g. Media
  - Part S1
- Explicit Resource e.g. Media
Reduce redundant methods

- Remove all deprecated items
- Review and remove historical synonyms
- Retain all necessary details
- Keep translation XJDF $\leftarrow \rightarrow$ JDF simple
• Audits are the same as in JDF
• Products are no longer JDF Nodes but are defined as a list of <Product>
• ResourceLink and Resource Elements have been merged into one ResourceSet or ParameterSet element
Qui Bono?

- The XJDF interface is simpler and therefore:
  - More robust
  - Projects can be implemented more cost efficiently
    - Less Flexibility translates to less misunderstanding.
    - XJDF can be implemented by non-experts (e.g. in a home grown system)
  - XJDF Projekts can grow on an organic growth path
    - Amount/ Time/ Device
    - ...
    - Complete automation
Honi soit qui mal y pense

- XJDF is **NOT** a JDF Dialekt.
  - Compatibility by format conversion
- XJDF must be implemented
  - Short-term Pain for long-term Gain
  - Long-term maintenance of 2 interfaces
  - XJDF can be implemented by non-experts (e.g. in a home grown system)
XJDF project status

• Very active work group in CIP4
  • Weekly telephone conferences
  • Face to face meetings every 2 months
  • https://confluence.cip4.org/display/PUB/XJDF
• JDF 1.5 und XJDF co-exist in a common master specification
• JDF Open source Converter available (Java)
  • JDF ➔ XJDF
  • XJDF ➔ JDF
• https://confluence.cip4.org/display/PUB/JDFEditor
Summary

• XJDF defines a simplified JDF structure that:
  – Retains much of JDF 1.x semantics
  – Aligns with modern XML Tools
  – Is useful as an interface
  – Is less useful as an internal application representation
  – Enables quick and simple integration in printing

• XJDF and JDF will be maintained in parallel
  – Common master specification with conditional output

• 66% of the work is on chapter 1-4 of the spec
  – Of the 66% work, at least 50% are deletions!
XJDF Prototypes

• Heidelberg Prinect: Prototypes working for 4 years
  • Focus: WebToPrint; Print subcontracting, CAD Connectivity
• Partners:
  • Vendors, that have also implemented JDF
  • Web To Print vendors with no JDF experience
  • Printer software (home grown)
Disclaimer

XJDF is work in progress and still subject to major discussions and modifications.

For more details, see:

https://confluence.cip4.org/display/PUB/XJDF

You can also follow the discussions by registering as a CIP4 visitor (or even better – CIP4 Member) and then accessing:

https://confluence.cip4.org/display/xjdf/XJDF+WG
Inter-Instrument Agreement for M1 Conditions and Its Implications for Graphic Reproduction

Veronika Lovell, Ph.D.
Robert Marcus, Ph.D.
Danny C. Rich, Ph.D.
ISO 13655 Spectral measurement & colorimetric computation

- This standard has always recommended the use of CIE D50 for colorimetric computations
- In 2009 it adopted the requirements of ISO 3664:2009 and now requires a CIE D50 simulator
  - The preference is to have a close simulation of D50 being used to acquire the spectral data.
- CIE D50 simulators require lamps with both visible and ultraviolet radiations in the correct ratios.
  - Paper, Textiles and Plastics industry use large integration sphere (150mm diameter) and xenon lamps to create the desired mix of UV and VIS radiations.
- The changes in ISO 3664 and ISO 13655 were implemented to handle the presence of OBA in the paper substrate.

Albuquerque, NM 2015
ISO 13655 Spectral measurement & colorimetric computation

- The ISO Standard has created a series of measurement conditions known as the M-series
  - **M1** is a close simulation of CIE D50 as defined by ISO 3664
  - **M0** is the traditional incandescent lamp used in older instruments
  - **M2** is any lamp with the UV removed
  - **M3** is any lamp with a polarizer and analyzer in the optics

- No known sources have the right spectral distribution and size for conformance to both ISO 13655 M1 and instrument geometry.
  - So the standard requires an undeveloped technology to achieve full conformance to an M1 option a instrument source
Reproduction engineers are particularly concerned with production substrates that contain OBA

- Many proofing substrates contain no FWA and so there is difference in the appearance of the substrates

CIE Publication 176 reported on the magnitude of the errors encountered

- Differences in apparent reflectance was directly attributable to the presence of OBA in the paper.
- Differences of up to 3 CIELAB units were reports for solids
- Differences of up to 12 CIELAB units were reports for tones.

It was determined important that the total radiance factor of the substrate be captured correctly – with the UV content of D50
It was thus important to be able to produce the correct amount of UV to VIS radiance on the surface of the specimen during a color reading.

The paper industry accomplishes this by using large integrating spheres with UV-rich xenon lamps and UV blocking filters. The use of a UV blocking filter was first reported by Gaertner and Griesser. The ratio of the UV to the VIS is controlled by removing some UV until the correct ratio is obtained.

The Griesser method requires space between the lamp and the influx optics. This space is not available in a portable, hand-held 45:0 instrument, as required by ISO 13655.

Some other method of obtaining the M1 condition is required.
ISO 13655 Spectral measurement & colorimetric computation

- ISO 13655 provides for an alternative method to providing an exact simulation of CIE illuminant D50
- There are many published approaches to obtaining the total spectral radiance factor
  - Most approaches require constructing one or more sources with varying amounts of UV Radiations
- Imura proposed the “virtual fluorescent standard” or VFS method in a series of articles in the journal *Color Research and Application*
- This approach has proved to be the most widely applied commercial method for adjusting relative total spectral radiance factor readings to the values that would have been acquired had the instrument used an exact D50 simulator as the source
- All instruments in this study incorporated the Imura VFS method

Albuquerque, NM 2015
Experimental Procedure

- 50 Papers stocks were selected including:
  - *publication stocks*
  - *label stocks*
  - *office papers*
  - *packaging papers*
  - *boards*

- CIE Whiteness Index (per ASTM E313) ranged from 57 to 133
- 3 Modern portable spectrodensitometers with ISO 13655 M1 compliance were used to read the papers
- All instruments were standardized according to their manufacturer’s requirements
- All papers were read over a white backing sheet
  - *Munsell N925 backing substrate*
Experimental Procedure (cont.)

- Measurements were collected from each paper a total of 3 times (replicate determinations).
- Each measurement was comprised of 3 readings taken from different areas of specimen.
- The figure to the right shows the data for all 500 papers on 1 of the instruments.
- The total spectral radiance factor curves exhibit the class shape and range of values for optically brightened white papers.
Experimental Procedure (cont.)

- The measurements were uploaded into an Excel workbook
- The measurements were not corrected or adjusted for any instrument parameters
- ASTM E308 Table 5-9 (D50/2°) was then used to compute the tristimulus values
  - The E308 standard is widely used in most instrument software
  - Just to be certain that only the measurement differences were studied the worksheet utilized the tabular weights for all instrument readings
- The measurements from each instrument were compared in pairs
  - 1 vs 2, 1 vs 3, 2 vs 3 as was done in the work by Wyble
  - The repeatability of the three readings was also captured
Results and Discussion

- The Table shows the contrasts for each of the 3 pairs of instruments
- The 3 reading repeatability for each instrument was:
  - 1: 0.06 ΔE*
  - 2: 0.09 ΔE*
  - 3: 0.10 ΔE*
- While the average differences appear good, the 95% cumulative values are 10X the repeatability.
  - *This indicates a distinct difference*

<table>
<thead>
<tr>
<th></th>
<th>1 vs 2</th>
<th>1 vs 3</th>
<th>2 vs 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave</td>
<td>ΔL*</td>
<td>Δa*</td>
<td>Δb*</td>
</tr>
<tr>
<td></td>
<td>-0.80</td>
<td>0.07</td>
<td>-0.30</td>
</tr>
<tr>
<td></td>
<td>-0.76</td>
<td>0.07</td>
<td>-0.32</td>
</tr>
<tr>
<td></td>
<td>-0.56</td>
<td>0.33</td>
<td>0.41</td>
</tr>
<tr>
<td>Med</td>
<td>ΔL*</td>
<td>Δa*</td>
<td>Δb*</td>
</tr>
<tr>
<td></td>
<td>-0.86</td>
<td>-0.01</td>
<td>-0.08</td>
</tr>
<tr>
<td></td>
<td>-0.89</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>-0.45</td>
<td>0.20</td>
<td>0.40</td>
</tr>
<tr>
<td>95%</td>
<td>ΔL*</td>
<td>Δa*</td>
<td>Δb*</td>
</tr>
<tr>
<td></td>
<td>-0.56</td>
<td>0.33</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>0.07</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>0.09</td>
<td>0.05</td>
<td>-0.37</td>
</tr>
<tr>
<td></td>
<td>0.39</td>
<td>0.48</td>
<td>0.90</td>
</tr>
</tbody>
</table>

M1 Mode
Since the specimens are nearly neutral and spectrally non-selective, it is not unreasonable to assume that major differences is in the scale of reflectance factor assigned to the non-fluorescent standard.

A correction for white reference scale was undertaken following the recommendations of CIE Publication 130.

However, recent reports have indicated that printed white standards and some plastic standards containing titanium dioxide are photochromic and not suitable for scale transfer.

Thus a pale gray patch from a ChromaChecker target was used to adjust the readings of instruments 1 and 3 to those of instrument 2.

The white patch on the ChromaChecker target contains OBA and so would not be suitable.
The plot at the right shows the ChromaChecker white patch and the pale gray patch.

- The average $\Delta E_{00}$ values across the 42 patches:
  - 1 vs 2 is 0.86
  - 1 vs 3 is 0.77
  - 2 vs 3 is 0.64

- For just the pale gray patch
  - 0.71, 0.69, 0.17

- For just the white patch
  - 1.50, 0.74, 1.82

- So the white is clearly more difficult to read
After applying the scaling factors the three instrument contrasts for the ChromaChecker were:

- 0.38, 0.49, 0.62 $\Delta E_{00}$ respectively
- Thus instruments 1 & 2 and 1 & 3 were improved but 2 & 3 did not change.
- On the pale gray all differences were 0.0 and on the white patch the $\Delta E_{00}$ were reduced to 0.98, 0.67, 1.64 respectively. So the scaling improved the readings.

The unusual behavior of instruments 2 and 3 continue to be an issue, even after rescaling.

The readings of the papers were then rescaled using the pale gray patch measurements.
The table shows the results of the readings of the 50 papers after white scale correction. The white scale adjustment removed only about half of the variations. Small improvements in some readings can be observed but some contrasts were slightly worse. Such behaviors are indicative of a concomitant, untreated systematic variable.

<table>
<thead>
<tr>
<th></th>
<th>1 vs 2</th>
<th>1 vs 3</th>
<th>2 vs 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave</td>
<td>ΔL*</td>
<td>Δa*</td>
<td>Δb*</td>
</tr>
<tr>
<td>Med</td>
<td>0.36</td>
<td>0.08</td>
<td>-0.43</td>
</tr>
<tr>
<td>95%</td>
<td>0.40</td>
<td>0.07</td>
<td>-0.41</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>0.36</td>
<td>0.29</td>
</tr>
<tr>
<td>Ave</td>
<td>ΔL*</td>
<td>Δa*</td>
<td>Δb*</td>
</tr>
<tr>
<td>Med</td>
<td>0.27</td>
<td>-0.08</td>
<td>-0.08</td>
</tr>
<tr>
<td>95%</td>
<td>0.25</td>
<td>-0.06</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>0.68</td>
<td>0.12</td>
<td>0.40</td>
</tr>
<tr>
<td>Ave</td>
<td>ΔL*</td>
<td>Δa*</td>
<td>Δb*</td>
</tr>
<tr>
<td>Med</td>
<td>0.08</td>
<td>0.15</td>
<td>-0.34</td>
</tr>
<tr>
<td>95%</td>
<td>0.12</td>
<td>0.11</td>
<td>-0.47</td>
</tr>
<tr>
<td></td>
<td>0.42</td>
<td>0.57</td>
<td>0.75</td>
</tr>
</tbody>
</table>

M1 Mode
Results and Discussion (cont.)

- Similar contrast comparisons were performed for the M0 and M2 measurement modes.
- Because of the unusual behaviors between instruments 2 and 3 only instruments 1 and 2 are included in this phase.
- The M0 results are slightly worse than the M1 results but not really as bad as expected.
- The M2 results are also slightly worse than the M1 results which is a little surprising.

<table>
<thead>
<tr>
<th></th>
<th>1 vs 2</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ΔL*</td>
<td>Δa*</td>
</tr>
<tr>
<td>Ave</td>
<td>-1.32</td>
<td>0.11</td>
</tr>
<tr>
<td>Med</td>
<td>-1.29</td>
<td>0.09</td>
</tr>
<tr>
<td>95%</td>
<td>-1.01</td>
<td>0.32</td>
</tr>
</tbody>
</table>

|                | ΔL*    | Δa*      | Δb*    | ΔE*    | ΔE00   |
| Ave            | -0.15  | 0.12     | -0.32  | 0.52   | 0.43   |
| Med            | -0.12  | 0.09     | -0.32  | 0.51   | 0.42   |
| 95%            | 0.14   | 0.34     | 0.27   | 0.93   | 0.72   |

| 1 vs 2         |        |          |        |        |        |
| Ave            | -1.34  | -0.04    | 0.36   | 1.46   | 0.96   |
| Med            | -1.31  | -0.02    | 0.29   | 1.45   | 0.92   |
| 95%            | -1.06  | 0.08     | 1.05   | 1.96   | 1.28   |

| Adjusted       |        |          |        |        |        |
| Ave            | -0.18  | -0.05    | 0.28   | 0.52   | 0.45   |
| Med            | -0.14  | -0.03    | 0.18   | 0.44   | 0.41   |
| 95%            | 0.09   | 0.07     | 0.95   | 0.98   | 0.92   |

Albuquerque, NM 2015
Statistical Analysis

- Two groups of papers were selected from the main set.
  - Group 1 had 4 papers with similar trade names from the same manufacturer
  - Group 1 had similar surface, smooth, coated papers
  - Group 2 had similar CIE Whiteness but different surfaces (coated, uncoated, smooth and matte).

Both Paper & Instrument were significant contributors to the variance.
In the MANOVA, both the instrument and the paper substrate were significant contributors to the variance.

In the report from Wyble, et. al. they noted that as modern spectrocolorimeters have very high precision (repeatability) it makes even minor differences in the product or instrument identifiable.

- Here we see that even seemingly minor differences in the instruments are differentiable.

The question remains as to why the instruments did not improve greatly when the white tile scale was improved and the illumination was simulated to M1.
Discussion

- For completeness, we have included plots of the total spectral radiance factors for each of the two subgroups of papers.
- The plots in the next slide show the 3 measurement conditions, M0, M1, M2 and the eight papers taken from the set of 50.
- The set on the left show the four papers with similar surfaces and coatings while the set on the right show the four with similar optical properties
  - The M2 mode does a pretty good job of removing the emission peak in the left side.
  - The M2 mode does a pretty good job of showing the differences between the papers on the right side.
  - The M0 mode seems to have the most consistency in the emission peaks even though the CIE Whiteness is similar, the papers are actually quite different structurally and also under UV exclusion.
Discussion (cont.)
Discussion (cont.)

- For reference purposes, the ISO $\Delta b^*$ ($b^*$ difference between M1 and M2 modes) values for the two paper groups are:
  - Group 1 – (10.0, 10.6, 11.4, 11.1)
  - Group 2 – (6.2, 9.0, 6.6, 2.4)

- The lower $\Delta b^*$ for paper 43 confirms the results shown in the spectral plots.

- We have seen that using the M2 condition can improve inter-model agreement for papers with different OBA amounts but not for differences in surface structure
  - *Surface structure impacts the way the incident light flux is reflected and interacts with the geometry of the instrument*

- CIE Publication 176 describes the steps required to remove this concomitant variable in the reproducibility of color measurements
Conclusions

- All instruments tested demonstrated excellent repeatability
- The M1 process on each instrument resulted in a high level of excitation of the OBA
- The inter-model agreement was improved slightly by adjusting the white scale factor
- The inter-model agreement was not significantly improved for highly fluorescent papers
- The inter-model agreement was improved more significantly for papers with a neutral ink printed on them
- Differences in geometry of the instrument, especially the ratio of influx to efflux area affected the inter-model agreement
- The M1 measurement mode will not resolve all issues related to the agreement between visual and instrumental assessment of print & proofs
An Analysis of M0 and M1 Measurement Conditions

- Bruce Leigh Myers, Ph.D.
- Rochester Institute of Technology
Inherent Variation

- The Hallmark of a Seasoned Professional
- New Metrics = New Challenges
Special Case of Color Measurement

- Terminology Confusion
  - Inter-Instrument Agreement
  - Inter-Instrument Disagreement
  - Inter-Model Agreement
  - Instrument Uncertainty
Manufacturers’ Perspective

- Instruments Certified Using BCRA Series II Tiles
  - Stability
  - Traceable
  - Widely Adopted
- Recertification Services
  - Recommended for ‘Normal Use’
Making a Flawed Situation Even More Confusing

- No Consistency on HOW Specifications are Published
  - Average of 12 BCRAs, Max. on Single BCRA, or Both?
  - Tolerancing Method?

<table>
<thead>
<tr>
<th>Published Inter-Instrument Agreement Specifications for Graphic Arts Spectrophotometric Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4 $\Delta E_{cmax}$ MAX</td>
</tr>
<tr>
<td>0.3 $\Delta E^*$ MAX, 0.15 Average</td>
</tr>
<tr>
<td>0.3 $\Delta E_{ab}$ Average</td>
</tr>
<tr>
<td>&lt; 1 $\Delta E$ MAX, &lt;0.5 $\Delta E$ Average</td>
</tr>
<tr>
<td>0.3 $\Delta E^*$, 0.15 $\Delta E_{cmax}$ Average</td>
</tr>
</tbody>
</table>

R·I·T
Green BCRA with Same Tolerance Number Using $\Delta E^*$, $\Delta E_{cmc}$, $\Delta E_{94}$ and $\Delta E_{00}$
Efforts to Drive Variance

- Internal SOPs
  - BCRAs
  - IDEAlliance LabREF
- Round Robin
- Third Party, e.g.
  - ChromaChecker
  - Vogelsong Color Ref
Motivation

- Climate Comprised of Factors Surrounding Color Measurement Accuracy
- Introduction of M1
Research Questions

- Are There Differences in Variance in M1 and M0 Readings With Instruments Capable of Measuring Both?
- Are There Differences in Variance Among M1 Instruments and M0 Legacy Instruments?
Methods

- Read and Record $\Delta E_{00}$ in Color Pairs with M1, M0 and Legacy (M0) Instruments
- Evaluate White Points of M1, M0 and M0 Legacy Instruments
- Color Pairs
  - Twelve Color Samples in IDEAlliance LabREF
  - Two Paper Samples (One OBA, One No OBA)
Data Collection

- Goal to Measure with as Many Instruments as Possible
  - Began at GraphExpo in Fall
  - Instruments at RIT
  - Customers and Vendors
## Descriptive Data: Ranges

<table>
<thead>
<tr>
<th></th>
<th>M0</th>
<th>M1</th>
<th>M0 Legacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE(_{00}) Paper</td>
<td>2.7</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>DE(_{00}) White</td>
<td>.38</td>
<td>.42</td>
<td>.5</td>
</tr>
<tr>
<td>DE(_{00}) Black</td>
<td>.74</td>
<td>.44</td>
<td>1.39</td>
</tr>
<tr>
<td>DE(_{00}) Cyan</td>
<td>.47</td>
<td>.48</td>
<td>.52</td>
</tr>
<tr>
<td>DE(_{00}) Magenta</td>
<td>.34</td>
<td>.37</td>
<td>.28</td>
</tr>
<tr>
<td>DE(_{00}) Yellow</td>
<td>.18</td>
<td>.19</td>
<td>.26</td>
</tr>
<tr>
<td>DE(_{00}) Gray</td>
<td>.82</td>
<td>.82</td>
<td>.58</td>
</tr>
<tr>
<td>DE(_{00}) Red</td>
<td>.33</td>
<td>.39</td>
<td>.37</td>
</tr>
<tr>
<td>DE(_{00}) Green</td>
<td>.6</td>
<td>.31</td>
<td>.63</td>
</tr>
<tr>
<td>DE(_{00}) Blue</td>
<td>.39</td>
<td>.21</td>
<td>.53</td>
</tr>
<tr>
<td>DE(_{00}) Brown</td>
<td>.61</td>
<td>.29</td>
<td>.49</td>
</tr>
<tr>
<td>DE(_{00}) Purple</td>
<td>.27</td>
<td>.21</td>
<td>.32</td>
</tr>
<tr>
<td>DE(_{00}) Pastel</td>
<td>.29</td>
<td>.22</td>
<td>.42</td>
</tr>
</tbody>
</table>
Evaluation of Paper Samples
Boxplots DE$_{00}$ Paper
Evaluation of Paper Samples
M1 vs. M0

- M1 Delta-E\textsubscript{00}: (\(M = 7.7, \ SD = 0.47\))
- M0 Delta-E\textsubscript{00}: (\(M = 5.6, \ SD = 0.67\))
- \(M = -2.05, \ 95\% \ CI[-2.44—1.68], \ t(36) = -10.97\)
- \(p < 0.01.\)

There were 19 M0 and 19 M1 Instruments analyzed. An independent-samples t-test was run to determine if there were differences in Delta-E in reading an OBA paper and a non-OBA paper by measurement condition. There were no outliers in the data, as assessed by a visual inspection of the bloxplot. There was homogeneity of variances for Delta-E\textsubscript{00} Paper, as assessed by Levene’s test for equality of variances (\(p = 0.13\)). Delta-E\textsubscript{00} Paper for each level of Measurement Condition (M0/M1) were normally distributed, as assessed by Shapiro-Wilk’s test (\(p > 0.05\)).
Evaluation of Paper Samples
M0 vs. M0 Legacy

- M0 Delta-E_{00}: (M = 5.6, SD = 0.67)
- M0 Legacy Delta-E_{00} (M = 5.7, SD = 0.38)
- p > 0.05
Boxplots $\text{DE}_{00} \text{ Black}$
Evaluation of LabREF Black
M0 vs. M1 and M0 vs. M0 Legacy

- M1 Delta-E\(_{00}\): (\(M = 0.20, SD = 0.13\))
- M0 Delta-E\(_{00}\): (\(M = 0.21, SD = 0.17\))
- \(p > 0.05\)

- M0 Delta-E\(_{00}\): (\(M = 0.21, SD = 0.17\))
- M0 Legacy Delta-E\(_{00}\): (\(M = 0.25, SD = 0.30\))
- \(p > 0.05\)
Boxplots $DE_{00} \ \text{Gray}$
Evaluation of LabREF Gray

- M1 Delta-$E_{00}$: ($M = 0.54$, $SD = 0.21$)
- M0 Delta-$E_{00}$: ($M = 0.52$, $SD = 0.18$)
  - $p > 0.05$

- M0 Delta-$E_{00}$: ($M = 0.52$, $SD = 0.18$)
- M0 Legacy Delta-$E_{00}$: ($M = 0.53$, $SD = 0.19$)
  - $p > 0.05$
Boxplots $\text{DE}_{00}$ Brown

![Boxplots DE00 Brown](image)

- M0
- M1
- M0 Legacy

DE Brown vs M Condition
Evaluation of LabREF Brown

- M1 Delta-E_{00}: (M = 0.56, SD = 0.19)
- M0 Delta-E_{00}: (M = 0.59, SD = 0.12)
  - p > 0.05

- M0 Delta-E_{00}: (M = 0.59, SD = 0.16)
- M0 Legacy Delta-E_{00}: (M = 0.58, SD = 0.14)
  - p > 0.05
Boxplots $DE_{00}$ White

![Boxplot diagram showing $DE_{00}$ values across different M Conditions (M0, M1, M0 Legacy).](image-url)
Evaluation of LabREF White M1 vs. M0 and M0 vs. M0 Legacy

- M1 Delta-E$_{00}$: ($M = 0.23$, $SD = 0.12$)
- M0 Delta-E$_{00}$: ($M = 0.27$, $SD = 0.13$)
- $p > 0.05$

- M0 Delta-E$_{00}$: ($M = 0.27$, $SD = 0.13$)
- M0 Legacy Delta-E$_{00}$: ($M = 0.40$, $SD = 0.15$)
- $p > 0.05$
White Points, M0, M1 and M0 Legacy

M0 = Brown, M1 = Cyan, M0 Legacy = Green
Conclusions: Instrument Accuracy in Workflow

- Support for Widely Recognized Realizations
  - *Difference Information is Best Method*
  - *Careful Specification of Measurement Parameters Necessary*
Implications

- Instrument Manufacturers:
  - Provide Common Inter-Instrument Agreement Specifications for Real Comparison
  - Implement Black Trap Calibration
Future Research

- Continue Data Collection with Additional Instruments
- Measurement Systems Analysis
  - Fixed Effects (Measurement Condition)
  - Random Effects (Various Instruments)
  - Restricted Maximum Likelihood (REML)
Thank You!

- In addition to my colleagues at RIT including the Printing Applications Lab, I would like to thank the following companies for their support with this project:
  - Konica Minolta Sensing
  - Techkon USA
  - X-Rite
Active and Intelligent Packaging

Dr. Mark Bohan and John Bodnar
Printing Industries of America
Session
Overview

- What do we mean by smart packing?
- Types of packaging available
  - Active packaging
  - Smart or intelligent packaging
  - Use case examples
- Closing thoughts
Smart Packaging

Why are we looking to use this?

- Enhance the customer experience
  - Add value in some means

- Improving the product

- Quality control about the product

- Additional information
Active Packaging
Overview

- Enhance performance of the product
  - Interact directly with the product
  - Food applications

- Manufactured into the packaging materials
- Printed or coated

Albuquerque, NM 2015
Oxygen Absorbers
Why do we use

- Extend shelf life
- Reduced growth of pathogens
- Improved product quality
- Reduced oxidation
  - Vitamins, spices…
- Extend pharmaceutical life
Oxygen Absorbers
Active Packaging

- Chemicals to absorb $O_2$
  - $Fe \rightarrow Fe(OH)_3$
  - $H2 \rightarrow H_2O$

- Applications
  - Sachets
  - Bags
  - Labels
  - Bottles

www.appepackaging.com

Albuquerque, NM 2015
Moisture Absorption
Active Packaging

- Applications include
  - *Pharmaceutical*
  - *Electronics*
  - *Food applications*

- Materials
  - *Sachets: Silica gels, calcium oxide ....*
  - *Sheets: Multi layer with superabsorbent polymers*
    - Polyacrylate salts. Starch copolymers ....

www.multisorb.com
Thermochromic Inks
What Temperature is the Product At?

- Color change inks
  - *Indicate the current temperature*
- Food products
- Drinks and for promotions
  - *Fanta “Funstigator”*
Active Packaging

Some additional examples

- Ethylene absorbers
  - *Strawberries*

- Releasing elements
  - $CO_2$, preserving agents

- Antimicrobial
  - *Silver applications for office, electronics …*

- Heating elements
  - *Metals for microwaves*
Smart (Intelligent) Packaging

Overview

- Indicator on packaging
  - *Internal or external*

- Monitor the product and provide information
  - *Quality*
  - *Change*
  - *History*

- Communicate

Albuquerque, NM 2015
Time Temperature Indicators (TTI)
Also referred to as Time Temperature Integrators

- Temperature over time
  - Warning above/below set temperature
  - Color change over time
- Partial or full history
  - Different solutions available
- Different activators
Oxygen / Carbon Dioxide
Smart Packaging

- Oxygen sensors
  - Detect leaks in packaging
  - Issue with responsiveness
  - Microbial action

- CO₂ indicators
  - React to changes in pH
  - Used in meats ....

Albuquerque, NM 2015
Shock Indicators
Labels, circuits or sensors

- Look at shocks or impacts
  - Record over time
  - If pre-determined value exceeded

- Delicate materials
  - Shipping, handling and use
Interacting With Packaging
Customer Use of NFC (RFID from a producer)

- Utilize NFC enabled device
  - *NFC tag*

- Provide added value to the consumer
  - *Growth worldwide in linking packaging with mobile*
Chateau Le Pin
NFC integrated into wine labels

- Reliable anti counterfeiting solution
  - $3,000 average, up to $10,000

- Evaluated many technologies

- Linked the ID to the bottle and customer
  - Encrypted

- Created added value
  - Details of wine, virtual cellar, notes on wine etc.

http://www.rfidjournal.com
MIT

Research published using NFC

- Sensors connected to NFC tags
  - NFC tag adapted to detect the chemical using carbon nanotubes
  - Simple scan with phone
  - Used either by manufacturer or customer
Smart Packaging
Growth for Communication

- Integrating RFID/NFC communication into packaging
- Added functionality to the user
  - *Instructions*
  - *Interactive guides*
  - *Additional content*
  - *Promotions*
  - *Live updates*
Smart Packaging
Closing thoughts
Thanks for listening!

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Patterning for Transparent Conductive Grids

Dr. Liam O’Hara, Clemson – Presenting

Colleen Twomey, Cal Poly
Dr. Xiaoying Rong, Cal Poly
Dr. Chip Tonkin, Clemson
Dr. Malcolm Keif, Cal Poly
TCOs, TCFs, etc

- Transparent conductive oxides/film
- Used as transparent electrode
Options: Transparent Conductors

- **Subtractive**
  - *Indium Tin Oxide (ITO)*
  - *Zinc Oxide*
- **Additive…**
  - *Silver nanowire*
  - *Conductive polymer*
    - PEDOT:PSS, Loctite ECI 5000,
  - *Graphene / CNT*
  - *Patterned grid (silver)*

Source: IDTechEx
ITO Coating/etching

- Widely used
- Subtractive processing
  - ITO flood coated
  - Laser, plasma or chemically etched to pattern
- Brittle
- Expensive
  - Indium is mined and in limited supply

Image source: http://www.oxford-instruments.com
Silver Nanowire

- Ultra-fine wire
  - High conductivity
  - High transparency

Image source: Cambrios.com
Organic Polymers

- PEDOT:PSS...
  - *Poly(3,4-ethylenedioxythiophene) Polystyrene sulfonate*
  - *Macromolecular salt*
  - *Heraeus Clevios*
  - *AGFA Orgacon*
- Loctite ECI 5000

Image source: wikipedia.org
Related Literature

- The effect of grid shape on the properties of transparent conductive films based on flexographic printing.
  - Liu W., Fang Y., Xu Y., Li X., Li L.
- Flexo Optimization
  - 300 CPI anilox
  - 150N pressure

Summary of Liu, et. al. paper...

- Grid shape and printing parameters had an effect on performance of printed TC:
  - Concluded that hexagonal shape was optimum.
  - Printing pressures influenced result.
  - Sintering influenced conductivity.
  - Different length of side (L) and different line width (2a).

TC Research

67th Annual Technical Conference
Albuquerque, NM 2015

Microcell vs No microcell

20 μ
30 μ
40 μ
50 μ
60 μ
70 μ
80 μ
90 μ
Printed Electronics Press Run Variables

- OMET VaryFlex Press
- Pchem/Novacentrix PF1-722 Silver Flexographic Ink (nanoparticle)
- 3M 1920 (light medium) and 3M 1820 (firm) tape
- DPR solvent processed plate (.045” at ~ .013” relief)
- 8000 and 4000 dpi imaging with and without the application of Microcell patterns in solid areas

- Banded Anilox:
  - A: 1200 lpi/1.03 bcm
  - B: 1100 lpi/1.53 bcm
  - C: 1000 lpi/1.75 bcm
  - D: 900 lpi/2.22 bcm
  - E: 800 lpi/2.85 bcm
  - F: 700 lpi/3.58 bcm
Resolution — Why it Matters

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<td>2100 DPI</td>
<td>2540 DPI</td>
<td>4000 DPI</td>
<td>8000 DPI</td>
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<td>Pixels/in²</td>
<td>4,410,000</td>
<td>6,451,600</td>
<td>16,000,000</td>
<td>64,000,000</td>
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<tr>
<td></td>
<td>46% more pixels than 2100 DPI</td>
<td>148% more pixels than 2540 DPI</td>
<td>300% more pixels than 4000 DPI</td>
<td></td>
</tr>
</tbody>
</table>

Source: Rory Marsoun, Esko

Albuquerque, NM 2015
Bias Relative to Drum Rotation (raster)
Plate Results

6.35µm

3.175µm

6.35µm

4000 dpi
File: 1 pix line

8000 dpi
File: 1 pix line

8000 dpi
File: 2 pix line

Source: Colleen Twomey
TC Results

- Conductive traces printed at 200 fpm
- Sheet resistance by anilox band
  - A: 1200 lpi / 1.03 bcm \( \Rightarrow \pm 3.06 \, \Omega/\square \)
  - B: 1100 lpi / 1.53 bcm \( \Rightarrow \pm 2.11 \, \Omega/\square \)
  - C: 1000 lpi / 1.75 bcm \( \Rightarrow \pm 1.17 \, \Omega/\square \)
  - D: 900 lpi / 2.22 bcm \( \Rightarrow \pm 0.62 \, \Omega/\square \)
  - E: 800 lpi / 2.85 bcm \( \Rightarrow \pm 0.37 \, \Omega/\square \)
  - F: 700 lpi / 3.58 bcm \( \Rightarrow \pm 0.26 \, \Omega/\square \)
Various Patterns & Ratios of TCs

1. = 6.35μ-500μ-6x
2. = 9.525μ-500μ-8x
3. = 9.525μ-510μ-6x
4. = 6.35μ-1mm-6x
5. = 15.875μ-1mm-6x
6. = 9.525μ-900μ-5x
7. = 12.70μ-1mm-4x
8. = 9.525μ-1mm-6x
9. = 12μ/6μ-1mm
10. = 9.525μ-1mm-Circ
11. = 12.70μ-1mm-4x-b
12. = 12.70μ-1mm-6x
Theoretical Transparency

\[ T_\Delta = \frac{\sqrt{3}}{4} \frac{L^2 - 6aL}{L^2 - 3aL} \times 100\% = \left(1 - \frac{12aL}{\sqrt{3}L^2 - 12aL}\right) \times 100\% \]

\[ T = \frac{(L - 4a)^2}{(L - 2a)^2} \times 100\% = \left(1 - \frac{2a}{L - 2a}\right)^2 = 100\% \]

\[ T_{Hex} = \frac{\frac{3}{2} \sqrt{3} L^2 - 12aL}{2 \frac{\sqrt{3}}{2} L^2 - 6aL} \times 100\% = \left(1 - \frac{12aL}{\frac{3}{2} \sqrt{3} L^2 - 12aL}\right) \times 100\% \]

\( L = \) line length

\( a = \frac{1}{2} \) line width


Albuquerque, NM 2015
Printed Transparent Grid

- Print Conditions
  - Silver ink
  - 1000 cpi / 1.75 BCM
  - 200 fpm

- Results
  - Lines on the plate are 11 µm
  - Printed vertical lines are 25 µm
  - Printed diagonal lines are 30 µm

Plate-to-Print

Albuquerque, NM 2015
Photos of Transparent Grid Patterns

Grid Pattern 8, 1820

Grid Pattern 11, 1820

Grid Pattern 8, 1920

Grid Pattern 11, 1920
Analysis: Resistance

- Heavy volume anilox bands tend to provide less resistance - less than 15 ohms
- 1820 tape provided lower resistance.

![Mean resistance chart]

Albuquerque, NM 2015
Analysis: Transmission

- The square/diamond shape grid in addition to the hexagon grid performed the best no matter the anilox volume/line screen.
- 1820 tape performed best
  - Grids 4, 7, 8, 11 provided transmissivity numbers ≈ 92%
Visual Appearance

1 Inch

Transparent Grid Patterns

6.35μ - 1mm - 6x
9.525μ - 1mm - 6x
12.70μ - 1mm - 6x
Hexagons!

- Triangles, squares, and hexagons are the only regular polygons to tessellate the Euclidean plane.
  - Shared “walls”
  - Hexagons maximize open area.
- But…
  - Must optimize to print fine conductive lines reliably.
  - Maximize open area of film.
  - Retain resolution needed for touch screen.
Optimization Strategy

- Given that high light transmission and low resistance are opposing variables…

1. Determine minimum line width able to reproduce on various axes.
2. Determine “open area” (L & W of lines) based on…
   - Resolution required if touch screen.
   - Resistance requirements
   - Redundancy to eliminate open circuit
3. Optimize transparency-to-resistance ratio – Q ratio

### Line Length to Width Ratio

<table>
<thead>
<tr>
<th>Rs</th>
<th>Line length (μm)</th>
<th>Line width (μm)</th>
<th>Length/width ratio</th>
<th>Transmission (T)</th>
<th>Estimated resistance (R)</th>
<th>Q ratio (T/R)</th>
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</thead>
<tbody>
<tr>
<td>0.37</td>
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<td>577</td>
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<td>0.016696486</td>
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</table>
6.35μ line width -- 1mm in width (sw) – line length of 577 μm – 90:1 ratio
The reality...

- Many inks are not entirely opaque
- Lines widths do not “gain” uniformly
- Resistance varies with line uniformity variations
- Any artifacts (scratches) will impact performance
<table>
<thead>
<tr>
<th></th>
<th>Resistance Horizontal</th>
<th>Resistance Vertical</th>
<th>Resistance Diagonal</th>
<th>Mean resistance across pattern</th>
<th>Solid density (right)</th>
<th>Grid Patch (zero on film)</th>
<th>Film density</th>
<th>Density of grid patch w/film</th>
<th>Transmissivity*</th>
<th>Mean transmissivity across pattern</th>
<th>Ratio Transmissivity to conductivity</th>
<th>Mean Ratio across pattern</th>
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<td>0.035</td>
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<td>92.27%</td>
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<td>0.01</td>
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<td>92.26%</td>
<td>3.6</td>
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<tr>
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<td>92.26%</td>
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<td>92.26%</td>
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<td>92.62%</td>
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<td>92.26%</td>
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<td>86.10%</td>
<td>86.10%</td>
<td>8.5</td>
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</tbody>
</table>
In Summary

- Your starting point is....
  - Hexagonal shape with minimum line width.
  - Theoretical line length/width ratio $\approx 80$-$100$.
  - Control your press parameters to maintain line integrity.
Thank You!

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Liam O’Hara, lohara@clemson.edu
PRINTING ELECTRONICS ON NOVEL PAPER SUBSTRATES

Presented by: Mark Heise
TAGA 2015
Outline

• Introduction
• Context of this work
• Materials and Methods
• Results
• Conclusion
Introduction: Overview

• Improvements to surface roughness and porosity of paper enables the printing of circuits and components using conventional printing processes.
• This allows for new substrate considerations for interesting properties and applications.
• Explore the printing of RFID antennas on paper with various inks, printing methods, and sintering techniques.
Introduction:
LEADING MANUFACTURER
OF TECHNICAL & CREATIVE PAPERS

- World leader in technical and creative papers
- €1.5 billion in sales
- 1.1 million tones of paper per year
- 5000+ employees
- Security, technical, coated, & graphic papers

20 production sites mostly located in Europe
Introduc.on: Interest in Printed Electronics

- Printed Electronics
  - Conventional printing processes used to manufacture printed circuits and components (screen printing, ink jet, flexo, gravure,...)
  - Opportunity to use low-cost and flexible substrates (PET, PEN, PI, paper,...)
  - Fast growing field since the 2000s (<1800 new articles per year)

- Flexible and large area electronics
- Very high throughput
- Low cost manufacturing
- Low complexity
- Huge potential of R2R printing processes
Introduction: Substrate Selection

- Main properties to consider when selecting a substrate:
  - Roughness
  - Temperature resistance
  - Cost


Introduction: Paper and Electronics

- Paper is generally not used because of excessive roughness and porosity
  - Printed features disconnect, short, and can be inconsistent
  - Conductive ink absorbed by paper can reduce effectiveness

Hodgson, A., The role of paper in the future of printed electronics
Introduction: Paper and Electronics

- Paper has interesting and favorable properties compared to plastic substrates
  - Competitive price
  - Good thermal resistance
  - Biodegradability
  - Ready to print (no pre-treatments)
  - Very good for R2R (proven for decades already)
  - Easy assimilation for graphic printers
Outline

- Introduction
- Context of this work
- Materials and Methods
- Results
- Conclusion
**Context:**

**Powercoat Roughness**

Roughness of different substrates

![Bar chart showing roughness of different substrates](chart.png)

AFM measurements (on 5x5 μm squares)
Context:
Powercoat Temperature Resistance

PowerCoat dimensional stability vs temperature

- PEN
- Thermostabilised PET
- Polymide
- PowerCoat™

![Graph showing dimensional stability vs temperature for different materials.](image)

The graph illustrates the young modulus (PA) at different temperatures (°C) for four materials: PEN, Thermostabilised PET, Polymide, and PowerCoat™. The y-axis represents the young modulus in PAs, ranging from 1.0E+07 to 1.0E+10. The x-axis represents the temperature in °C, ranging from 50 to 250.
Context:

“IoT” and Connected Objects
Outline

• Introduction
• Context of this work
• Materials and Methods
• Results
• Conclusion
Materials and Methods: Printing Step

- Printing was done using an Argon CMP UNOSTAR 2 industrial screen printing press.

- Two silver inks were printed:
  - Agfa silver nano-ink Orgacon SI-P1000x (solid content 58%) using a 180 l/cm mesh
  - A conventional silver microflakes ink (solid content 75%) using a 120 l/cm mesh
Materials and Methods: Substrates and Sintering

• **Two different substrates** were used:
  - A heat-stabilized PET plastic film, Mylar A, from Dupont with a thickness of 125 μm
  - A 100% pure paper substrate, Powercoat XD, from Arjowiggins with a thickness of 125 μm

• As the PET substrate cannot sustain high temperatures, sintering was done in an oven at **150°C** for **15 minutes**
• Higher thermal resistance of paper allows sintering at higher temperature of **180°C** for only **5 minutes**
Materials and Methods:
Electrical Measurements

- Dry ink film **thickness** was measured, both, using **mechanical profilometer** and **SEM** cross-sections
- Electrical performance was measured on kelvin test structures using four-point method on a Suss-Microtech PM5 prober
- Resistivity was calculated using the following equation:
  - Resistivity \( [\Omega,m] = \frac{R \times w \times t}{l} \)
  - \( t = \) thickness (m)  \( w = \) line width (m)  \( l = \) length (m)
Materials and Methods:

NFC Antennas

- As the printing test pattern was also made of several NFC antenna, designed for smart-card standard (85.6 * 53.98 mm², ISO 7816), some of them were characterized in terms of (R,L,C) components and quality factor using an Agilent 4386B impedance analyzer.
Outline

- Introduction
- Context of this work
- Materials and Methods
- Results
- Conclusion
Results:
Dry Ink Thickness

**Profilometer and SEM cross-sections for micro-flakes on paper**

- **Average ink thickness (μm)**
  - Microflakes ink
    - PET: 8.7
    - XD paper: 7.1

Average thickness based on 10 mechanical profiles + SEM observations

**Profilometer and SEM cross-sections for nano-ink on PET**

- **Average ink thickness (μm)**
  - Nano ink
    - PET: 1.6
    - XD paper: 1.9
Results:
SEM Views

SEM pictures on printed Powercoat Paper

Size of the micro-flakes is between **1 and 10 µm**

Nano-particles are about **100 to 150 nm** after sintering step
Results: Electrical Performances

<table>
<thead>
<tr>
<th>Resitivity [μΩ.cm]</th>
<th>HS-PET (150°C – 15 min)</th>
<th>XD Paper (150°C – 15 min)</th>
<th>XD Paper (180°C – 5 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microflakes ink</td>
<td>33.1</td>
<td>26.1</td>
<td>23.1</td>
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<tr>
<td>Nano-ink</td>
<td>9.9</td>
<td>7.9</td>
<td>7.1</td>
</tr>
</tbody>
</table>

- At same sintering conditions resistivity on paper is slightly better than on PET
- Due to higher sintering temperature on paper substrates electrical performances are 30% better than on PET
- Nano-ink resistivity is more than 3 times better than microflakes ink
Results:
NFC Antennas

• Best performance antenna (higher Q factor) consists on a 4 turns coil, with 1.5 mm width and 0.5 mm gap.
• Coil resonant frequency is 36 Mhz (14 MHz with a 50 pF NFC chip)

<table>
<thead>
<tr>
<th></th>
<th>HS-PET</th>
<th>Powercoat XD Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microflakes ink</td>
<td>56.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Nano-ink</td>
<td>80.5</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Use of paper instead of PET lead to **20 to 30% gain** on Q factor
Results:
Reported Q Factors

**SCREEN-PRINTED ANTENNAS:**

- **Q = 3** for 13.4 µm of silver paste
- **Q = 5.2** for 19 µm of silver paste
- **Q > 15** high ink deposit

**INKJET PRINTED ANTENNAS:**

- **Q = 5 (4 layers) / Q = 10 (10 layers = 8µm !!!)**
- **Q = 1.7** for 1.4µm
- **Q = 9.4 / 3 to 5 layers on Polyimide**
Other Applications

- AFELIM invitation with embedded NFC tag, March 2015 (French Association for printed electronics)
- Luxury packaging with digital content launched using NFC enabled smartphone
- Advertising inserts in magazines
- NFC Business cards
Outline

• Introduction
• Context of this work
• Materials and Methods
• Results
• Conclusion
Conclusion

• By using nano ink instead of microflakes:
  • Printing thickness can be as low as 2 μm (180 l/cm mesh)
  • Resistivity is 3 times better than widely used microflakes ink

• By using Powercoat XD paper substrate
  • Electrical performances are 10 to 30% better than on PET due to an improved sintering process (up to 200 °C)
    • Thus, better circuit or can save $ on ink
  • Paper substrate is a recyclable and biodegradable material
Conclusion

• NFC antennas were printed with high quality factors
  • 7.6 for less than 2 μm of nano-ink on paper (5.2 on PET)
  • 9.6 for microflakes ink on paper (7.6 on PET)

• Finally, the combination **nano-ink/Powercoat paper** allows printers to use **4 times less ink** than microflakes/PET for similar electrical performances

• The results confirm the potential of using screen-printed Agfa nano-ink on Arjowiggins Powercoat XD paper to manufacture NFC tags in a greener way
Investigation of the Implementation Aspects of the M1 Condition

David R. Wyble
Avian Rochester, LLC

John Seymour
Quadtech Inc.
A Tale of Two Instruments

Non-fluorescent samples: Instrument #1 CIELAB = Instrument #2 CIELAB

Fluorescent samples: Instrument #1 CIELAB ≠ Instrument #2 CIELAB
A Tale of Two Instruments

Non-fluorescent samples: Instrument #1 CIELAB = Instrument #2 CIELAB

Fluorescent samples: Instrument #1 CIELAB ≠ Instrument #2 CIELAB

The discrepancy is caused by the difference in instrument source content in the excitation region of the fluorescent sample.
Questions For Today

Given the powerful combination of FTS standards and bispectral data:

1. Are ISO 3664 and ISO 13655 adequate for the evaluation of instrument sources?

2. Using various hypothetical instrument sources how do measurements of the acrylic standards compare?
Questions For Today

Given the powerful combination of FTS standards and bispectral data:

1. Are ISO 3664 and ISO 13655 adequate for the evaluation of instrument sources?

2. Using various hypothetical instrument sources how do measurements of the acrylic standards compare?
FTS Acrylic Standards

- FTS standards sourced from Avian Technologies, LLC. Previously made by Color Control Systems. Same products, same formulations.

- FTS = Fluorescent Transfer Standards. Also to pay homage to the late Frederick T Simon, who originally developed the product line.

- Inorganic fluorescent compounds intended to mimic the behavior of typical paper OBAs.

- Full disclosure...
FTS Acrylic Standards

<table>
<thead>
<tr>
<th></th>
<th>FTS</th>
<th>17b</th>
<th>15a</th>
<th>13a</th>
<th>11a</th>
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<tr>
<td>CIE W</td>
<td>155</td>
<td>142</td>
<td>128</td>
<td>108</td>
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</table>

Tungsten
UV
Daylight
NRC Measurements

CIE Illuminants

“Total Radiance Factor”

FTS
Bispectral Measurements

- Think reflectance but in 2D.
- Each column represents a complete reflected spectrum at one incident wavelength.
Bispectral Measurements

- Think reflectance but in 2D.
- Each column represents a complete reflected spectrum at one incident wavelength.
Bispectral Measurements

- Think reflectance but in 2D.
- Each column represents a complete reflected spectrum at one incident wavelength.
Bispectral Calculations

sum over all incident wavelengths (excluding diagonal) to find the "emission region"

sum over all detection wavelengths (excluding diagonal) to find the "excitation region"
On to the questions:

Are ISO 3664 and ISO 13655 adequate for the evaluation of instrument sources?

Danny Rich
On to the questions:

Are ISO 3664 and ISO 13655 adequate for the evaluation of instrument sources?

Danny Rich
On to the questions:

Are ISO 3664 and ISO 13655 adequate for the evaluation of instrument sources?

Chromaticity
Color Rendering Index
Visible Metamerism Index
UV Metamerism Index

Source is a conforming D50 simulator

Danny Rich
Three Ways to Achieve M1

Simply match the D50 spectral power distribution

Adjust the UV to achieve D50 colorimetry (single flash, Gärtner and Griesser)

Mix reflectance from high and low UV sources to achieve D50 colorimetry. (dual flash, Imura)
Three Ways to Achieve M1

Simply match the D50 spectral power distribution

Adjust the UV to achieve D50 colorimetry (single flash, Gärtner and Griesser)

Mix reflectance from high and low UV sources to achieve D50 colorimetry. (dual flash, Imura)
Experiment

Hypothetical Illuminants

“Total Radiance Factor”

FTS tiles

CIELAB
Virtual Sources 1: CIE Daylight

CIE Daylight between 4976K and 5028K are M1 complaint. The range is only about 1/2%
### Virtual Sources 1: CIE Daylight

<table>
<thead>
<tr>
<th>FTS</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>11a</td>
<td>0.003</td>
<td>0.047</td>
</tr>
<tr>
<td>13a</td>
<td>0.007</td>
<td>0.078</td>
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<tr>
<td>15a</td>
<td>0.008</td>
<td>0.118</td>
</tr>
<tr>
<td>17b</td>
<td>0.010</td>
<td>0.133</td>
</tr>
</tbody>
</table>

**Ranges**
Virtual Sources 1: CIE Daylight

But can we measure it?

Yes.
Virtual Sources 1: CIE Daylight

<table>
<thead>
<tr>
<th>FTS</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.003</td>
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<td>17b</td>
<td>0.010</td>
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Compliant CIE Daylight

\[ \lambda \leq 400 = 0 \]
Virtual Sources 1: CIE Daylight

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<tr>
<th>FTS</th>
<th>$a^*$</th>
<th>$b^*$</th>
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<tbody>
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<td>0.041</td>
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<tr>
<td>17b</td>
<td>0.003</td>
<td>0.044</td>
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</table>

Compliant CIE Daylight
$\lambda \leq 400 = 0$

Typical UV Cut Filter
Fully eliminate Fluorescent Emission
Virtual Sources 2: Scale D50 UV

![Graph showing relative power vs. wavelength (nm)]
Virtual Sources 2: Scale D50 UV

±40%: still M1 complaint
Virtual Sources 2: Scale D50 UV

<table>
<thead>
<tr>
<th>FTS</th>
<th>$a^*$</th>
<th>$b^*$</th>
</tr>
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<tbody>
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<td>1.13</td>
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Ranges
Virtual Sources 2: Scale D50 UV

<table>
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<tr>
<th>FTS</th>
<th>a*</th>
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<table>
<thead>
<tr>
<th>FTS</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
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<tr>
<td>15a</td>
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<td>0.99</td>
</tr>
<tr>
<td>17b</td>
<td>0.29</td>
<td>1.16</td>
</tr>
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</table>

Compliant Scaled UV

Compliant Scaled UV

$\lambda \leq 400 = 0$
Conclusions for question #1

Are ISO 3664 and ISO 13655 adequate for the evaluation of instrument sources?

<table>
<thead>
<tr>
<th>Metric</th>
<th>CIE Daylight</th>
<th>Scaled UV</th>
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</thead>
<tbody>
<tr>
<td>Chromaticity</td>
<td>X</td>
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<tr>
<td>CRI</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Visible Metamerism</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>UV Metamerism</td>
<td>✓</td>
<td>X</td>
</tr>
</tbody>
</table>

Which metrics bound compliance for these sources?
Conclusions for question #1

Are ISO 3664 and ISO 13655 adequate for the evaluation of instrument sources?

Large b* range!
Question #2

Using various hypothetical instrument sources how do measurements of the acrylic standards compare?

To reasonably model instrument sources, we first examine four currently implemented instrument sources:

- Barbieri SpectroPad Series 2
- Techkon SpectroDens
- Konica-Minolta FD-7
- X-Rite eXact, and i1Pro
Real World M1

Barbieri SpectroPad Series 2

“Thanks to 7 LEDs, D50 illumination is reached. This illumination is based on LED technology by Just Normlicht. It fully matches the new measurement condition M1 introduced with the ISO standard 13655-2009.”
Real World M1

Techkon SpectroDens

“Using the latest LED technology, the new SpectroDens provides D50 illumination and therefore fulfills the M0 – M3 measuring conditions in accordance to ISO 13655.”
Real World M1

Konica-Minolta FD-7

Product literature mentions their “Virtual Fluorescent Standard”, which is a phrase used in the dual-flash papers by Imura. We infer that the FD-7 uses the two flash method. Their literature also states that the light source is LED based.
X-Rite eXact, and i1Pro

Product literature refers to “gas filled tungsten (illuminant type A) and UV LED”. It is not clear the precise method of the i1Pro. An X-Rite patent describes a method similar to the two-flash.

Note that the X-Rite Isis is based on an i1Pro. Also, the i1Pro is the OEM for the EFI ES-2000.
Real World M1

Existing Instrument Summary

This short review demonstrates that different companies have implemented the M1 condition by the use of different physical light sources. Thus, there is at least the potential for this to be a source of disagreement between different models of spectrophotometer.

Forgive the legalese: The authors are not endorsing any of these products, nor are they necessarily agreeing with the claims of the product literature we reference. Our sole criterion was the claim of M1 compliance.
Real World Results

Facility #1: A, B1, C1, D
Facility #2: B2, C2, E (no 9a)

Tag A 64th Annual Technical Conference, Albuquerque NM, March 2015
Hypothetical Sources

Four sources were modeled, each with an adjustable UV component and one or more visible components.
Experimental Procedure

We illuminate a fluorescent sample with D50 and the test source. Adjust UV component to minimize $\Delta E^*_{ab}$
Experiment: Two Paths to CIELAB

Hypothetical Instrument

“Total Radiance Factor”

FTS tiles or paper

CIELAB
Experiment: Two Paths to CIELAB

D50

“Total Radiance Factor”

FTS tiles or paper

CIELAB
Experimental Results: $\Delta E_{ab}$ to D50

Is the FTS tile as good a standard as paper?
Experimental Results: $\Delta E_{ab}$ to D50

Is the FTS tile as good a standard as paper?
Experimental Results: $\Delta E_{ab}$ to D50

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Experimental Results: $\Delta E_{ab}$ to D50

Is the FTS tile as good a standard as paper?
Experimental Results: $\Delta E_{ab}$ to D50

Is the FTS tile as good a standard as paper?
Conclusions for question #2

Using various hypothetical instrument sources how do measurements of the acrylic standards compare?

- Calibrating against paper does produce slightly better results.
- We believe that the difference between the test sources and D50 accounts for more of the color differences.
- The technique can expose the differences between illumination technologies.
Future Work

• Modeling of the dual flash method.

• Better understanding of the implications of differences in the bispectral matrices of paper and FTS standards.

• Can the acrylic standards adequately simulate the behavior of the fluorescent compounds in commercial papers?

• How might acrylic fluorescent standards be applied to the instrument profiling process?
Acknowledgements

• Danny Rich of SunChemical Corp, for generously sharing his spreadsheet used for evaluating illuminants.

• Gerry Gerlach of Integrity Graphics and IdeAlliance, for asking important questions, and for loaning his (borrowed) KonicaMinolta FD-7 spectrophotometer.

• Techkon USA for loaning their SpectroDens spectrophotometer.

• Tom Lianza of PhotoResearch Inc, for the use of his X-Rite exact spectrophotometer.

• Max Derhak of Onyx Graphics, for facilitating the Barbieri measurements on the Onyx Spectro Pad 2 spectrophotometer.

• A list of people, many of whom I don’t even know, that have been exchanging email for a few months on many related topics: Danny Rich, Gerry Gerlach, Mike Rodriguez, Roy Bohnen, Ronald Tomey, Steve Smiley, David McDowell, David Steinhardt, Gary Russell, Claas Bickeböller, Mark Lombardi, Ray Cheydleur, Jodi Baker.

• Avian Technologies, LLC, for travel funding.
Thank you
The Effect of OBA in Paper and Illumination Intensity on Perceptibility of Printed Colors

Changlong Yu*, Robert Chung*, and Bruce Myers*

* Rochester Institute of Technology, Rochester, NY

67th Annual Technical Conference · Albuquerque, NM 2015
Introduction

- Color aims for commercial printing are traditionally based on paper substrates without optical brightening agents (OBAs). Today, OBAs are widely used in printing papers.
- Print buyers demand brighter paper. The use of OBAs provide brighter stocks at lower cost and with less environmental impact.
Problem Statement

- When OBA-loaded papers are used in printing, three issues arise:

  1. Color of the paper is out of specifications.

  2. Printed colors, e.g., solids and grays, and their conformance are influenced by the paper color.

  3. Color mismatch between contract proofs and final prints.
Research Objectives

1. Conduct psychometric experiments to quantify visual color difference between prints with and without the presence of OBA in M1 lighting.

2. Study the relationship between visual color difference (Visual Difference Index) and color difference metrics, namely, $\Delta E^*$ and $\Delta E_{00}$.

3. Investigate whether visual color difference indices (VDI) depend on the illumination level.
Methodology, Overall

1. Preparing color samples
2. Screening observers
3. Conducting visual ranking experiments
4. Performing data analyses
Methodology

1. Preparing color samples

- A total 27 pairs of printed color patches (3.5” x 7” in size), derived from the IT8.7/4 target (1,617 color patches), were prepared that sample the color space in lightness, hue, and chroma, using the same colorants printed on the paper with OBA (Invercote G) and the same paper without OBA (Invercote T).
Methodology

2. Screening observers

- *Farnsworth-Munsell 100 Hue Tests were conducted in the (D50, P1) standardized viewing condition.*

- *A total of 35 students and staff from the College of Imaging Arts and Sciences at RIT volunteered to participate in the study.*
  - One observer was color-deficient.
  - 34 observers were eligible for the psychometric experiments.
Methodology

3. Conducting visual ranking experiments
   - GTI viewing cabinet capable of adjusting the illuminant intensity to ISO 3664 P1 and P2 conditions
   - Two anchor reference pairs of ‘Noticeable difference’ and ‘No difference’ were presented.
   - Rating the visual color differences (VDI) using a four-point scale
     - 0 = No Difference
     - 1 = JND
     - 2 = More than JND
     - 3 = Noticeable Difference
Methodology

4. Performing data analyses
   - Individual scores on visual ranking were tabulated and averaged in terms of VDI.
   - The linear relationship between visual difference index (VDI) and color difference metrics (ΔEs) was analyzed.
   - Two-way tables and the Chi-square test were employed to test if there is association between illumination levels and visual color difference (VDI).
Results

1. Frequency distribution of sample pairs by visual ranking

2. Frequency distribution of sample pairs by $\Delta E_{ab}^*$ and $\Delta E_{00}$
Results

2. Relationship between visual color difference (VDI) and color difference metrics

- VDI vs. $\Delta E_{00}$ has a stronger linear correlation with visual color difference than $\Delta E_{ab}^*$. 

![Graphs showing VDI vs. $\Delta E_{ab}$ and VDI vs. $\Delta E_{00}$ correlations.](image)
Results

- Light, pastel, and neutral colors show more color difference.
- Dark and saturated colors show less to no color difference.
Results

3. Relationship between perceived color difference and illumination intensity
   - There is no significant association between illumination levels and perceived color difference indices.
   - However, observers tend to see more color differences, e.g., sample pair 12, under P1 than under P2 conditions.
Further Research

- ISO/FDIS 15397 (2013) describes the use of CIE-b* (D50, 2-degree) value of the paper to quantify the OBA amount in paper under two measurement (M1 and M2) conditions, i.e.,

\[ OBA = b^*_{M2} - b^*_{M1} \]

- We define \( \Delta OBA \) as the OBA difference between any color pairs, including substrates, S1 & S2.

\[ \Delta OBA = OBA_{S1} - OBA_{S2} \]

- The larger the \( \Delta OBA \) is, the more critical is the viewing illumination and the color management task.
Further Research

- In this research, $\Delta OBA$ also shows a linear relationship with VDI.
  - Similar to $\Delta E_{00}$, $\Delta OBA$ applies not only to substrate, but also printed colors.
Conclusions

- $\Delta E_{00}$ has a more linear correlation with visual color difference than $\Delta E^*_{ab}$ would.
- There is no significant association between illumination levels and perceived color difference.
- $\Delta OBA$ describes the potential of gamut clipping in color management and the criticalness of M1 lighting in visual assessment of proof and print.
Acknowledgments

- We want to express our appreciations to
  - Iggesund Paperboard for donating Invercote T and G papers
  - GTI for providing ISO 3664 (2009) compliant viewing booth
  - X-Rite for providing ISO 13655 (2009) M1 spectrophotometer
  - RIT School of Media Sciences for providing the academic environment enabling us to excel and learn.

Any Questions?
M1 Simulation by Varying Printing and Proofing Substrates

Bob Chung

RIT School of Media Sciences

67th Annual Technical Conference · Albuquerque, NM 2015
Introduction

- Standardization in color management and color printing, by means of reference printing conditions, enables repeatability and predictability in color reproduction workflows.
- Market does not want to standardize paper color.
  - *When paper colors are not accounted for in the color reproduction workflow, color repeatability and predictability suffer.*
    - One of the factors that affects paper color is the addition of OBA.
New Level of Standards

- GCATS.21 Standard (2013)
  - Establishes principles for using color characterization data as the definition of printing across multiple technologies.
  - Specifies color measurement according to ISO 13655 M1 with white backing.
  - Uses the substrate correction method, defined in ISO 13655, to adjust the data before proofing and printing.
Literature Review

- Chung studied how OBA affects white point of the substrate and printing conformance (Advanced Materials Research, 2011).
- Chung studied printing conformance to substrate-corrected dataset (TAGA Proceedings, 2013).
- Chung invited four proofing solution providers to participate in the proof-to-brightened print color match study (IARIGAI, 2013).
Literature Review

- ISO/FDIS 15397 states that the difference of the CIE-\(b^*\) values (D50, 2-deg) indicates the OBA amount or degree of fluorescence in a substrate.
  - \(OBA = b^*_{M2} - b^*_{M1}\)

- While OBA is a material characteristic, \(\Delta OBA\) is the OBA difference between two substrates, e.g., print and proof.
  - \(\Delta OBA = OBA_{Proof} - OBA_{Print}\)
Literature Review

- RIT studied the perceptibility of color difference of printed color pairs, due to OBA difference in paper, and its relationship with $\Delta E_{00}$ (TAGA, 2015).
  - Fluorescent agents affect CIE-$b^*$ value of a substrate, but its $L^*$ stays the same.
  - There is a linear relationship between visual difference and $\Delta E_{00}$.
  - Since $\Delta OBA$ is the main contributor of $\Delta E_{00}$, there is also a linear relationship between visual difference and $\Delta OBA$. 
Objectives

- Given that color measurement and color viewing conform to M1, this research sets out to answer two questions:

  1) *In what way, the white point and the OBA amount of a substrate influence the print-to-proof color match, and*

  2) *What are the recommended practices in achieving the proof-to-print visual match when printing and proofing substrates varying in OBA amounts?*
Methodology

1) Select a CRPC or a reference dataset.
2) Select three printing and three proofing conditions (varying in OBA amount).
3) Study the relationship between white point and OBA amount.
4) Select a pictorial color (SCID) image.
5) Simulate the SCID image, as printed, in relation to CRPC.
6) Simulate the SCID image, as printed and proofed, visually.
7) Simulate the SCID image, as printed and proofed, quantitatively.
8) Estimate the simulation error.
Methodology

- Reference dataset and ICC profile
  - **CGATS.21-2 CRPC6**
  - **ICC profile: GRACoL2013_CRPC6.icc**

- Three printing conditions
  - Papers with similar L* (93~95), but varying OBA
  - ICC Profiles, built from substrate-corrected dataset, using i1 Profiler

<table>
<thead>
<tr>
<th>CGATS 2010 Database</th>
<th>LAB_L</th>
<th>LAB_A</th>
<th>LAB_B</th>
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<td>-0.03</td>
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</tr>
</tbody>
</table>
Methodology

- Three proofing conditions
  - Low OBA: Epson Standard Proofing Paper 205
  - Medium OBA: Epson Proofing Paper Production
  - High OBA: Mid-States FSC 7S Paper Outre

- ICC profiles (courtesy of Bruce Bayne, Alder Technology, Inc.)

<table>
<thead>
<tr>
<th>Substrate</th>
<th>M1 LAB_L</th>
<th>M1 LAB_A</th>
<th>M1 LAB_B</th>
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<td>1.13</td>
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<td>pfH_Outre</td>
<td>95.45</td>
<td>1.69</td>
<td>-9.86</td>
<td>95.03</td>
<td>-0.92</td>
<td>-0.12</td>
<td>9.74</td>
</tr>
</tbody>
</table>
Methodology

- SCID image, ISO 12640, N4A (Bar set)
  - Re-size the image (300 ppi, CMYK) to 3” wide with borders for visual assessment.
  - Re-sample the image to 5 ppi for quantitative assessment.
Methodology

- Simulate the SCID image, as printed, visually.
  - Open the SCID image in Adobe Photoshop.
  - Assign a printer ICC profile, sccaX, where X is OBA amount (L, M, and H).
  - Convert the image from the CMYK space to Adobe RGB space using absolute colorimetric rendering.
  - Save as Scene_sccaX_adobe.jpg.
Methodology

- Simulate the SCID image, as proofed, visually.
  - Open a SCID image in Adobe Photoshop.
  - Convert the image via a device link profile, DL(sccaX-pfY).icc using absolute colorimetric rendering.
    - Device link profiles are built using i1 Profiler.
  - Assign the proofer profile, pfY.icc, to the converted image.
  - Convert the above image from pfY space to Adobe RGB space using absolute colorimetric rendering.
  - Save as Scene_sccaX-pfY_adobe.jpg.
Methodology

- Simulate print-to-proof visual comparison
  - Place simulated print (adobe.jpg) and simulated proofs (adobe.jpg) in Microsoft PowerPoint.
    - Place print and proof in edge contact.
    - Add legends.
    - Add a neutral background.
Methodology

- Simulate SCID image, as printed and proofed, quantitatively
  - *In ColorThink s/w*,
    - Generate a CIELAB color list from a print (reference) and color lists from three proofs (samples).
    - In Excel s/w, compare color difference ($\Delta E_{00}$) between reference and sample color lists.
Methodology

- Simulate device error
  - Begin with a CIELAB color list (reference).
  - Perform ‘round-trip’ by assigning the same ICC profile twice (B-to-A, then A-to-B) in absolute colorimetric rendering. This is the sample list.
  - Assess $\Delta E_{00}$ distribution between the two color lists.
Results – Device Error

- Round trip analyses of all three printing and proofing conditions show similar performance.
  - Color differences at 95th percentile of the distribution is about $1\ \Delta E_{00}$. 
Results – Visual Simulation of Printing

- CRPC as the print reference
  - Visual differences, due to substrate difference, are intentional.
Results – Quan. Simulation of Printing

- $\Delta E_{00}$ distribution of colorlists between CRPC6 and three SCCA datasets vary widely.
  - Low OBA print has the largest $\Delta E_{00}$ and visual difference to CRPC6.
  - Medium OBA print has the smallest $\Delta E_{00}$ and visual difference to CRPC6.
Results -- Print-to-Proof Simulation

- Case 1 – Low OBA print as the reference
  - The print substrate and the three proofing substrates show large variations in $\Delta OBA$ and $\Delta E_{00}$.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>LAB_L</th>
<th>LAB_A</th>
<th>LAB_B</th>
<th>LAB_L</th>
<th>LAB_A</th>
<th>LAB_B</th>
<th>OBA</th>
<th>$\Delta E_{00}$ (sccaL_McCoy)</th>
<th>$\Delta OBA$ (sccaL_McCoy)</th>
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Results -- Print-to-Proof Simulation

- Case 1 -- Low OBA print as the reference
Results -- Print-to-Proof Simulation

- **Case 1 -- Low OBA print as the reference**
  - Color differences at 95th percentile of the distribution is about $2 \Delta E_{00}$ or less.
Results -- Print-to-Proof Simulation

- **Case 2 -- Medium OBA print as the reference**
  - *The print substrate and the three proofing substrates show less \( \Delta \text{OBA} \) and \( \Delta E_{00} \) variation than those in Case 1.*

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Results -- Print-to-Proof Simulation

- Case 2 -- Medium OBA print as the reference
Results -- Print-to-Proof Simulation

- Case 2 -- Medium OBA print as the reference
  - Color differences at 95th percentile of the distribution is $2 \Delta E_{00}$ or less.
  - The high OBA proof has the smallest $\Delta E_{00}$ at 95th percentile of the distribution.
Results -- Print-to-Proof Simulation

- Case 3 -- High OBA print as the reference
  - The print substrate and the three proofing substrates have more ΔOBA and ΔE\(_{00}\) variation than those in Case 2.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>LAB_L</th>
<th>LAB_A</th>
<th>LAB_B</th>
<th>LAB_L</th>
<th>LAB_A</th>
<th>LAB_B</th>
<th>OBA</th>
<th>ΔE(_{00}) (sccaH_McCoyG)</th>
<th>ΔOBA (sccaH_McCoyG)</th>
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Results -- Print-to-Proof Simulation

- Case 3 – High OBA print as the reference

Highlight clipping is visible.
Results -- Print-to-Proof Simulation

- Case 3 – High OBA print as the reference
  - The low OBA proof has the largest $\Delta E_{00}$ at 95th percentile of the distribution.
  - Highlight clipping causes color mismatch between low OBA proof and high OBA print.
Discussions

- $\Delta E_{00}$, OBA, and pictorial color matching

  - $\Delta E_{00}$ metric, in the form of a distribution, is indicative of the pictorial color difference between two color images.
  
  - $\Delta OBA$ is one of many factors that contributes to $\Delta E_{00}$.
  
  - $\Delta L^*$ and $\Delta b^*$ between two substrates can cause gamut clipping that contribute to the $\Delta E_{00}$ magnitude and influence the visual match between a proof and a print.
Discussions

- $\Delta OBA$ and the viewing illumination
  - *Color match between a high OBA proof and a low OBA print depends more on the viewing light source than the color match between a low OBA proof and a low OBA print.*
  - $\Delta OBA$ is indicative of the criticalness of lighting in color match, *i.e.*, the match becomes more metameric when $\Delta OBA$ is high.
Conclusions

- Guidelines for proof-to-print visual match where OBA amounts of the print vary
  - Viewing and color measurement are in M1 compliance.
  - Printing is calibrated to the substrate-corrected dataset.
  - Select a proofing substrate that has adequate “head room” to avoid gamut clipping and proof to the substrate-corrected dataset.

- In order to match OBA-loaded prints, experiences have shown that a proofing substrate should have
  - A slightly larger L* value (no higher than 2 L*) and
  - A larger negative CIE-b* value (no more than 5) than the printing paper.
Thank You.

Any Questions?
Buying From Web2Print Storefronts: 
Color Managed or Caveat Emptor?

Erica B. Walker, Clemson University Department of Graphic Communications
Suzanne Edlein, Clemson University Department of Graphic Communications
Dr. David E. Barrett, Clemson University Eugene T. Moore School of Education
Questions, Comments?

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@SuzanneEdlein

eblack4@clemson.edu  
edlein@clemson.edu
Research Question

“What happens to the expected color in our files when we upload them to ten popular W2P portals?”
Question 1

“Can we expect to receive a printed piece that matches the L*a*b* values of the file submitted; and, do the results vary based on the color space of the file submitted?”
Question 2

“Do consumer rankings of visual color match to a target correlate to the grand mean $\Delta E$ rank of the print providers?”
“What is a consumer’s tolerance for acceptable color differences based the grand mean $\Delta E$?”
Question 4

“Is there a correlation between color quality, cost, and delivery speed?”
Methodology

1. Determine how the L*a*b* values shift between the file and the print
2. Determine if output can be controlled with file type/embedded profiles
3. Investigate consumer’s color discrimination and threshold for color shifts
Mimic likely consumer behavior by using AdobeRGB working space. We did not apply profiles allowing the RIP to process files normally.
Question 1.1: L*a*b* Shift Based on Color Space?

Tagged Scenario: GRACoL 2006

Embed GRACoL 2006 CMYK profile to the raster & vector components of the file and compare to the AdobeRGB L*a*b* readings.
Question 2: Consumer L*a*b* Alignment?

Consumer’s Color Discrimination

Survey a consumer population to rank color differences between the best performing print provider’s sample and the rest of the print provider’s samples.
Survey a consumer population to rank color differences between the best performing print provider’s color outcome and the rest of the printer providers samples and determine color outcomes that they would reject.
Vector Art: Spot Colors

X-Rite ColorChecker Chart
Measurable Vector Postcard

An introduction to the Graphic Communications Internship Program

Internships provide the real-world component in Clemson’s Graphic Communications program. All GC majors are required to do at least two internships to receive their degree, and many complete three. Students are encouraged to work in different geographic locations, process areas, and segments of the industry in order to gain a broad workplace experience. It is believed that the ultimate success of Clemson Graphic Communications graduates is due to their overall knowledge of the industrial and business settings.

Employers have been hiring Clemson GC interns for more than 25 years. Most employers also view this as an investment in their own future as they preview upcoming talent and contribute to the development of prospective employees.

Many companies have employed interns on a continuous basis as an inherent part of their human resources program. Both the intern and the employer realize the benefits of having a talented, young intern do real work that contributes to the organization.

For more information, please contact Carol Jones at 864-656-3447 or jensone@clemson.edu

Greeting card illustrations by Jonathan Balcombe, Clemson Creative Services/Intern. Scan to read this feature intern’s story!

“First, let me say, you can’t have your intern back!”

“We hope our intern’s future may include our company.”

“I can’t stress how mature, resourceful and intuitive our intern has been.”

“Experience beyond her years– an absolute pleasure”
Two Identical Versions, but...

➔ **Version 1**: RGB with AdobeRGB color space and no further color management policies

➔ **Version 2**: CMYK, with GRACoL 2006 specifications embedded in the PDF
Vector-Raster Postcard

An introduction to the Graphic Communications Internship Program

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Why Hire an Intern?

Employers have been hiring Clemson GC interns for more than 25 years. Most employers also view this as an investment in their own future as they preview upcoming talent and contribute to the development of prospective employees. Many companies have employed interns on a continuous basis as an inherent part of their human resources program. Both the intern and the employer realize the benefits of having a talented, young intern do real work to contribute to the organization.

What Do Intern Employers Say?

"First, let me say, you can’t have your intern back!"

"Our intern has certainly embraced his internship as his ‘real’ job. His positive attitude, motivation, communication skills and technical ability should certainly place him in the lead for future employment."

"Our intern performed as a full-time Graphics Coordinator with experience beyond her years. She was an absolute pleasure to work with and will be sorely missed by the entire department and by me."

"We are excited for our intern’s future and hope it may include our company."

"I am completely satisfied with our intern. I can’t stress how mature, resourceful and intuitive he has been."

For more information, please contact Carol Jones at jensenc@clemson.edu or 864-656-3447
Two Identical Versions, but...

➔ **Version 1**: RGB raster image in AdobeRGB color space and no further color management policies

➔ **Version 2**: CMYK raster image with GRACoL 2006 specifications embedded
Ordering Web2Print
Warning!

Only 2 of the 10 companies had warnings regarding color on their websites when we approved the proofs in the W2P system.
Measurements

Three types of data collection:

➔ L*a*b* measurements
➔ Visual check ranking the accuracy of the raster images
➔ Visual analysis to select “unsatisfactory” color
Measurement Parameters

- X-Rite 530 (Series 001982), Observer Angle: 2° D50
- 10 of the 50 cards from each provider
- 12 color patches, 3 readings per patch
- Total of 7200 measurements
- Average of L*a*b* measurements compared to original L*a*b* values to get ΔE values for each color patch on each card
## Data Files

### SAMPLE SET EO-1

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<th>X Low</th>
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<th>Y High</th>
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### GRACol 2006 Tagged

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### Statistics

- **Total records:** 100
- **Rejected records:** 0
- **Included records:** 100
- **Tagged records:** 100
- **X PctRoll:** 1.0
- **Y PctRoll:** 1.0
- **# PctRoll:** 1.0

### Source

- Data source: SpectraSolutions Instrument Series (SSR) 8001
- Instrument used: GRACol 2006
- Spectral range: 1800-700 nm
- Target sample: Polystyrene solution
- Date: 2023-10-10
- Manufacturer: SpectraSolutions
- Model: GRACol 2006
- Software version: 2.5.2

### Notes

- Data files are in Excel format.
- Files include spectral data for different sample sets.
- All data points are within the specified wavelength range.
- Statistical analysis shows high accuracy and consistency across all records.
Standard Stock?

We attempted to order 100lb glossy stock from each vendor, but there are differences between each printer’s paper.
Preliminary Analysis

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</table>

Sample data from printer TT for each spot color patch and in each color space.
Grand Means
All print providers attained the lowest ΔE values in the gray tones.

Saturated tones: Yellow/Orange, Red, and Green had the most widely varying ΔE values between the print providers.
In the GRACoL CMYK color space, the overall variance in ΔE values is slightly smaller.

Grays measure lower ΔE values in both color spaces than the other color groups.

Skintones are slightly closer to their intended values in the GRACoL color space.
3 x 3 x 2 Model

➔ 3 Representative Print Providers
➔ 3 Representative Colors
➔ 2 Color spaces
Print provider EX is representative of the lowest performing print providers

Mean ΔE values:
RGB- 15.89
CMYK- 11.74
Print provider NS is representative of the mid-level print providers

Mean ΔE values:
RGB- 9.45
CMYK- 8.59
Print provider ER is representative of the highest performing print providers.

Mean ∆E values:
RGB- 3.66
CMYK- 3.90
Summary of Findings - Measurements

In our 3 x 3 x 2 statistical analysis, each of the following factors was significant [.000 = P values] :

1. Print provider
2. Color space
3. Color

In addition, there were some interactions
Interactions

![Graph showing interactions between ColorSpace and Mean DeltaE for different Colors (Gray6.5, green, LightSkin).]

<table>
<thead>
<tr>
<th>Color</th>
<th>ColorSpace</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray6.5</td>
<td>AdobeRGB</td>
<td>3.660</td>
</tr>
<tr>
<td></td>
<td>GRACoL CMYK</td>
<td>2.702</td>
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<tr>
<td>green</td>
<td>AdobeRGB</td>
<td>13.124</td>
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<td></td>
<td>GRACoL CMYK</td>
<td>4.585</td>
</tr>
<tr>
<td>LightSkin</td>
<td>AdobeRGB</td>
<td>10.417</td>
</tr>
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<td>GRACoL CMYK</td>
<td>7.935</td>
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<td>AdobeRGB</td>
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<td></td>
<td>GRACoL CMYK</td>
<td>6.242</td>
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<td>green</td>
<td>AdobeRGB</td>
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<td>GRACoL CMYK</td>
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</tr>
<tr>
<td></td>
<td>GRACoL CMYK</td>
<td>4.424</td>
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</tbody>
</table>
Summary of Findings

• Grays have the smallest ΔE values in either color space
• 7 of 10 printers performed better with the embedded GRACoL files, but only slightly
• Only 2 printers hovered near the ΔE value of 5, and they did so with either color space file
• Across the board saturated tones were the most difficult to match, especially Yellow/Orange
## Grand Mean

<table>
<thead>
<tr>
<th>Code</th>
<th>GRACoL Mean</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER</td>
<td>3.8979</td>
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<tr>
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<td>EO</td>
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</tr>
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<td>RS</td>
<td>9.3603</td>
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<td>CT</td>
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<td>9</td>
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<tr>
<td>EX</td>
<td>11.7425</td>
<td>10</td>
</tr>
</tbody>
</table>

Ranking the printers based on grand mean ΔE
Visual comparison

- Surveyed 48 people
- Asked them to put the samples in order based on visual match from a target image
- Asked them at what point they would not be happy to pay for the sample
# Visual Comparison

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<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tr>
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<td>1</td>
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<td>6</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>17</td>
<td>13</td>
</tr>
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</table>

On average people are satisfied with the first 5.79 output samples
Spearman Rank Order Correlation

<table>
<thead>
<tr>
<th></th>
<th>meandeltaeGR</th>
<th>top5asrank</th>
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</thead>
<tbody>
<tr>
<td>Spearman's rho</td>
<td></td>
<td></td>
</tr>
<tr>
<td>meandeltaeGR</td>
<td>Correlation</td>
<td>.888**</td>
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<tr>
<td></td>
<td>Coefficient</td>
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<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.001</td>
</tr>
<tr>
<td>N</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>top5asrank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlation Coefficient</td>
<td>.888**</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.001</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
## Cost-Speed-Quality

<table>
<thead>
<tr>
<th>Code</th>
<th>GRACoL Ranking</th>
<th>Cost per 50-CMYK</th>
<th>Shipped # of days after ordering</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER</td>
<td>1</td>
<td>$64.05</td>
<td>8</td>
</tr>
<tr>
<td>PS</td>
<td>2</td>
<td>$57.77</td>
<td>2</td>
</tr>
<tr>
<td>TT</td>
<td>3</td>
<td>$116.99</td>
<td>1</td>
</tr>
<tr>
<td>EO</td>
<td>4</td>
<td>$72.50</td>
<td>1</td>
</tr>
<tr>
<td>RT</td>
<td>5</td>
<td>$163.97</td>
<td>6</td>
</tr>
<tr>
<td>NS</td>
<td>6</td>
<td>$161.40</td>
<td>2</td>
</tr>
<tr>
<td>OT</td>
<td>7</td>
<td>$140.86</td>
<td>1</td>
</tr>
<tr>
<td>RS</td>
<td>8</td>
<td>$37.85</td>
<td>1</td>
</tr>
<tr>
<td>CT</td>
<td>9</td>
<td>$68.90</td>
<td>3</td>
</tr>
<tr>
<td>EX</td>
<td>10</td>
<td>$159.43</td>
<td>same day</td>
</tr>
</tbody>
</table>

No discernible pattern between cost-speed-quality for the W2P providers.
Suggestions - Future Research

➔ Work directly with the print providers to explore how to align expectations with outcome of printed products within the print providers’ established workflow
➔ Explore if reproduction differences happen more often with specific printing methods
➔ Continue exploring the public's tolerance for acceptable color consistency in W2P products
➔ Select images that focus on key “problem colors,” specifically highly saturated tones, for a more targeted visual comparison
Thank you!

• Special thank you to the following people who supported our research:
  • Julie Shaffer, Printing Industries of America
  • Dr. Samuel Ingram, Department of Graphic Communications
  • Dr. John Leininger, Department of Graphic Communications
  • Dr. Liam O’Hara, Department of Graphic Communications
  • Steve Smiley, SmileyColor & Associates
  • Joe Finan, INX International Ink Co.
References

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http://whattheythink.com/video/view.cfm?id=70844&slug=frank-romano-color-management

Images:
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The Next Generation of High Speed Folding Technologies

- Jörg W. Dähnhardt
- VP Postpress
- Heidelberg USA, Inc.
Agenda

- The Impact of Next Generation of High-Speed Folding Technologies
  - Current feeding challenges
  - Typical Solutions
  - PFX Feeder
  - Additional Components
  - Economic Evaluation
Current Feeding Challenges

- Reliable feeding and folding typical up to 210 m/min;
- Net output can’t be increased beyond that at the same rate as gross output
- Speed Restrictions due to
  - Paper curl
  - Paper waviness
  - Paper weight
  - …
Current Feeding Challenges

Optimization potential:
50 - 65% of the error messages at folders are double sheets and pick-up problems at the feeder (even more with competitor machines)
Conventional Feeder
The PFX Feeder

- PFX = **Pallet Feeder eXtended**
- Feed from the Press Pallet
- Change feeding concept: Single sheet vs Shingled sheets
- Optimize the width
- Automate the set-up
The PFX Feeder
The PFX Feeder

- Idea: use offset press concepts
The PFX Feeder

- Sheet Separation via pulsed air and lifting suckers
- 1\textsuperscript{st} acceleration via suction head with asymmetrical suction roller
The PFX Feeder

- Sheet Separation via pulsed air and lifting suckers
- 1st acceleration via suction head with asymmetrical suction roller
- 2nd acceleration via suction roller from bottom
Processing of oblong formats

Feed sheets like on a press – portrait vs. landscape

30-40% more sheets/min can be conveyed
The PFX Feeder

- Implications Down-Stream

Under-shingled
The PFX Feeder

- 2nd station with „frog“ system
- Spreading of single sheet stream into two parallel sheet streams in the second station
- Reduced speed of units after the first folding unit
The PFX Feeder in action

Closer look at the PFX Streamfeeder
The PFX Feeder – Economic Impact

- Gain 30% by going to landscape feeding
- Gain additional 25% to 33% by shingling

Feeder work mode: negative sheet gap onto the transfer table
The PFX Feeder – Economic Impact

- Additional Benefits:
  - Minimize WIP by balancing the press output with the folder productivity -> impact on working capital
  - Optimize floor space:
    Less space for WIP
    Less space because less equipment
  - Palletized Feeder
    Better ergonomics for operator
    Less work to prepare piles / signatures
  - Folding with two units, automated set-up;
    no conversion of folder necessary
The PFX Feeder – Economic Impact

- Gain additional 11% by optimized lay-outs
- 144 pages, circulation of 48,000 copies

9 x 16p./printed sheets = 432,000 printed sheets
16 page example – brochure format 8.5 x 11” (A4), 144 pages volume, circulation 48,000 cp.

36 hours production time

8 x 18p./printed sheets = 384,000 printed sheets
18 page example – brochure format 8.5 x 11” (A4), 144 pages volume, circulation 48,000 cp.

32 Std. Production Time
The PFX Feeder – Economic Impact

9 x 16p./printed sheets = 432,000 printed sheets
In example product – brochure format A4, 144 pages volume, circulation 48,000 cp.

8 x 18p./printed sheets = 384,000 printed sheets
With example product – brochure format A4, 144 pages volume, circulation 48,000 cp.

- 41% production time
The PFX Feeder – Economic Impact

In example product – brochure format A4 (8 1/4 x 11 3/4"), 144 pages volume, circulation 48,000 cp.

<table>
<thead>
<tr>
<th>Press</th>
<th>Signatures</th>
<th>Pages per signature</th>
<th>Number of Brochures</th>
<th>Sheets</th>
<th>Run Speed</th>
<th>Hours</th>
<th>Savings</th>
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<tbody>
<tr>
<td>Normal Fold</td>
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<td>48,000</td>
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<td>12,000</td>
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<td>18</td>
<td>48,000</td>
<td>384,000</td>
<td>12,000</td>
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<tr>
<td><strong>Savings</strong></td>
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<table>
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<th>Sheets</th>
<th>Run Speed</th>
<th>Hours</th>
<th>Savings</th>
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<td>432,000</td>
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<tr>
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<tr>
<td><strong>Savings</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>22</strong></td>
</tr>
</tbody>
</table>

- Total Time conventional: 90 hours
- Total Time with Frog and PFX: 64 hours
- One less signature to run on a perfect binder.
- Additional press time & folder time to run additional jobs.
The PFX Feeder – Economic Impact

TH 96

300 days/year
* 16 hour/day
* 8,000 sheets/hour
→ 38.4 million sheets/year

TX 96

300 days/year
* 16 hour/day
* 12,000 sheets/hour
→ 57.6 million sheets/year

+ 19 million sheets/year
The PFX Feeder – Economic Impact

- Automated Make-Ready: Less time, less waste
- Feeding consistency significantly improved
- Output +50% Compared to High-end folder without PFX Feeding technology
- Output +>100% Compared to 3-5 year old folder
- Reduced WIP
- Reduced Floor Space

- Consider a replacement scenario: One TX folder vs. three older folders:
60 million signatures per year

67th Annual Technical Conference
taga15.printing.org
The Next Generation of High Speed Folding Technologies

- Jörg W. Dähnhardt
- VP Postpress
- Heidelberg USA, Inc.
The GL SPECTIS 1.0 Series and Measurement of Lighting

Eric Dalton
Vice President
JUST Normlicht, Inc.
The GL SPECTIS 1.0 Series
Why do we need to measure?

1 Facility – 10 Viewing Areas – **50 percent** within tolerance
Why do we need to measure?

1 Facility – 13 Areas – 0 Percent passed
Why do we need to measure?

1 Facility – 14 Areas – **42 Percent** passed
What does ISO 3664 specify?

- Spectral Measurements for CRI, chromaticity, and metamerism indices.
  - $P1 \& P2$: 300nm to 730nm
  - $T1 \& T2$: 380nm to 730nm
  - Both require a band pass of 5nm or narrower

- Illuminance and luminance
  - Photometer that meets requirements of CIE 69-1987 which is no longer a valid standard (ISO 19476:2014)
  - Cosine corrected
  - Environmental light should be included
The GL SPECTIS 1.0 Series
Specifications

- Spectroradiometers
- Class B Cosine Correction
- Spectral Range: 340nm – 750nm
- CMOS Image Sensor
- 256 pixels
- Stray light reduction 0.002 (2 * E -3)
- Measurement Uncertainty 0.0012 u’,v’
What makes the GL SPECTIS 1.0 series

- Schematic of one of GL Optic’s spectroradiometer
What makes the GL SPECTIS 1.0 series

- Calibration Method
  - *Patent-pending technique to improve accuracies*
What makes the GL SPECTIS 1.0 series

- Calibration Light Source
What makes the GL SPECTIS 1.-0 series

- Enhanced Measurement Accuracies with Effective Stray Light Correction
  - Stray-light induced by signal of 600 nm
What makes the GL SPECTIS 1.0 series

- Enhanced Measurement Accuracies with Effective Stray Light Correction
  - *Use 8 high-grade band-pass color filters*
Comparison of 300-780

- JUST Virtual proofStation 36W Lot 4L
Comparison of 300-780

- JUST Virtual proofStation 36W Lot 4L
Comparison of 300-780

- JUST Virtual proofStation 36W Lot 4L
Comparison of 300-780

- Commercially available viewing booth Lot C4E
Comparison of 300-780

- Commercially available viewing booth Lot C4E
Comparison of 300-780

- Commercially available viewing booth Lot C4E
FOGRA ISO 3664:2009 compliance test

SPECTIS 1.0
CRI = 95.7
MI vis = 1.027
MI uv = 1.001
CH err = 0.00310

SPECTIS 5.0
CRI = 95.9
MI vis = 1.049
MI uv = 1.170
CH err = 0.00282

Albuquerque, NM 2015
FOGRA ISO 3664:2009 compliance test

SPECTIS 1.0
CRI = 92.5
MI vis = 0.799
MI uv = 1.495
CH err = 0.00292

SPECTIS 5.0
CRI = 92.8
MI vis = 0.844
MI uv = 1.550
CH err = 0.00187

Albuquerque, NM 2015
GL SPECTROSOFT

- ISO 3664:2009 Compliance Testing
ISO 3664:2009 Compliance Report

**ISO 3664 Assessment**

<table>
<thead>
<tr>
<th>11</th>
<th>12</th>
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<tr>
<td>Y = 94% =&gt; PASS</td>
<td>Y = 98% =&gt; PASS</td>
<td>Y = 93% =&gt; PASS</td>
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</table>

<table>
<thead>
<tr>
<th>21</th>
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<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y = 96% =&gt; PASS</td>
<td>Y = 95% =&gt; PASS</td>
<td>Y = 96% =&gt; PASS</td>
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</tbody>
</table>

<table>
<thead>
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<th>32</th>
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</thead>
<tbody>
<tr>
<td>Y = 87% =&gt; PASS</td>
<td>Y = 92% =&gt; PASS</td>
<td>Y = 89% =&gt; PASS</td>
</tr>
</tbody>
</table>

**Metamerism Indices**

- Mm = 0.90
- Mm = 1.50

**Certification according to ISO 3664:2009 PASS**
Any Questions?

Eric Dalton  
Vice President  
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www.gloptic.com  

Albuquerque, NM 2015
Matching Printed Color Images under the Influence of OBA Using a Soft Proofing System

Peng Cheng*, Robert Chung*, and Bruce Myers*

* Rochester Institute of Technology, Rochester, NY

67th Annual Technical Conference · Albuquerque, NM 2015
Introduction

- Standard datasets and ICC profiles do not account for the OBA factor.
- Print buyers prefer printed colors using OBA-loaded papers.
- Color mismatch occurs between OBA-loaded prints and non-OBA hardcopy proofs.
Problem Statement

- To overcome the color mismatch, substrate-corrected colorimetric aims (SCCA), acting as the source profile in the color proofing workflow, improves the color match between brightened print and non-brightened hardcopy proof (Chung, 2013).

- Will the SCCA method improve the color match between brightened prints and a soft proofing system?
Literature Review

- ICC color management (A-B-A)
  - Source ICC profile – account for OBA via SCCA
  - Destination profile – calibrated media and device
  - Rendering intent – Absolute colorimetric

- M1 workflow
  - M1 measurement condition, per ISO 13655 (2009)
  - M1 viewing condition, per ISO 3664 (2009)
  - Soft proofing scenario, per ISO 14861 (2011)
Research Questions

1. Is there a significant association between the source ICC profile and its soft proofing performance?

2. Will the source ICC profile, generated from the SCCA dataset using M1 metrology, improve soft proof-to-brightened print match?

*Note: Substrate-corrected colorimetric aims (SCCA) is defined as “color characterization data that are corrected for the colorimetric difference between production and the reference substrate” (CGATS TR016).*
Methodology

- Soft proofing hardware setup
  - *Integrated viewing conditions*
    - Eizo CG242W monitor
    - GTI integrated viewing booth
- Test sample and ICC profile generation
- Soft proofing application interface
- Observer screening
- Psychometric experiments
Methodology

- Soft proofing hardware setup
- Test samples and ICC profile generation
  - *roman16 bvmd Reference Images*
  - *Hardcopy reference on Invercote T (non-OBA) and Invercote G (OBA)*
- Soft proofing application interface
- Observer screening
- Psychometric experiments
Methodology

- Soft proofing hardware setup
- Test sample and ICC profile generation
- Soft proofing application interface
  - *The monitor profile, based on D50 white point, 120 cd/m² luminance, and 2.2 gamma, gave the best match.*
  - *Soft proof display in Adobe Photoshop*
    - View > Proof Setup > Custom > select the sample ICC profile embedded in image in “Device to Simulate” box > check “Preserve CMYK Numbers” > check “Simulate Paper Color” > OK
- Observer screening
- Psychometric experiments
Methodology

- Soft proofing hardware setup
- Test sample and ICC profile generation
- Soft proofing application interface
- Observer screening
  - Farnsworth-Munsell 100 Hue Test
  - 30 qualified observers out of 33 candidates
- Psychometric experiments
Methodology

- Soft proofing hardware setup
- Test sample and ICC profile generation
- Soft proofing application interface
- Observer screening
- Psychometric experiments
  - **Experiment 1**
    - A = Invercote T profile-embedded image
    - B = Invercote G profile-embedded image

Does color match depend on hardcopy type and the source profile used in soft proofing?
Methodology

- Soft proofing hardware setup
- Test sample and ICC profile generation
- Soft proofing application interface
- Observer screening
- Psychometric experiments
  - **Experiment 2**
    - $X = \text{Invercote T profile-embedded image}$
    - $Y = \text{Invercote G profile-embedded image}$
    - $Z = \text{SCCA profile-embedded image}$

Which source profile, used in soft proofing, matches the OBA-loaded print the best?
Results

- **Hypothesis testing**
  - *Chi-Square test analysis in SPSS at 0.05 level of significance*

<table>
<thead>
<tr>
<th></th>
<th>Image 1 White paper</th>
<th>Image 2 High Key</th>
<th>Image 3 Low Key</th>
<th>Image 4 Yellow</th>
<th>Image 5 Magenta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expt. 1</td>
<td>Reject(^{[1]})</td>
<td>Reject</td>
<td>Reject</td>
<td>Do not reject</td>
<td>Reject</td>
</tr>
<tr>
<td>((H_0): there is no association between prints and types of profile embedded)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expt. 2</td>
<td>Reject</td>
<td>Reject</td>
<td>Reject</td>
<td>Reject</td>
<td>Reject</td>
</tr>
<tr>
<td>((H_0): there is no association between types of profile embedded and match performance)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[1] “Reject null hypothesis” means there is significant association between print samples and types of profile embedded in image.

[2] “Do not reject null hypothesis” means there is no association between types of profile embedded in image and soft proof-to-OBA print match performance.
Results and Discussion

- **Experiment 1**
  - *Soft proofing performance, with the exception of Image 4 (Yellow), depends on the correct source ICC profiles and the hardcopy type combination.*

[Experiment 1 - Image 2]

![Chart showing OBA (Invercote G) and Non-OBA (Invercote T) profiles](chart.png)
Results and Discussion

- **Experiment 1**
  - *Why is Image 4 (Yellow) the exception?*
    - The OBA effect is mainly in the blue region. But yellow predominant image absorbs blue light.
    - Quantitative analysis of the pixelated image indicates that there is less color difference (cumulative relative frequency of ∆E<sub>00</sub>) in Image 4 than other images.
Results and Discussion

- **Experiment 2**
  - *Invercote G and SCCA profiles match the OBA-loaded prints. Invercote T profile performs the worst.*
  - *SCCA profile matches OBA-loaded low-key Image 3 & yellow image 4 better than fully characterized Invercote G profile.*

![Experiment 2 – Image 3]
Conclusions

- OBA causes color mismatch between soft proofs and brightened prints.
  - *The degree of color mismatch depends on image contents.*

- Both fully characterized and SCCA solutions can improve soft proof-to-brightened print color match.
  - *SCCA is a reasonable solution for new jobs that have not yet been printed.*
Acknowledgments

- Mr. Bob Henry of Iggesund Paperboard Company
- Mr. William Li of Eastman Kodak Company
- RIT School of Print Media
The Next Generation of High Speed Folding Technologies

Jörg W. Dähnhardt
VP Postpress
Heidelberg USA, Inc.
Agenda

- The Impact of Next Generation of High-Speed Folding Technologies
  - Current feeding challenges
  - Typical Solutions
  - PFX Feeder
  - Additional Components
  - Economic Evaluation
Current Feeding Challenges

- Reliable feeding and folding typical up to 210 m/min;
- Net output can’t be increased beyond that at the same rate as gross output
- Speed Restrictions due to
  - Paper curl
  - Paper waviness
  - Paper weight
  - …
Current Feeding Challenges

Optimization potential:

50 - 65% of the error messages at folders are double sheets and pickup problems at the feeder
(even more with competitor machines)
Conventional Feeder
Conventional Feeder
The PFX Feeder

- PFX = Pallet Feeder eXtended
- Feed from the Press Pallet
- Change feeding concept: Single sheet vs Shingled sheets
- Optimize the width
- Automate the set-up
The PFX Feeder
The PFX Feeder
The PFX Feeder

- Idea: use offset press concepts
The PFX Feeder
The PFX Feeder

- Sheet Separation via pulsed air and lifting suckers
- 1st acceleration via suction head with asymmetrical suction roller – 65 m/min
The PFX Feeder

- Sheet Separation via pulsed air and lifting suckers
- 1st acceleration via suction head with asymmetrical suction roller
- 2nd acceleration via suction roller from bottom
Processing of oblong formats

Feed sheets like on a press – portrait vs. landscape

30-40% more sheets/min can be conveyed
The PFX Feeder

- Implications Down-Stream

Under-shingled
The PFX Feeder

- 2nd station with „frog“ system
- Spreading of single sheet stream into two parallel sheet streams in the second station
- Reduced speed of units after the first folding unit
The PFX Feeder – Economic Impact

- Gain 30% by going to landscape feeding
- Gain additional 25% to 33% by shingling

Feeder work mode: negative sheet gap onto the transfer table
The PFX Feeder – Economic Impact

- Additional Benefits:
  - Minimize WIP by balancing the press output with the folder productivity -> impact on working capital
  - Optimize floor space:
    Less space for WIP
    Less space because less equipment
  - Palletized Feeder
    Better ergonomics for operator
    Less work to prepare piles / signatures
  - Folding with two units, automated set-up;
    no conversion of folder necessary
The PFX Feeder – Economic Impact

- Gain additional 11% by optimized lay-outs
- 144 pages, circulation of 48,000 copies

<table>
<thead>
<tr>
<th>Pages</th>
<th>Printed sheets</th>
<th>Production Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>432,000</td>
<td>36 hours</td>
</tr>
<tr>
<td>18</td>
<td>384,000</td>
<td>32 Std. Production Time</td>
</tr>
</tbody>
</table>

*Note: 8.5 x 11" (A4) format, printed at 12,000 sheets/h.*
The PFX Feeder – Economic Impact

9 x 16p./printed sheets = 432,000 printed sheets
In example product – brochure format A4, 144 pages volume, circulation 48,000 cp.

Folding machine
KH82 or TH82
Ø 8,000 sheets/h. =
54 hours production time

8 x 18p./printed sheets = 384,000 printed sheets
With example product – brochure format A4, 144 pages volume, circulation 48,000 cp.

Folding Machines
TH82 with PFX feeder and twin lay system
Ø 12,000 sheets/h (overlapping sheet stream) =
32 hours production time

432,000 folded sheets (16p. cross-fold)

384,000 folded sheets à 18 pages

- 41% production time

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The PFX Feeder – Economic Impact

In example product – brochure format A4 (8 1/4 x 11 3/4"), 144 pages volume, circulation 48,000 cp.

<table>
<thead>
<tr>
<th>Press</th>
<th>Signatures</th>
<th>Pages per signature</th>
<th>Number of Brochures</th>
<th>Sheets</th>
<th>Run Speed</th>
<th>Hours</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Fold</td>
<td>9</td>
<td>16</td>
<td>48,000</td>
<td>432,000</td>
<td>12,000</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>PFX Frog Fold</td>
<td>8</td>
<td>18</td>
<td>48,000</td>
<td>384,000</td>
<td>12,000</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td><strong>Savings</strong></td>
<td><strong>4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>11%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Folding</th>
<th>Signatures</th>
<th>Pages</th>
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<th>Run Speed</th>
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<tr>
<td>PFX Frog Fold</td>
<td>8</td>
<td>18</td>
<td>48,000</td>
<td>384,000</td>
<td>12,000</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td><strong>Savings</strong></td>
<td><strong>22</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>41%</strong></td>
</tr>
</tbody>
</table>

- Total Time conventional: 90 hours
- Total Time with Frog and PFX: 64 hours
- One less signature to run on a perfect binder.
- Additional press time & folder time to run additional jobs.
The PFX Feeder – Economic Impact

- **TH 96**
  - 300 days/year
  - *16 hour/day
  - *8,000 sheets/hour
  - \( \rightarrow 38.4 \text{ million sheets/year} \)

- **TX 96**
  - 300 days/year
  - *16 hour/day
  - *12,000 sheets/hour
  - \( \rightarrow 57.6 \text{ million sheets/year} \)

+ 19 million sheets/year

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The PFX Feeder – Economic Impact

- Automated Make-Ready: Less time, less waste
- Feeding consistency significantly improved
- Output +50% Compared to High-end folder without PFX Feeding technology
- Output +>100% Compared to 3-5 year old folder
- Reduced WIP
- Reduced Floor Space

Consider a replacement scenario:
One TX folder vs. three older folders:
**OLD**

- **3 Shifts**
- KD 78
- MBO K760
- MBO K760
- 60 million signatures per year
- 3 x Make-ready
- 538 ft²
- 538 ft²
- 538 ft²
- Efficiency

**NEW**

- **3 Shifts**
- TX 96
- 538 ft²
- Make-ready
- Efficiency
- 1 x Make-ready
- 538 ft²
- > 60 million signatures per year

**Savings per year:**

- 6 at $40,000 → $240,000
- 1076 ft² at $4 sft/year → $4,304
- ⅔ Less Makeready Cost → $35,000

Albuquerque, NM 2015
The Next Generation of High Speed Folding Technologies

Jörg W. Dähnhardt
VP Postpress
Heidelberg USA, Inc.
Forensic Markings for Progressive Barcodes

Steven Simske, Marie Vans, Stephen Pollard & Guy Adams
HP Labs
Outline

- Barcodes
  - Standard & Non-Standard Barcodes
  - Color Tiles, IIOs, & Progressive Barcodes
- Tri-Purpose IIOs
  - Forensics with SDED
  - Applications of SDED
- Results & Conclusions

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67th Annual Technical Conference
tagaatc.printing.org
Barcodes

- 1 Dimensional -
- 2 Dimensional -
- 3 Dimensional –
- 4 Dimensional -

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Barcode Standards

- **Data Matrix**: high density marks
  - *Electrical components, food industry*
    - ISO/IEC16022:2006 - Data Matrix bar code symbology specification
    - Data capacity: 2335 bytes
  - ISO/IEC 24778:2008 - Aztec Code bar code symbology specification
  - Data capacity: 1914 bytes

- **Aztec**: marks with no quiet zone
  - *Transportation/Travel industry, airline & train tickets*

[Image of a mobile phone with a QR code]
Barcode Standards - Continued

- QR-Code: probably the most ubiquitous
  - *Marketing, URLs to Websites*
    - Data capacity: 3706
  - *Security implications*
    - No security …or…
    - Validation step
Non-Standard Barcodes

- **ColorTile**

- **Progressive Barcode**

  The example shown here comprises:
  1. 64 data tiles, max 165 bits total
  2. 8 non-payload tiles:
     a. Two black for orientation & corner detection
     b. 6 color {RGBCMY} for color calibration
     c. Colors are 180 rotated from their color opponency pair, providing the greatest contrast in hue space and thus the most reliable opposite-corner orientation detection possible.
IIOs- Statistical Probability

- Progressive barcodes instantiation of IIO: Incremental Identifying Object
- Statistical probability assigned at each step of the progression
- Associated with any transition between two steps in a workflow
- Based on how many bits are written and how many remain

\[
\frac{N_{IU}!}{N_{RB}!} \geq \prod_{i} P_i
\]

\(P_i = \text{Step } i\)
\(N_{RB} = \text{the number of residual (0 bits) at end of the workflow}\)
\(N_{IU} = \text{number of initial unwritten bits}\)
IIOs – Statistical Probability -Continued

- If barcode is unique at step $i-1$, then total number of barcodes of the current state is $1$.
- If the progressive barcode is binary, then the number of bits in the workflow is $N_{RB} - N_{IU}$.
- If there are $N_C$ colors, number of bits increases to:

$$\left[ \frac{\ln(N_c)}{\ln(2)} \right] \times (N_{RB} - N_{IU})$$

- The size (height and width in tiles) of progressive barcode used in the workflow can be determined from these equations along with the number of bits to write at each state.
IIOs – Data Capacity

- Each color tile independent
- Define a tile to be $N$-ary, where $N =$ number of colors allowed at each tile:
  \[ \frac{\log_2(n)}{\log_2(2)} = \log_2(n) \text{ bits at any stage} \]
- $n=2$, e.g. DataMatrix, QR, Aztec: 1 bit per tile
- Color tile with six colors \{RGBCMY\}: 2.585 bits/tile
- 8 colors allowed \{RGBCMYWK\}: 3.0 bits/tile
- Color tile barcode $X$ data tiles wide & $Y$ data tiles high contains exactly:
  \[ XY \log_2(n) \text{ bits} \]
Standard Barcodes with Progressive Barcodes

- Allows use of “static” data encoded in black & white modules for standard purposes:
  - *point of sale*
  - *serial numbers (serialization)*
  - *product information*

- Allows “separate channel” for encoding changing workflow-related information

- Static data: off-the-shelf reader reads the “black-as-black” modules and the “rest-as-white” (white is a “dual channel”)

It’s obvious that the color information must be special

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Example Progression

- Reader-Friendly Progressive Barcodes
- Columns indicate progression along workflow
- Colors saturated enough so that 2D barcode reader still interprets them as “white”
- 2D barcode reads the same throughout the progression.

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Example GS1 Workflow

- GS1 world-wide track and trace standards
- Progressive barcodes for GS1 product workflows using multiple barcodes
- Original GS1-compliant barcode contains a product ID and remains static as its second channel of content progresses
- Concurrently, information encoded in the colors changes at each step.
- The data within the white-as-N-ary modules used for data normally encoded in separate barcodes

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Tri-Purpose Barcodes – Adding Forensics

- Static black & white + color progression + forensics
- Progressive barcodes provide a secure means to transition from node to node in a workflow
- Does not incorporate the physical attributes of the current printed barcode.
- The shape distortion encoding difference (SDED) approach solves this issue.
Shape Distortion Encoding Difference-SDED

- Divide idealized perimeter of the barcode
  - E.g. 10 line segment elements along each of the 4 sides
- One element for each of 40 exposed “sides” of one of 36 edge modules of 100 module example.
- Compute a sum squared error (SSE) of the residual, of some image related metric $p$, for each of the 40 elements
- Overall SSE of progressive barcode designated $SSE_{Det}$, defined as:

$$SSE_{Det} = \sum_{\text{elems}} \sum_{p(i) \in \text{element}} (p(i) - \mu_{element})^2$$

$p(i) = \text{orthogonal displacement with respect to the deterrent model of each point on the perimeter for a particular element}$

$\mu_{element} = \text{mean of such over the whole of that element.}$

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SDED - Continued

- Sum in $\text{SSE}_{\text{Det}}$ is divided by $40n$ to determine the atomic unit of encoding
  - $n$ is the number of samples of $p$ per element
- A 40-position string, $P$, is created for the deterrent (progressive barcode)
  - dividing $\text{SSE}$ of each element by atomic unit & rounding
- SDED for comparing any two deterrents defined as:
  \[
  SDED = \sum_{j \in \text{elems}} |P_1(j) - P_2(j)|
  \]
- A form of modified Hamming Distance: expected value of $P(*)$ is 1 at each element.
SDED Example

- Original image P: \{0300100100401010002001230124005002040120\}
  - *implies the original image had significant variability at positions 1, 11, 24, 28, 31 and 36 since the encoding is for 3, 4, 3, 4, 5 and 4, respectively, at those positions.*

- Same barcode imaged later, some variability in the encoding likely
  - *Eg: the following may be recorded:*
    - Second image P: \{0210100000500110003001130115006002030120\}

- The modified Hamming Distance between the two is 12.

- Threshold between matching images and non-matching images difficult to replicate during printing, difficult to tamper with
SDED Workflow

1. Capture previous IIO while capturing the document, compute $P$ string, e.g. \{0300100100401010002001230124005002040120\}.

2. Expand the IIO into a binary form (simplified one shown). \{01110001001001111010100011001111111011111100111110011011110\}.

3. Use this string (with padding, deleting, scrambling, encryption, or other encoding techniques needed for specific workflow & IIO type) to determine new information for the IIO.

4. Archive previous image.

5. Print new document with altered IIO (and other altered workflow data) included.

Note that this new document has cleaned-up IIO and new forensic boundary, which is not reflected in the IIO (yet) in the scenario depicted.

This approach resets the forensic information for IIO boundary each time there is a new document.
SDED Applications

- Combine barcodes directly with the current forensics.
  - Reading device collects forensics at same time as current image of the IIO
  - Incremental elements written to IIO reflect the forensics of original IIO, which “never change”,
  - There is only ever one physical item printed to—such as a unique label, packaging, special document, etc.
    - Encryption/signing of the incremental data generally required
      - Note that image registration issue here is non-trivial
SDED Applications - Workflow kiosk

- All-in-one or copier
  - *workflow-enhancing appliance or dual path print required*
- Steps:
  1. *Print document with IIO updated to previous stage*
  2. *Capture IIO and compute its forensics, e.g. sequence P*
  3. *Convert P into additional IIO modules*
     - Note: all conversions are possible here:
     - E.g. we can convert magenta to red by overprinting with yellow, etc.
  4. *Run the page through workflow kiosk (e.g. laserjet printer) again, register & overwrite IIO to make it the current IIO_{fm}*
     - Note: Registration aided by page find/placement information coming from scanning platen

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Conclusions

- Progressive Barcodes/IIOs can significantly increase data density
- SDED approach can be used to generate secure IIOs for document workflows
  - A series of experiments have been performed between false and valid images using a very high resolution scanning device
    - Number of segments $N$ and atomic unit of coding was varied
  - Results showed that by using the SDED measure on between 50 and 400 samples of the string $P$ best forensic security (at 200 samples) had a probability of false detection less than $10^{-9}$.
  - Encoding the position string $P$ into the payload modules of the barcode can provide authentication and forensic capabilities on the fly.

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Questions?

Thank you for your kind attention
Working Toward a Color Space Built on DE2000

John “the Math Guy” Seymour
Applied Mathematician & Color Scientist
QuadTech
Problem to be Solved

To make a ramp that looks linear
Why is this a problem?

Is one of these half way between white and black?
Why is this a problem?

Isn’t 50% reflectance half way?
Why is this a problem?

- Human eye is nonlinear
- Very sensitive at low reflectance
- Not very sensitive at high reflectance
- Much effort has been put into “the formula”
History Lesson – Munsell Color Space

Albert Munsell
1858 - 1918
History Lesson – Munsell Color Space
History Lesson – Munsell Color Space

Munsell mixed paints to achieve perceptual linearity
The “1931 Standard Observer”
Tristimulus Values: X, Y, and Z

7.1 Calculation of tristimulus values

The CIE Standard (CIE, 1986a) on standard tristimulus values of a colour stimulus begins with the value of the colour stimulus function $\phi_\lambda(\lambda)$, functions and integrating each set of products over the entire visible spectrum, 360 nm to 830 nm, numerical summation at wavelength interval $\Delta \lambda$.

\[
X = k \sum \phi_\lambda(\lambda) \bar{x}(\lambda) \Delta \lambda \\
Y = k \sum \phi_\lambda(\lambda) \bar{y}(\lambda) \Delta \lambda \\
Z = k \sum \phi_\lambda(\lambda) \bar{z}(\lambda) \Delta \lambda
\]
Chromaticity Diagram

MacAdam Ellipses
Chromaticity space is NOT perceptually linear!
The Measurement of Appearance, Richard Hunter, 1987
The CIELAB color space is a three-dimensional, approximately uniform color space produced by plotting in rectangular coordinates, $L^*, a^*, b^*$, quantities defined by the equations:

$$L^* = 116 \left( \frac{Y}{Y_n} \right) - 16$$  \hspace{1cm} (8.3)

$$a^* = 500 \left[ f(\frac{X}{X_n}) - f(\frac{Y}{Y_n}) \right]$$  \hspace{1cm} (8.4)

$$b^* = 200 \left[ f(\frac{Y}{Y_n}) - f(\frac{Z}{Z_n}) \right]$$  \hspace{1cm} (8.5)

where

$$f(\frac{X}{X_n}) = \left( \frac{X}{X_n} \right)^{1/3}$$  \hspace{1cm} if \hspace{1cm} $\left( \frac{X}{X_n} \right) > (24/116)^3$  \hspace{1cm} (8.6)

$$f(\frac{X}{X_n}) = \frac{841}{108}(\frac{X}{X_n}) + 16/116$$  \hspace{1cm} if \hspace{1cm} $\left( \frac{X}{X_n} \right) \leq (24/116)^3$  \hspace{1cm} (8.7)

and

$$f(\frac{Y}{Y_n}) = \left( \frac{Y}{Y_n} \right)^{1/3}$$  \hspace{1cm} if \hspace{1cm} $\left( \frac{Y}{Y_n} \right) > (24/116)^3$  \hspace{1cm} (8.8)

$$f(\frac{Y}{Y_n}) = \frac{841}{108}(\frac{Y}{Y_n}) + 16/116$$  \hspace{1cm} if \hspace{1cm} $\left( \frac{Y}{Y_n} \right) \leq (24/116)^3$  \hspace{1cm} (8.9)

and

$$f(\frac{Z}{Z_n}) = \left( \frac{Z}{Z_n} \right)^{1/3}$$  \hspace{1cm} if \hspace{1cm} $\left( \frac{Z}{Z_n} \right) > (24/116)^3$  \hspace{1cm} (8.10)

$$f(\frac{Z}{Z_n}) = \frac{841}{108}(\frac{Z}{Z_n}) + 16/116$$  \hspace{1cm} if \hspace{1cm} $\left( \frac{Z}{Z_n} \right) \leq (24/116)^3$  \hspace{1cm} (8.11)

where $X, Y, Z$ are the tristimulus values of the test object color stimulus considered and $X_n, Y_n, Z_n$ are the tristimulus values of a specified white object color stimulus. In most cases, the specified white object color stimulus should be light reflected from a perfect reflecting diffuser illuminated by the same light source as the test object. In this case, $X_n, Y_n, Z_n$ are the tristimulus values of the light source with $Y_n$ equal to 100.\(^{18}\)
People Involved in Standard

Members of the Technical Committee during the preparation of this report were:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nationality</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.J. Alessi</td>
<td>USA</td>
</tr>
<tr>
<td>E.C. Carter</td>
<td>USA</td>
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<tr>
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<td>C.S. McCamy</td>
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<td>L. Morren</td>
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<td>J.H. Nobbs</td>
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<td><strong>D.C. Rich</strong></td>
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<td>A.R. Robertson</td>
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<tr>
<td>J.D. Schanda (chair)</td>
<td>Hungary</td>
</tr>
<tr>
<td>R. Sève</td>
<td>France</td>
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<td>P.W. Trezona</td>
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<tr>
<td>K. Witt</td>
<td>Germany</td>
</tr>
<tr>
<td>H. Yaguchi</td>
<td>Japan</td>
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</tbody>
</table>

Albuquerque, NM 2015
Color Difference, ΔE

\[ \Delta E = \sqrt{(a_1 - a_2)^2 + (b_1 - b_2)^2} \]
Color Difference, $\Delta E$

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$
Colour materials industries (textiles, paint, plastics, etc.) tended to adopt CIELAB and found significant evidence of non-uniformity of this colour space. McLaren introduced and McDonald further developed the idea of empirically correcting an approximate uniform colour space to improve the association between visual and numerical colour difference (McLaren, 1972; McDonald 1980a, 1980b, 1980c). The corrections generally are related to the location of a colour-difference pair in the colour space and the direction of difference between the colour-difference pair. This has led to the development of many CIELAB-based colour-difference models with a variety of empirical corrections fitted to specific sets of visual colour-difference data. Among these the CMC model has been widely adopted by the textile industry (Clarke, 1984).
$$\Delta E_{CMC}$$

$$\Delta E_{CMC}(l : c) = cf \cdot \sqrt{\left(\frac{\Delta L^*}{l \cdot S_L}\right)^2 + \left(\frac{\Delta C^*}{c \cdot S_c}\right)^2 + \left(\frac{\Delta H^*}{S_H}\right)^2}$$
$\Delta E_{\text{CMC}}$
\[ \Delta E_{\text{CMC}}(l : c) = cf \cdot \sqrt{\left( \frac{\Delta L^*}{l \cdot S_L} \right)^2 + \left( \frac{\Delta C^*}{c \cdot S_C} \right)^2 + \left( \frac{\Delta H^*}{S_H} \right)^2} \]

\[
S_L = \frac{0.040975 \cdot L^*}{(1 + 0.01765 \cdot L^*)} \quad \text{for} \quad L^* \geq 16
\]

\[
S_L = 0.511, \quad \text{for} \quad L^* < 16
\]

\[
S_C = \frac{0.0638 \cdot C^*}{(1 + 0.0131 \cdot C^*)} + 0.638
\]

\[
S_H = S_C (T \cdot f + 1 - f)
\]

\[
f = \left\{ \frac{(C^*)^4}{(C^*)^4 + 1900} \right\}^{\frac{1}{3}}
\]

\[
T = 0.56 + 0.2 \cos (h + 168^\circ), \quad \text{if} \quad 164^\circ < h < 345^\circ
\]

\[
T = 0.36 + 0.4 \cos (h + 35^\circ), \quad \text{else},
\]

ASTM D2244-07
McLaren-Style Corrections

- $\Delta E_{JCP79}$ – McDonald (1979)
- $\Delta E_{CMC}$ – McDonald, Clark, and Rigg (1986)
- $\Delta E_{BFD}$ – Luo and Rigg (1987)
- $\Delta E_{94}$ – CIE (1994)
- $\Delta E_{LCD}$ – Kim (1997)
- $\Delta E_{00}$ – CIE (2000)
ΔE₀₀ Formula

\[
\Delta E_{00} = \left[ \left( \frac{\Delta L'}{k_L S_L} \right)^2 + \left( \frac{\Delta C'}{k_C S_C} \right)^2 + \left( \frac{\Delta H'}{k_H S_H} \right)^2 + R_T \left( \frac{\Delta C'}{k_C S_C} \right) \left( \frac{\Delta H'}{k_H S_H} \right) \right]^{0.5}
\]
\[ \Delta E_{00} = \sqrt{\left( \frac{\Delta L'}{k_L S_L} \right)^2 + \left( \frac{\Delta C'}{k_C S_C} \right)^2 + \left( \frac{\Delta H'}{k_H S_H} \right)^2 + R_T \left( \frac{\Delta C'}{k_C S_C} \right) \left( \frac{\Delta H'}{k_H S_H} \right)} \] (B.1)

where

\( \Delta L' \) is the transformed lightness difference between specimens 1 and 2, see Equation (B.2);

\( \Delta C' \) is the transformed chroma difference between specimens 1 and 2;

\( \Delta H' \) is the transformed hue difference between specimens 1 and 2;

\( R_T \) is the rotation function, see Equation (B.11);

\( k_L, k_C \) and \( k_H \) are the parametric factors for variation in the experimental conditions;

\( S_L, S_C \) and \( S_H \) are the weighting functions, see Equations (B.7) to (B.9).

First, a localized modification of the scaling along the \( a^* \) axis is made which is most significant for colours at low chroma.

\[ L' = L^* \] (B.2)

\[ a' = a^*(1 + G) \] (B.3)

\[ b' = b^* \] (B.4)
with
\[ G = 0.5 \left\{ \sqrt{c_{ab}^7} - \sqrt{c_{ab}^7 + 25} \right\} \] (B.5)

and
\[ \tilde{c}_{ab}^* = 0.5(c_{ab1}^* + c_{ab2}^*) \] (B.6)

where
- \( L' \) is the transformed lightness;
- \( a' \) is the transformed \( a^* \) (red-green opponent) co-ordinate;
- \( b' \) is the transformed \( b^* \) (yellow-blue) co-ordinate;
- \( G \) is a quantity that depends on the mean chroma of specimens 1 and 2.
The transformed $L'$, $a'$, $b'$ values are then used to calculate hue angle, chroma and lightness. These new quantities are designated by a prime mark. With these results the weighting functions and the rotation function are determined using the following equations:

\[
S_L = 1 + \frac{0.015(L' - 50)^2}{\sqrt{20 + (L' - 50)^2}}
\]

(B.7)

\[
S_C = 1 + 0.045 \hat{C}'
\]

(B.8)

\[
S_H = 1 + 0.015 \hat{H}'
\]

(B.9)

with

\[
T = 1 + 0.17 \cos(\hat{h}' - 30^\circ) + 0.24 \cos(2\hat{h}') - 0.32 \cos(3\hat{h}' + 6^\circ) - 0.20 \cos(4\hat{h}' - 63^\circ)
\]

(B.10)

where $S_L$, $S_C$ and $S_H$ are the weighting functions;

$\bar{L}'$ is the mean of the transformed lightnesses for specimens 1 and 2;

$\bar{C}'$ is the mean of the transformed chromas for specimens 1 and 2;

$T$ is a quantity that depends on the mean of the transformed hue angles for specimens 1 and 2;

$\bar{H}'$ is the mean of the transformed hue angles for specimens 1 and 2.
Finally, the rotation function is calculated from the following equations:

\[ R_T = -R_C \sin(2\Delta \Theta) \]  \hspace{1cm} (B.11)

with

\[ \Delta \Theta = 30^\circ \exp\left\{ -\left( \sqrt{\left( \overline{h}' - 275/25 \right)^2} \right) \right\} \]  \hspace{1cm} (B.12)

and

\[ R_C = 2\sqrt{\frac{C'^7}{C'^7 + 25^7}} \]  \hspace{1cm} (B.13)

where

\( R_T \) is the rotation function;

\( \Delta \Theta \) is the hue angle difference depending on the mean of the transformed hue angles for specimens 1 and 2;

\( \overline{h}' \) is the mean of the transformed hue angles for specimens 1 and 2;

\( R_C \) is a quantity that depends on the mean of the transformed chromas for specimens 1 and 2;

\( C' \) is the mean of the transformed chromas for specimens 1 and 2.
Parsimony

… even if you have 11,000 data points, you should be very careful about using eleven parameters in your regression.

http://johntemathguy.blogspot.com/2012/07/when-regression-goes-bad.html
2.0 $\Delta E_{00}$ “Ellipses” Shown in L*a*b*
Uniform Color Space vs. Color Difference Formula

- The space itself is linear
- You can use Euclidean distance formula
- No corrections based on color
Uniform Color Spaces (Proposed)

- Lab\(_{mg}\) (Colli, Gremmo, and Moniga, 1989)
- ATD (Guth, 1994)
- DCI-95 (Rohner and Rich, 1995)
- LLAB (Luo, Lo, and Kuo, 1995)
- ??? (Tremeau and Laget, 1995)
- CIECAM97 (CIE standard, 1997)
- RLAB (Fairchild, 1998)
- IPT (Ebner and Fairchild, 1998)
- L*'a*'b*' (Thomsen, 1999)
- DIN99 (DIN standard 6176, 2000)
- CIECAM02 (CIE standard, 2002)
- QTD (Granger, 2008)
- L\(^{E}a^{E}b^{E}\) (Berns, 2008)
- LAB2000 (Lissner and Urban, 2010)
Problem to be Solved

Right now, I’m just looking at $L^*$
Three-dimensional, approximately uniform, colour space produced by plotting in rectangular coordinates, $L^*, a^*, b^*$, quantities defined by the equations:

\[
L^* = 116 \left( \frac{Y}{Y_n} \right)^{1/3} - 16
\]

\[
a^* = 500 \left( \frac{X}{X_n} - \frac{Y}{Y_n} \right)
\]

\[
b^* = 200 \left( \frac{Y}{Y_n} - \frac{Z}{Z_n} \right)
\]

where

\[
f(X) = \begin{cases} 
(X/X_n)^{1/3} & \text{if } (X/X_n) > (24/116)^3 \\
(841/108)(X/X_n) + 16/116 & \text{if } (X/X_n) \leq (24/116)^3 
\end{cases}
\]

and

\[
f(Y) = \begin{cases} 
(Y/Y_n)^{1/3} & \text{if } (Y/Y_n) > (24/116)^3 \\
(841/108)(Y/Y_n) + 16/116 & \text{if } (Y/Y_n) \leq (24/116)^3 
\end{cases}
\]

and

\[
f(Z) = \begin{cases} 
(Z/Z_n)^{1/3} & \text{if } (Z/Z_n) > (24/116)^3 \\
(841/108)(Z/Z_n) + 16/116 & \text{if } (Z/Z_n) \leq (24/116)^3 
\end{cases}
\]

where $X, Y, Z$ are the tristimulus values of the test object colour stimulus considered and $X_n, Y_n, Z_n$ are the tristimulus values of a specified white object colour stimulus. In most cases, the specified white object colour stimulus should be light reflected from a perfect reflecting diffuser illuminated by the same light source as the test object. In this case, $X_n, Y_n, Z_n$ are the tristimulus values of the light source with $Y_n$ equal to 100.
Parsimony for $L_{mg}$?

\[ L_{mg} = \frac{34.7231 - 0.01765L + \ln(0.040975L)}{0.040975} \]

\[ L_{mg} = \frac{L^*}{0.511} \]

\[ L^* \geq 16 \]

\[ L^* < 16 \]
## Parsimony for $\Delta L$

<table>
<thead>
<tr>
<th>Color Difference Equation</th>
<th># of parameters for $\Delta L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta E_{ab}$</td>
<td>3</td>
</tr>
<tr>
<td>$\Delta E_{CMC}$</td>
<td>6</td>
</tr>
<tr>
<td>$\Delta E_{94}$</td>
<td>3</td>
</tr>
<tr>
<td>$\Delta E_{00}$</td>
<td>6</td>
</tr>
<tr>
<td><strong>Uniform Color Space</strong></td>
<td></td>
</tr>
<tr>
<td>$LAB_{mg}$</td>
<td>7</td>
</tr>
<tr>
<td>L** (Rohner and Rich)</td>
<td>5</td>
</tr>
<tr>
<td>$\Delta E_{99}$ (DIN 99)</td>
<td>5</td>
</tr>
</tbody>
</table>
Building L_{00}

\{
\{0, 0, 0\} \rightarrow 1.0 \Delta E_{00}
\{1.734, 0, 0\} \rightarrow 1.0 \Delta E_{00}
\{3.442, 0, 0\} \rightarrow 1.0 \Delta E_{00}
\{5.124, 0, 0\} \rightarrow 1.0 \Delta E_{00}
\ldots
\}
Building $L_{00}$
Building $L_{00}$

The only thing worthwhile in this whole presentation
Error in $L_{00}$
## Parsimony for ΔL

<table>
<thead>
<tr>
<th>Color difference equation</th>
<th># of parameters for ΔL</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔE_{ab}</td>
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<td>L** (Rohner and Rich)</td>
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<tr>
<td>ΔE_{99} (DIN 99)</td>
<td>5</td>
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<tr>
<td>L_{00}</td>
<td>2</td>
</tr>
</tbody>
</table>
This general formula is nothing new!

- Delboeuf Equation (1872)
  \[ D = 10 - 6.1723 \log_{10} (40.7h + 1) \]

- Richter’s equation (1953)
  \[ V = 6.1723 \log_{10} (40.7Y + 1) \]
Applying the Equation to $a_{00}b_{00}$
Progress so far

- $L_{00}$ – Looks good
- $a_{00}, b_{00}$ – same approach doesn’t help much
Stay tuned…

John “the Math Guy” Seymour
Applied Mathematician
& Color Scientist
QuadTech

http://johnthemathguy.blogspot.com/

Albuquerque, NM 2015
Managing Tone for Spot Colors

Marc Levine – Director of Enterprise Print Quality
Matthews-SGK
Who am I?

• Work with large consumer product companies
• Manage supply chain print quality
• Help brands realize consistent design intent
• Not a scientist
• Not a professor
• Not a mathematician
• Excel Junkie
Why am I here?

• Spot colors are commonly used in packaging to reproduce equity **brand colors**.
• It is increasingly common for packaging artwork to include **spot color solids, tints, overprints and extended color process** in artwork designs.
• Brands are increasingly looking to standardize quality through **specifications**.
• Today’s specifications for print do not address these important needs.
Background on this effort

- Measuring TVI of a spot color, April 2013
  - John Seymour for IDEAlliance
  - Computing TVI of spot colors using wavelength of maximum density DOES NOT WORK for a whole lot of spot color inks.
  - Colorimetric Tone Value (CTV) – Bill Birkett & Charles Spontelli, TAGA 2005

- Spot Colors and Tone Value, September 2013
  - Mark Samworth
  - deltaE-to-paper is a little better than Murray Davies spectral TV, but not as good as we would like it to be.
  - Future work should test different metrics as well as different data sets

- A Regression-Based Model of Colorimetric Tone Reproduction for use in Print Standards, April 2005 2013
  - William Birkett & Charles Spontelli for TAGA
  - Introduces Colorimetric Tone Value (CTV)
A quick example...

- Photoshop on the bottom, linear Status T MD on top.
A quick example…

- Photoshop on the bottom, ISO Curve A Status T MD on top.
SCHMOO

- **Spot**
- **Color**
- **Halftone**
- **Metric**
- **Optimization**
- **Organization**

- …or should it be observation and optimization?
- A subcommittee of IDEAAlliance
Not Shmoo
Committee Members

Consultants
▪ Don Hutcheson @hutchcolor
▪ Steve Smiley @smileycolor
▪ Bob Hallam @pixelologie
▪ Ron Ellis @ronellisconsulting
▪ Mike Rodriguez @consulting
▪ Mike Strickler @mspgraphics

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▪ Paula Gurnee @INX
▪ Jim Roth @flintgrp

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▪ Dave McDowell @npes

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▪ Ray Cheydleur @xrite
▪ Chris Halford @xrite
▪ Thomas Lianza @xrite
▪ Stone Xianfeng Zhao @xrite
▪ Hanno Hoffstadt @gmgcolor
▪ Juergen Seitz @gmgcolor
▪ Mark Samworth @esko
▪ Service Providers
▪ Marc Levine @schawk
▪ Garett Long @sgs
▪ Gary Russell @phototype
▪ Donald Schroeder @fujifilm
▪ Phil Sylvester @fujifilm
▪ Sam Ingram @clemson

Printers
▪ Steve Balschi @printpack
▪ Kiran Deshpande @cheseapeakecorp
▪ Eileen Henry @hammerpackaging
▪ Bill Pope @graphicpackaging
▪ Awadhoot Shendye @northamericancolor
Challenges with current methods

- Not consistent across different print processes
- Not consistent across different ink colors
- Not consistent across different substrates
- In general, do not correlate with expected visual behavior (smooth, even development from substrate to solid ink)
Objectives

Identify a new metric for computing tone that will...

• Produce a consistent visual tone behavior
• Produce a consistent result across different inks, substrates, processes, and colors
• Use a standard tone target across different inks, substrates, processes, and colors (50 is a 50)
• Better mirror the design intent of the artwork
• Create a method that can easily be implemented into color measurement devices & QC tools
Not Objectives

- Matching the tint dE between different print conditions
- Perfect visual behavior
Test Data

Collect spectral ramp data (54 ramps)
- Paper to solid in discrete steps
- Mixture of processes, substrates, inks, and colors
- Create Lab tif for visual evaluation
Test Metrics

9 different metrics, spectral and colorimetric

- Status T Murray Davies (STD)
- Spectral Density (max filter) Murray Davies (SPD)
- Integral Base Normalized Value (IBNV) - Lianza
- Coefficient-based spectral filter (PTRU) - Russell
- Colorimetric Tone Value (CTV) - Birkett
- Colorimetric STR (STR) - Hoffstadt
- XYZ Magnitude (XYZ) – Long
- DeltaE-to-Paper (DEP) - Samworth
- L-star linearization (LSD ) - McDowell
Test Procedure

- Compute tone value for each metric
- Compute linear tone correction curve
- Compute corrected Lab or spectral value
- Render corrected Lab values to bitmap image for evaluation
- Final print run test using selected metric (TBD)
Status T Density – Murray Davies

- Industry-standard method (US) for color tone / ISO5-3
Spectral Density – Murray Davies

- Industry-standard method spot color tone / ISO 5-3
Integral Base Normalized Value (IBNV)

- Spectral filter, based in inverse paper spectra
XYZ Magnitude (XYZ)

- Sum of X, Y, and Z
PT_Ru

- Spectral filter, based on 3 coefficients
Colorimetric Tone Value (CTV)

- Based on Lx, Ly, and Lz functions
Colorimetric Tone Value (STR)

- Based on S, T, and R functions
DeltaE-to-Paper (DEP)

- Paper-relative linear dE
Linear L-star (LSD)

- Uses L function with dynamic switch to a* or b*
Status T Density – Murray Davies
Spectral Density – Murray Davies
Integral Base Normalized Value (IBNV)
XYZ Magnitude (XYZ)
Colorimetric Tone Value (CTV)
Colorimetric Tone Value (STR)
Linear L-star (LSD)
DeltaE-to-Paper (DEP)
Findings

• Overall, colorimetry-based metrics produce more consistent visual development
• Status T & Spectral Density produce similar results
• PTRU showed best performance of spectral formulas, but requires use of coefficients for calculations
• CTV and STR are effectively the same formula
• LSD has appealing visual result, but requires thresholds to switch between L, a, and b linearization.
Results – CTV is preferred metric

• Produces consistent visual results across all samples
• Aligns with Adobe Creative Suite color rendering
• Colorimetric formula easily integrates in PDF
• Simplified formula easy to use in spreadsheet form
• Can be used with both spectral and colorimetric data
CTV Formula

To convert from Lab to $L_xL_yL_z$:

\[ L_y = L \]
\[ L_x = L + \frac{116a}{500} \]
\[ L_z = L - \frac{116b}{200} \]

To convert from $L_xL_yL_z$ to Lab:

\[ L = L_y \]
\[ a = \frac{500(L_x - L_y)}{116} \]
\[ b = \frac{200(L_y - L_z)}{116} \]

To compute CTV from Lab values, first convert the Lab values to $L_xL_yL_z$, then evaluate CTV:

\[ CTV = \sqrt{\frac{(L_{xp} - L_x)^2 + (L_{yp} - L_y)^2 + (L_{zp} - L_z)^2}{3}} \]
Next steps

• Continue to evaluate additional data
• Complete final project testing (press runs)
• Work with ISO committee to find a home for the metric (ISO 13655)
Acknowledgements

- Steve Smiley
- Mike Rodriguez
- John Seymour
- Danny Rich
- Bill Birkett
- Tom Lianza
- Gary Russell
- Garrett Long
- Mark Samworth
- Hanno Hoffstadt
- Dave McDowell
Questions, Comments?
The Effect of Press Variation on Color Stability on 7-color and 4-color Process Color Tint Builds

Matthew Furr
Application Engineer, Esko
Agenda

• Introduction

• Objective / Scope

• Methodology

• Hypothesis

• Experimental Design

• Results & Interpretation
CMYK Gamut

Gamut - a subset of colors which can be accurately represented in a given circumstance, such as within a given color space or by a certain output device.
Improved inks, plates, anilox rolls, presses, prepress applications and separations have enabled converters to move from the traditional limitation of ‘spot’ colors, to a more expanded, advanced, computerized screen and process printing technique using process inks.
CMYKOGV Gamut
Objective / Research Question

The effect of press variation on color stability with 4-color and 7-color process color tint builds.
Inks act as levers on the color tint build.
Inks act as levers on the color tint build.
Differences in Hue

= 140.3°

= 86.4°
Differences in Hue

- Blue to Yellow: $140.3^\circ$
- Green to Yellow: $86.4^\circ$

Differences in Chroma
Hypotheses

1. Maximum GCR results in the least color variation.
2. A color build logic using 7C and Maximum GCR results in the least color variation.
3. 7C build logic results in the lowest ink consumption.
<table>
<thead>
<tr>
<th></th>
<th>K</th>
<th>O</th>
<th>V</th>
<th>C</th>
<th>G</th>
<th>M</th>
<th>Y</th>
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<tr>
<td>L* a* b*</td>
<td>16.3, -.6, -.8</td>
<td>67.7, 52.8, 77.3</td>
<td>28.2, 47, -61.8</td>
<td>59.6, -42.2, -40</td>
<td>63.6, -70, .9</td>
<td>51.3, 66, -13.1</td>
<td>87.7, -9.4, 97.4</td>
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Sample Selection
600 Pantone colors were selected for comparisons.
• Randomized Targets
• Comparisons Grouped
Over Impression of Printing Plates
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<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Set 12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Set 13</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Set 14</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>O</td>
<td>V</td>
<td>C</td>
<td>G</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>-----</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Set 15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Set 16</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Set 17</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Set 18</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
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<td>Set 19</td>
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<td>Set 20</td>
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<td>+</td>
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<td>Set 21</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Data Reporting

Color Difference:
1. $\Delta E \text{ CIE 1976}$
2. $\Delta E \text{ 2000}$

3 Types of Variation:
1. Common Component
2. Alternative Component
3. Gray Component
Managing Data
4C No GCR

PANTONE 1595
C M Y K
5 74 100 0

Common Component
Alternative Component
Grey Component

7C Max GCR

PANTONE 1595
C M Y K O
0 72 100 5.9 0

Common Component
Alternative Component
Grey Component
How much of the stability is related to the grey component?
Common Component
Alternative Component
Grey Component

4C No GCR

PANTONE 1595
C 6
M 74
Y 100
K 0
O 0

4C Max GCR

PANTONE 1595
C 0
M 72
Y 100
K 5.9
O 0

Common Component
Alternative Component
Grey Component
### ΔE 2000 in Grey Component Variation

<table>
<thead>
<tr>
<th></th>
<th>4C No GCR</th>
<th>4C Max GCR</th>
<th>7C Max GCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-O</td>
<td>3.10</td>
<td>0.72</td>
<td>0.87</td>
</tr>
<tr>
<td>M-O</td>
<td>2.81</td>
<td>0.60</td>
<td>0.72</td>
</tr>
<tr>
<td>M-V</td>
<td>1.49</td>
<td>0.62</td>
<td>0.61</td>
</tr>
<tr>
<td>C-V</td>
<td>1.36</td>
<td>0.80</td>
<td>0.58</td>
</tr>
<tr>
<td>C-G</td>
<td>3.04</td>
<td>1.59</td>
<td>1.94</td>
</tr>
<tr>
<td>Y-G</td>
<td>3.24</td>
<td>1.76</td>
<td>2.13</td>
</tr>
</tbody>
</table>
Variation is reduced by 36%
ΔE 2000 — Common Component Variation

2 Component Builds

<table>
<thead>
<tr>
<th></th>
<th>4C Max GCR</th>
<th>7C Max GCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-O</td>
<td>2.03</td>
<td>1.83</td>
</tr>
<tr>
<td>O-M</td>
<td>4.03</td>
<td>3.53</td>
</tr>
<tr>
<td>M-V</td>
<td>4.00</td>
<td>3.24</td>
</tr>
<tr>
<td>V-C</td>
<td>3.12</td>
<td>2.40</td>
</tr>
<tr>
<td>C-G</td>
<td>2.82</td>
<td>2.02</td>
</tr>
<tr>
<td>G-Y</td>
<td>2.59</td>
<td>2.00</td>
</tr>
</tbody>
</table>
### ΔE 2000 — Common Component Variation

#### 3 Component Builds

<table>
<thead>
<tr>
<th>Component</th>
<th>4C Max GCR</th>
<th>7C Max GCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-O</td>
<td>1.88</td>
<td>1.63</td>
</tr>
<tr>
<td>O-M</td>
<td>3.42</td>
<td>2.60</td>
</tr>
<tr>
<td>M-V</td>
<td>3.76</td>
<td>2.88</td>
</tr>
<tr>
<td>V-C</td>
<td>3.54</td>
<td>1.84</td>
</tr>
<tr>
<td>C-G</td>
<td>2.35</td>
<td>1.53</td>
</tr>
<tr>
<td>G-Y</td>
<td>2.04</td>
<td>1.67</td>
</tr>
</tbody>
</table>
PANTONE 1595
C M Y K O
5 74 100 0 0

Common Component
Alternative Component
Grey Component

PANTONE 1595
C M Y K O
0 72 100 5.9 0

Common Component
Alternative Component
Grey Component
ΔE 2000 — Alternative Component Variation

2 Component Builds

<table>
<thead>
<tr>
<th></th>
<th>4C Max GCR</th>
<th>7C Max GCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-O</td>
<td>2.03</td>
<td>1.83</td>
</tr>
<tr>
<td>O-M</td>
<td>4.03</td>
<td>3.53</td>
</tr>
<tr>
<td>M-V</td>
<td>4.00</td>
<td>3.24</td>
</tr>
<tr>
<td>V-C</td>
<td>3.12</td>
<td>2.40</td>
</tr>
<tr>
<td>C-G</td>
<td>2.82</td>
<td>2.02</td>
</tr>
<tr>
<td>G-Y</td>
<td>2.59</td>
<td>2.00</td>
</tr>
</tbody>
</table>
\[\Delta E\, 2000 \rightarrow \text{Alternative Component Variation}\]

### 3 Component Builds

<table>
<thead>
<tr>
<th></th>
<th>4C Max GCR</th>
<th>7C Max GCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-O</td>
<td>4.60</td>
<td>2.27</td>
</tr>
<tr>
<td>O-M</td>
<td>1.95</td>
<td>0.75</td>
</tr>
<tr>
<td>M-V</td>
<td>2.09</td>
<td>0.53</td>
</tr>
<tr>
<td>V-C</td>
<td>4.04</td>
<td>1.12</td>
</tr>
<tr>
<td>C-G</td>
<td>1.68</td>
<td>1.07</td>
</tr>
<tr>
<td>G-Y</td>
<td>2.12</td>
<td>0.88</td>
</tr>
</tbody>
</table>
Variation is reduced by 28%
Total Area Coverage

- 18.8% difference in the 2 Component builds
- 12.2% difference in the 3 Component builds
Summary of Findings:

1. Print Maximum GCR
2. 7C Max GCR resulted in lower Common Component variation when compared to 4C Max GCR
3. 7C Max GCR resulted in significantly lower Alternative Component Variation when compared to 4C Max GCR
4. 18.8% difference in TAC in builds with 2 components
5. 12.2% difference in TAC in builds with 3 components
Thanks to my committee and advisors!

Dr. Duncan Darby  
Associate Professor

Dr. Sam Ingram  
Graphic Comm.  
Department Chair

Dr. Chip Tonkin  
Director of  
Sonoco Institute

Mark Samworth  
Color Solutions  
Architect - Esko

Bobby Congdon  
Research Associate at  
Sonoco Institute

Bradley Gasque  
Research Associate at  
Sonoco Institute
Building Micro Surface Texturization For White Inks And Coatings In Flexo

Dr. John Anderson
WW Business Development Packaging
Eastman Kodak
Introduction

- Issues with white ink
- Why is white ink so important?
- Initiation of project to address white needs
- Lessons along the way
  - Size Matters!
  - Measurement Parameters & Bounce
- Custom target and results
- Conclusion
Issues With White Inks

- **Color / Appearance**
  - *White inks are the foundation of many colors for packaging*
  - *Pinholes in the white result in inconsistent color for inks overprinting it, and traditional “muddy” colors in Flexo*

- **Economics / Productivity**
  - *50% of ink spend in most flexible packaging facilities is white today*
  - *White is the heaviest ink deposit, requires most drying, so controls press speeds*
Pinholes Relate To The Color, Color Cleanliness And Final Tonal Range

- Image shows 2 pictures of same white over a black background, one with pinholes, one without
- Color overlay with 50% transparency illustrates the effect caused by pinholes
- Circle represents spectro aperture – do the measurements change?

Pinholes affect the measured color, effectively turning it darker, and increasing variability in the measurements e.g. $\Delta E = ??$
Development Project – Not So Easy

- Q4 2012 initiated by 2 printers using NX plates
  - One using Kodak for all plates
  - One using Kodak for all but white
- Project looked for how to optimize press conditions for white using standard DigiCap NX
- Press / component variables tested included:
  - Ink pigmentation, grind levels, ink viscosity, ink temperature
  - Anilox volume, anilox lpi, anilox format (60°, E-Flow, GTT, etc)
  - Tape compressibility, press speed, press formats, substrates, etc.
Progressive Development Of Patterns

- Results highlighted importance of size, mottle, and controlled flow
- Resulted in development of custom patterns and features to optimize ink laydown
- The steps were:

1. Low
2. Med
3. High
Initial Checkerboard Patterns & White Images

440 LPI
7 bcm

50X
1:1
200X

50X
2:2
200X

50X
3:3
200X

50X
4:4
200X

50X
5:5
200X

67th Annual Technical Conference

tagaatc.printing.org
Size Alone Was Not Enough – What Next

- Utilizing the SQUAREspot head using the 5x10 micron feature (½ pixel) in DigiCap NX
- Applied for mottle reduction
- Applied various shapes to evaluate a variety of properties
- Unmatched consistency and repeatability in fine details
Test Target Using 5x10 Micron Features

- Sample pattern structures with DigiCap NX applied to address mottle
- Improved results but still not satisfied
Pictures & Measurements @ 50X

- Opacity measurements aligned with expectations
- Ink film weight did not follow same logic
Pictures & Measurements @ 200X

- 200X magnification shows greater details
- Pin-holes were not solved in any case
- 3x3B vs 3x3 showed promise
- Highlights use of high magnifications around 200X to gain greater understanding and optimization
Lessons Learnt Along The Way

- Size matters
  - *The pattern structure must match the anilox volume range*

- What to measure
  - *Dry ink film weight is not reliable enough, don’t use it*
  - *Opacity is a good guide but not enough alone*
  - *Visual inspection for mottle / pin holes is required*
  - *Mottle can be measured for verification*

- Bounce is extremely important
  - *Need to address bounce in the design of the targets*
  - *Need sufficient measurements to eliminate effect*
3D Representation Of White Opacity From A Solid White Patch

400 Measurement Per Patch
Multiply Vertical Scale by 100 For Opacity
Press Harmonics Around The Cylinder Also Needs To Be Addressed

- Image shows white opacity around a print cylinder
- Range of measurements is often bigger than normal difference in tests
- Need to take sufficient measurements to average results
- Highlights that spot opacity measurements alone is not sufficient
Resulted In A Unique Banded Plate Test Target

Web Print Direction

| 9x250mm solid strips with each DigiCapNX pattern going around repeat |
| 9x250mm 110lpi tint strips with each DigiCap NX pattern |

50x50mm squares of each DigiCapNX pattern including pattern ID label

Pattern ID label: Plate type ID label
Sample View Of The Surface Patterns

- Limited set of custom patterns developed for use with high volume anilox rolls
  - Initially suited to white solvent based inks and coatings
- Simple process to identify correct pattern for ink and anilox combination
  - Uses opacity measurements and magnified visual inspection

SEM Image At 500X
Real White Ink Print Example @ 200X

Low Volume
- Opacity = 56.2

Mid Volume
- Opacity = 58.5

High Volume
- Opacity = 62.7

Opacity = 58.1
- Opacity = 60.2
- Opacity = 64.1

Albuquerque, NM 2015
Conclusion

- Pin-holes are a critical factor in the performance of inks, especially white inks and coatings
- White is the foundation for all other colors and should be a key focus for color and consistency
- Kodak have developed specific plate surface technologies to allow minimized pin-holes and increased opacity with the same or less ink
  - *Focused on simple application based on anilox volume range used*
- This technology provides benefits in terms of:
  - *Color gamut, color cleanliness, shelf impact*
  - *Productivity and press efficiency*
Any Questions?

john.anderson3@kodak.com
New EB curable CI-Flexo Ink Technology
Providing Sustainable Printing Solutions
For Packaging Applications

Im Rangwalla
Energy Sciences Inc.
Wilmington MA 01887
Agenda

- Market Size and Market Needs
- EB CI-Flexo Technology
- Print Results
- Conclusions
- Future Developments
Global Flexible Packaging By Region 2013

Total $ 97 Billion
CAGR – 2.6 % in NA from 2003-2013

Source: FPA 2014
### 2013 Flexible Package Materials Purchase in NA

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Films</td>
<td>41%</td>
<td></td>
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<tr>
<td>Resin</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>Inks</td>
<td>7%</td>
<td>$1.106 Billion</td>
</tr>
<tr>
<td>Foil</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Ctgs&amp;Adh</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>12%</td>
<td></td>
</tr>
</tbody>
</table>
Market Requirements For Printing

- Runs are increasingly shorter
- Improved print quality like Gravure
- New designs with gloss and glitter
- Shorter delivery times
- Higher productivity
- Lower prices increased competition
- Higher profit margins
- Sustainable packaging
- Food Packaging Friendly
If You Print Using Gravure

Strengths
• High Print Quality
• Brilliant Colors
• High Productivity For Long Runs
• Long time proven technology
• Several Established Ink Suppliers

Disadvantages
• Solvent Inks
• Long Lead Time for New Cylinders
• Long Time To Market
• High Cost of Cylinders
• Too Expensive For Short Print Jobs
## Technical Developments

<table>
<thead>
<tr>
<th>Process for Flexible Packaging</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravure for flexible packaging</td>
<td>No new developments</td>
</tr>
</tbody>
</table>
| Flexo for flexible packaging | • General flexography technology, Photo polymer plate development  
• CI-Flexo inks with EB-curing |
| Sheet-offset for labels and folding cartons | No new developments |
| Web-Offset for folding cartons and flexible packaging | Variable formats/repeat |
# Converter Printing Comparison in NA For 2013

<table>
<thead>
<tr>
<th>Print Type</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
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</thead>
<tbody>
<tr>
<td>Flexo</td>
<td>64%</td>
<td>63%</td>
<td>64%</td>
</tr>
<tr>
<td>Gravure</td>
<td>10%</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Offset&amp;Oth</td>
<td>&lt;1%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Digital</td>
<td>NA</td>
<td>NA</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Unprint</td>
<td>27%</td>
<td>21%</td>
<td>23%</td>
</tr>
</tbody>
</table>
# EB CI-Flexo Technology Development

<table>
<thead>
<tr>
<th>Patent or Application Number</th>
<th>Filing Date</th>
<th>Assignment</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 5,690,028</td>
<td>June, 1996</td>
<td>Cavanaugh Corporation USA</td>
<td>Method of achieving wet trapping by heating the subsequent ink to reduce viscosity</td>
</tr>
<tr>
<td>US 6,772,683</td>
<td>Feb, 2002</td>
<td>Sun Chemical USA</td>
<td>Method of achieving wet trapping by evaporating non-reactive diluent and increasing viscosity of the applied layer</td>
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<tr>
<td>US 8,729,147</td>
<td>May 20, 2014</td>
<td>Technosolutions Brazil</td>
<td>Method of achieving wet trapping by evaporating a non-reactive diluent and adjustment of Hansens solubility parameters to form an organo gel in the applied layer</td>
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<tr>
<td>WO/2011/091364</td>
<td>Jan, 2011</td>
<td>Sun Chemical USA</td>
<td>Method of achieving wet trapping by controlling the storage modulus of the ink. Each applied ink layer will have decreased modulus</td>
</tr>
</tbody>
</table>
Hansen Solubility Parameter

“Like Dissolves Like”

- d Energy From Dispersion Forces
- p Energy From Polar Forces
- h Energy From Hydrogen Bonds
## Typical Formulation

<table>
<thead>
<tr>
<th>Type</th>
<th>Type</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monomers</td>
<td>TMPTA, TMPEOTA, HDDA, TRPGDA etc.</td>
<td>40-50</td>
</tr>
<tr>
<td>Oligomers</td>
<td>Polyester acrylates, Epoxy acrylates, etc</td>
<td>8-12</td>
</tr>
<tr>
<td>Pigments</td>
<td>Yellow, Cyan, Magenta, Black, other line inks</td>
<td>20-25</td>
</tr>
<tr>
<td>Additives &amp; Dispersants</td>
<td>Tego Brands, Disperbyk</td>
<td>2-10</td>
</tr>
<tr>
<td>Gellant Polymer</td>
<td>Poly Vinyl Butyral</td>
<td>2-5</td>
</tr>
<tr>
<td>Solvent</td>
<td>Glycol Ethers like Dowanol PM</td>
<td>10-15</td>
</tr>
</tbody>
</table>
How does it work?

• Gel-based multicolor flexo printing system allows single-stage EB curing
• Wet-in-wet? No!

• Gel-on-gel!
EB CI Flexo Process

Small Thermal Dryer

EB Ink eliminates interstation dryers. Needs small overhead dryer
Objectives Gelflex-EB

- Significant decrease of VOC emission
- Up to 60% less ink consumption
- Higher print quality
- Highest physical properties (gloss, resistance)
- Faster time to market
- Cost reduction (improved ROI)
- Safe for operators and Use
Breaking the gel

• Heating (till 35⁰C-95⁰F)
• Stirring
• Adding a small amount of solvent (needed for adjusting the solubility parameters).
• Printing with high viscosity (300-600 cP)
Our researches

• kind of flexo plates and substrates
• volumes/liniatures of aniloxes
• temperatures and viscosities of the ink
• lay down and trapping properties of the ink
• liniature of screen images and tonal curve
• consistency
What we have learned

• Up to 60% less ink consumption
• Low or no viscosity adjustments
• 5-10 times less emission of solvents
• All kinds of flexo plates suitable Kodak NX with digicap preferred
• Most kinds of substrates suitable EB conditions may need optimization
• Up to 70 l/cm (180 l/inch) is possible
60% less ink consumption

- 2.5-3.0 cm³/m²
- 1.6-1.9 BCM

460-500 l/cm anilox
1170-1270 l/inch anilox

Standard SID:
- Yellow: 1.00 – 1.10 D
- Magenta: 1.25 – 1.35 D
- Cyan: 1.30 – 1.40 D
- Black: 1.50 – 1.70 D
Last down white

- 5.0-6.0 cm³/m²  300-400 l/cm anilox
- 3.0-4.0 BCM  750-1000 l/inch anilox

- Gelflex-EB last down white contains no solvent at all!
5-10 X less VOC emission

• a 24/7 flexo machine produces appr. 50 million m2/y, is using appr. 200 tonne solvent p/y*

• Under same conditions: Gelflex-EB has an usage of appr. 20-25 tonne p/y*

• *when printing transparent film with last down white on a 8 color CI-Flexo press
QTECS

- Quality
- Time
- Environment
- Costs
- Safety
QTECS: Quality

• 60 l/cm (152 l/inch) as a standard
• Tonal curve like offset
• High dot quality
• Smooth vignettes
• Perfect lay down
• Good trapping properties
• High gloss
Quality: a closer look (1)

- Tonal curve like offset
- Smallest dot i.e. 4% is in print not bigger than 8%
- Smooth vignettes
- Increased details by applying i.e. 170 l/inch
Quality: a closer look (2)

- Perfect lay-down
- Excellent trapping properties (85-100%)
Quality: a closer look (2)

- Perfect lay-down with high gloss
- Excellent trapping properties (85-100%)

Solvent based  
Gelflex-EB
QTECS: Time

- Less or no washing times during job changes
- Faster make ready of new jobs
- Quick color matching
- Faster time-to-market
QTECS: Environment

- 5-10 less emission of solvents
- No or reduced thermal oxidizers
- Less power consumption of the press
- Less storage and transport of inks and solvents
- Green sustainable platform
<table>
<thead>
<tr>
<th>Calculation of emission</th>
<th>(example)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web width flexo machine</td>
<td>1,20 meter</td>
</tr>
<tr>
<td>Printing speed</td>
<td>200 meter/minute</td>
</tr>
<tr>
<td>Ink coverage</td>
<td>130% printed design all colors together</td>
</tr>
<tr>
<td>Volume anilox</td>
<td>2,5 cm³/m²</td>
</tr>
<tr>
<td>Ink release/m²</td>
<td>1,6 gr/m²</td>
</tr>
<tr>
<td>Total transferred ink per/m²</td>
<td>2,1 gr/m² total printed surface</td>
</tr>
<tr>
<td>Amount of solvent in the ink</td>
<td>12% methoxy-propanol PM</td>
</tr>
<tr>
<td>Amount of solvent to evaporate/m²</td>
<td>0,25 gr/m²</td>
</tr>
<tr>
<td>Amount solvent to evaporate per second</td>
<td>1.0 grams</td>
</tr>
<tr>
<td>Emission freight</td>
<td>3.6 kg/hour</td>
</tr>
</tbody>
</table>
QTECS: Costs

- 50% less energy consumption
- 5-10% less down-time costs
- 5-10% less waste of substrates
- 60% less transport costs of inks and solvents
- 60% less costs of storage inks and solvents
- Less or no costs for oxidizers
# Calculation model reduced costs of inks

<table>
<thead>
<tr>
<th></th>
<th>Solvent flexo ink</th>
<th>Gelflex-EB ink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume anilox CMYK</td>
<td>5,0 cm³/m²</td>
<td>2,5 cm³/m²</td>
</tr>
<tr>
<td>Transferred wet ink on substrate</td>
<td>3,3 gr/m²</td>
<td>1,6 gr/m²</td>
</tr>
<tr>
<td>Volume anilox White</td>
<td>10,0 cm³/m²</td>
<td>5,0 cm³/m²</td>
</tr>
<tr>
<td>Transferred wet white ink on substrate</td>
<td>6,5 gr/m²</td>
<td>3,25 gr/m²</td>
</tr>
<tr>
<td>Total kg use of CMYK ink per year</td>
<td>105,625 kg</td>
<td>52,813 kg</td>
</tr>
<tr>
<td>Total kg use of white ink per year</td>
<td>146,250 kg</td>
<td>73,125 kg</td>
</tr>
<tr>
<td>Average price of ink (CMYK) per kg</td>
<td>€ 6,50*</td>
<td>€ 12,00*</td>
</tr>
<tr>
<td>Average price of ink (white) per kg</td>
<td>€ 5,00*</td>
<td>€ 8,00*</td>
</tr>
<tr>
<td>CMYK ink costs to this volume</td>
<td>€ 686,562</td>
<td>€ 633,750</td>
</tr>
<tr>
<td>White ink costs to this volume</td>
<td>€ 731,250</td>
<td>€ 585,000</td>
</tr>
<tr>
<td>Total inks costs (CMYK+White)</td>
<td>€ 1,417,812</td>
<td>€ 1,218,750</td>
</tr>
<tr>
<td>Saving per year:</td>
<td></td>
<td>€ 199,062</td>
</tr>
</tbody>
</table>

*Price Indication for Europe

**Production of m²/year per machine**
25,000,000 m²

**Average printed area color (in %)**
130 %

**Average printed area white (in %)**
90 %
### Calculation model reduced costs of solvents at a production of 25 million m²/year

<table>
<thead>
<tr>
<th></th>
<th>Solvent flexo ink</th>
<th>Gelflex-EB ink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of solvent in CMYK ink</td>
<td>50 %</td>
<td>12 %</td>
</tr>
<tr>
<td>Amount of solvent in white ink</td>
<td>50 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

**Indication of the use of solvent per year:**

<table>
<thead>
<tr>
<th></th>
<th>Amount of solvent in CMYK ink</th>
<th>Amount of solvent in white ink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of solvent in CMYK ink</td>
<td>52.813 kg</td>
<td>6.338 kg</td>
</tr>
<tr>
<td>Amount of solvent in white ink</td>
<td>73.125 kg</td>
<td>0 kg</td>
</tr>
<tr>
<td>Amount of solvent to adjust viscosity</td>
<td>12.594 kg</td>
<td>634 kg</td>
</tr>
</tbody>
</table>

**Total amount solvent per year:**

- **Solvent flexo ink**: 138.531 kg
- **Gelflex-EB ink**: 6.971 kg

**Average price of ethanol (mix) per kg**: € 1,00

**Average price of Dowanol PM per kg**: € 1,90

**Total costs of solvent per year**:

- **Solvent flexo ink**: € 138,531
- **Gelflex-EB ink**: € 13,254

**Reduced costs**:

- **Total costs of solvent per year**: € 125,285
- **Total saving per year ink and solvent**: € 324,348

**Additional costs for EB curing**: Cost of an EB equipment, Costs for the use of Nitrogen

**Extra reduced costs**:

- Less or No investment and gas/power for thermal oxidizer
- Less thermal/blowing energy cost
QTECS: Safe

- Food Law Compliant
  - FDA, EEC Directives, Nestle List
- Lowest odor, taint and extractable levels
- Safe for operators to handle
- No photoinitiators
- No migration of monomers at all.
Extensive opportunities

- Avoid lamination in some cases
- In-line lamination is an opportunity
- EB coatings inline with Gelflex-EB ink with EB curable functional coatings.
- Thermal and Scratch resistance
- Excellent bond strengths using conventional adhesives
General machine conditions

- Low Voltage EB Operating at 110-125 and 30-35 kGy of dose at < 200ppm oxygen
- ISD with just cool air. Overhead dryer at 1/3 capacity at 300-350 mpm.
- Closed and robust doctor chambers with blades used for resin based inks.
- Pumping system capable to operate in 300-600 cps viscosity ranges.
- Thermoregulation to control ink temperatures.
- Stirring devices in ink containers.
Conclusions

- Higher productivity gains
- Faster time-to-market
- Higher print quality in comparison to solvent platforms
- Better white properties
- Better color matching
- Improved ROI
- Decreasing VOC emissions up to 90%
- The best contribution for a sustainable green platform
Future Developments

• Reduce solvent content eventually to 100% solids
• Faster Evaporating Solvent Like Ethanol
• More Special Colors
• First down white with wet trapping capability
• Faster Speeds up to 600 mpm
Thank You For Your Attention
MANUFACTURING THE FUTURE WITH 3D PRINTING 2.0
3D Systems (NYSE:DDD) is a leading provider of 3D printing centric design-to-manufacturing solutions

Leadership Through Innovation and Technology

• 3DS invented 3D printing with its Stereolithography (SLA) printer and was the first to commercialize it in 1989.
• 3DS invented Selective Laser Sintering (SLS) printing and was the first to commercialize it in 1992.
• 3DS invented the Color-Jet-Printing (CJP) class of 3D printers and was the first to commercialize 3D powder-based systems in 1994.
• 3DS invented Multi-Jet-Printing (MJP) printers and was the first to commercialize it in 1996.
3D PRINTING 2.0

THE WAY WE DESIGN | WHAT WE CREATE | HOW WE MANUFACTURE

DISRUPTIVE | TRANSFORMATIVE | IMPACTFUL

KONICA MINOLTA
Iterate on Concepts Early to Lower Design Costs

Concept Models

Cost per Change

Desired Change Count

Concept Development | Detailed Design | Build Test | Manufacture / Ship
Concept Models

- Compare alternative design concepts side-by-side
- Improve early design decisions that impact every design and engineering activity that follows
- Reduce or eliminate costly design changes later
Functional Prototypes

- Test functionality
- Test new inventions
- Identify functional design revisions early
- Test form, fit and assembly
- Hands-on feedback
- Prove design theories through practical application
Functional Prototypes

• Accuracy is important
• Feature detail resolution
• Material characteristics matched to application
Rapid Tooling

• Accelerate manufacturing start-up
• Protect increased investment
  – Rapid tooling verification
  – First run jigs & fixtures
• Confidence to make supply-chain commitments
Production Parts

- **Complexity is free** with additive manufacturing
- Unleash unlimited geometries to reach new levels of functionality
- Improve quality and performance
Production Parts

• Reduce manufacturing steps reducing time and cost
• Reduce manufacturing waste
• Produce metal parts
  – Direct metal printing
  – Casting pattern printing
3D Printers for Every Need

LIVING ROOM | CLASSROOM | GARAGE | DESKTOP | LAB | FACTORY

Under $1,000

Up to $1,000,000
Professional 3D Printers

3D Systems ProJet® series
The Widest Range of 3D Printers for the Office, Lab or Workshop
ProJet® x60 series

Print beautiful full color models quickly and affordably
ProJet x60 Series

Full Color Printing

Highest Throughput

Fastest Print Speed

Easy-to-Use

Affordable
Communicate with Color

COLOR
Communicate with Color

A picture may be worth a thousand words, but how much money is a full color 3D model worth?
Fastest Print Speed

Get concept models in hours - not days.

- Up to 10x faster than competitive technologies
- Print 1 – 4 layers per minute
- Fabricates and colors in a single step
- Pro Draft Mode produces parts up to 35% faster
Test More Ideas Faster

Built in 2 hours using ProJet x60
Quicker Iterations

**HIGHEST THROUGHPUT. FASTER PRINTING.**

- **ProJet® 660Pro Draft Mode**: 9.75 Hours
- **ProJet® 660Pro Vibrant**: 16.5 Hours
- **ObJet® 30Pro**: 50.2 Hours

**Draft Mode** prints 35% faster than the already fast **ProJet® color modes**.
Safe and Office-Friendly

For Office, School, or Production Environments

• Quiet, Safe and Odor-Free
• Zero-hazardous waste **AND** zero-liquid waste
• All-in-one options available for built-in printing, core recycling, and finishing
• Eco-friendly and safe finishing options available
Print more Parts and Iterations

AFFORDABLE
Test More Ideas to Improve Product Quality

**PART COST**

- $2.50-$10/cubic inch
- Part costs adjusts to your needs
- Fraction of the cost of other professional 3D printers.

<table>
<thead>
<tr>
<th></th>
<th>Draft</th>
<th>Monochrome</th>
<th>Basic Color</th>
<th>Functional</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$2.50-$6/cu in</td>
<td>~$3-7/cu in</td>
<td>~$4-8/cu in</td>
<td>~$5-8/cu in</td>
<td>$5-10/cu in</td>
</tr>
</tbody>
</table>
ProJet® 3510 series plastic printers

Print functional plastic parts in high definition with ease
Print Beautiful Parts...

- No stair-stepping on curved sidewalls
- Exceptionally Smooth Surfaces
... with Micro-fine Detail Resolution

- Features down to 0.01 inches (0.25 mm)
- No geometry limitations
Consistently Sharp Edges and Corners

- Clean, straight edge definition
- Exceptional small hole definition
High Performance Materials For More Applications

- **VisiJet® M3 X**
  - White, injection molded plastic look and feel
  - ABS-like performance

- **VisiJet® M3 Black**
  - Black, injection molded plastic look and feel
  - High strength and flexibility plastic

- **VisiJet® M3 Crystal**
  - Translucent
  - Tough polypro/ABS-like performance
  - Class VI Certified for medical applications

- **VisiJet® M3 Proplast**
  - Translucent White
  - Durable plastic performance

- **VisiJet® M3 Navy**
  - Blue
  - Durable plastic performance

- **VisiJet® M3 Techplast**
  - Gray
  - Durable plastic performance

- **VisiJet® M3 Procast**
  - Dark blue for improved surface inspection
  - Castable plastic
Fast & Easy Job Submission

• Intuitive and automated software
  – Automatic part placement and build optimization tools
  – Intuitive extensive part editing tools
  – Automatic support generation
  – Print jobs held in easy-to-manage job queue

• Quick-start print job, as easy as 1-2-3...

1. Remove build platform with completed parts attached
2. Insert clean build platform
3. Press start button on printer
   Printer begins next print job in queue
Optimized Capacity

- Stack & nest parts to use entire build volume
  - Take advantage of longer free periods
  - Gain additional thru-put without sacrificing build time
  - Maximize utilization of the available build volume

Why print in only 2-dimensions when it’s a 3D printer?
Automated Process – from File to Ready-to-Use Part

• Fast and easy support removal
  – Wax supports simply melt away with no support scars
  – Hands-free process saves time and labor
  – No geometry limitations
  – Fine delicate features preserved
  – Safe finishing process
Competition?

ProJet™ 3500

Brand X-jet

0.4mm
ProJet® 4500 full color plastic printer

Combine the power of vibrant full color with durable plastic parts.

New for 2014!
High-Quality Full-Color Printing


**Enhance** communication and design

**Improve** marketing

**Impress** customers
Applications

Customized end-use products
Applications

Durable concept models
Key features

Almost 1,000,000 brilliant colors

Amazing small feature detail

Relative size to model
ProJet 4500 Summary

- Prints both flexible and strong high-res CMY color plastics fast
- Ready-to-use parts and assemblies directly from the printer
- Only continuous-tone full-color plastic 3D printer available today
- Green safe print process reduces part cost by as much as 25x
ProJet® 5500X composite plastic printer

Big, engineered composite material parts, with the best quality, accuracy and toughness.

New for 2014!
ProJet 5500X

Big, engineered composite material parts, with the best quality, accuracy and toughness.
Multiple engineered composite materials

- Rigid, ABS-like white plastic
- Rubber-like black tires
- Moderately flexible front wing
Multi-material benefits
Accurate parts
New VisiJet® Composite Materials

- VisiJet® CR-WT Rigid White ABS-like Material
  - Durable
  - Rigid
  - High temperature resistance
New VisiJet® Composite Materials

• VisiJet® CF-BK Black Rubber-like Material
  – Rubber-like look and feel
  – Extreme flexibility
  – Absorbs shocks and impacts to enhance durability
New VisiJet® Composite Materials

- VisiJet® CR-CL Clear Polycarbonate-like Material
  - See-thru clarity when polished
  - Simulates polycarbonate or glass
  - Functional durability resists scratching
ProJet 5500X Summary

• High-performance simultaneous engineered composite printing
• Multi-material linking up to 2X faster than comparable printers
• Highest quality, most accurate and toughest multi-material parts
• Larger or more parts with 60% greater capacity than others
• Industrial grade print head equipped with a 5-year warranty
Production 3D Printers

3D Systems ProX™ series
High-Throughput 3D Printers for the Production Floor
ProJet® SLA printers

Transform how you manufacture with SLA, the gold standard in 3D printing
Why Choose SLA 3D Printers?

- Brodest Range of Applications
- Best Surface Quality
- Cost-efficient Scale-Up
- Unmatched Accuracy and Precision
- Lowest Unit Cost Production
- Produce Large, Whole Parts
Unmatched Accuracy and Precision

0.25 mm
# 3D Systems SLA Printers

<table>
<thead>
<tr>
<th></th>
<th>ProJet 6000</th>
<th>ProJet 7000</th>
<th>iPro 8000</th>
<th>ProX 950</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum Build volume</strong></td>
<td>10 x 10 x 10 in (250 x 250 x 250 mm)</td>
<td>15 x 15 x 10 in (380 x 380 x 250 mm)</td>
<td>26 x 30 x 22 in (650 x 750 x 550 mm)</td>
<td>59 x 30 x 22 in (1500 x 750 x 550 mm)</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>0.001-0.002 inch (0.025-0.05 mm) per inch of part dimension</td>
<td>0.001-0.002 inch (0.025-0.05 mm) per inch of part dimension</td>
<td>0.001-0.002 inch (0.025-0.05 mm) per inch of part dimension</td>
<td>0.001-0.002 inch (0.025-0.05 mm) per inch of part dimension</td>
</tr>
<tr>
<td><strong>Maximum Resolution</strong></td>
<td>0.075 mm, 0.050 mm layers</td>
<td>0.075 mm, 0.050 mm layers</td>
<td>0.075 mm, 0.050 mm layers</td>
<td>0.075 mm, 0.050 mm layers</td>
</tr>
</tbody>
</table>
ProX™ 500

Economically manufacture injection molding-grade plastic parts for demanding end-use applications

New for 2014!
SLS – Manufacture Flight Hardware On Demand

Representative Parts
ProX 500 Summary

Tough and durable parts with true 3D mechanical properties

Fast build speed and high throughput with automated 3D part nesting

Best-in-class part surface finish, resolution and definition

"Green" process with little material waste

Reduced part manufacturing cost enables volume manufacturing applications
ProX 100, 200, 300 Direct Metal Production Printers

High density, metal printed parts from a large choice of materials with the highest detail and precision
Print fully functional metal parts in hours
Large choice in standard metal alloys and ceramics

- More than 15 materials tested and available
- Steel, CrCo, Inconel, Al and Ti alloys
- Al2O3 ceramic

Inconel 718  Al2O3  AlSi12  Pure Cu
Unmatched design and manufacturing freedom
Highest accuracy, best detail resolution

150 micron wall thickness
ProX 100, 200 and 300 Direct Metal Printers - Summary

Print fully functional metal parts in hours

• Reduce time and cost of manufacturing complex metal parts
• Gain flexibility – in cycle time + part complexity
• Benefit from large choice of materials
• Finest detail resolution and highest precision in metal printing
• High repeatability guarantees true manufacturing applications
CubePro

Professional 3D Printer for large, multi-color, multi-material prints

For schools, office & business

MSRP US $2,799 to 4,399
CubePro Three Models

CubePro
Single Jet

CubePro Duo
Dual Print Jets

CubePro Trio
Three Print Jets
Print Big - Make Precise

**Largest Print Volume** in its class
275mm x 265mm x 240mm
10.8 in. x 10.45 in. x 9.5 in.

**Controlled Print Chamber**
High quality ABS printing
Large accurate reliable prints
## Print Volume

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Color</td>
<td>275mm 10.75”</td>
<td>265mm 10.45”</td>
<td>240mm 9.5”</td>
</tr>
<tr>
<td>Duo</td>
<td>230mm 9.1”</td>
<td>265mm 10.5”</td>
<td>240mm 9.5”</td>
</tr>
<tr>
<td>Trio</td>
<td>185mm 7.3”</td>
<td>265mm 10.5”</td>
<td>240mm 9.5”</td>
</tr>
</tbody>
</table>
New Durable Engineering Materials

ABS, PLA, Nylon print materials

Nylon & ABS – Durable, Functional & Prototyping Materials

PLA - High fidelity and feature detail

Mix & match up to three colors or materials in same print
Superior Accuracy & Thinnest Layers

• High accuracy, feature detail & resolution
• Thinnest layers at 3 mil (70 µm) for smooth surfaces
• Standard prints at 8 mil (200 µm) & 12 mil (300 µm)
• 2X accuracy compared to sub-3K printers in the market
Wide Array of Color Choices

25 vibrant print colors in ABS & PLA

Glow-in-the-dark colors for special creations
Cube – 3rd Generation!

Ultra portable, plug & play 3D Printer with advanced printing features under $1,000

For homes, schools, offices & business
Only printer in its class with dual color & dual material printing

6” x 6” x 6” (152 mm) print vol.

ABS & PLA in same prints
Hi-res 70 microns (3 mil) layer thickness
Smart Technology

**PrintJet**
Integrated with cartridge
Renewed with each cartridge
Enables instant loading of cartridge
Eliminates clogs

**Print Plate**
Auto-levelling
Zero Calibration
Ensures reliable prints

**Support Generation**
Fully Automated
Award Winning Technology

- Awards for: ‘Reliability,’ ‘Easiest to Use,’ ‘Best Technology’
Target Market

- **Finders**: Gadget centric technology geeks
- **Families**: Providing children with an academic edge
- **Makers**: Hobbyists, inventors and tinkerers interested in consistent modeling
- **Designers**: Artists, animators, architects, engineers and innovators
- **Businesses**: Seeking competitive edge through affordable rapid prototyping and innovation
Thank You

For more information, visit 3dsystems.com
Effective Workflow for Substrate-Correction Concept: Proof to Press and Press to Characterization Dataset

Brenda Pang & Lewis Lam
Advanced Printing Technology Centre (APTEC)
Hong Kong
Objectives

• Introduce a workflow to apply substrate-correction concept, based on ISO/PAS 15339
• To test the feasibility of the workflow, including:
  • Dataset matching
  • Proof to press matching
Key concepts in ISO/PAS 15339

- **Color characterization data**: Tabulation of data that represents the relationship between device code values (e.g. CMYK) and the color (CIELAB) produced on the printed sheet by those values in a specific printing process.

- **Characterized reference printing condition (CRPC)**: identified printing condition and its color characterization data that is used as the aim for a particular printing job.
Key concepts in ISO/PAS 15339

Characterized reference printing condition (CRPC)

Table 4 — Characterized reference printing conditions, typical uses

<table>
<thead>
<tr>
<th>CRPC</th>
<th>Name</th>
<th>Typical use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Universal ColdsetNews</td>
<td>Small gamut printing (newsprint)</td>
</tr>
<tr>
<td>2</td>
<td>Universal HeatsetNews</td>
<td>Moderate gamut printing on improved newsprint type paper</td>
</tr>
<tr>
<td>3</td>
<td>Universal PremUncoated</td>
<td>Utility printing on a matt uncoated type paper</td>
</tr>
<tr>
<td>4</td>
<td>Universal SuperCal</td>
<td>General printing on super-calendared paper</td>
</tr>
<tr>
<td>5</td>
<td>Universal PubCoated</td>
<td>Typical publication printing</td>
</tr>
<tr>
<td>6</td>
<td>Universal PremCoated</td>
<td>Large gamut (typically commercial) printing</td>
</tr>
<tr>
<td>7</td>
<td>Universal Extra Large</td>
<td>Extra large gamut printing processes</td>
</tr>
</tbody>
</table>
Key concepts in ISO/PAS 15339

- **Substrate-correction (SCCA):** where the printing substrate to be used has a color that differs from the reference printing condition by more than 2 but less than 5 CIEDE2000, the data may be adjusted before proofing and printing.

\[
X_c = X_d \times (1 + C) - X_{\text{min}} \times C
\]

with

\[
C = \frac{X_{\text{sn}} - X_{\text{sd}}}{X_{\text{sd}} - X_{\text{min}}}
\]
Ideal production workflow - 1

• Designer uses ISO-standard paper and standard profile for print and proof
• Printer prints based on the standard profile
Ideal production workflow - 2

- Designer knows the printing paper color and use profile generated by printers from the exact paper used in printing.
- Printer prints to substrate-corrected dataset.
But in real world ...

- Design may take several months, printers may not know which paper will be used
  - Printers cannot provide the press ICC profile
- Designers - use standard profile in graphics & digital proof
- Printers - calibration depends on actual paper to be used in printing

Color cannot match (proof to press)
Alternative Workflow

- Designer creates and proofs to a CRPC (paper undecided)
- Printer can (a) adjust the job data and print to SCCA’s CRPC or (b) not adjust the job data and print to CRPC.
Alternative Workflow

Design and Digital File preparation

- Design
  - ICC Color Separation
    - GRACoL
    - FOGRA
    - 15339 CRPC

- Digital Proof
  - ICC Digital Proof
    - GRACoL
    - FOGRA
    - 15339 CRPC

Print Production (File Color Conversion)

- ICC Color Separation
  - GRACoL
  - FOGRA
  - 15339 CRPC

- Digital Proof
  - ICC Digital Proof
    - GRACoL
    - FOGRA
    - 15339 CRPC

- Device-Link

- Press Calibration
  - ISO TS10128

- Print Production
  - SCCA
  - New press ICC Profile (use Substrate Correction)

- Printing
  - ICC Color Separation
  - GRACoL
  - FOGRA
  - 15339 CRPC

- CTP Output Curve

Verification

- Data verification
  - GRACoL
  - FOGRA
  - CRPC
Key points

• Designers - select the appropriate standard CRPC profile or apply SCCA
• Printers - control the color conversion
  - More knowledgeable
  - Use device-link
    • Keep color purity
  - Use substrate-corrected concept
    • Consideration of exact paper to be used
Software and Measurement Device

• Measurement condition:
  - ISO 13655 M1
• Measurement Devices:
  - X-Rite i1 Pro2
  - X-Rite i1 iO2
• White backing measurement
• Software:
  - CGS ORIS PressMatcher
  - X-Rite i1 Profiler
Test form
Methodology

1. Press runs
   - Internally test in school
   - Test conducted in 3 printing companies
     • Book printer, Commercial printer, Packaging printer

2. Substrate
   - Coated paper
   - Uncoated paper
   - Clay Coated News Back paper (CCNB)
3. Press calibration
   - Conduct calibration print
   - Measure test target and calculate RIP curve
   - Conduct 2\textsuperscript{nd} print run by using new RIP curve
   - Measure IT8.7/4 for creating characterization data and ICC profile
4. **File color conversion**
   - Source profile: 15339 CRPC print condition
   - Destination profile: Press profile (with or without applied SCCA)

5. **Print converted file**
   - Only control solid aims

6. **Printing aims**
   - 15339 CRPC datasets: CRPC3 & 6
   - Based on CGATS TR016 deviation printing tolerance
# Findings 1 – Coated paper

<table>
<thead>
<tr>
<th></th>
<th>Internal Test</th>
<th>Commercial Printer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured paper white</td>
<td>L* 92.17, a* 1.73, b* -7.0</td>
<td>L* 92.08, a* 1.67, b* -6.5</td>
</tr>
<tr>
<td>Reference paper white (CRPC6)</td>
<td>L* 95, a* 1, b* -4.0</td>
<td></td>
</tr>
<tr>
<td>Delta E2000</td>
<td>3.08</td>
<td>2.71</td>
</tr>
</tbody>
</table>
# Summary – Coated paper

Press to CPRC6 (with or without applied SCCA)

<table>
<thead>
<tr>
<th>Tolerance (DeltaE2000)</th>
<th>Internal Test</th>
<th>Commercial Printer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Meet CRPC 6 (no SCCA)</td>
<td>Meet CRPC 6 (applied SCCA)</td>
</tr>
<tr>
<td>CMY</td>
<td>C</td>
<td>1.59</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1.99</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>1.97</td>
</tr>
<tr>
<td>K</td>
<td>6</td>
<td>1.79</td>
</tr>
<tr>
<td>50% CMYK</td>
<td>2.5</td>
<td>1.73</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>2.80</td>
</tr>
<tr>
<td>IT8.7/4 (ave)</td>
<td>--</td>
<td>2.36</td>
</tr>
<tr>
<td>IT8.7/4 (95th)</td>
<td>5</td>
<td>3.88</td>
</tr>
<tr>
<td>Gray</td>
<td>5</td>
<td>1.80</td>
</tr>
</tbody>
</table>
## Findings 2 – Woodfree Paper

<table>
<thead>
<tr>
<th></th>
<th>Book Printer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured paper white</td>
<td>L* 91.43, a* 2.54, b* -10.95</td>
</tr>
<tr>
<td>Reference paper white</td>
<td>L* 96, a* 1, b* -4.0</td>
</tr>
<tr>
<td>(CRPC3)</td>
<td></td>
</tr>
<tr>
<td>Delta E2000</td>
<td>5.82</td>
</tr>
</tbody>
</table>
## Summary – Woodfree paper

Press to CPRC3 (with or without applied SCCA)

<table>
<thead>
<tr>
<th></th>
<th>Tolerance (DeltaE2000)</th>
<th>Book Printer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Meet CRPC 3 (no SCCA)</td>
</tr>
<tr>
<td>CMY</td>
<td>4</td>
<td>C 1.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M 2.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y 2.12</td>
</tr>
<tr>
<td>K</td>
<td>6</td>
<td>1.34</td>
</tr>
<tr>
<td>50% CMYK</td>
<td>2.5</td>
<td>C 1.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M 2.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y 2.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K 3.77</td>
</tr>
<tr>
<td>IT8.7/4 (ave)</td>
<td>--</td>
<td>1.99</td>
</tr>
<tr>
<td>IT8.7/4 (95th)</td>
<td>5</td>
<td>3.67</td>
</tr>
<tr>
<td>Gray</td>
<td>5</td>
<td>1.90</td>
</tr>
</tbody>
</table>
Conclusion – for Coated & Woodfree paper

Based on these findings, the workflow is workable for coated paper & woodfree paper:

- Satisfied results on solids, gray and IT8/7.4 for coated paper and woodfree paper:
  - Most are within tolerance
- Closed results with or without applied SCCA
# Findings 3 – CCNB Paper

<table>
<thead>
<tr>
<th></th>
<th>Internal Test</th>
<th></th>
<th>Packaging Printer</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper 1</td>
<td>L* 91.75 a* 1.51 b* -3.47</td>
<td>2.17</td>
<td>Paper 3</td>
<td>L* 92.10 a* 0.47 b* -2.23</td>
</tr>
<tr>
<td>Paper 2</td>
<td>L* 91.77 a* 1.53 b* -3.56</td>
<td>2.15</td>
<td>Paper 4</td>
<td>L* 89.06 a* 1.62 b* -4.07</td>
</tr>
</tbody>
</table>

Reference paper white (CRPC6) L* 95, a* 1, b* -4.0
# Summary – CCNB Paper

**Press to CPRC6 (with or without applied SCCA)**

<table>
<thead>
<tr>
<th></th>
<th>Internal Test</th>
<th>Paper 1</th>
<th>Paper 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tolerance</td>
<td>Meet CRPC 6 (no SCCA)</td>
<td>Meet CRPC 6 (applied SCCA)</td>
</tr>
<tr>
<td></td>
<td>(DeltaE2000)</td>
<td>C</td>
<td>M</td>
</tr>
<tr>
<td>CMY</td>
<td>4</td>
<td>1.90</td>
<td>2.31</td>
</tr>
<tr>
<td>K</td>
<td>6</td>
<td>3.04</td>
<td>3.15</td>
</tr>
<tr>
<td>50% CMYK</td>
<td>2.5</td>
<td>1.30</td>
<td>3.99</td>
</tr>
<tr>
<td>IT8.7/4 (ave)</td>
<td>--</td>
<td>4.64</td>
<td>2.45</td>
</tr>
<tr>
<td>IT8.7/4 (95th)</td>
<td>5</td>
<td>6.74</td>
<td>4.17</td>
</tr>
<tr>
<td>Gray</td>
<td>5</td>
<td>5.74</td>
<td>2.69</td>
</tr>
</tbody>
</table>
### Summary – CCNB Paper

Press to CPRC6 (with or without applied SCCA)

<table>
<thead>
<tr>
<th></th>
<th>Paper 3</th>
<th>Paper 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tolerance</strong></td>
<td><strong>Meet CRPC 6 (no SCCA)</strong></td>
<td><strong>Meet CRPC 6 (applied SCCA)</strong></td>
</tr>
<tr>
<td><strong>CMY</strong></td>
<td>C 1.47 M 1.21 Y 2.56</td>
<td>C 2.94 M 2.68 Y 2.61</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>4.28</td>
<td>4.60</td>
</tr>
<tr>
<td><strong>50% CMYK</strong></td>
<td>C 3.71 M 3.60 Y 2.69</td>
<td>C 2.46 M 1.33 Y 1.60</td>
</tr>
<tr>
<td><strong>IT8.7/4 (ave)</strong></td>
<td>--</td>
<td>2.91</td>
</tr>
<tr>
<td><strong>IT8.7/4 (95th)</strong></td>
<td>4.70</td>
<td>2.97</td>
</tr>
<tr>
<td><strong>Gray</strong></td>
<td>4.84</td>
<td>1.92</td>
</tr>
</tbody>
</table>
Digital proof

- Measure IT8.7/4 for creating characterization data and ICC profile
- Rendering intent: absolute
- Software used: CGS ColorTuner Web
# Summary of CCNB paper – Proof (CRPC 6) to Press (with or without SCCA)

<table>
<thead>
<tr>
<th></th>
<th>Meet Press on CPRC6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tolerance (DeltaE2000)</td>
</tr>
<tr>
<td>C M Y</td>
<td>4</td>
</tr>
<tr>
<td>K</td>
<td>6</td>
</tr>
<tr>
<td>50%C 50%M 50%Y 50%K</td>
<td>2.5</td>
</tr>
<tr>
<td>IT8.7/4 (ave)</td>
<td>--</td>
</tr>
<tr>
<td>IT8.7/4 (95th)</td>
<td>5</td>
</tr>
<tr>
<td>Gray</td>
<td>5</td>
</tr>
</tbody>
</table>
Conclusion – for CCNB paper

• Press to CRPC 6- if without applied SCCA, the results are not fully satisfied:
  • Especially on the 50% CMYK
  • Due to the CCNB substrate base which is not the same as CRPC 6 substrate
  • Better to have another CRPC for CCNB paper
• Proof to press - if without applied SCCA in proof, the results are not fully satisfied
• Based on these findings, applied SCCA for CCNB from proof to press has better result
• More tests will be conducted in future
Acknowledgements

- C & C Joint Printing Co., (Guangdong) Ltd.
- Cheong Hing Printing Co., Ltd.
- Green Production (Overseas) Group
- Pro-Act Training & Development Centre (Printing)
- CGS
Thank You!

www.aptec.hkprinters.org
brendaok@aptec.hkprinters.org
An Investigation of Factors Influencing Color Tolerances

Lufei Yu*, Robert Chung*, Bruce Myers*

* Rochester Institute of Technology, Rochester, NY

67th Annual Technical Conference · Albuquerque, NM 2015
Introduction

- Print buyers demand quality printing.
  - *Quality printing means conformance to specifications*
- Specifications are developed by standardization bodies.
  - *Regional standards are developed by printing associations, e.g., IDEAlliance in the U.S.*
  - *International standards are developed by ISO TC130.*
History of ISO TC130

- TC130 Graphic technology started in 1971.
  - TC130 was reactivated in 1989.
  - TC130 has 14 Working Groups.
  - WG3 is responsible for developing and revising specifications in printing standards.
  - A good example is the ISO 12647 series of printing standards.
History of ISO 12647-2

- Originally published in 1996.
  - $\Delta E^*_{ab}$ metric was used to define color tolerances of CMYK solids. Density of solids are specified as informative.

<table>
<thead>
<tr>
<th></th>
<th>Black</th>
<th>Cyan</th>
<th>Magenta</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation tolerance</td>
<td>4</td>
<td>5</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Variation tolerance</td>
<td>2</td>
<td>2.5</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

*Source: ISO 12647-2: 1996*
History of ISO 12647-2

- Revised in 2004.
  - Magnitudes of tolerance for CMYK solids were changed from unequal to equal.

<table>
<thead>
<tr>
<th></th>
<th>Black</th>
<th>Cyan</th>
<th>Magenta</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation tolerance</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Variation tolerance</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: ISO 12647-2: 2004
History of ISO 12647-2

- The most recent revision was in 2013.
  - $\Delta E^*_{ab}$ remained as the normative metric. $\Delta E_{00}$ was added as an informative metric.

<table>
<thead>
<tr>
<th>Process colour</th>
<th>Deviation tolerance</th>
<th>Variation tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OK print</td>
<td>Production print</td>
</tr>
<tr>
<td></td>
<td>$\Delta Eab$</td>
<td>$\Delta E_{oo}^a$</td>
</tr>
<tr>
<td>Black</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cyan</td>
<td>5</td>
<td>3,5</td>
</tr>
<tr>
<td>Magenta</td>
<td>5</td>
<td>3,5</td>
</tr>
<tr>
<td>Yellow</td>
<td>5</td>
<td>3,5</td>
</tr>
</tbody>
</table>

*a Tolerance values for DE2000 are given for information only

Source: ISO 12647-2: 2013
There is a lack of understanding or documentation as to

- How was the magnitude of $\Delta E_{ab}^*$ tolerance initially specified in 1996?
- Why were these magnitudes revised in 2004?
- How was the magnitude of $\Delta E_{00}$ tolerance specified in relation to $\Delta E_{ab}^*$ tolerance?
Research Questions

1. What factors influence the magnitude of color tolerance?
2. Is there tolerance equivalency between the old metric ($\Delta E_{ab}^*$) and the new metric ($\Delta E_{ab}^*$)?

Note: The same $\Delta E_{00}$ tolerance may represent visual agreement for all colors. This means there is no point to determine the $\Delta E_{ab}^*$ and $\Delta E_{ab}^*$ equivalency. But, this is outside the scope of the study.
Tolerance & $\%$Pass

- Tolerance is the permissive color difference that determines whether a printed job passes or fails.
- The passing probability of a job, known as $\%$Pass, is the percentage of jobs that conform to all normative requirements in a database (Chung & Feng, 2012).

$\%$Pass = \frac{A}{A + B} \times 100
Using the boundary data to determine the new tolerance metric ($\Delta E_{00}$) from the old metric ($\Delta E_{ab}^*$)

- No unique solution -- Single $\Delta E_{ab}^*$ will map to a range of $\Delta E_{00}$ (Chung & Chen, 2011).
Real Database Approach

- Finding %Pass of two metrics using a database (Chung, Urbain & Sheng, 2014)

\[
\%Pass_{Metric_1} = \frac{A + B}{A + B + C + D} \times 100
\]

\[
\%Pass_{Metric_2} = \frac{A + D}{A + B + C + D} \times 100
\]

- If the relation between %Pass and tolerance can be determined, the equivalent tolerance is when both tolerance metrics produce the same %Pass.
Methodology, Part 1

- To determine the relation between tolerance & %Pass,
  - Select Fogra PSO database (185 jobs for CMYK solids)
  - CIELAB values of the ISO 12647-2 aims
  - OK sheet for each job

<table>
<thead>
<tr>
<th>Job</th>
<th>Sample ID</th>
<th>* Backing despription</th>
<th>LB09</th>
<th>L* Aim</th>
<th>a* Aim</th>
<th>b* Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>BB</td>
<td>0</td>
<td>46</td>
<td>72</td>
<td>-5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>M1:09</td>
<td>46</td>
<td>72</td>
<td>74</td>
<td>-3</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>M1:09:BB</td>
<td>48</td>
<td>74</td>
<td>74</td>
<td>-3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Job</th>
<th>Sample ID</th>
<th>* Backing despription</th>
<th>LB09</th>
<th>L* Aim</th>
<th>a* Aim</th>
<th>b* Aim</th>
<th>OK</th>
<th>Dev TOL</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>BB</td>
<td>0</td>
<td>46</td>
<td>72</td>
<td>-5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>M1:09</td>
<td>46</td>
<td>72</td>
<td>74</td>
<td>-3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>M1:09:BB</td>
<td>48</td>
<td>74</td>
<td>74</td>
<td>-3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Methodology, Part 1

- Compute $\Delta E_{ab}^*$ and $\Delta E_{00}$ for each job in the database.
- Compute %Pass according to ISO 12647-2 (2013) specified tolerances.
Results, Part 1

- $\Delta E_{ab}^*$ distribution of CMYK solids and %Pass at 5 $\Delta E_{ab}^*$ tolerance.

- $\Delta E_{00}$ distribution of CMYK solids and %Pass at 3.5 $\Delta E_{00}$ for CMY and 5 $\Delta E_{00}$ for K.
Methodology, Part 2

To determine the tolerance equivalency between the old metric and the new metric,

1) **Determine %Pass by varying $\Delta E_{ab}^*$ and $\Delta E_{00}$ tolerances.**

2) **For each metric, plot %Pass as a function of tolerance.**
The graphs of %Pass vs. tolerance show that:

- %Pass is proportional to tolerance magnitude.
- $\Delta E_{00}$ is a larger metric than $\Delta E^*_{ab}$.
  - There is a larger $\Delta E^*_{ab}/\Delta E_{00}$ ratio for Yellow solid than for Black solid.
By using the ray-tracing techniques, we can find the equivalent $\Delta E_{00}$ that would yield the same \%Pass as the specified $\Delta E^*_{ab}$ color by color.
Discussions

- %Pass for both metrics according to ISO 12647-2 are high.

<table>
<thead>
<tr>
<th>ISO 12647-2</th>
<th>C</th>
<th>M</th>
<th>Y</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>∆E*ab</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%Pass</td>
<td>99.5</td>
<td>97.8</td>
<td>96.2</td>
<td>95.7</td>
</tr>
<tr>
<td>∆E00</td>
<td>3.5</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>%Pass</td>
<td>96.8</td>
<td>98.4</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
**Discussions**

- Using the equal %Pass as the tolerancing criteria, it will yield unequal tolerances.

<table>
<thead>
<tr>
<th>Proposed Method</th>
<th>C</th>
<th>M</th>
<th>Y</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>ΔE</em>\text{ab}</em>*</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>%Pass</td>
<td>99.5</td>
<td>97.8</td>
<td>96.2</td>
<td>95.7</td>
</tr>
<tr>
<td><strong>ΔE\text{00}</strong></td>
<td>4.1</td>
<td>3.2</td>
<td>2.4</td>
<td>3.8</td>
</tr>
<tr>
<td>%Pass</td>
<td>98.9</td>
<td>97.8</td>
<td>95.7</td>
<td>96.2</td>
</tr>
</tbody>
</table>
Conclusions

- The proposed method, using equal %Pass in a real database, provide us a solution to find the equivalent tolerances between $\Delta E^*_{ab}$ and $\Delta E_{00}$.

- Regional printing associations and certification bodies should apply the methodology with larger databases, including non-conforming jobs, to assess how tolerances and %Pass perform in the industry.
Acknowledgments

- Mr. Jürgen Gemeinhardt, Fogra, Munich, Germany
- RIT School of Print Media, Rochester, New York

Thank you

Q&A
G7 for every print device?

Martin Habekost, Ryerson University
Vanessa Blum, Ryerson University
Overview

- Introduction
- Equipment Used
- Results
- Conclusion
Introduction

- This project was carried out to take a snapshot of the compliance of inkjet and toner-based print devices representing the following markets:
  - Consumer
  - Home office/small office
  - Professional use
Introduction

- A paper from 2013 published in the Circular of the International Circle by Donevski et al. (Doveski, D., Micic, D. Borkovic, J. Properties of Printer Calibration Targets, International Circular of Graphic Education and Research, Vol. 6, 2013, pp. 70 – 79) used a HP Deskjet 940c in the research
- They used the gray finder target for their research, since they didn’t have the Curve software.
- The RGB input values were modified to achieve the desired aim points
Equipment Used

Print Devices:
- Canon MX522
- HP OfficejetPro 8600
- Epson 3880
- Xerox Phaser 7800

Software & Hardware:
- i1Profiler
- X-Rite i1iSis
- Curve3
- InDesign CS6
- Apple MacBook Pro with OSX 10.10.2 and 10.9.4

Materials:
- Husky offset, 20lb, 75g/m²
- Epson Presentation Paper Matte, 27lb, 102g/m²
Test Target – P2P25X
Test Target – IT8.7/4 & iSis default RGB
Print parameters for the Canon MX 522

![Print parameters for the Canon MX 522](image-url)
Print parameters for the OfficejetPro 8600
Print parameters for the Epson 3880
Print parameters for the Xerox Phaser 7880
Results
Results for the Canon MX522

Results from the standard unchanged print dialogue for color settings

Albuquerque, NM 2015
Results for the Canon MX 522

- Over 25 different settings for color matching were tried
- Settings through the print dialogue from InDesign, leaving the printer driver settings alone
- No changes to the color settings in InDesign, changes done at the printer driver level
Results for the Canon MX 522

- On plain paper the best results were achieved with an intensity setting of 20
- Notice the crossover at 55%
Results for the Canon MX 522

Results on plain paper with intensity set to 20.
Results for the Canon MX 522

- After experimenting with the various print settings on plain paper, just a few settings were tested with the available presentation paper.
- The results on presentation paper gave better results in regards to gray balance.
- The paper type was changed in the printer driver and the brightness setting in the color dialogue was set to dark.

Albuquerque, NM 2015
Results for the Canon MX 522

Based on the previous test these were the chosen settings for testing on presentation paper:

- Standard settings, paper type: presentation paper
- Standard settings, paper type: presentation paper, intensity 20
- Standard settings, paper type: presentation paper, contrast 30
- Standard settings, paper type: presentation paper, brightness: dark

Albuquerque, NM 2015
Results for the Canon MX 522

Results on presentation paper, brightness set to dark
Results for the HP OfficejetPro 8600

- The first print was using the standard settings without any changes being done in the printer driver.
- The following results are from prints done on plain paper.
Results for the OfficejetPro 8600

Results for standard print settings (no changes)
Results for the OfficejetPro 8600

Results with “Preserve RGB numbers” from the color management options in InDesign

Albuquerque, NM 2015
Results for the Officejet Pro 8600

- Prints on the presentation paper with the correct paper selection in the printer driver did not result in any improvement in regards to the obtainable gray balance.
Results for the Epson 3880

- The first prints were done on plain paper with no changes done to the default settings of the printer driver.
Results for the Epson 3880

Plain paper
Results for the Epson 3880

Presentation paper

Albuquerque, NM 2015
Results for the Phaser 7800

Plain paper

Albuquerque, NM 2015
Results for the Phaser 7800

- Results on presentation paper did not differ much from the print results on plain paper.
- Without the use of color management the printer driver for the Phaser 7800 offers a slew of options to influence the color output in the “Xerox features, color options” settings.
Phaser color change menus
Phaser color change menus
Phaser color change menus
Phaser color change menus

- All these options were not explored in this project
- We wanted to rely solely on some standard presets in the printer driver or any option the color management dialogue in InDesign offers.
Conclusions and outlook

- Why should the consumer care about this?
- Consumers should be given the option to adjust their printers for a more gray balance print result
- Could a gray card finder be developed?
- Consumer will print out a test chart from the printer driver and do an adjustment like it can be done for a nozzle check/nozzle alignment test chart.
Acknowledgements

- School of Graphic Communications Management
- Faculty of Communication and Design
- Both at Ryerson University
Thank you for your attention!
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Parameters that Control Misting During Printing

- Doug Bousfield, Professor
  - Paper Surface Science Program
  - Department of Chemical and Biological Engineering
    - University of Maine
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Motivation

- Misting often limits processing speeds and causes environmental issues.
- A number of parameters influence the results such as speed, rheology, and substrate.
- Still not well understood.
Phenomenological Facts about Misting

- Misting increases as
  - Temperature increases
  - Humidity decreases / electrostatic fields increase
  - Ink film thickness increases
  - Roller speed increases, misting = k (speed)^n
  - Air Entrainment increases

Misting Mechanisms

- Mist Formation
  - Film-Split
  - Film-Split + Air-Entrainment

- Sling Formation
Objective and Background

- fill the gap between the industrial press misting performance and the rheological characterization of inks
  - Misting data at similar conditions to commercial presses
  - Visual performance / misting data
- Results for 6 inks are provided in this presentation.

<table>
<thead>
<tr>
<th>Ink ID</th>
<th>Viscosity (Pa.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13.6</td>
</tr>
<tr>
<td>B</td>
<td>59.3</td>
</tr>
<tr>
<td>C</td>
<td>11.8</td>
</tr>
<tr>
<td>D</td>
<td>41.5</td>
</tr>
<tr>
<td>E</td>
<td>8.7</td>
</tr>
<tr>
<td>F</td>
<td>7.8</td>
</tr>
</tbody>
</table>
Pressure Profiles and Visual Representations

- Pressure pulse for ink A with roll speeds of 1 and 1 m/s. Different series are the same ink but repeated passes through the nip.

Gap held between rolls
To around 100 mm

FIXED GAP RESULTS

- Surface of roll corresponding to the above pressure profiles.
Dimensionless Groups: Definition

- **Misting No., \( N_m \)**
  \[ N_m = \frac{M_m}{2\pi R N_{Rev} \rho W h} \]

- **Pressure No. \( N_{\Delta P} \)**
  \[ N_{\Delta P} = \frac{(h / D) \Delta P}{\frac{1}{2} \rho U^2} \]

- **Reynolds No., \( Re \)**
  \[ Re = \frac{\text{inertial force}}{\text{viscous force}} = \frac{\rho h U}{\eta} \]

- **Weber No., \( We \)**
  \[ We = \frac{\text{centrifugal force}}{\text{surface force}} = \frac{\rho U^2 h}{\sigma} \]

Note, this misting number is different than what Olsen’s thesis suggests.
Misting No. vs. Reynolds No.

- Mist number as a function of Reynolds number. The data is for six inks at three different speeds.
Impact of Centrifugal Forces on Misting Generation

- Criteria for a fluid surface to sling out droplets
  - To grow fluid surface defects, a modification of the analysis of Roper et al. (1997)

\[ \text{We} > \left( \frac{2\pi L}{\lambda} \right) \quad \text{where} \quad L = \left( Rh \right)^{1/2} \]

- To breakup the filament from the coated fluid (sling) before the filament rotates a complete cycle and meet the nip again. So the time for the filament to break needs to be shorter than the following

\[ t_{\text{filament-break-to-sling}} < \frac{2\pi R}{U} \]
Lubrication analysis

Accounts for surface tension, centrifugal forces, geometry, and viscosity.

Axisymmetric around $r=0$

Particle differential equation for $h$ that is solved with finite difference methods
Growth of a Disturbance into a Filament

- Growth of a disturbance into a filament for a film thickness of 100 µm, a speed of 10 m/s, viscosity of 1 Pas, an initial disturbance of 50 µm, a surface tension of 30 mN/m, and roll radius of 0.1 m for a total elapsed time of 60 ms.
Impact of Initial Disturbance Size

- The difference in height between the highest and lowest points of the film for conditions above but for different initial disturbances.
- Large initial disturbance is needed to generate a spout in the time available.
Growth often too slow to generate drops.

Key finding – growth is slow if starting from small disturbance, but large if it starts from a filament remain.
Mechanism

- When do we break at one point and when two points?
Problem setup
A few issues

- How to move mesh.
- Boundary condition at surfaces.
- Initial velocity conditions.
- Initial radius or filament shape.
Thin filament or Cosserat equations

- Mass and momentum equation averaged in radial direction.

\[
\left( \frac{\partial v}{\partial t} \right) = - \frac{v}{R^2} \frac{\partial v}{\partial z} + \frac{\partial}{\partial z} \left( R^2 P \right) + \frac{1}{R} \left( \frac{\partial R}{\partial z} \right)^{1/2} \left( 1 + \frac{\partial R}{\partial z} \right)^{3/2} + \frac{\partial^2 R}{\partial z^2} \right \} R \frac{\partial R}{\partial z} + 2 \frac{\partial}{\partial z} \left( R^2 \frac{\partial v}{\partial z} \right) \left[ \frac{1}{bR^2} \right]
\]

\[
P = \frac{\partial v}{\partial z} - \left( \frac{1}{R} \left( \frac{\partial R}{\partial z} \right)^{1/2} \left( 1 + \frac{\partial R}{\partial z} \right)^{3/2} \right)
\]

For a Newtonian fluid. Other rheology not hard.
Other rheology

\[ \rho R^2 \left( \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial z} \right) = \frac{\partial}{\partial z} \left( R^2 T_{zz} \right) + 2\sigma \left( \frac{1}{R \left( 1 + \frac{\partial R}{\partial z} \right)^{1/2}} + \frac{\partial^2 R}{\partial z^2} \left( 1 + \frac{\partial R}{\partial z} \right)^{3/2} \right) R \frac{\partial R}{\partial z} \]

Axial stress. Term.
Work in dimensionless quantities.

- R (filament radius), L (initial length), U (velocity of roll surface normal), \(\mu, \rho, \sigma\) (fluid properties). Three units. Leads to three dimensionless groups that control.

- In the real case, the filament stretching starts at zero and increases linearly as \(A = U_w^2/R_r\) web speed and roll radius.
Quantities

- \( r^* = \frac{R}{R_0} \) filament radius
- \( z^* = \frac{L}{R_0} \) filament length
- \( u^* = \frac{U}{\mu/\sigma} \) velocity
- \( t^* = t \frac{\sigma}{\mu R_0} \) time
- \( Oh = \frac{\mu}{(R_0 \sigma \rho)^{1/2}} \)

- \( A^* = A \frac{\mu^2 R_0}{\sigma^2} \) where \( A \) is the rate of increase.

- Velocity at end increases then as \( A^* t \)

- 3 parameters: \( z^*, A^*, Oh \)
Key results

Initial length did not influence if it was less than the unstable wavelength
$L< pR$

As Oh increases, filaments generated are thin and have a chance to break at one point.

As speed increases, much more fluid left in the middle.

Pulling from one end, instead of from both, promotes breakup at one point.
Oh = 10   \( A^* = 0.1 \)
Oh = 1 A = 1
Oh = 1 \ A = 0.1
Oh = 10  A = 0.1
Other cases

Oh = 10 A=0.01

Oh = 100 A = 0.1
Pulling one boundary causes single point breakup

Oh = 1  A = 0.1

Fluid

James, 2009
Oh = 0.006
Oh = 10  A = .1

Only pulled to the right
James, Oh = 0.13
Breaking lengths

![Graph showing breaking lengths](image)

- **James et al. Newtonian**
- **Filament model**

The graph plots \( \ln(L/L_0) \) against Oh, with data points and two fitted curves representing different models.
Results agree with experiments

- High viscosity leads to thin filaments and longer breaking lengths. **Oh controls.**

- Increase speed leads to more fluid being left in drop --- relates to more misting in experiments. **Small A* reduces misting.**

- Initial thickness scales problem, but not the onset of misting. (nip loads in experiments).
Practical implications

- The only parameter that is reasonable to control is ink rheology. High viscosity inks linked with less misting. We still do not understand viscoelasticity of inks on misting.
- Control of the filament forming stage is important. Can additives me included to generate smaller scale filaments?
Acknowledgements

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Armstrong World
BASF
Goss International
IMERYS
OMNOVA Solutions
Stora-Enso

• International Paper
• MWV
• SAPPI Fine Paper NA
• SCA
• Specialty Minerals Inc.

Part of this work was in cooperating with Sun Chemical
Thank you for your attention
Understanding Gain in Flexography: An Evolving Model of Geometric Factors that Influence Ink Distribution on Plates vs Print

Timothy Gotsick
VP / General Manager

MacDermid Printing Solutions

Technical Association of the Graphic Arts
Print is made of 2-d dots
3 dimensions $\rightarrow$ 2 dimensions
$\rightarrow$ “Dot Gain” $\leftarrow$
Standard Gain Analysis

The Press

“The Black Box”

Albuquerque, NM 2015
But where does print gain come from?
What are the root causes of dot gain?

Print Result

Type of Effect
Mechanical
Optical Density

Factors

Mechanism
Ink Spreading
Ink Rheology
Substrate-Ink Interaction
Dot Deformation
Inking (Anilox)
Printing (Substrate)

Optical Density
Uniformity
Smoothness

Albuquerque, NM 2015
Truly Big Dots

- Molded from 32 Shore A photopolymer
- 7 cm tall
- 1 cm tip
- $\Theta = 53^\circ, 62^\circ, 71^\circ, 79^\circ$
Dot Compression Analyzer

- Compression adjustment mechanism
- Digital force gauge
- ‘Print’ surface
- The Dot

Albuquerque, NM 2015
Dot Compression LIVE!
Contact Patch Expansion

![Diagram showing contact patch expansion with compression](image-url)
Contact Patch Growth

Contact Patch vs Compression by Angle

Compression, mm

Contact Patch, mm²

- 79
- 71
- 62
- 53

Albuquerque, NM 2015
Dot Force vs Compression

Force vs Compression for multiple dot shoulder angles

- **53**
- **62**
- **71**
- **79**

Albuquerque, NM 2015
Dot Force Increase

compression
Corrugated Postprint

Case Study
The Problem

“Fluting”
“Washboarding”
“Striping”
Board vs Dot

- Board structure changes the impression level experienced by dots across the surface of the board
  - Dots printing on flute ‘tip’ are harshly compressed
  - Dots printing on flute ‘valley’ are minimally compressed

Albuquerque, NM 2015
Quantifying Fluting

Flute Analysis

<table>
<thead>
<tr>
<th>Average Density</th>
<th>Flutting Wave Length</th>
<th>Flutting Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2842</td>
<td>0.2705</td>
<td>0.0240</td>
</tr>
<tr>
<td>Peak-to-Valley Avg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0481</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Dot Area</th>
<th>Peak Dot Area</th>
<th>Valley Dot Area</th>
<th>F-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>52.7272 %</td>
<td>55.7980 %</td>
<td>49.4817 %</td>
<td>6.32</td>
</tr>
</tbody>
</table>

Density

#14 Digital High Imp Uncoated

Albuquerque, NM 2015
Dot Shape affects Fluting

Least 0.0 1.19% 2.69% 4.29% 6.12% 7.0

Digital #12 12
Digital #13 13
Analog #2 2
Digital #14 14

Albuquerque, NM 2015
Low Fluting Conditions

Contact Patch vs Compression by Angle

Minimal compression at valley
High Fluting Conditions

Contact Patch vs Compression by Angle

- Contact Path, mm²
- Compression, mm

- 79
- 71
- 62
- 53

Compression at tip
Dot Shape determines Compression Response

*Digital MGC „Standard“*

*Digital MGC „LUX“*
Steeper shoulders are better

Dots

Angle → F-factor

49 → 3.24

52 → 4.18

73* → 2.01

71* → 2.34

* Near dot top
Fluting varies through the tone range

![Diagram showing Fluting variation through tone range with DMGC F factor and DMAF F factor graphs. The tone range is from 0% to 90%, and the F factor range is from 0 to 9. There are images of fluting patterns at different tone percentages.](attachment:fluting_variation.png)
Conclusions (pt. 1)

- Fluting is caused by differences in the impression environment to which dots are subjected at the flute tips and valleys.

- Dot shoulder angle influences dot gain because:
  - Contact patch size (gain) increases with impression, but it increases less for dots with shallower shoulder angles.
  - Impression force increases with impression, but it increases less for dots with shallower shoulder angles.

- The dot shoulder angle model of gain prediction seems to explain empirical results well.
Highlight dot stability

Case Study
The Quest for the Smallest Dot

1% vs <1%

Dot size vs stability: How low can you go?

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Gain throughout the tone range

- **Theoretical**
- **Measured**

**174 lpi File Dot Size, %**

- **Dot Diameter, mils**

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Gain is a **bigger** problem for **smaller** dots

Gain vs Dot Size

- **Equation:** \( y = 3.6729x^{-0.537} \)
- **R²:** 0.9779

![Graph showing the relationship between dot size and gain](image)

- **X-axis:** 174 lpi File Dot Size, %
- **Y-axis:** Increase in Dot Size from File to Print
Dot Compression, 79° shoulder
When Dots Fail

Force vs Compression for multiple dot shoulder angles

Dot Failure
Detailed Dot Failure Study

Precision dot shoulder angle array

7 cm height
1 cm diameter top
All made from the same photopolymer
Finding the ‘Critical Angle’

Force vs Shoulder Angle

No dot failure observed

“Critical Shoulder Angle”

Dot failure observed

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Force at Failure vs Shoulder Angle

\[ y = -12.435x + 1046.3 \]

\[ R^2 = 0.9954 \]
Failure vs Shoulder Angle

\[ y = -0.0562x^2 + 7.8175x - 253.23 \]

\[ R^2 = 0.9983 \]
Dot shape effects on printing pressure

Further Work
What are the root causes of dot gain?

Print Result

Type of Effect

Factors

Mechanism

Dot Gain

Mechanical

Optical Density

Ink Spreading

Dot Deformation

Uniformity

Smoothness

Ink Rheology

Substrate-Ink Interaction

Inking (Anilox)

Printing (Substrate)
Ink Flow Effects on Gain

Analysis of Squeezing Flow during printing

Press Parameters
- Current Time: 1.000 msec
- Printing Pressure: 160 psi
- Ink Viscosity: 50 cP
- Dot Angle: 60°
- Dot Diameter: 40.64 micron
- Initial Ink Height: 1.7 micron
- Total Press Time: 1.0 msec

Current Print Parameters
- Gap Height: 0.1182 micron
- Print Diameter: 50.89 micron
- Diameter Increase: 25.2%
- Area Increase: 56.8%

Final Print Parameters
- Gap Height: 0.1182 micron
- Print Diameter: 50.89 micron
- Diameter Increase: 25.2%
- Area Increase: 56.8%

Current Ink Position

Gap Height vs. Time

Starting position
Current gap

Graph showing relationship between Gap Height (micron) and Time (msec)
Graph showing relationship between Gap Height (micron) and Radius (micron)
Pressure = Force / Area

As impression increases: Both Force and Area increase

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Pressure vs Compression

Compression, mm

Pressure, N/mm²

79
71
62
53
Conclusions (pt. 2)

- Highlight dot stability is strongly influenced by shoulder angle
  - A quantitative model of compression (or force) vs shoulder angle has been demonstrated
- Dot pressure vs compression behavior was more complex, but dots with steeper shoulders were able to generate more pressure. The implications of this finding remain under study.
Thank You

Presented by:

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Printing Solutions

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Linkedin

Albuquerque, NM 2015
The Effects of Web Tension on Tack Forces During Printing

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Motivation

- Tack Pressure \((P_m)\) or “Tack” is negative gauge pressure seen at exit of printing press.
- Tack pressure causes \(z\)-directional forces on web at nip exit.

Goals:
- Determine critical velocity \((U_c)\) and load \((L_c)\) for print damage
- Correlate \((U_c)\) and \((L_c)\) on two different presses
Experimental Setup

- Nip loading (L)
- Velocity (U)
- Viscosity (µ)
- Flooded Conditions
- Web tension (T)
  - may adjust L and α in exp.
- Take-off angle (α)

Find nip load from gauge pressure on by pistons attached to rubber roller axis.

Web Studies, TAGGA15
Albuquerque, NM 2015
Take off angle of web

\[ + \text{angle} - \text{angle} \]

ink
## Fluids Tested with Web

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Viscosity, sdv (Pas)</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicone Oil Standard 60Pas</td>
<td>61.7, 0.8</td>
<td>Newtonian</td>
</tr>
<tr>
<td>(bottom parallel plate)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10,000 SUS oil</td>
<td>7.1, 0.2</td>
<td>Newtonian</td>
</tr>
<tr>
<td>Boiled Linseed Oil</td>
<td>0.0407, 0.0006</td>
<td>Newtonian</td>
</tr>
<tr>
<td>Magenta Ink</td>
<td>55.3, 1.3</td>
<td>Shear Thinning</td>
</tr>
<tr>
<td>Yellow Ink</td>
<td>72.7, 18.8</td>
<td>Shear Thinning</td>
</tr>
<tr>
<td>Cyan Ink</td>
<td>102.9, 6.5</td>
<td>Shear Thinning</td>
</tr>
</tbody>
</table>
Determining Tension

- Tension changes with web stiffness.
- Neglect spring effect.
- Mylar PET should have similar effects to acrylic web

\[ T = \frac{mg - 2k\Delta x}{2W\sin(\theta)} \]
Pressure variation across a steel web flooded with 60Pas silicone oil

- 60Pas silicone oil
- 6.5kN/m
- 1.3mm thick steel web
- 170N/m web tension
- Sensors 1,3, and 4. (Sensor 2 neglected due to functionality issues)
Effect of varying tension vs. varying sensor location

6.5kN/m
Mylar PET

No web

0 rods

12 rods

23 rods
Summary on sensor location

- Tension has minor effect for these conditions.
- Subsequent studies will pick sensor1 at the center of the nip for comparison.
  - *Typically higher tack pressure at nip center.*
Comparison of ink tack pressure to Newtonian oil

6.5kN/m Mylar PET
Summary of ink tack pressure

- Velocity independence for shear thinning inks?
- SUS oil tack pressure is dependant on velocity.
- Loading effect reduced for higher viscosity inks.
### Dimensionless Parameters

<table>
<thead>
<tr>
<th>Dimensionless Parameter</th>
<th>Equation</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_m^*$ (Tack)</td>
<td>$P_m^* = \frac{P_mR}{\mu U}$</td>
<td>1E+7</td>
<td>10</td>
</tr>
<tr>
<td>$T^*$ (Tension)</td>
<td>$T^* = \frac{T}{\mu U}$</td>
<td>1E-1</td>
<td>1E+5</td>
</tr>
<tr>
<td>$L^*$ (Line Load)</td>
<td>$L^* = \frac{L}{\mu U}$</td>
<td>1E+1</td>
<td>1E+7</td>
</tr>
<tr>
<td>$E^*$ (Nip Elasticity)</td>
<td>$E^* = \frac{ER}{\mu U}$</td>
<td>1E+2</td>
<td>1E+6</td>
</tr>
<tr>
<td>$\alpha$ (Release Angle)</td>
<td>$\alpha$</td>
<td>20deg</td>
<td>-20deg</td>
</tr>
</tbody>
</table>
Linseed oil with $-22^\circ$ take-off angle for different tensions

- Zero deg, lowest $P_m^*$
- Small variation in tension may be related to:
  - Release point
  - Line-load
  - Roll compression

6.5 kN/m Acrylic
Zero degree take-off angle optimal for Newtonian Fluids?

- Coating industry may already be optimized for low $Pm^*$ with zero degree take-off angle for Newtonian fluids.
Effect of web tension at $\alpha=5^\circ$ is insignificant.
Flooded Web Result Summary

(No tension or take-off angle correction)

Some conditions, no influence of take-off angle or tension → can use basic model

- Different loads, velocities, viscosities, rheologies, nip release angles, web tensions, web materials

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Let's separate results based on angle (Newtonian oils sensor1 data only)

- For angles 0 degrees or more, $P_m^*$ is linearly related to flooded nip case without web by 5/3 factor.
- Web effects diminished for higher viscosity fluids → Less web inertia effects.

**5/3 conversion factor for 0° or 20° take-off angle**

**Linseed Oil**

- 60Pas Silicone oil and 10kSUS oil

- Range of tension plotted, but little effect.

- Lowest pressure for 0 degree release angle with Newtonian fluid.
Effect of Tension and Release Angle for Cyan Ink

- Tension does not contribute to tack pressure.
- More positive nip release angle, larger tack due to faster film split.

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Cold-Set Ink Correlation

Better than Newtonian Fluid Correlation

Shear thinning nature Changes angle effects:

Positive Angle, large $Pm^*$

Negative Angle, small $Pm^*$

Lowest pressure for most negative release angle with cold-set inks.

$y = 0.7147x$

$R^2 = 0.9484$

$y = 1.0905x$

$R^2 = 0.9431$

$y = 1.4997x$

$R^2 = 0.8921$

- Higher tension, smaller $Pm^*$ for inks.
- Cyan offset coldset ink used for all angles.
- Yellow offset ink, Coldset Magenta offset ink used for 5 deg data as well.
- Error bars include tension variation.

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Negligible effect of loading for low Pm* predicted

- Low loading, less web effect to lower tack pressure

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Effects of Printing on Board Grade
Uncoated Paper (Hansol) vs. Plastic

\[ y = 0.8675x \quad R^2 = 0.9647 \]

\[ y = 0.7147x \quad R^2 = 0.9484 \]

**Larger Tack Pressure On Paper By factor of 1.2**

- Cold-set Cyan Ink
- Variety of Tensions
- Variety of Line Loads
- Different Velocities
- -22 degree take-off angle

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Conclusions

Comprehensive study of tack pressure development on fluids of different rheologies, viscosities, line loads, and roller surface velocities for flooded cases with a web.

- Nip pulse with and without web have different negative pulse shapes (4 possibilities, see slide 2).
- Peeling forces can cause secondary negative tack pulse with web under tension only.
- No significant effect of change in non-porous web material on tack force development under flooded conditions apart from changing applied tension.
- Paper increases tack forces with ink.
**Conclusions**

- Variation in tack pressure to cross-sensor pressure distribution. *Tack pressure larger in center of nip.*
- *Web tension does not drive tack force*, only influences main press drivers of tack pressure development.
  - *Actual loading of fluid*
  - *Release angle*
  - *Release location*
- *Effect of line load is diminished with viscosity* for inks.
- For Newtonian fluids tack increases with viscosity and velocity. However, *tack pressure independent of velocity for inks.*
- *Zero degree take-off angle is optimal for Newtonian fluids. For inks as negative as possible take-off angle is optimum for reduced forces.*
ACKNOWLEDGEMENT

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Armstrong World
Goss International
IMERYS
International Paper
OMNOVA Solutions
OMYA

• BASF
• MWV
• SAPPI Fine Paper NA
• SCA
• Specialty Minerals Inc.
• Stora-Enso

Albuquerque, NM 2015
ROOM
retouch once output many
The journey

- References for color communication
- Standardizations impact
- Expectation management
- A new reference?
- Automation in color communication
References for color communication

1 Idea as automated as possible through all variables to deliver 1 Result

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References for color communication

- Physical references
- Fashion, textile
- Colorimetrical targets
- Transparency (!?)
Standarizations impact

- Standards for analogue printing processes
- Including paper categories
- ... ink on paper
- Result: powerfull tools for color communication
Standardizations impact

The result rules the idea
Standardizations impact

- Fogra-datasets, CGATS21-datasets, japanese datasets, etc., and more to come(!)
- Many ICC-profiles

- ... but all those tools are based on a snapshot of quality criteria in the standardization, of local interpretations, of common measurement technologies and viewing cabinets, and of those analogue printing conditions with all its restrictions.
Standardizations impact

- Outdated normlight tubes were typically displaying fluorescent effects with only around 20% of the effect of D50 (!)

Wood-free Coated and Uncoated Paper
Standardizations impact

- Former “no filter” (today called M0) references did not respect fluorescence properly

Wood-free Coated and Uncoated Paper
Standardizations impact

Expectation management

- How to communicate these variations?
- How to handle productions that are going to be produced with several technologies, on several substrates?
Expectation management
Expectation management

- Actual tools allow a visual accuracy that was not there in the past. WYSIWIG! (under D50)
- High End reproduction has to consider the used substrate
- Many other than analogue printing processes have to be considered (digital print, tv, internet, ...)
- Number of output conditions for a high end production will continuously increase
Expectation management

1 Idea as automated as possible through all variables to deliver 1 Result

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Expectation management

Abbildung A-135: Mikroskopaufnahmen von Primärfarben-Volltöne, die standardisiert auf Bilderdruckpapier (1), Naturpapier (2) und Zeitungspapier (3) gedruckt wurden.

Expectation management
Expectation management

Proof

Print

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A new reference?

--- ISOcoatedv2
--- JapanColor coated
--- PSR-LWCplusv2
A new reference?
A new reference?
Automation in color communication

- Controlled expectation
- Gamut Mapping excellence
- Common appearance through all output conditions
- Reduce absolute color references to where it has to be
- Use a “paper transparency”
Automation in color communication

- An empirical way
Automation in color communication

- An empirical way
Automation in color communication

- An empirical way
Automation in color communication

- From an unrealistically brilliant RGB
Automation in color communication

- To a still vibrant “paper transparency”, a reference
Automation in color communication

- To coated
Automation in color communication

- To uncoated
Automation in color communication

- To SNAP

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Automation in color communication

1 Reference  39 Standards  50+ Printing Substrates  40+ Printers  1 Target

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https://www.youtube.com/watch?v=MOXQo7nURs0
Introducing iccMAX
New Frontiers in Color Management

Max Derhak – ICC Co-Chair
Onyx Graphics Inc.
Phil Green – ICC Technical Secretary
Norwegian Colour & Visual Computing Laboratory
William Li – ICC Co-Chair
Eastman Kodak Company
Outline

- ICC Mission Statement
- ICC.1
- Introducing iccMAX
- Connections with iccMAX
- Material Connection
- Expanded transform elements
- Printing and iccMAX Examples
- Resources and Conclusions

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ICC Mission Statement

- The purpose of the ICC is to promote the use and adoption of open, vendor-neutral, cross-platform color management systems.
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- With “Color Management” being defined as the “communication of the associated data required for unambiguous interpretation of color content data, and application of color data conversions, as required, to produce the intended reproductions”.

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ICC Mission Statement

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  • With “Color Management” being defined as the “communication of the associated data required for unambiguous interpretation of color content data, and application of color data conversions, as required, to produce the intended reproductions”.

  • The ICC enables the “Communication of Color”
Communicating about Color with ICC

- ICC Profile Specification (ISO 15076-1):
  - v4 ICC profile
  - Defines data container format for color management interchange
  - Color Management Model (CMM) applies transforms from profiles
  - Widely used around the world in many, predominantly graphic arts workflows
  - Widespread adoption in commercial and academic software
  - Very successful at spreading color management to many parts of the world

- So why change?
Challenges in “Communicating Color”

- Differences in Light Sources
- Characteristics of Surfaces
- Variations in Observer
- Lighting / Viewing Angles
- Modeling Everything
- Variations in Reproduction Intent
- Keeping things simple
Reasons for Change

ICC v4 only addresses the question “What does it look like?”
And to lesser extent - “What is it?”

- Basic assumptions of ICC v4 profiles limit applications
  - D50/2° colorimetric profile connection space (PCS)
  - Diffuse uniform illumination and reflectance assumption
  - No relationship to spectral / material definition of color

- Structure of ICC v4 unsuitable for some workflows
  - V4 supports matrices, curves and N-dim LUTs in a predetermined sequence
  - Integer based encoding of data within transforms
  - No ‘programmability’ of transforms
  - Large file size for high input dimensionality

- Desire to open color management platform and stimulate new development beyond ICC members

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Introducing iccMAX

iccMAX takes off where v4 ends…
2 related but different profile formats for different purposes
What are the main use cases for iccMAX?

- Spectral processing
  - Alternate PCS colorimetry
  - Alternate illuminants and observers
- Extended color metrology
  - Support for bi-spectral and multi-angle measurement and processing
- Extended namedColor profiles (packaging)
  - E.g. multiple tints, spectral processing, overprint, non-0:45 measurements, alternative illuminants and observers
- Material Connection
  - Ability to determine material amounts as well as appearance
- Extended transform functionality
  - Programmable transforms
- Alternative to embedding transforms in profile
  - Pointers to reference encodings
  - Pointers to full profile by URL
iccMAX Workflows

- iccMAX defines a Platform for defining color management workflows
  - iccMAX profile encoding is defined by the iccMAX specification
  - iccMAX workflows are defined by iccMAX Interoperability Conformance Specification (ICS) documents separate from the iccMAX specification
    - ICS documents define workflow specific requirements utilizing features of iccMAX specification
    - ICS documents will be registered with the ICC for defining various domain specific workflows
- Not every feature of iccMAX specification needs to be implemented to support an iccMAX based workflow
  - Allows for future iccMAX extensions
- ICC is providing a reference implementation of an iccMAX V5 CMM
iccMAX High Level Features

- Spectral PCSs to enable spectral communication of color information
  - Illuminant and observer can be defined

- Color appearance processing in the PCS
  - Facility to store appearance attributes in a profile

- Extended CMM functionality
  - Support for spectral and bi-spectral (fluorescent) data
  - New Gamut Boundary Description
  - Encoding of BRDF parameters
  - New encoding of Named Colors to support tints

- Hierarchical data encoding

- multiProcessElements with programmable transforms
  - Functional operators, conditional evaluation and vectorized operations

- Abbreviated profiles
  - References to color encoding standard or to existing profile
iccMAX Color Spaces

- Colorimetric Profile Connection Spaces
  - Can use same as defined in ICC.1 (XYZ and L*a*b*)
  - Observer and Illuminant can vary as defined by spectral viewing conditions tag

- New Extended Color Space Signatures Types
  - Allow from 1 to 65535 channels to be defined

- Device color spaces and color encodings
  - Color space signatures as defined in ICC.1
  - Profiles can point to registered color space encodings and associated transform
    - Additional extended N-channel color space signatures defined
      - “ncxxxx” multi-channel color space with XXXX channels defined in header

- Material Connection Spaces
  - Additional tags define material connection channel names and default values
    - “mcXXXX” “material” values with XXXX channels defined in header
iccMAX Connections

1. **Named Color connections**
   - Provides relationship between named colors and colorimetric, spectral as defined by header PCS fields as well as optional BRDF information
   - Can be linked with colorimetric and spectral connection tags

2. **Colorimetric Connections** (How does an observer see it?)
   - Connection provided by B in A2Bx/B2Ax transform tags
   - Can be linked with both Colorimetric and Spectral connection tags

3. **Spectral Connections** (What is its relationship to light?)
   - Connection provided by B in D2Bx/B2Dx transform tags
   - Can be linked with both Colorimetric and Spectral connection tags

4. **Material Connections** (What is it?)
   - Connection provided by M in A2M0, M2A0, M2B0, and M2A0 transform tags
   - M2B0 tags can be connected to B2Ax Colorimetric connection tags
   - M2S0 tags can be connected to B2Dx Spectral connection tags

5. **BRDF Connections** (How does it look at different angles?)
   - Profile transforms provided in BRDF tags
   - Colorimetric or Spectral tags (or both) can be defined in the same profile
   - Input class profiles can optionally include Material (A2M0) tag in the same profile
iccMAX Profile Connection Conditions

- Source and destination profiles can have different Connection Spaces
- Profile Connection Conditions provide additional information and transforms for the CMM to perform spectral and custom colorimetric PCS processing (e.g. illuminant, observer, viewing conditions, conversion transforms, …)
- PCC information can come from either the profile or externally provided to the CMM

![Diagram showing source and destination profiles with PCS Transform and Rendering Intent Transform]

- Allows PCS data in profiles to use actual viewing conditions
- PCC is required in profile if D50 PCS is not used
### ICC.1 PCS Support

<table>
<thead>
<tr>
<th>From Lab</th>
<th>From XYZ</th>
<th>From Reflectance</th>
<th>From Transmittance/Transmissive</th>
<th>From Radiant/Emission</th>
<th>From Fluorescence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To Lab</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Using PCC</td>
<td>Using PCC</td>
<td>Using PCC</td>
</tr>
<tr>
<td><strong>To XYZ</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Using PCC</td>
<td>Using PCC</td>
<td>Using PCC</td>
</tr>
<tr>
<td><strong>To Reflectance</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Extract PCC illuminant</td>
</tr>
<tr>
<td><strong>To Transmittance/Transmissive</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Extract PCC illuminant</td>
</tr>
<tr>
<td><strong>To Radiant/Emission</strong></td>
<td>No</td>
<td>No</td>
<td>Apply PCC Illuminant</td>
<td>Apply PCC illuminant</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>To Fluorescence</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

*Operations to perform conversions are outlined in Appendix A of iccMAX Specification*

*Note: PCC = Profile Connection Conditions*
Material Connection Workflows

- Some workflows require a connection based upon a description that defines what the color channels are rather than how they look or are related to light (PCS’s).
- Examples include:
  - **Fine Art Pigment Identification**
    - Going from Multi-spectral capture to Pigment identification to Visualization of paint pigments.
  - **Medical imaging**
    - Scanning to RGB + channels that provide bio-marker information to visualization of scan with bio-markers.
  - **Ink Visualization**
    - Going from printed ink channels to visualization of different ink orders or use of spot inks.
- **Note:** Could be mostly implemented as Device Link Profiles – but number of channels and channel order are fixed.

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MCS Connection Example

Device (Multi-Spectral) Input Channels

MID

Header
MCS Subset: No

AToM0Tag
0 0
... 1
N 2
0 3

Material Type Array Tag
Channel 0: “M3”
Channel 1: “M8”
Channel 2: “M5”
Channel 3: “M1”

MCS

MToB0Tag
0 L
1 a
2 b
3
4

Material Type Array Tag
Channel 0: “M8”
Channel 1: “M11”
Channel 2: “M5”
Channel 3: “M3”
Channel 4: “M2”

Material Default Values Tag
Channel 0: 0
Channel 1: 0
Channel 2: 0
Channel 3: 0
Channel 4: 0

MVIS

Header
MCS Subset: No

PCS

Display Profile

RGB Channels

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Processing with multiProcessElements

- Allows processing workflows to be defined using an arbitrary order of flexible processing elements with 32bit floating point processing
- Completely defines transformations from input to output
Programmable Calculator Element

- Provides mechanism for encoding more complex (non-linear) device models
  - Avoids limitations of Color Look-Up Table (CLUT) accuracy and massive storage requirements when many input channels are used
  - Possible to embed and use other processing elements
  - Results in smaller and potentially more accurate profiles

- Defines a script based expression calculator to determine output channels based upon input channels
  - Uses a sequence of operations that apply to an Reverse Polish Notation (RPN) argument stack
  - Finite memory storage for temporary results
  - Nearly all operations are vector based (operating on multiple channels at same time)
  - Provides secure deterministic behavior

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Backwards compatibility with v4 / v2

- Current CMMs are not expected to process iccMAX profiles
- iccMAX profiles can connect to v2 and v4 profiles via the Standard Colorimetric PCS
  - Use Profile Connection Conditions to convert to/from Custom Colorimetric PCS if required
Printing and iccMAX - Two Use Cases

- Packaging
- Overprint Emulation
Packaging CM Challenges

- Packaging crosses multiple output production and manufacturing processes and providers
  - Different processes make color differently
  - Everyone needs to agree on color description
- Cannot communicate color using “simple appearance” (CIELAB)
  - Appearance changes under different lighting/viewing conditions
    - The final lighting condition varies and is unknown
  - Specialty inks/colorants
    - Metallics
    - Fluorescence
    - Gloss
- ICC v4 Named color profiles only communicate “simple appearance” for 100% solid colors
Packaging and iccMAX

- iccMAX uses a completely new Named Color Profile Architecture
  - Multiple tints for each named color
  - Can define various interactions with light
    - Spectrally based Measurements (over white/black) provide input to a Spectral Profile Connection Space (PCS)
    - Measurements over multiple measurement geometries
    - Colors can be defined to account for lighting and observer angles using BRDF
    - Fluorescence (where surface transforms light from one wavelength to another) can be characterized
  - Uses expandable hierarchal encoding that allows for possible future needs to be addressed
- iccMAX Named color profiles can be used with other iccMAX profile classes in color workflows
Multi-Ink Overprint CM Challenges

- V4 ICC color profiles encode color transforms for N-channel device input using N-dimensional look-up tables.
- N-dimensional look-up tables (LUTs) grow in size at an exponential rate (that becomes prohibitive for large values of N).
- Connecting profiles by device channels requires that the order and number of channels match exactly.
  - What if first profile uses different order or some channels are not used?
Multi-Ink Overprint and iccMAX

- iccMAX utilizes transforms defined by the MultitProcessElements tag type
  - A programmable transform mechanism
  - Can conditionally apply lower dimensional LUTs
  - Can directly encode device models
  - Can directly encode overprinting models

- Material Connection Space provides flexible routing for device like channel connections
In Conclusion …
Resources

- iccMAX preliminary specification
- iccMAX preliminary Interoperability Connection Specifications
- iccMAX reference implementation
- Sample iccMAX profiles for different workflows
  - Tool to convert between XML and binary profile representations
  - Source code and compiled .exes to apply profiles to images
  - ProfileDump utility to check profile conformance
New Frontiers with iccMAX

- ICC v4 addresses many common Color Management problems
- Color in the “Real World” is much more complex than what can be communicated using ICC v4 profiles
- iccMAX communicates answers to the color questions
  - What is it?
  - How does it interact with light?
  - What does it look like?
- iccMAX provides a flexible platform for modeling and defining color workflows
- iccMAX encompasses the complexities of color in the “Real World” thus enabling new frontiers of Color Management
Thank You!

Questions?
A Case for a Linear Difference Metric

Edward M. Granger

XYZ Color Science
1920 – Definition of Luminance

y - Color Matching Function

Relative Response

400 450 500 550 600 650 700
Wavelength - nm.

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1930 – CIE 1931 xyz
1940 MacAdam Ellipses
1976 Color Space Battle
Working Color Gamut

CIE De200 Study Data

World of Color
Color Measurement
Camera – Spectrum Locus
Spectrometer vs Camera

- **Spectrophotometer**
  - Calibration Target
  - Known Illumination
  - Computed Sample Spectral Reflectance
  - Known $xyz$ Color Matching Functions
  - Defined Color Space
  - Single Point Measurement

- **Camera**
  - Filter – CCD Combination – No Target
  - Unknown Illumination
  - Unknown Sample Spectral Reflectance
  - Unknown Color Matching Functions
  - Unknown Color space
  - Produces an Image
Gamut Comparison

- Spectrum
- Beta RGB
- sRGB

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A Linear Color Difference Metric

- Primaries – sRGB
- Guth Opponent Ideas
- Test with MacAdam Ellipse Data
- Minimize Unknown Coefficients
- Test Against
  - CIE 1976 Luv
  - CIE 1976 Lab
  - CIE DE 2000
QTD Vectors

- $T = R - G$
- $D = 0.5(R + G) - B$
- $A = 0.2127R + 0.7152R + 0.0722B$
- $Q = A + K1(\text{Red} + \text{Green} + \text{Yellow} + \text{Blue})$
- Rewritten
  - $Q = A + K1(|T| + |D|)$
T – D Diagram and Hue Angle

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Determine K1
Q, P and Color Difference

- $Q = A + 0.125 \times (|T| + |D|)$
- $P = K2 \times \ln \left( \frac{Q}{Q_0} \right)$
- $\Delta P = P_2 - P_1$
MacAdam Warped Space

QTD Color Space
Eccentricity of Macadam Ellipses

JND for MacAdam Ellipses
QTD Color Difference Model

- \( T = R - G \)
- \( D = 0.5 \times (R+G) - B \)
- \( A = 0.2127 \times R + 0.7252 \times G + 0.0722 + G \)
- \( Q = A + 0.125 \times (|T| + |D|) \)
- \( P = 65.5 \times \ln\left(\frac{Q}{Q_0}\right) \)
- \( \Delta P = \left(65.5 \times (\Delta A^2 + \Delta T^2 + \Delta D^2)^{0.5}\right)/ Q \)
QTD - DE2000 Comparison

- **QTD**
  - 5 equations
  - Eccentricity – 1.95
  - Saturation
  - Agrees with 1976 $\Delta E$
  - All linear calculation
  - 2 constants for definition
  - T-D axes align with unique hues
  - Hue correlates to Munsell

- **DE2000**
  - 22 equations
  - Eccentricity – 2.9
  - No saturation support
  - $\Delta E$ factor of 2 low
  - Nonlinear Calculation
  - Many constants
  - $a-b$ axes do not align with unique hues
  - Hue correlates to Munsell

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Conclusions

- The sRGB primaries can produce a nearly uniform color space
- QTD has
  - *Color wheel T-D plot*
  - *T-D axes align with unique hues*
  - *Predicts brightness*
  - *Predicts $\Delta E$ better than the CIE Metrics*
- CIE DE2000 fails to predict $\Delta E$ for MacAdam data
- What is a JND?
Halftone Type of Both Soft-proofing and Hard-proofing Applications for High-Fidelity Printing Systems Using Six and Seven Colorants

By Mei-Chun Lo  24/March/2015

Shih Hsin University, Taiwan

MailTo : mcl@cc.shu.edu.tw
Motivations

To bridge the gap between HDR imaging and Hi-Fi color reproduction.

The intent of this research has two tasks:

1) to derive an HDR contone to Hi-Fi halftone-conversion model, via fitting spectral-reflectance approach.

(isomerism, color-gamut, tone-and-detail)

2) to derive a halftone-palate type of image display model, for both soft- and hard-proofing of simulation of high-fidelity printing system.
Methodologies

High-Fidelity Color Printing
Ideal CIE Camera Model
Halftone palettes /Dithering
High-Fidelity Color Printing
High-Fidelity Color Printing

- **Multi-Color Separation** (5-8 colors).

- Two directions suggested and induced:
  
  a. Imaging detail, e.g., CMYKLcLm.
  
  b. Gamut of printability, e.g., CMYKRGB, or CMYKOG.
Printer/Printing Models

- Neugebauer-Type Equation
- Masking-Type Equations

A modified type masking-type model using a multispectral approach was carried out here.
Colorimetric Density

- All of the colorimetric parameters were converted to colorimetric densities in the use of logarithm method as follows:

\[
D_r = D_c = \log \left( \frac{X}{X^0} \right)
\]

\[
D_g = D_m = \log \left( \frac{Y}{Y^0} \right)
\]

\[
D_b = D_y = \log \left( \frac{Z}{Z^0} \right)
\]
## Masking-Type Equations

<table>
<thead>
<tr>
<th>Simple linear regression</th>
<th>$f(x,y,z) = D_r = a_0 + a_1 x + a_2 y + a_3 z$</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>2nd-order regression</th>
<th>$f(x,y,z) = D_r = a_0 + a_1 x + a_2 y + a_3 z + a_4 xy + a_5 yz + a_6 zx + a_7 x^2 + a_8 y^2 + a_9 z^2$</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3rd-order regression</th>
<th>$f(x,y,z) = D_r = a_0 + a_1 x + a_2 y + a_3 z + a_4 xy + a_5 yz + a_6 zx + a_7 x^2 + a_8 y^2 + a_9 z^2 + a_{10} xyz + a_{11} x^3 + a_{12} y^3 + a_{13} z^3 + a_{14} xy^2 + a_{15} x^2 y + a_{16} y^2 z + a_{17} y^2 z + a_{18} z^2 x + a_{19} x z^2$</th>
</tr>
</thead>
</table>

※ $x = D_c = c$, $y = D_m = m$, $z = D_y = y$

*(Principal Density or Equivalent Neutral Density)*

**Note:** Forward model for 3-colors CMY superimposed
Third-order Model. (Colorant Models)

- Due to the failure of **additivity and proportionality**, a second- or third-order model would outperform to the first-order.

\[
D_{r-3c} = a_{1,1}c + a_{1,2}m + a_{1,3}y + a_{1,4}c^2 + \\
a_{1,5}m^2 + a_{1,6}y^2 + a_{1,7}cm + a_{1,8}cy + \\
a_{1,9}my + a_{1,10}c^3 + a_{1,11}m^3 + a_{1,12}y^3 + \\
a_{1,13}c^2m + a_{1,14}c^2y + a_{1,15}mc^2 + a_{1,16}m^2y + \\
a_{1,17}yc^2 + a_{1,18}ym^2 + a_{1,19}cmy
\]

Similar terms are used for the calculation of \(D_{g-3c}\) and \(D_{b-3c}\).
CMYKRGB (Press)

CMYKROG (Proofer)
Color Printing

~ Experiment of 6-colorant/7-ink Color Printing ~
Illustration of the use of Hi-Fi colorants, Green and Orange to extend the gamut only achieved using standard CMYK colorants

(solid with natural coloring: 4-colorant gamut; wireframes with colors: 6-colorant super-gamut (green: CMYKG subset), red: CMYKO subset, and blue: CMYK subset)).
7-Ink CMYKR RGB Separation (Press)

- Subdivide the superset of 7-ink into 4 subsets
  - A 4-ink CMYK (1617 color; IT8.7/4)
  - Three 5-colorant subsets: CMYKR, CMYKG, and CMYKB (each 1716 colors)

<table>
<thead>
<tr>
<th>Dominant Ink</th>
<th>Subgamut</th>
<th>Key Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>CMYK</td>
<td>Black (K)</td>
</tr>
<tr>
<td>Red</td>
<td>CMYKR</td>
<td>Red</td>
</tr>
<tr>
<td>Green</td>
<td>CMYKG</td>
<td>Green</td>
</tr>
<tr>
<td>Blue</td>
<td>CMYKB</td>
<td>Blue</td>
</tr>
</tbody>
</table>

Table: 4 subsets of 7-ink color separation
7-Ink CMYKRGB Separation (PRESS)

7-ink set used:

- CMYK: SAKATA INX T Ecopure J;
- Red ink: Pantone Red 032C;
- Green ink: Pantone Green C;
- Blue ink: Pantone Blue 072C
6-Colorant/Ink-subset (Proofer)

- **Epson Stylus Pro 9900** (Printer)
- **Subdivide the superset 6-ink into 3 subsets**
  - A 4-ink CMYK (1617 colors; IT8.7/4)
  - Two 5-colorant subsets: CMYKO and CMYKG (each 1716 colors)

<table>
<thead>
<tr>
<th>Dominant Colorant</th>
<th>Subgamut</th>
<th>Key Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>CMYK</td>
<td>Black (K)</td>
</tr>
<tr>
<td>Orange</td>
<td>CMYKO</td>
<td>Orange</td>
</tr>
<tr>
<td>Green</td>
<td>CMYKG</td>
<td>Green</td>
</tr>
</tbody>
</table>

Table: 3 subsets of 6-colorant color separation
Polynomial Regressive Masking Equations (using SVD)

\[ f(x, y, z) = a_0 + a_1 x + a_2 y + a_3 z \]

\[ f(x, y, z) = a_0 + a_1 x + a_2 y + a_3 z + a_4 xy + a_5 yz + a_6 zx + a_7 x^2 + a_8 y^2 + a_9 z^2 \]

\[ f(x, y, z) = a_0 + a_1 x + a_2 y + a_3 z + a_4 xy + a_5 yz + a_6 zx + a_7 x^2 + a_8 y^2 + a_9 z^2 + a_{10} xyz + a_{11} x^3 + a_{12} y^3 + a_{13} z^3 + a_{14} xy^2 + a_{15} x^2 y + a_{16} y^2 z + a_{17} y^2 z + a_{18} zx^2 + a_{19} xz^2 \]
Broadband Type of Third-Order Model
(Colorant Models)

\[ D_{r-3c} = a_{1,1} c + a_{1,2} m + a_{1,3} y + a_{1,4} c^2 + \]
\[ a_{1,5} m^2 + a_{1,6} y^2 + a_{1,7} cm + a_{1,8} cy + \]
\[ a_{1,9} my + a_{1,10} c^3 + a_{1,11} m^3 + a_{1,12} y^3 + \]
\[ a_{1,13} c^2 m + a_{1,14} c^2 y + a_{1,15} m^2 c + a_{1,16} m^2 y + \]
\[ a_{1,17} y^2 c + a_{1,18} y^2 m + a_{1,19} cmy \]

Similar terms are used for the calculation of \( D_{g-3c} \) and \( D_{b-3c} \).
# Polynomial Models using SVD method

In CMYKOG Model

<table>
<thead>
<tr>
<th>Order</th>
<th>Parameters</th>
<th>No. of Term</th>
<th>Polynomial Regression Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n^{\text{order}}$-SVD Equation</td>
<td>$m$</td>
<td>$(\sum_{i=0}^{n} H_i^m) + 1$</td>
<td>$C_{n+m-1}^m n^{\text{Order}}(m) + \sum_{j=1}^{C_{n+m-1}^m} a_j n^{\text{Order}}(m) + ... + 1$</td>
</tr>
<tr>
<td>3rd-SVD Equation (MB)</td>
<td>$R_{\lambda C}$, $R_{\lambda M}$, $R_{\lambda Y}$, $R_{\lambda K}$, $R_{\lambda E}$</td>
<td>$(\sum_{i=0}^{3} H_i^5) + 1 = 56$</td>
<td>$C_{5}^5 \sum_{j=1}^{C_{5}^5} a_j^3 (R_{\lambda C}, R_{\lambda M}, R_{\lambda Y}, R_{\lambda K}, R_{\lambda E}) + C_{2}^5 \sum_{j=C_{2}^5+1}^{C_{5}^5} a_j^2 (R_{\lambda C}, R_{\lambda M}, R_{\lambda Y}, R_{\lambda K}, R_{\lambda E}) +$</td>
</tr>
</tbody>
</table>

Note: 1) BB: Broadband, MB: Multispectral; 2) $R_{\lambda 5c}$ is the outcome for 3rd-SVD equation in multispectral model (forward process); 3) SVD: Singular Value Decomposition method
Polynomial Models using SVD method
In CMYKOG Model

\[
\sum_{j=1}^{C_n^{m+n-1}} a_j n^{Order} (m) + \sum_{j=C_n^{m+n-1}}^{C_n^{m+n-1}+C_n^{m+n-2}} a_j (n-1)^{Order} (m) + \ldots + 1
\]

\[
\sum_{j=1}^{C_3^7} a_j 3^{rd} (R_{\lambda C}, R_{\lambda M}, R_{\lambda Y}, R_{\lambda K}, R_{\lambda E}) + \sum_{j=C_3^7+1}^{C_3^7+C_2^6} a_j 2^{nd} (R_{\lambda C}, R_{\lambda M}, R_{\lambda Y}, R_{\lambda K}, R_{\lambda E}) + \sum_{j=C_3^7+C_2^6+C_1^5}^{C_3^7+C_2^6+C_1^5} a_j 1^{st} (R_{\lambda C}, R_{\lambda M}, R_{\lambda Y}, R_{\lambda K}, R_{\lambda E}) + 1
\]
Gray Component Replacement (GCR)

- The gray component is the determination of black-ink channel (K channel) for reversal model.
- Conditional rules for GCR (e.g.):
  - if \(D_{(4C, \text{min})} < 0.6 | D_{4C} < \text{FullColor}_{3C}\) \(\Rightarrow D_{GCR} = 0.0\) (\(D_{3C} = D_{4C}\));
  - if \(D_{(4C, \text{min})} \geq K_{100}\) \(\Rightarrow D_{GCR} = K_{100}\);
  - else \(\Rightarrow D_{GCR} = D_{(4C, \text{min})} \times 0.7\);

![Figure: A schema figure of Gray Component Replacement](figure.png)
Adaptive Type of GCR: $\beta = \left[\frac{(100-L^*)}{80}\right]^n$
Compute ratio_distance
=computeDistanceAndRatio2KeyColor(Lch_pixel.h);

extraComponent.E =
((Math.pow((1-ratio_distance),n_adjKCR_ConcaveC)))
*extraComponent.E;
Polynomial Models using SVD method
In CMYKOG Model

- **CMYK**
- **CMYKO**
- **CMYKG**

1. **R_{\lambda,5c}**
2. **Look Up Table**
   - **R_{\lambda,1}, R_{\lambda,2}, R_{\lambda,3}, R_{\lambda,4}**
   - or
   - **R_{\lambda,1}, R_{\lambda,2}, R_{\lambda,3}, R_{\lambda,4}, R_{\lambda,5}**
3. **3rd-SVD Regression Equation**
4. **FDA_{patch}**
5. **if (RMSE == Minimum) Break;**
6. **R_{\lambda,5cPc}**
7. **R_{\lambda,5cPr}**
8. **Narrow-Band Type Forward Model**
9. **Broad-Band Type Reverse Model**

Reference XYZ

CIE \( \Delta E_{00} \)

**KCR or GCR**

Iterating Recursion:
(Key Component FDA == 0 ~ 100)

Forward Model:

Reverse Model:
Summary of Prediction performances of the multi-spectral 2\textsuperscript{nd}-SVD model

<table>
<thead>
<tr>
<th>Subset</th>
<th>CMYK</th>
<th>CMYKO</th>
<th>CMYKG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Max</td>
<td>7.59</td>
<td>3.00</td>
<td>5.88</td>
</tr>
<tr>
<td></td>
<td>8.39</td>
<td>5.25</td>
<td>6.64</td>
</tr>
<tr>
<td>Average</td>
<td>1.16</td>
<td>1.33</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>1.98</td>
<td>1.06</td>
<td>1.92</td>
</tr>
<tr>
<td>$\Delta E_{00} &gt; 6$</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Count</td>
<td>0</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMSE (Mean)</td>
<td>0.0001</td>
<td>0.0018</td>
<td>0.0008</td>
</tr>
<tr>
<td></td>
<td>0.0018</td>
<td>0.0009</td>
<td>0.0036</td>
</tr>
</tbody>
</table>

- in terms of mean $\Delta E_{00}$, of four derived Models for transform processes of both the forward (denoted as F) and the reverse (denoted as R) under the $D_{50}$ condition.
Summary of Prediction performances of the multi-spectral 2nd-SVD model (CMYKOG)

<table>
<thead>
<tr>
<th>Subset</th>
<th>CMYK</th>
<th>CMYKO</th>
<th>CMYKG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Max</td>
<td>4.44</td>
<td>3.53</td>
<td>4.25</td>
</tr>
<tr>
<td></td>
<td>4.97</td>
<td>4.98</td>
<td>4.43</td>
</tr>
<tr>
<td>Average</td>
<td>0.80</td>
<td>0.76</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>0.88</td>
<td>1.44</td>
<td>1.43</td>
</tr>
<tr>
<td>$\Delta E_{00} &gt; 6$ Count</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RMSE (Mean)</td>
<td>9.70E-4</td>
<td>7.92E-4</td>
<td>9.54E-4</td>
</tr>
<tr>
<td></td>
<td>0.0017</td>
<td>0.0021</td>
<td>0.0040</td>
</tr>
</tbody>
</table>

- in terms of mean $\Delta E_{00}$, of four derived Models for transform processes of both the forward (denoted as F) and the reverse (denoted as R) under the D$_{50}$ condition.
Summary of Prediction performances of the multi-spectral 2nd-SVD model (CMYKRGB)

<table>
<thead>
<tr>
<th>Subset</th>
<th>CMYK</th>
<th>CMYKR</th>
<th>CMYKG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>F</td>
<td>R</td>
<td>F</td>
</tr>
<tr>
<td>Max</td>
<td>5.27</td>
<td>4.85</td>
<td>5.33</td>
</tr>
<tr>
<td>Average</td>
<td>1.15</td>
<td>0.92</td>
<td>1.26</td>
</tr>
<tr>
<td>(\Delta E_{00} &gt; 6) Count</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RMSE (Mean)</td>
<td>0.0013</td>
<td>0.0018</td>
<td>0.0011</td>
</tr>
</tbody>
</table>

- in terms of mean \(\Delta E_{00}\), of four derived Models for transform processes of both the forward (denoted as F) and the reverse (denoted as R) under the D50 condition.
Summary of Prediction performances of the multi-spectral 2^{nd}-SVD model (CMYKRGB)

<table>
<thead>
<tr>
<th>Subset</th>
<th>CMYKB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>F</td>
</tr>
<tr>
<td>Max</td>
<td>6.47</td>
</tr>
<tr>
<td>Average</td>
<td>1.00</td>
</tr>
<tr>
<td>$\Delta E_{00} &gt; 6$ Count</td>
<td>1</td>
</tr>
<tr>
<td>RMSE (Mean)</td>
<td>9.78E-4</td>
</tr>
</tbody>
</table>

- in terms of mean $\Delta E_{00}$, of four derived Models for transform processes of both the forward (denoted as F) and the reverse (denoted as R) under the D_{50} condition.
Multispectral CIE XYZ Sensing Model

~ Ideal CIE Camera Model~
Ideal CIE Camera Model

A spectra sensing model, virtually equipped with the simulated CIEXYZ three-band filters (with a set of ideal spectral responses)

- i.e. CIE 1931 Color Matching Function.
Development of Ideal CIE Camera Model

1. An appropriate real spectral color dataset
   - Munsell Book Glossy was used in this research

2. SVD and Winner Method
   - Basis vectors: using SVD method
   - Coefficients: approximated by using the well-known Winner-inverse solution
Computational Procedures of Spectral Hi-Fi 6-colorant/ink Separation Algorithm

AdobeRGB_D50 Work Space

Original (input images) → Ideal CIELAB Spectra Sensing Model → Reflectance Data → 6-Colorant CMYKOG Printer Process → 6-Colorant Fractional Dot Area Separation Sets → Reproduction (output images)

HDR RGB images → UnSharp Mask → RGB2XYZ Matrix → CIELAB

Obtain Basis Vectors based on Munsell Book using SVD + Wiener Approach

Spectral Power Distribution to Reflectance → 6-Colorant Printer Process

CIEXYZ / Reflectance Data → CIELCh / Reflectance Data → Determine subsets → Broadband Type → Multi-Spectral Type

Iterating to minimizing the RMSE

Determine Fractional Dot Area Sets → Output images
Halftone Pallette
Dithering
Sample code

The following sample code reads in an RGB image in a raw image file format, dithers it to a specific optimized 16-color palette found using Photoshop, and writes the output to a raw image file. The original image and dithered result are shown below. The raw input image file for this sample can be downloaded at Image:Amorphophallus titanium USBG small.raw.
The nearest palette color is chosen to the current pixel in question, and then compute the difference of that color from the original color in each RGB channel. Pieces of this difference are dispersed throughout several adjacent pixels not yet visited. SO: in MY APPROACH:

- Using $\Delta E_{00}$ instead of the difference of RGB
- $\text{CMYKRGB} \rightarrow 2^7 = 128$ palettes
- $\text{CMYKROG} \rightarrow 2^6 = 64$ palettes
4 Dithering Methods
Based on the concept of *error diffusion*

- Floyd-Steinberg
- Jarvis, Judice & Linke
- Stucki
- Atkinson
Color-Space Converter and dithering transformer settings

- **GAMMA**: 1.0 (Adjust for better contrast; 1.0 for no change)
- From ColorSpace: RGB
- To ColorSpace: LCH
- White point: D50
- Dithering algorithm: Floyd-Steinberg
- Dithering mode: Palette-mode_Customize()
- Steps: 7 (2-21, Steps used for dithering each of RGB channels)

Note: Make sure everything is in order!
Color picker (255,255,255/0,0,0)

Color-Space Converter and dithering transformer settings

- **GAMMA**: 1.0 [Adjust for better contrast; 1.0 for No change]
- **ax**: 0.2 [0~1]

- **from ColorSpace**: RGB
- **to ColorSpace**: LCH
- **white point**: D50

- **dithering algorithm**: Floyd-Steinberg

- **dithering mode**: Palette-mode_CustomFile
- **Steps**: 2 [2~21, Steps used for dithering each of RGB channels]

- **separate images**

*Note*: Make sure everything is in order!
Dithering algorithms: Floyd-Steinberg

Steps: 2
[2-21, Steps used for dithering each of RGB channels]

Separate images

Note: Make sure everything is in order!
### Color-Space Converter and dithering transformer settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GAMMA</strong></td>
<td>1.0</td>
</tr>
<tr>
<td><strong>ax</strong></td>
<td>0.2</td>
</tr>
<tr>
<td><strong>from ColorSpace</strong></td>
<td>LCH</td>
</tr>
<tr>
<td><strong>to ColorSpace</strong></td>
<td>RGB</td>
</tr>
<tr>
<td><strong>white point</strong></td>
<td>D50</td>
</tr>
<tr>
<td><strong>dithering algorithm</strong></td>
<td>Floyd-Steinberg</td>
</tr>
<tr>
<td><strong>dithering mode</strong></td>
<td>Palette-mode_CustomFile</td>
</tr>
<tr>
<td><strong>Steps</strong></td>
<td>2</td>
</tr>
</tbody>
</table>

- **Note:** Make sure everything is in order!

- **Dithering Algorithm Floydl-Steinberg**
- **Dithering Mode Palette-mode_CustomFile**
- **Steps 2** [2~21, Steps used for dithering each of RGB channels]
- **Separate Images**
- **Gamma** [Adjust for better contrast; 1.0 for No change]
- **ax** [0~1]

**File Adjust for better contrast; 1.0 for No change**
Conclusions

Satisfactorily derived:

1) An HDR contone to Hi-Fi halftone-conversion model, via fitting spectral reflectance approach.
2) The CIEXYZ type of camera (sensing) model
3) Halftone-palate type of image display models, for both soft- and hard-proofing of simulation of high-fidelity printing system,

Using CMYKRGB and CMYKOG colorants.
Future Work
Process of Scanner
Scanner/Camera Characterization

RGB → Gray Balancing (1D ↔ LUT) → R’G’B’

Chromatic Lightness-Division (3rd SVD)

Highlight Near-Neutral-Division (3rd SVD)

Shadow Near-Neutral-Division (3rd SVD)

Achromatic Gray Balance Algorithm (3D ↔ LUT)

Lab
Refined Device Characterization Model

Original

(before refined)  (after GB refined)

<table>
<thead>
<tr>
<th>Approach</th>
<th>No_GB</th>
<th>GB</th>
<th>L 4</th>
<th>L7</th>
<th>GM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ΔE</td>
<td>2.76</td>
<td>2.31</td>
<td>1.53</td>
<td>0.96</td>
<td>1.17</td>
</tr>
</tbody>
</table>
Development of a unique indicator label

M. Habekost,
J. Lisi,
K. Rampersad
Ryerson University
Overview

- Introduction
- Unique features of the label
- Manufacturing challenges
- Results
- Outlook
Introduction

- Cleaning and disinfecting multi-touch surface in hospitals and other public places can be a daunting task
- A hospital can easily have 10,000 pieces of equipment that need cleaning every day
- Tracking the cleaning progress is difficult
- What can be done?
Some background information

- Improper sanitation and cleaning can lead to new infections that a patient did not have when being admitted to a hospital
- Health care associated infections (HAI) are on the rise
- CDC: In 2002 there were 1.7 million cases of HAI
  - 99,000 were fatal
  - Every 4.5 out of 100 patients get infected with HAI
Some background information

- In Europe:
  - 7.1 out of 100 patients get HAI
- In developing countries:
  - 15.5 out of 100 patients
- $4.5 to 6.5 billion spent in the US every year to treat HAIs
- $54 to 110 million spent in Canada to treat HAIs
Some background information

Number of Patients (per 100) Contracting HAIs While in Hospital

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.A</td>
<td>4.5</td>
</tr>
<tr>
<td>Europe</td>
<td>7.5</td>
</tr>
<tr>
<td>Canada</td>
<td>10</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>15.5</td>
</tr>
</tbody>
</table>
Some background information

- According to CDC an implementation of existing infection prevention strategies could lead to savings of US$ 25 – 31.5 billion in the healthcare system
- Also a 70% reduction of HAIs
- What is the solution to this problem?
Solution to the problem

- The IndiClean label!
  - Works with the most commonly used disinfecting agents
  - Can be tailored to indicate a 12 or 24 hour time frame since cleaning
  - The small label format allows the sticker to be placed on door handles, intravenous poles, light switches, wheelchairs, hospital beds etc.
Solution to the problem
Unique features of the label

Lunanos IndiClean™
Wipe when it is white

Test v1.0
Unique features of the label
Manufacturing challenges

- Various printing methods were evaluated for their practicality:
  - Offset printing
  - Screen printing
  - Flexographic printing
  - Inkjet printing
Manufacturing challenges

- Offset
  - *Ruled out, due to the thin ink film that can be printed with an offset press*

- Screen printing
  - *Tests done, but not very successful*

- Flexographic printing
  - *Printing method of choice!*
Manufacturing challenges
Manufacturing challenges

Screen printing test
Manufacturing challenges

- Printing press used:
  - Comco Cadet 700
  - 4 print station
  - In-line design
  - Laminating capabilities
Manufacturing challenges

- First tests were made to find the best combination of anilox rollers to achieve optimum opacity
- Rollers with a BCM volume of 12, 7.7 and 5 were tested
- Multiple hits of the indicator ink were applied
Manufacturing challenges

- A functional barrier has to be applied to the printed label so it can work properly
- Various methods were tried to do this
  - Laminate with adhesive backing on it
  - Application of an adhesive in the press and application of clear barrier material afterwards
Results

- Initial tests of multiple hits of the indicator ink over black flexo ink
- Prints done with and without doctor blade applied
- Experimentation with various tint values to achieve optimum opacity
Results

With doctor blade  
No doctor blade
Results

Triple hit of the indicator ink with different tint percentages
Results

Lunanos Design ~ July 14, 2014
Key objectives: Print 3 colour design and laminate

95, 90, 90 Lunanos, 35% adhesive

25%, 45%, 55%, 65%
Results

- Tri-color artwork and lamination of artwork
- Does not work for applying indicator ink over prelaminted artwork
- Register could not be achieved
- Stretching effect when press was stopped
  - change artwork to a single color layout
Results

- After various trials in regards to the ideal combination of anilox rollers and changes to the ink formulation the following production steps have been established:
  - Print artwork as single color (black)
  - Apply two hits of the indicator ink with 12 BCM anilox rollers
  - Apply glue pattern for lamination step
  - Laminate and die-cut
Results

- Although various changes have been made to the ink formulation to improve opacity and ink transfer, the press results were not satisfactory.
- Require the help of an ink manufacturer to optimize the ink formulation.
Conclusions and outlook

- Design and press procedures have been established
- Artwork needs to be protected by a film laminate
- Final lamination has to be done through a lamination attachment for the flexo press
- Final production on press still needs to be verified
- Field test of the labels in a hospital
Thank you for your attention!
Contact info

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