Print Quality Optimization: Understanding the Power of Software

IMI Inkjet Conference 2020 – Tempe AZ – 12-13 February

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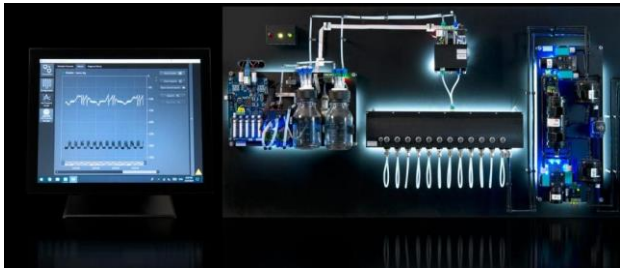
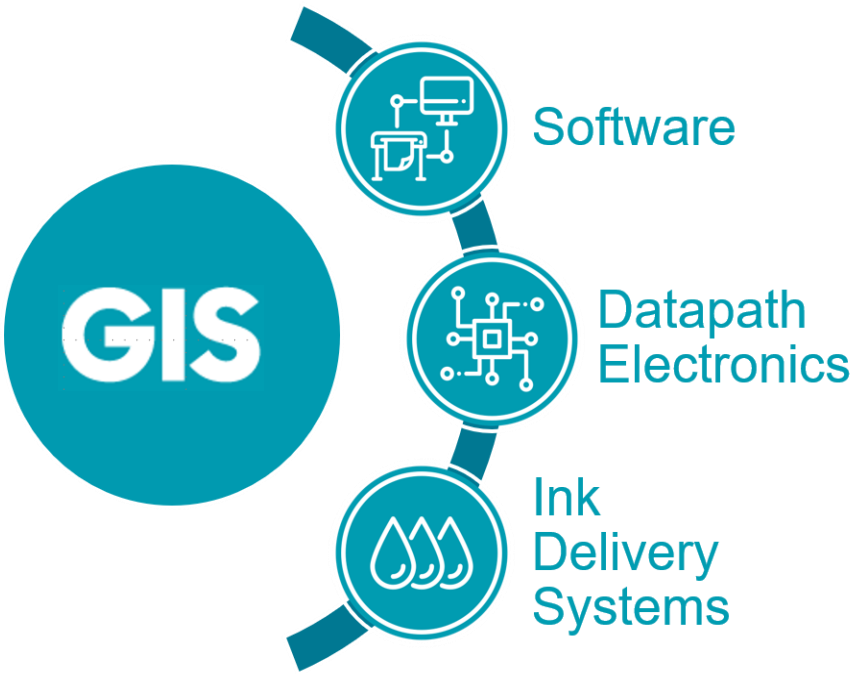
GIS Introduction

Complete image management from pixel to drop



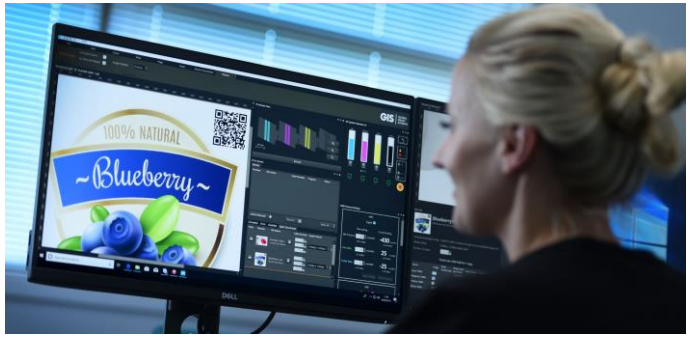
GIS customers - system builders, OEMs, integrators, fluid developers worldwide in many different applications and markets

The GIS EcoSystem

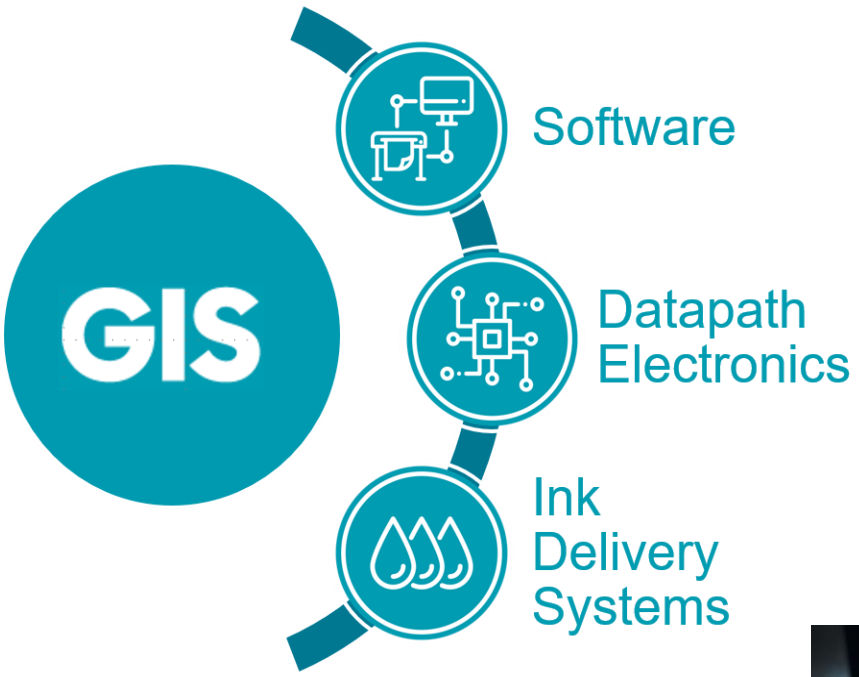


GIS Atlas™ Software

- Atlas Print Quality Tools
  - Printhead Density Correction
  - Missing Nozzle Compensation
  - Stitching Strategies
  - Geometry Engine
    - Rotation /Skew Correction
- Closed loop systems
- Customisable User Interface
- Atlas Screeners
- Atlas Variable PDF RIP
- Atlas Print Path Designer



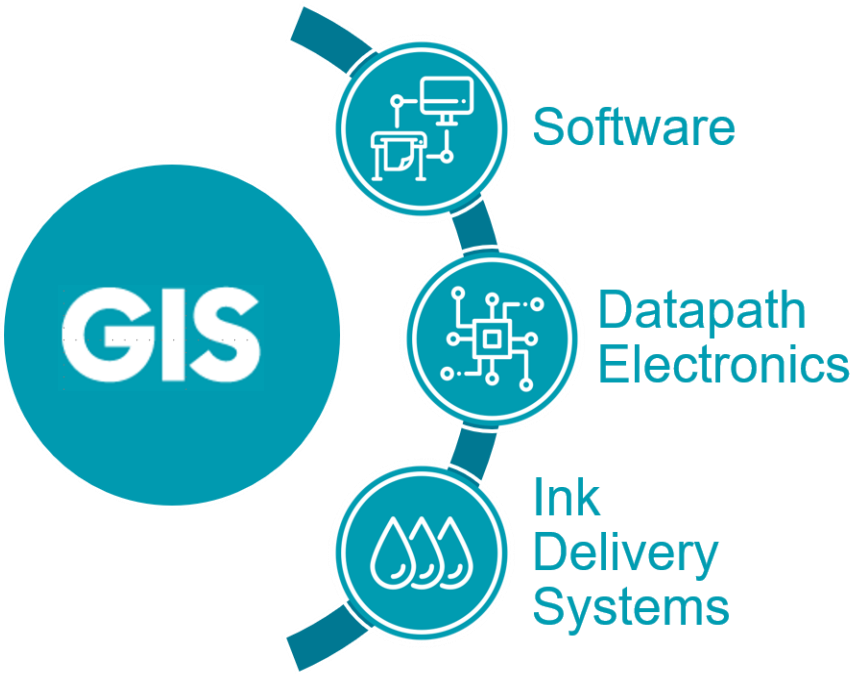
The GIS EcoSystem



GIS Datapath Electronics

- Support printheads from Fujifilm Dimatix, Konica Minolta, Kyocera, Ricoh SII, Toshiba Tec & Xaar
  - Epson – in development
- Choice of USB or Ethernet platforms
- Modular scaleable architecture
- Continuous diagnostics & monitoring
- Robust / Production proven

The GIS EcoSystem



GIS Ink Delivery Systems

- Standalone product
  - Can be used with any datapath electronics
- Fully customizable
  - Family of header tank designs and sizes for different printheads
  - Degassers, heaters, pumps etc
- All flow modes supported - including high pressure flow

Presentation Agenda

Factors affecting print quality

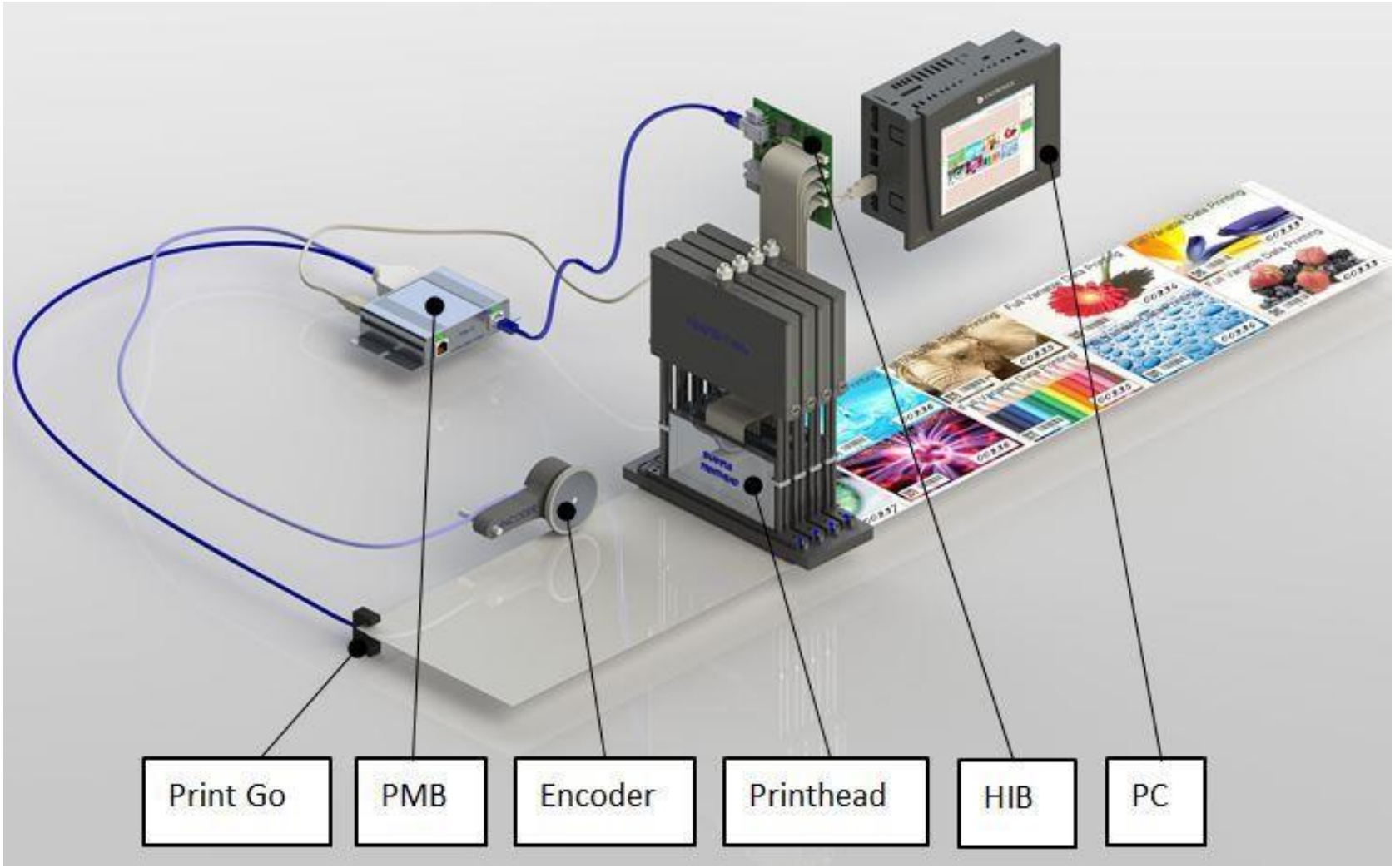
- Key print quality issues

Software correction methods

- Image Management
  - Stitching
  - Screeners
- Corrections & Compensations (just a few examples)
  - Printhead linearization
  - Rotation / skew correction
  - Missing nozzles compensation
  - Closed loop or offline correction

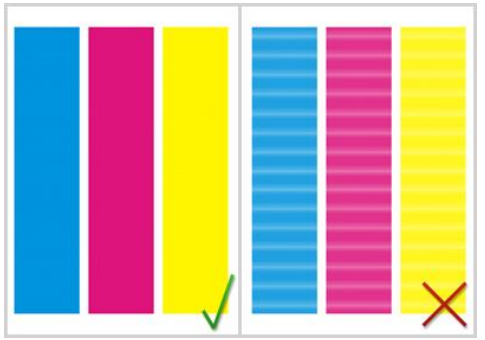
Print Quality Issues

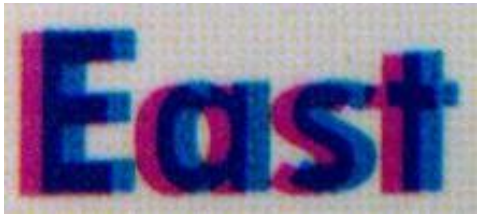
Simple Concept versus Complex Reality



Quality Issues….(Just a Few Examples)

- Jetting errors
- Image artefacts
- Poor edge definition
- Grainy images
- Density shift
- Nozzle drop outs
- Poor registration
- Texture/unevenness in areas of solid colour
- Colour not stable
- Colour bleed
- Ink supply issues
- Lack of thermal control
- Reticulation





Factors Effecting Print Quality

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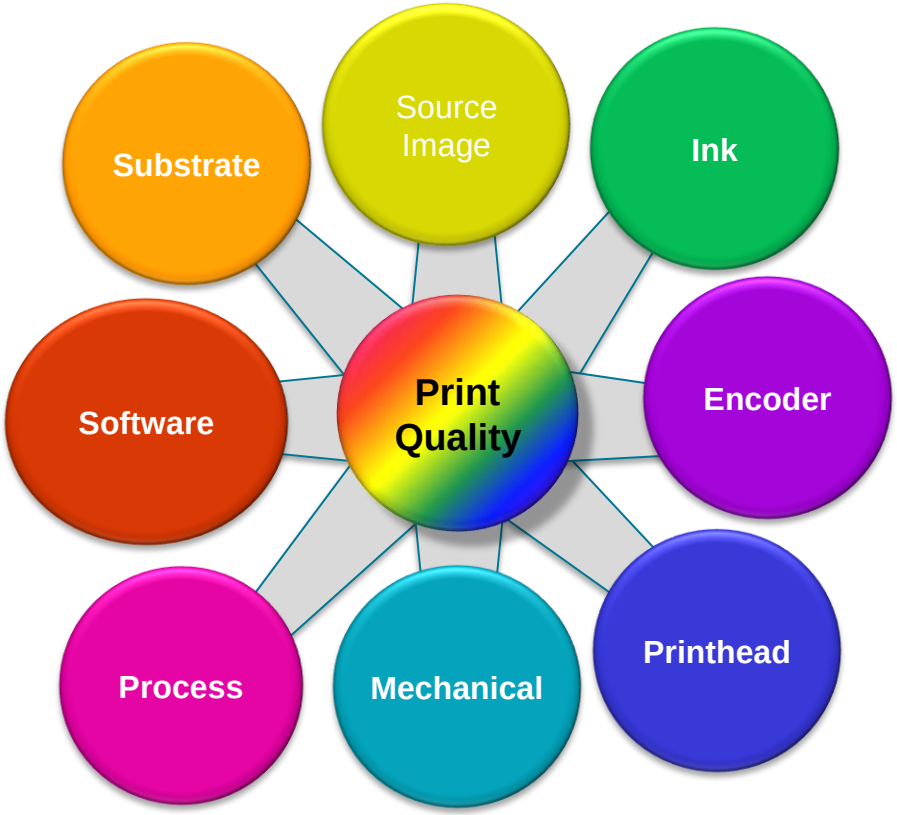
Inkjet printing systems have interacting & co-dependent parts



As inkjet enters more demanding applications – print quality requirements increase

Different Applications - Same Challenges

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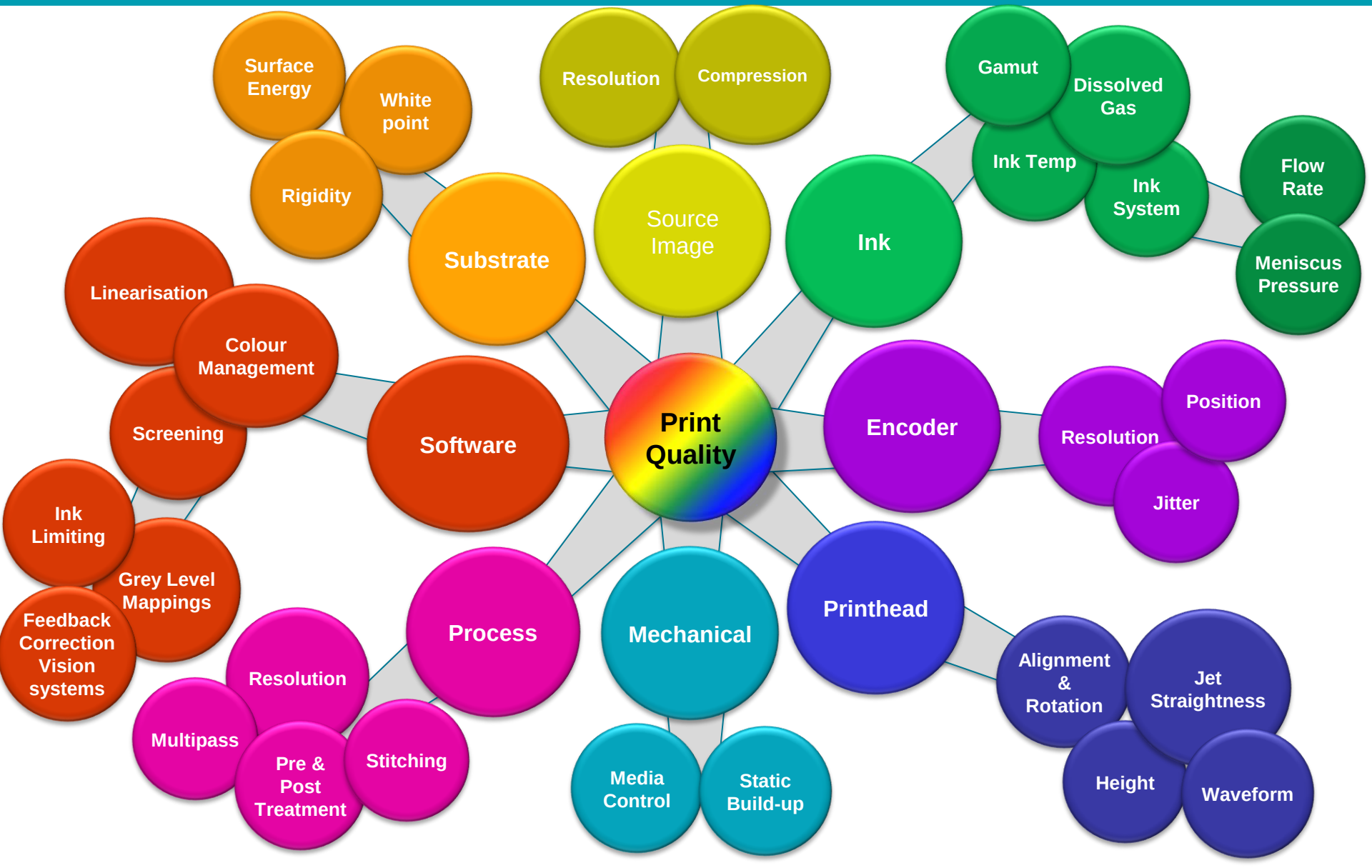
Graphics	Wide format Textiles Packaging Labels Ceramics Glass Laminates Varnish	**Need to achieve:-** • Flat colours • Uniform coatings • Invisible stitch zones • Colour consistency • Colour accuracy • Edge definition • Accurate drop placement • Accurate registration **Need to correct:-** • Uneven printhead density • Acceleration /deceleration issues • Missing nozzles • Rotation / skew • Banding
Materials Deposition	Functional coatings Encapsulation layers Conductive tracks Colour filters	

Factors Effecting Print Quality



Software Correction Technologies

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Software can compensate for many system imperfections

Software Correction Methods

Image management

- Screeners
- Printhead stitching

Corrections and compensations

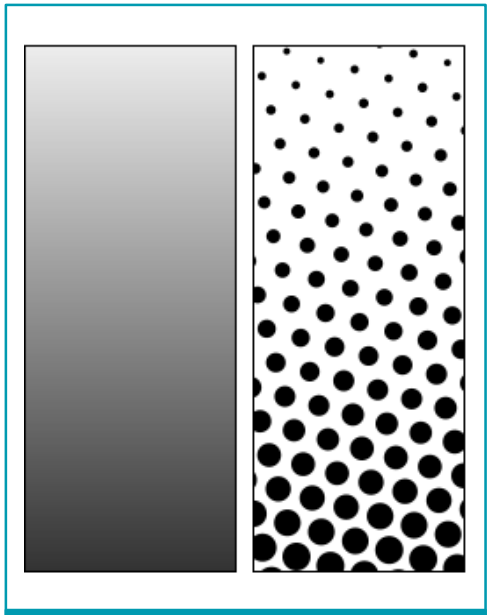
- Achieving flat colours with printhead density correction
- Colour and density correction
  - Grey level selection
  - Printhead linearisation
  - Colour channel linearisation
  - Colour management
- Nozzle out compensation
- Colour and density drift correction
- Ink flow compensation
- Substrate placement correction
- Geometry correction

(Some, but not all, are covered in this presentation)

Image Management - Screeners

Half Tone or AM Screening

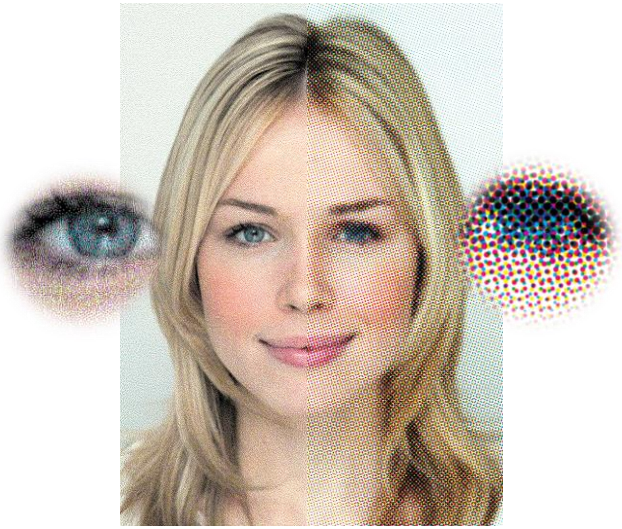
- Amplitude Modulated (AM) was the dominant form of screening for most of the C20th
- Halftone screening is technique that gives the viewer of a print the impression that they are seeing different shades or densities of ink
- It takes advantage of the eye's limited resolution and the brains ability to average colour across areas
- Up close, AM screening can look coarse and unappealing but from a distance the eye will have increasing difficult in distinguishing it from any other output method



Halftone or AM Screening

Frequency Modulated (FM) Screening

- Frequency Modulation keeps the dots the same size, but varies the distance between them
- Result is a much smoother greyscale
- Requires good dot gain control
- Also know as Stochastic screening
- Popular implementations are Error Diffusion (ED) or Ordered Dither (OD)



Frequency Modulated (Floyd Steinberg)

Amplitude Modulated

Error Diffusion vs Ordered Dither

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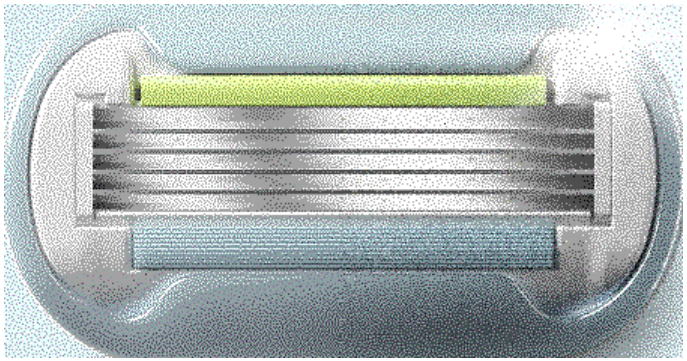
- Ordered Dither divides the image into fixed size cells, and turns on pixels in each cell according to the contone value
- Error Diffusion calculates the error caused by thresholding a given pixel and propagates it to neighbour pixels, in order to compensate for the average intensity loss or gain.

Error Diffusion Ordered Dither

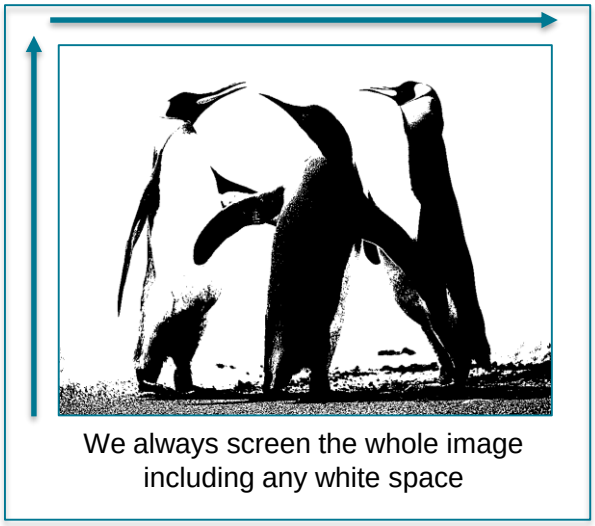
- Comparison is difficult without controlled viewing conditions
- But side-by-side ED shows slightly less grain in skin tones and better fine detail
- Differences become smaller at higher resolution



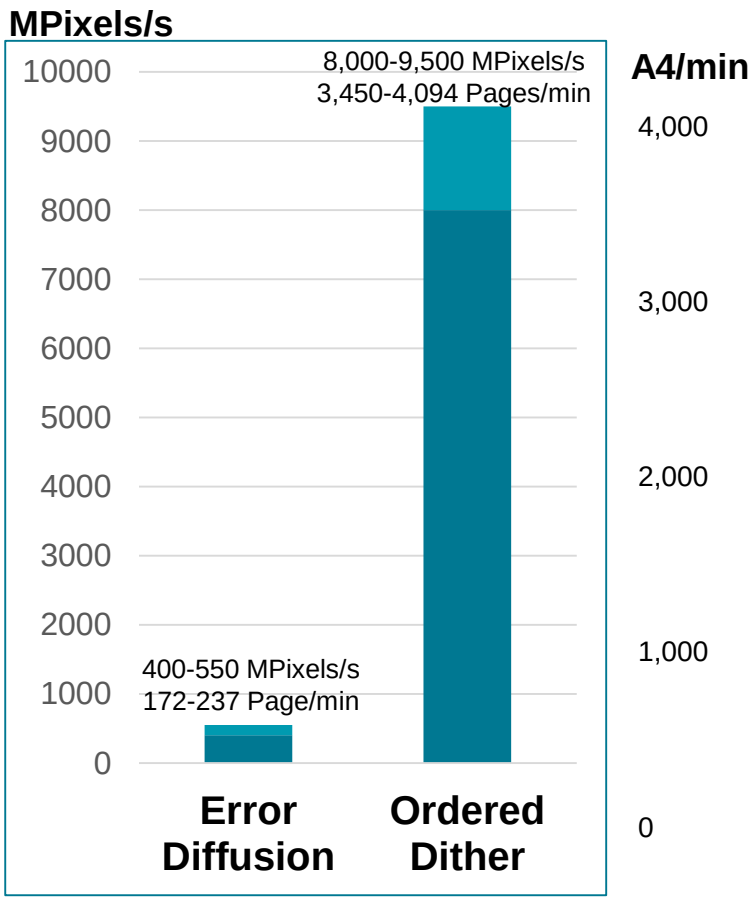
Error Diffusion Ordered Dither

Error Diffusion vs Ordered Dither

- Ordered Dither is significantly faster than Error Diffusion
- Throughput performance measured in millions of pixels per second - visualised in pages per minute
- These numbers are just for a single core



We always screen the whole image including any white space



Performance measured on various Intel i7 Core processors, 2013 onwards.

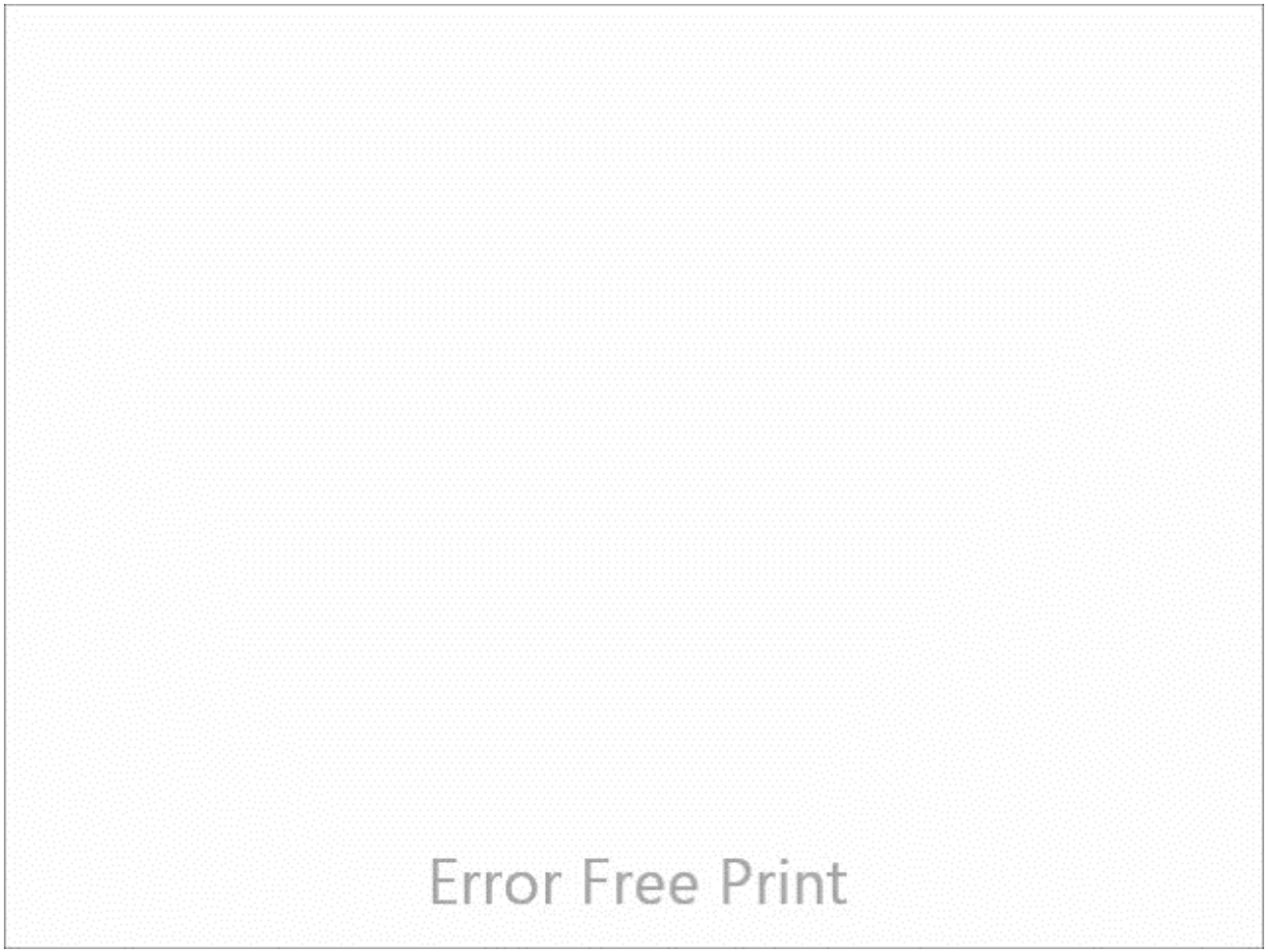
Image Management - Stitching

Exploring Stitching Strategies

- Multi-pass
- Single-pass

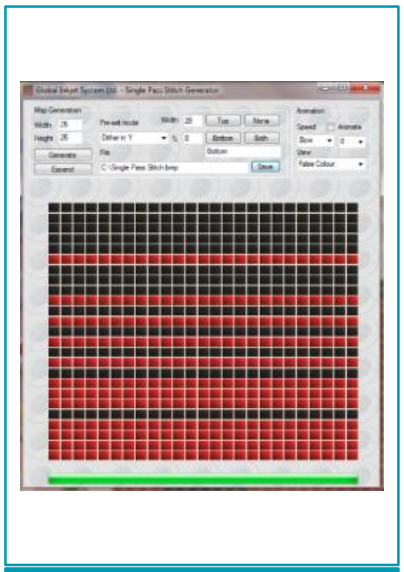
- Printhead-to-printhead non-uniformity
- Colour-to-colour density variation
- Alignment errors (printhead-to-printhead, colour-to-colour)
- Jetting errors (nozzle jet deviation)

Stitching Strategies – Understanding Errors



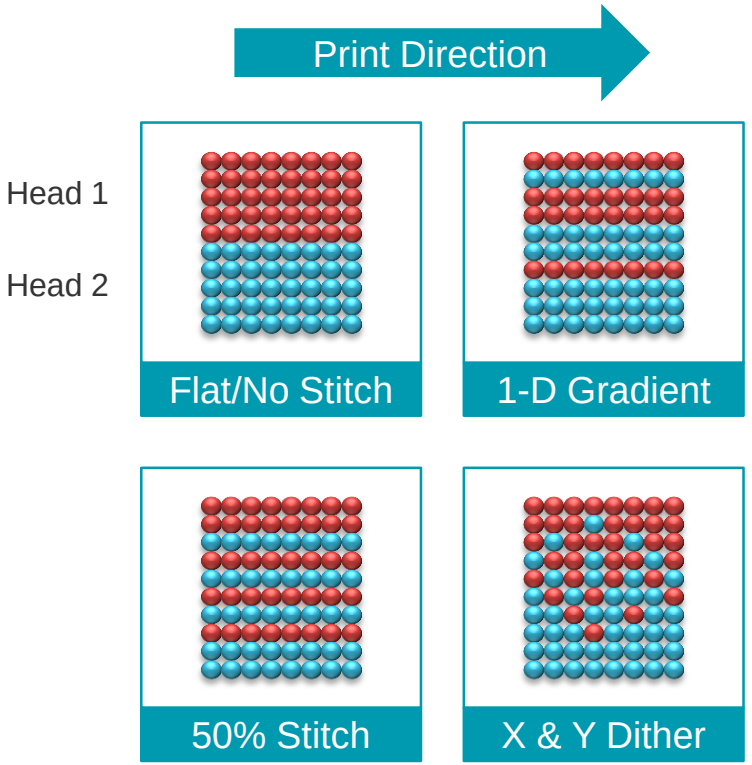
Hard Stitching (Masking)

- **Masking (Hard Stitching)**
  - Nozzle on/nozzle off
  - Wide variety of options
- **Stitches can massively improve output quality & different applications benefit from different strategies**



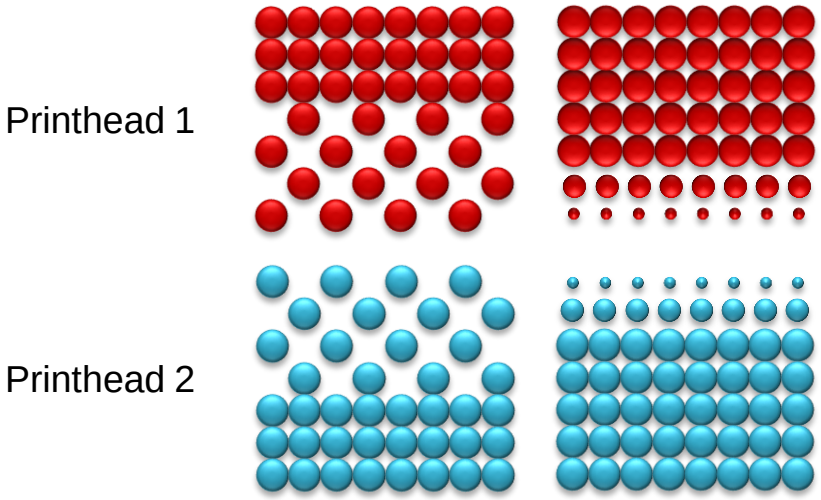
2-D Density

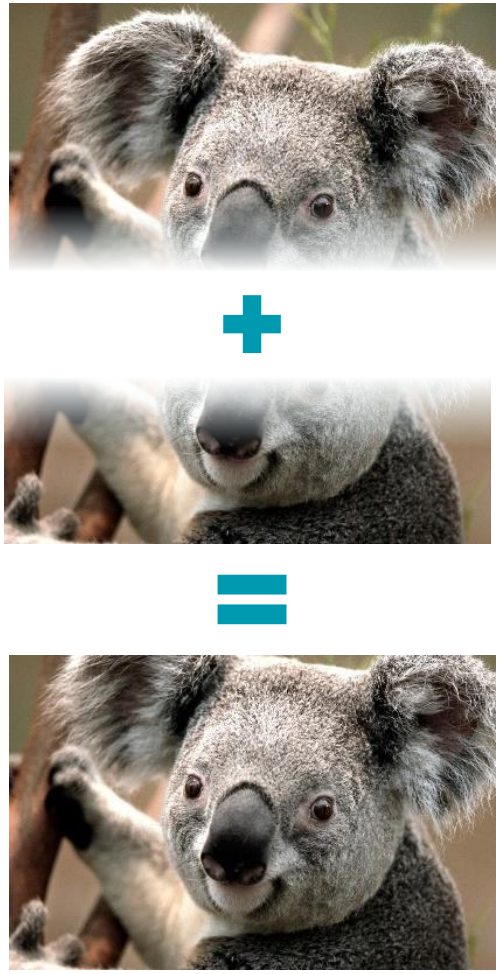
X & Y Dither



Soft Stitching – grey scale stitching

- **Greyscale stitching makes full use of the greyscale capabilities of the head**
  - Slowly reduces the density of the image printed by one printhead while increasing the density printed by the next printhead
- **Only adds value over masking in areas where the density of the image is greater than the smallest drop size**





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Software Correction Methods

A few examples…..

Linear Printhead Density

Inkjet systems need to:

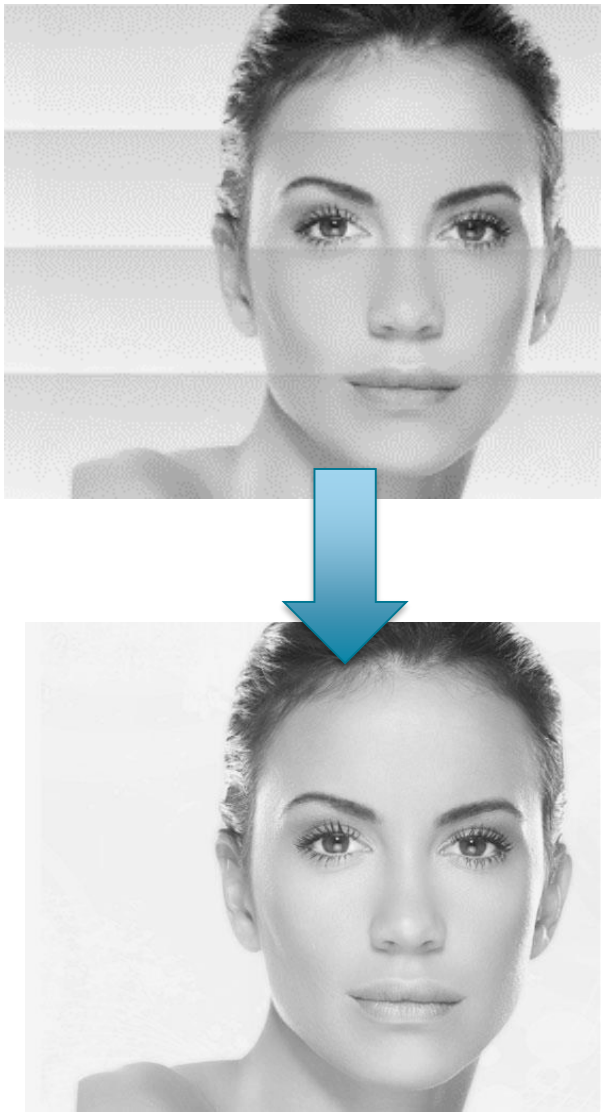
- Stitch printheads without visible joins
- Print large areas of solids/flat colours

Drop volumes not always consistent across printhead

- More apparent the more heads you have in an array
- “Non-linearity” in drop volume
- Even small difference can affect final print – particularly areas of solid colour
- We want uniformity - flat colours

Lots of reasons this can happen:-

- Printhead manufacturing issue - drop ejection may not be consistent
- Temperature variation in ink system - affects ink viscosity
- Piezo activity - heavy use of some sections of printhead creates warm areas
- Electronics - uncalibrated/low quality electronics may affect drop volume



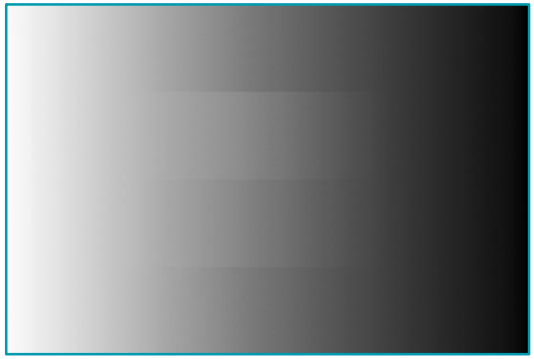
Printhead linerisation correction

Electronic/printhead solutions

- Depending on printhead technology
- Trim each nozzle/cluster of nozzles/nozzle bank
- Trimming can introduce drop alignment problems
  - (Tuning for volume will modify velocity)

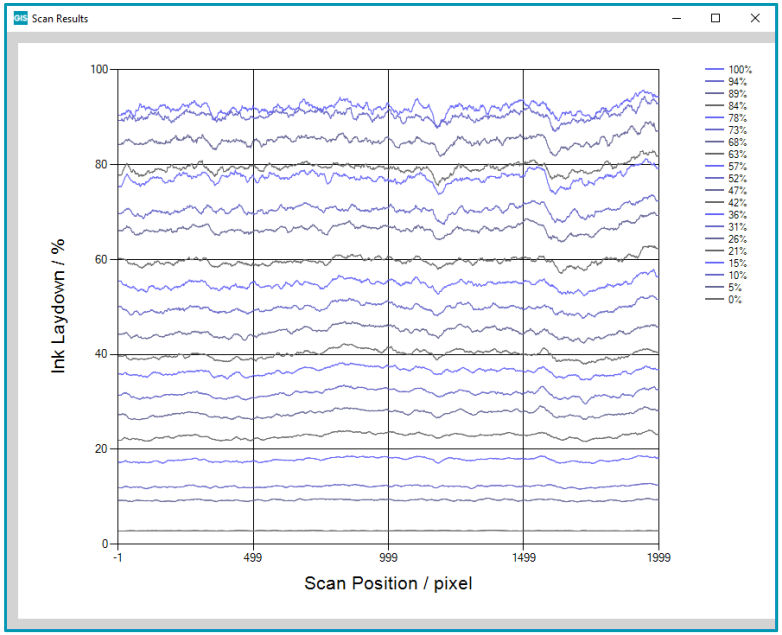
Image correction – offers greatest capability

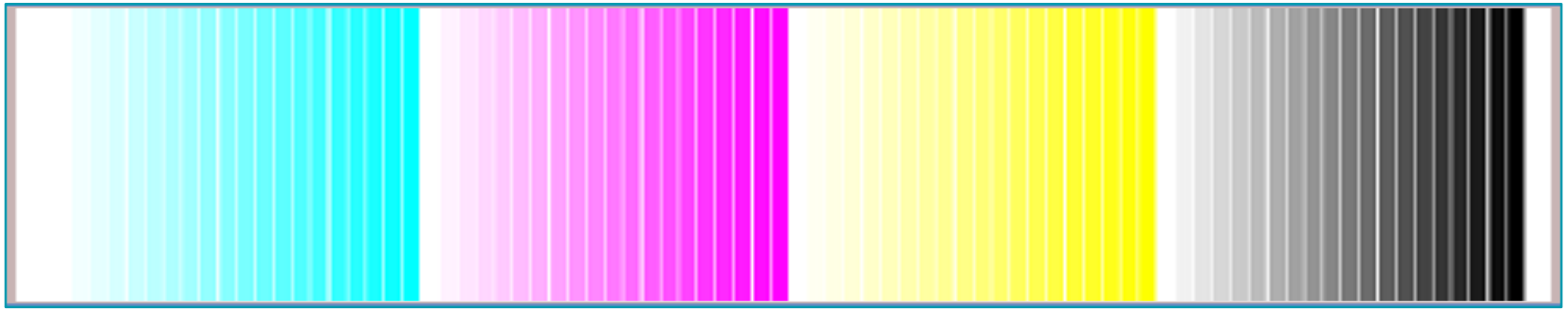
- RIP'ed data (contone or screened) can be manipulated to:
  - Reduce the number of drops in given area, or
  - Reduce the size or value of the greyscale drop in a given area



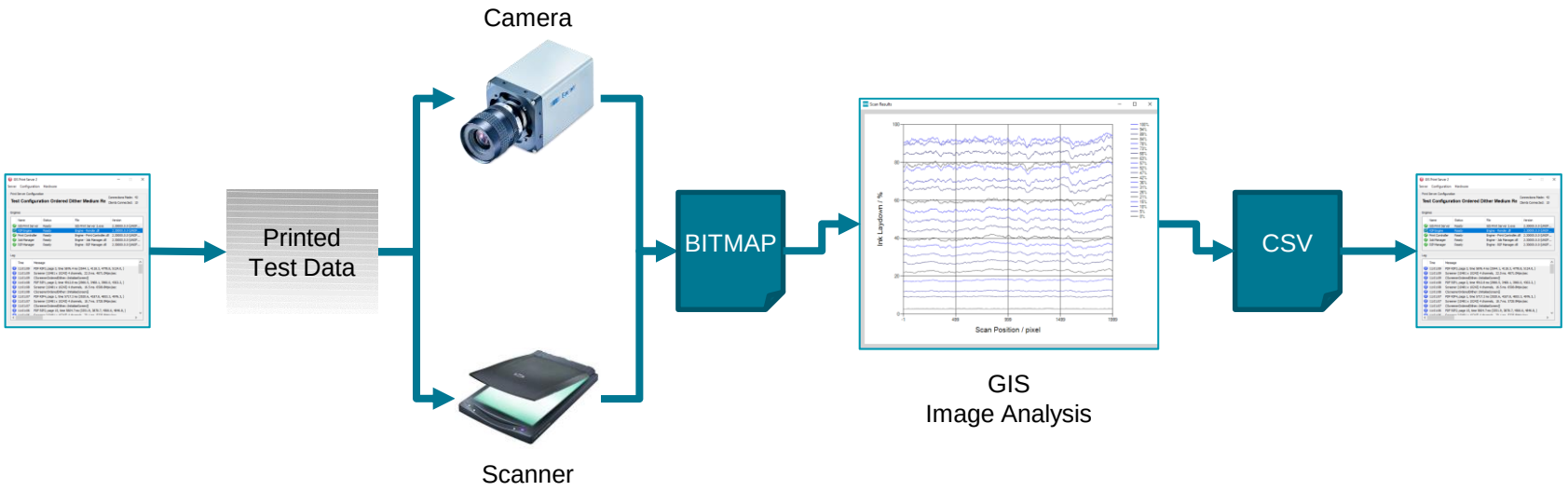
Printhead linearisation
(via image correction)

- Aim is to ensure achieve even density across a full printhead array for each grey level
- Achieved by printing grey scale test pattern for each colour channel and measuring the density across the printhead array at a range of grey levels
- Then adjusting the grey level mapping at intervals across the printhead array





Printhead Linearisation
(via image correction)



Missing Nozzles

Nozzle sizes are getting smaller

- More easily blocked or deflected

Large print bar arrays

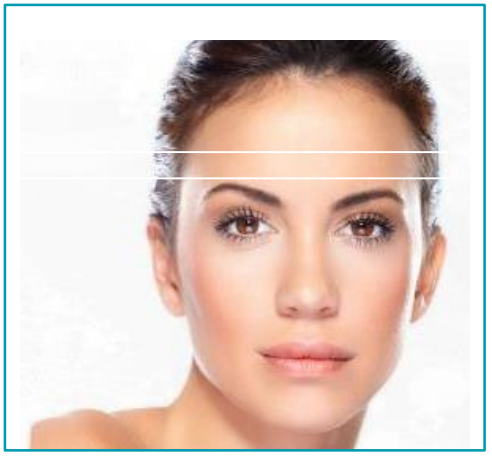
- Many more nozzles
- Higher probability of issues and lower MTBF
- Need coping strategies

Strategy 1: Redundancy

- Add second row of printheads per colour so when one nozzle fails another can be used
  - Expensive

Strategy 2: Hide the problem

- Identify where a nozzle is faulty and spread the jetting responsibility to neighbouring nozzles and/or colours



Nozzle Out Compensation

Isolated nozzles work best

- Clusters of nozzles much more difficult to hide
- Technology works best where there is some substrate bleed/ drop overlap

Many different strategies exist using neighbouring nozzles

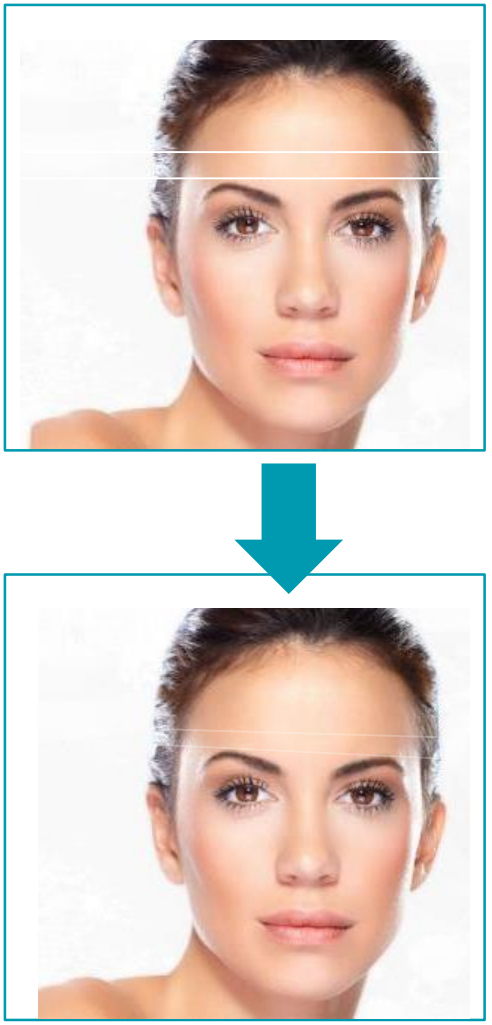
- Correction in contone or screened data
- Nozzle correction involves the “boosting” of neighboring nozzle density
- Hide error in same colour plane to neighbouring nozzles
- Hide error in other inks - in multi-ink backgrounds
  - If Cyan nozzle fails - could add a little black to hide white space
  - If Black fails – use composite (CMY) black

Works best in mid & light mid tones

- Also improves dark tones

Helps disguise/makes the missing nozzle less visible

- Less white space



Geometry Correction

- Key challenge is alignment & registration with pre-printed substrate
  - Pieces/sheets or in-line web
- Many different possible distortions (image and/or media) – can be solved by:-
  - Mechanical
  - Vision systems + software

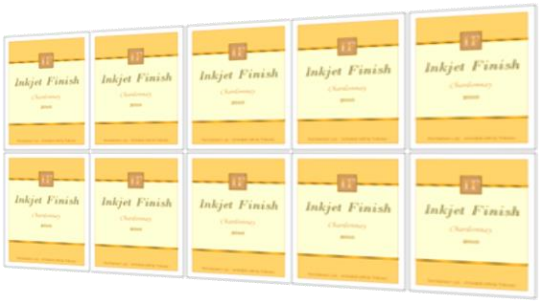
Translation (X & Y)

- Product detect (X translation)
- Feeders or software offset (Y translation)

Rotation

- Feeders
- Vision system + fiducials + software

Challenges of Finishing

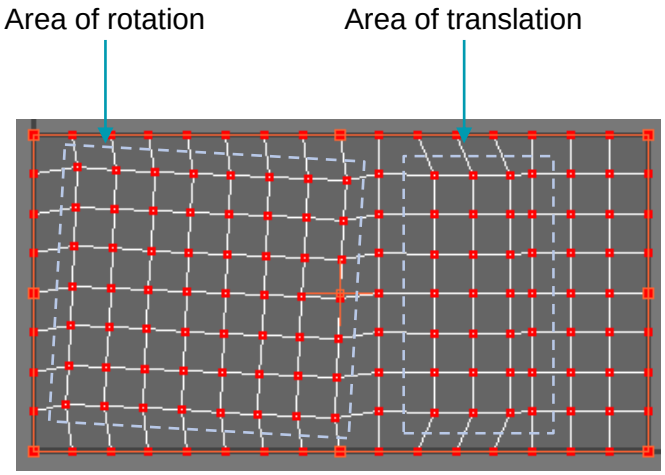


Trapezoid / Skew

- Vision system + fiducials + software

Stretch and Compression (X & Y)

- Vision system + fiducials + software
- Encoder + product detect



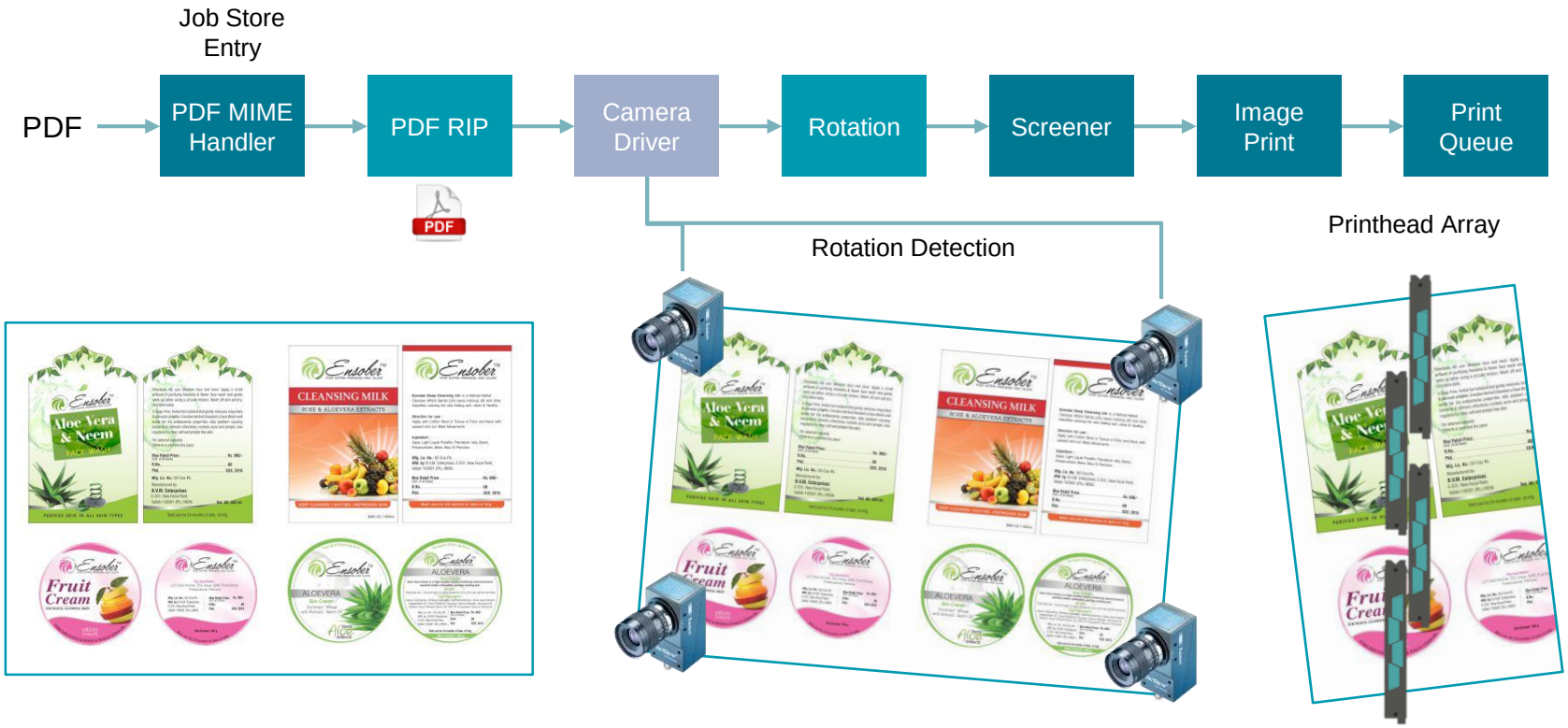
GIS Correction Map For Finishing Layer (inverse of error)

Mesh based correction accurately places finishing data in the desired location. Handles all translation, rotation, stretch, compression and skew as well as localized distortion correction

- General software conversion approach
- If you can measure the error – it can be corrected

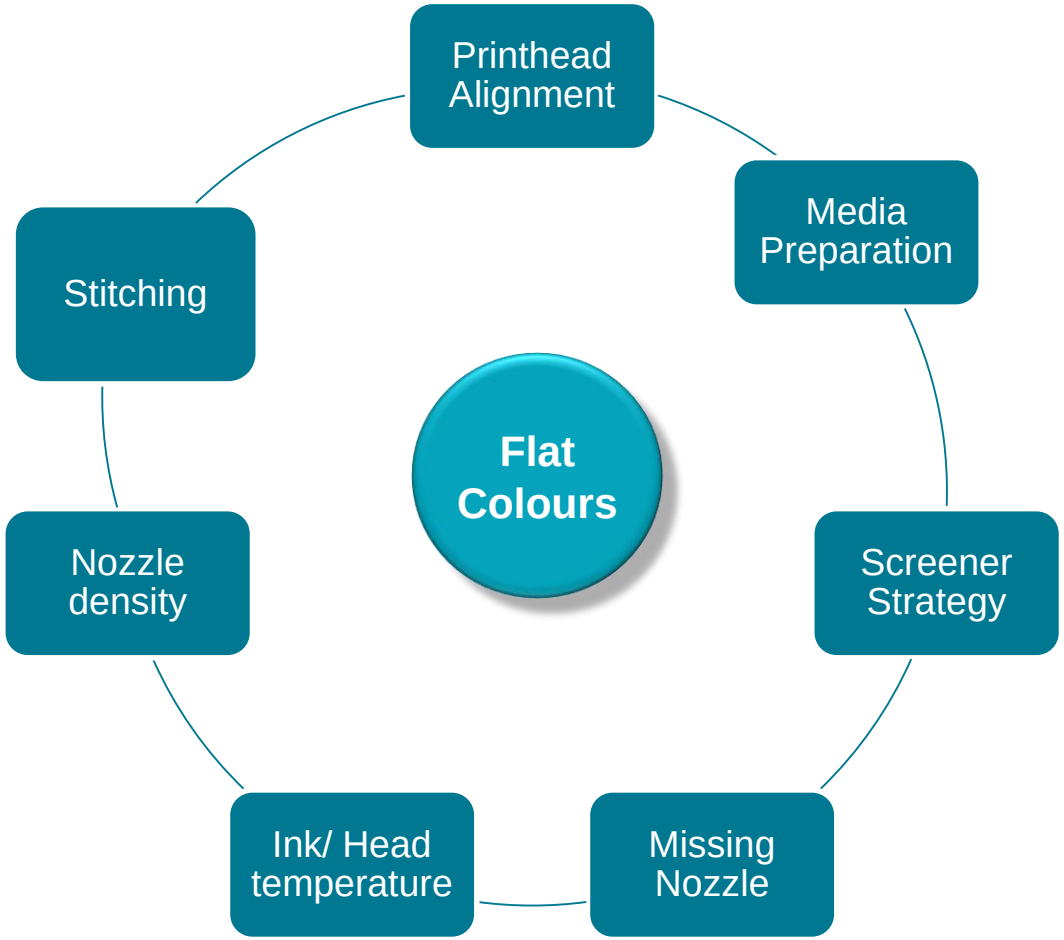
Software Correction - Example

Rotation Correction for Spot Varnish – Real Time



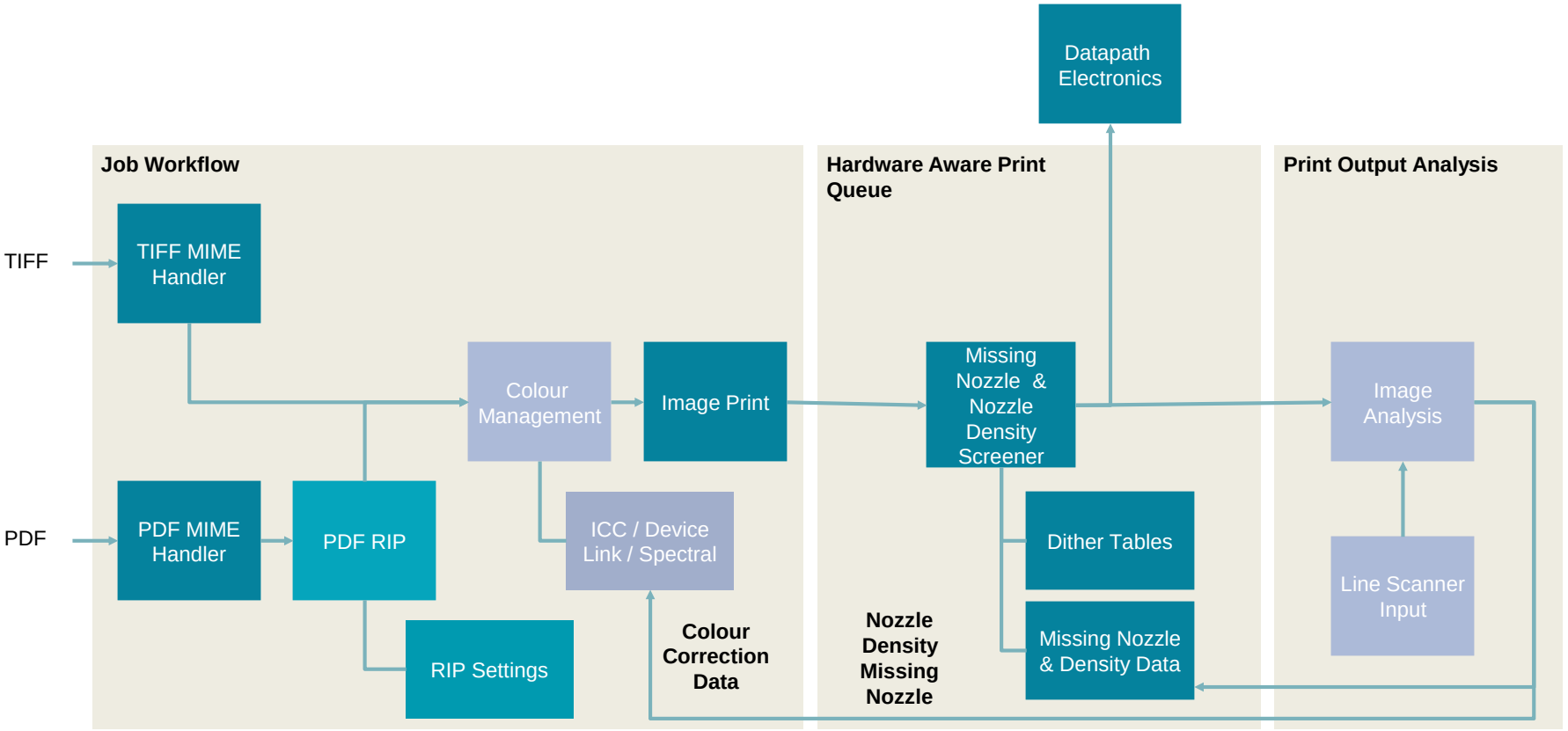
Software Correction – Interaction

- For example - many factors contribute to achieving flat solid colours / uniform coatings
- Inkjet printing systems have interacting & co-dependent parts
- Suite of technology solutions needed
- **Multiple strategies required for optimal results** (not just software)



Closed Loop Workflows

- Closed loop software technology can combine many software corrections tools to achieve consistent print quality
- Missing nozzle compensation, printhead density and colour shift correction – required for high end systems
- Requires very high data rate and processing capability



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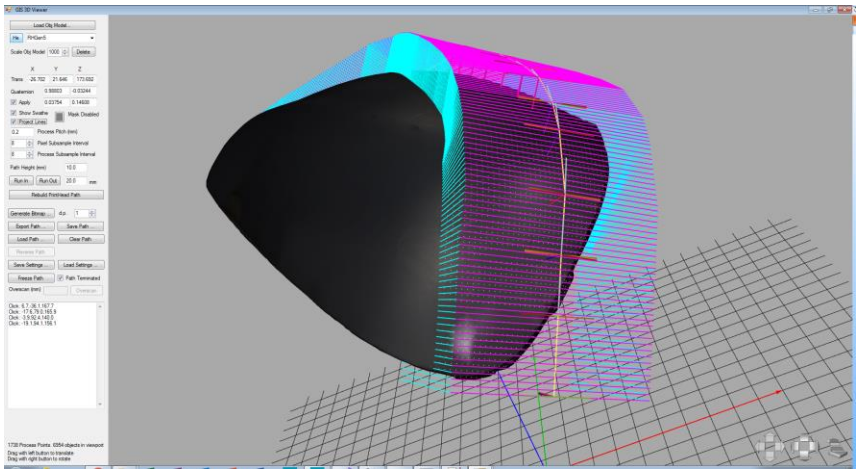
New Directions

Software Unlocks New Markets

Jetting Functional & Decorative Coatings on Industrial Parts

- Combined inkjet and robotics system control
- Unlocks new market opportunities in coating & decorating injection molded parts – automotive industry; industrial components
- Multiple software print quality tools enabled
- GIS Print Path Designer software



Motion Control

Print Data

GIS video at: https://vimeo.com/376156000/b2a720f1e5

Print Quality Summary

- Pressures on achieving & maintaining image quality will increase
- Advanced software capabilities are key

Software compensation can significantly improve image performance for system inaccuracies and errors

Inkjet systems have interacting & co-dependent parts. Multiple print quality strategies required for optimal results

Some corrections can be carried out offline, others require real-time correction with closed loop systems

Innovative software can unlock new applications & opportunities

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