GIS GLOBAL INKJET SYSTEMS

Inkjet Summer School
今さら訊けないインクジェット技術
ヘッド駆動技術の基本とインク供給系まで含めた装置設計のヒント

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Ohno Inkjet Consulting
OIJC

Who is it? What will he talk?

GIS GLOBAL INKJET SYSTEMS

金子明弘

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2009年10月～2015年7月　インクジェットヘッドメーカー

2015年8月～ Global Inkjet Systems

仮題

「ヘッド駆動技術の基本とインク供給系まで含めた装置設計のヒント」

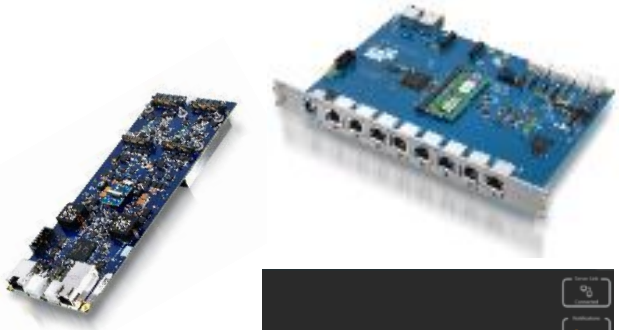
Who is it? What will he talk?

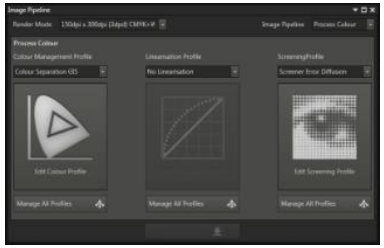
- GIS Introduction
- Drop on Demand Inkjet Technologies
  - Brief introduction
- Ink/Fluid Delivery Systems
  - Types of systems & designs
- Image Quality
  - Contributing factors
  - The importance of software
- Industrial Inkjet Applications
  - An overview

GIS – Company Overview

GIS GLOBAL INKJET SYSTEMS

- **Leading provider of technology solutions to industrial inkjet systems builders**
- **Supported printhead manufacturers**
  - Fujifilm Dimatix, Konica Minolta, Kyocera, Ricoh, SII, Toshiba Tec, Xaar
- **Founded November 2006**
  - Privately owned
- **Based in Cambridge, UK**
  - Technical support in UK, China and Japan
- **Employees 70**
- **Patent protected technology**
- **Supplier & partner to over 130 customers worldwide**





GIS Products

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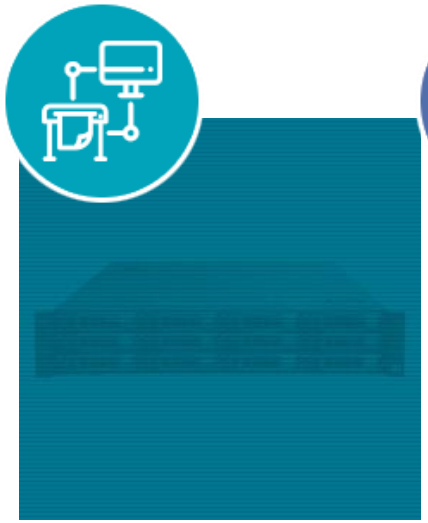
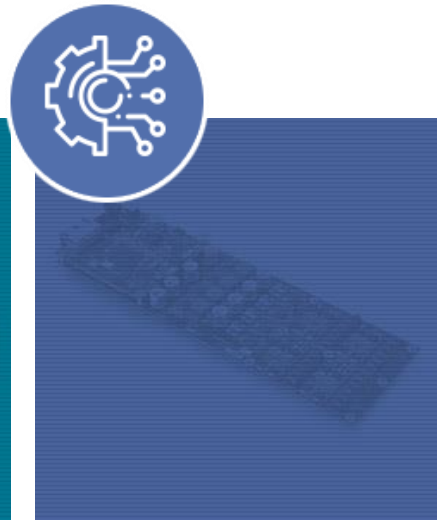
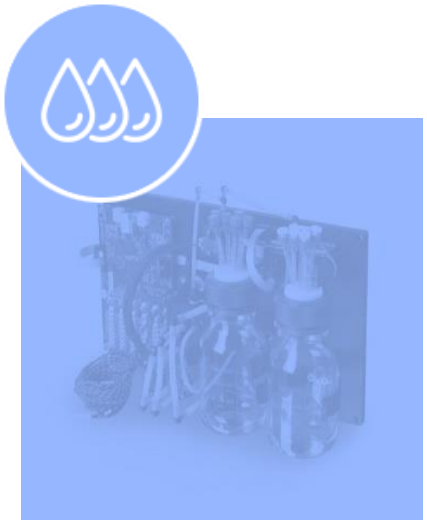
DFE
Atlas® User Interface



Machine Control
Atlas® Server



Print Controllers
Drive Electronics



IDS
Ink Systems

Drive Electronics

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Fujifilm Dimatix	Konica Minolta	Kyocera	Ricoh	SII	Toshiba Tec	Xaar	Others
Nova Galaxy S-Class Polaris Sapphire/Emerald StarFire SG1024 Samba G3L/G5L StarFire SG600 GMA65* * = in development	KM512 KM1024 KM1024i KM1024iSAE-C KM1800i KM1800iSHC-C	KJ4A-AA KJ4A-TA KJ4A-RH KJ4B-QA KJ4B-YH KJ4A/B-03 KJ4B-1200R*	MH2420 MH2620 MH2820 MH5420 MH5421 MH5440 MH5441 MH5220	RC1536*	CF1ou CF1L CF1LX CK1	1003 GS6 1003 GS12 1003 GS40 5601 3p0	Please contact us if you are interested in any printheads not listed.






- Boards provide access to all the standard printhead settings including voltage levels, binary & greyscale mode and waveform settings
- Standard data and power connectors

Atlas® Software Platform

GIS GLOBAL INKJET SYSTEMS

Comprehensive Software Platform

- Software for end users, machine development, commissioning and support
- Single platform to cover many products
- Supports scanning, single pass, direct-to-shape and custom applications

Quick Route to Market

- Rapidly develop user interfaces using production-ready components
- Enhance, restrict and customise components for your application
- Compatible with existing software / system platforms

Atlas®

Print Systems Integration

- Datapath / electronics
- RIP & Workflow (PDF-VT, JDF, variable data)
- Ink delivery / cleaning systems
- Vision, monitoring, verification
- Automation, motion, transport
- PLCs, heaters, dryers, UV curing

SDK Module Licencing

- Fully customisable interface – including fonts, icons, colours and branding
- Easy-to-implement language localisation
- Complete GUI control with the ability to create tools
- Integrate with third-party software

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AGENDA

Drop on Demand Inkjet Technologies

- Brief introduction

Ink/Fluid Delivery Systems

- Types of systems & designs

Image Quality

- Contributing factors
- The importance of software

Industrial Inkjet Applications

- An overview

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Technology Introduction

In this section we will cover:-

- Brief introduction to Drop on Demand inkjet technologies
  - Thermal
  - Valvejet
  - Piezo
- Understanding binary vs. greyscale printing

Continuous Inkjet vs. Drop on Demand

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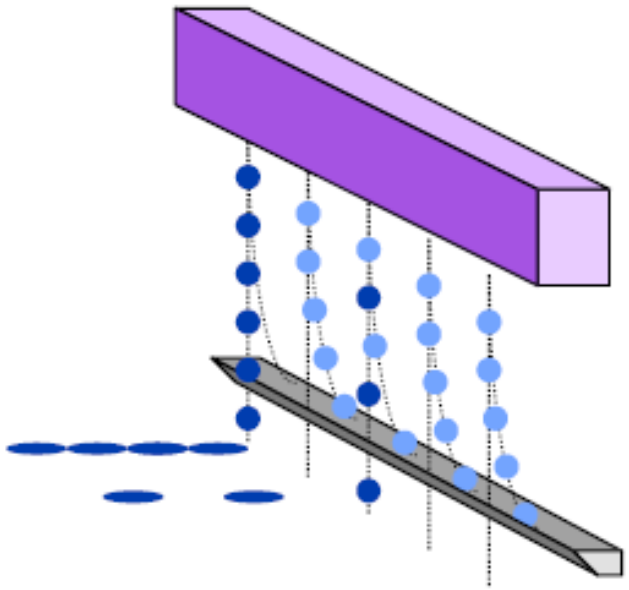
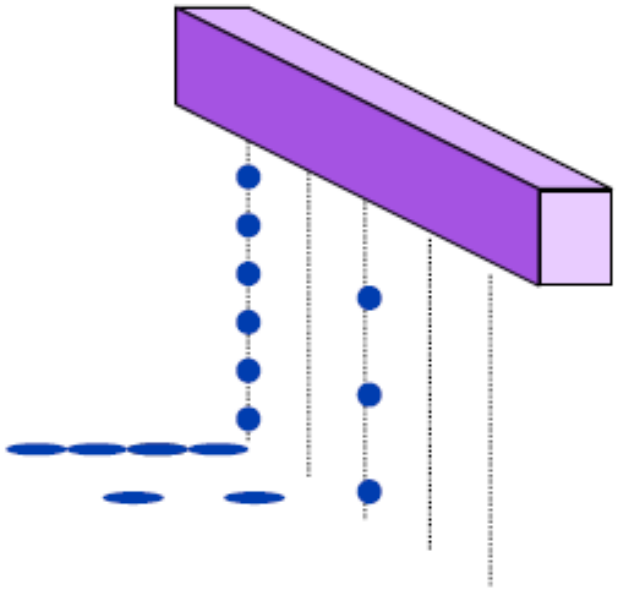


Continuous

drops generated continuously, switched to print



Drop on demand

drops generated only when required

Diagrams courtesy Pivotal Resources

Drop on Demand (DoD) Inkjet

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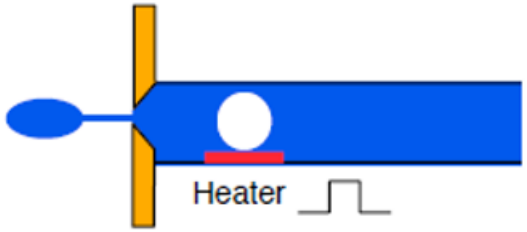
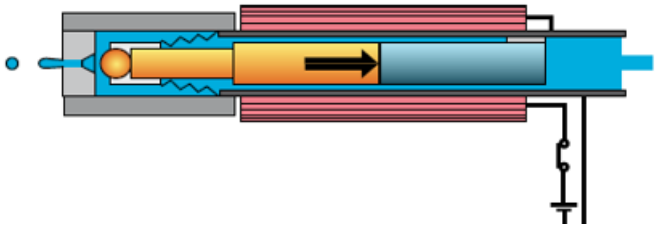
Drops generated only when needed

- Thermal



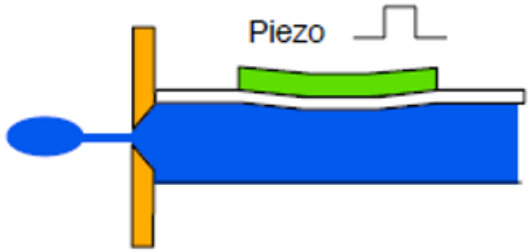
- Tiny heating element in the ink chamber; current applied causing it to heat rapidly; thin film of ink above heater vaporises into expanding bubble; causes pressure pulse that causes drop of ink to eject

- Valve jet



- Micro valve is actuated electromagnetically and ink flows through it directly; No current = valve closed; current applied, valve ball magnetically pulled back; the valve opens and a drop ejects

- Piezo

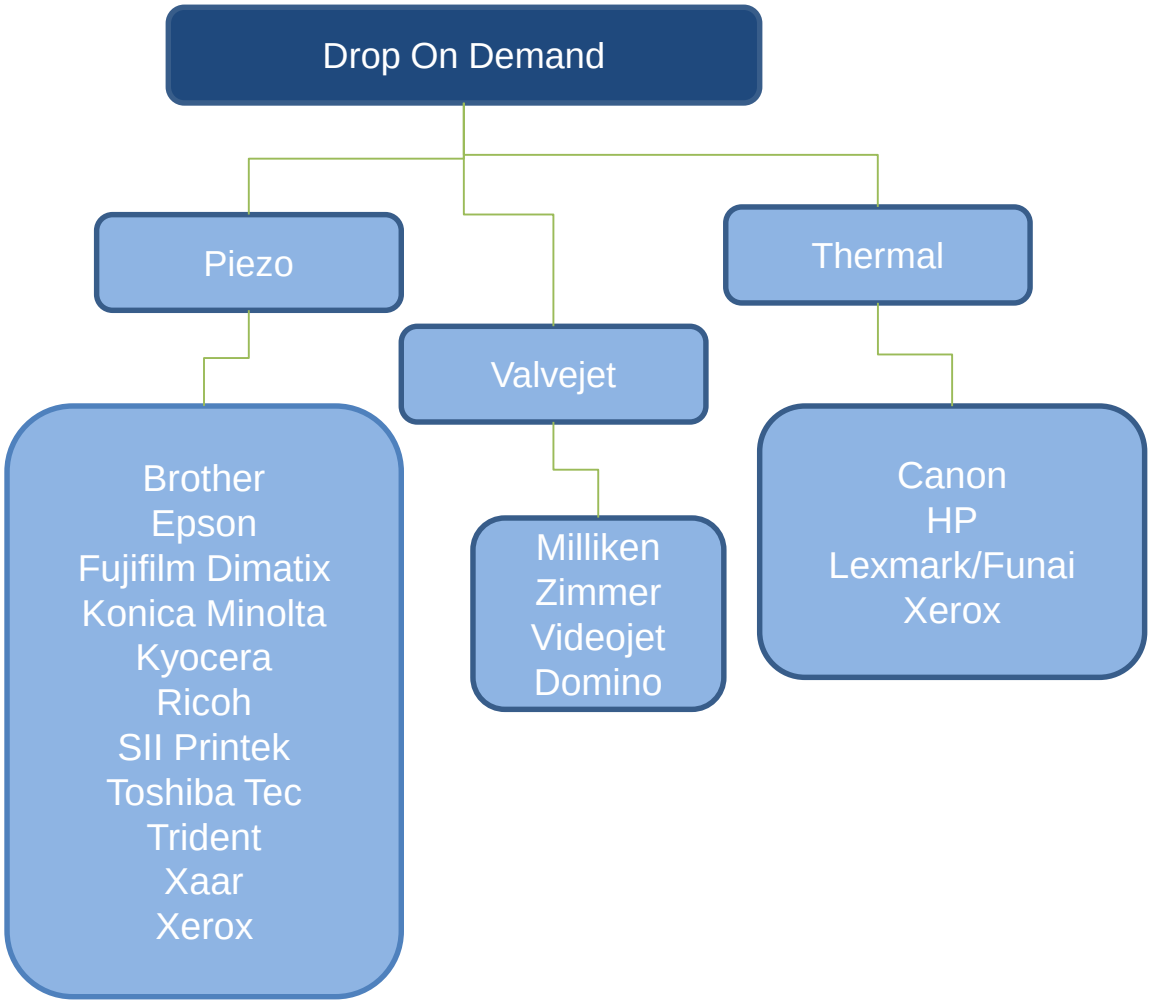


- Piezo ceramic material deforms when voltage applied; distortion creates pressure pulse that causes drop of ink to eject

The focus of this presentation is **Piezo DoD**

TIJ & Piezo diagrams courtesy Pivotal Resources

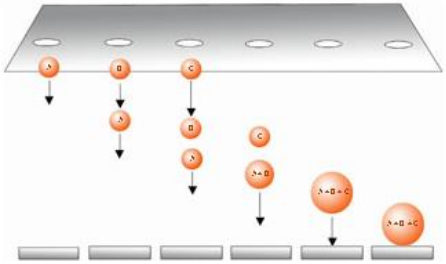
Drop On Demand Inkjet



Summary of technologies and players

Binary vs. Greyscale

- **Binary**
  - One drop size
  - On or off
- **Multi-pulse binary**
  - Special mode offered by some printheads
  - Ability to create larger drops
- **Greyscale**
  - Variable number of drops
    - Drops coalesce in flight or at nozzle plate
  - Directly vary drop volume
    - Vary waveform according to drop size required
    - Apply different waveforms to each bank of piezo



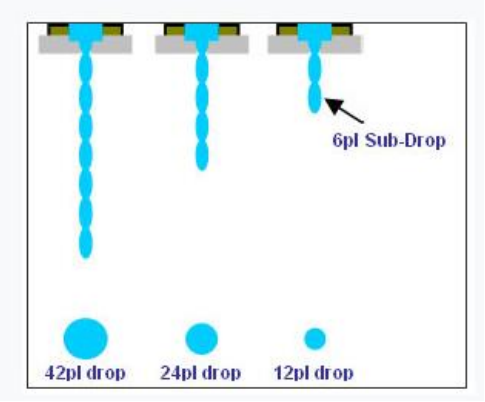


Image source: ImageXpert, Xaar

Binary vs. Greyscale

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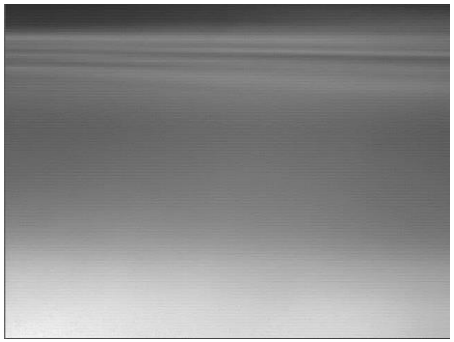
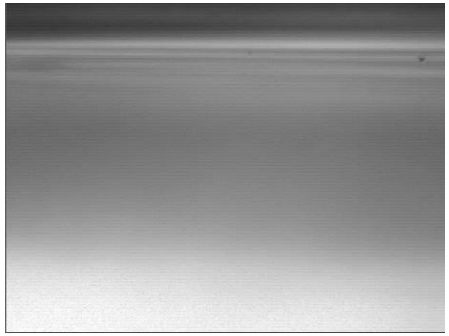
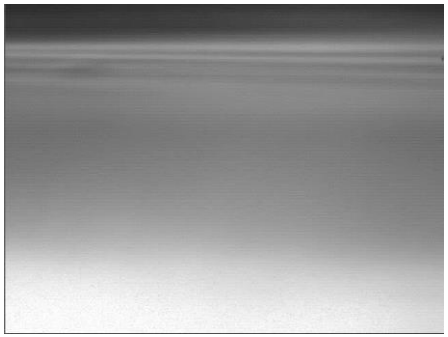
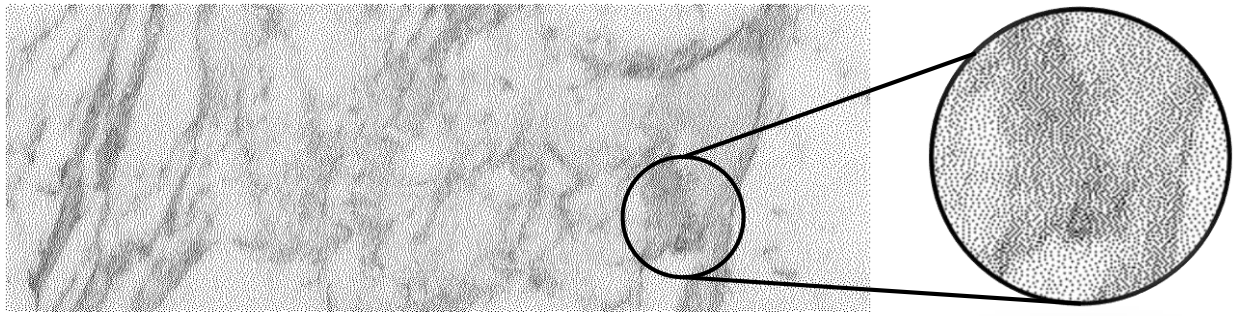


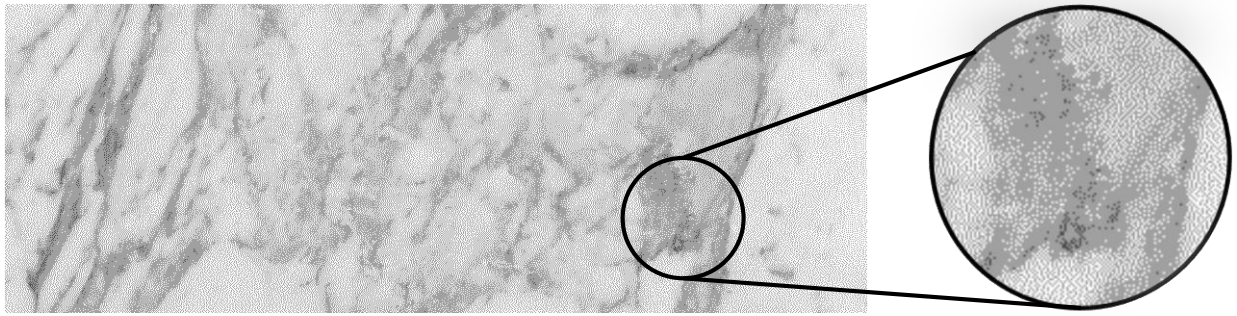




Effects of Grey Levels on Output



1 Level (Binary)



3 Level – Even Spacing

7 Level – Even Spacing

Image source: GIS

GIS GLOBAL INKJET SYSTEMS

Ink/Fluid Delivery Systems

In this section we will cover:-

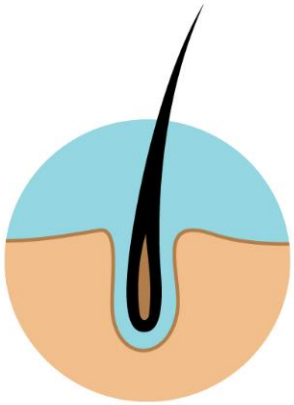
- Main functions and basic requirements of ink delivery systems (IDS)
- Flow modes and printhead types
- Design options & challenges
  - Heating
  - Degassing
  - Customizing print bars
- Typical IDS issues
  - Diagnosing common issues
  - Troubleshooting and solutions

Image source: GIS

Inkjet Inks – A Sense of Scale

1pl ink drop = 13 µm

Human hair = avg. 70 µm



Fine beach sand = avg. 90 µm

Image source: web images

Main Functions of Ink/Fluid System

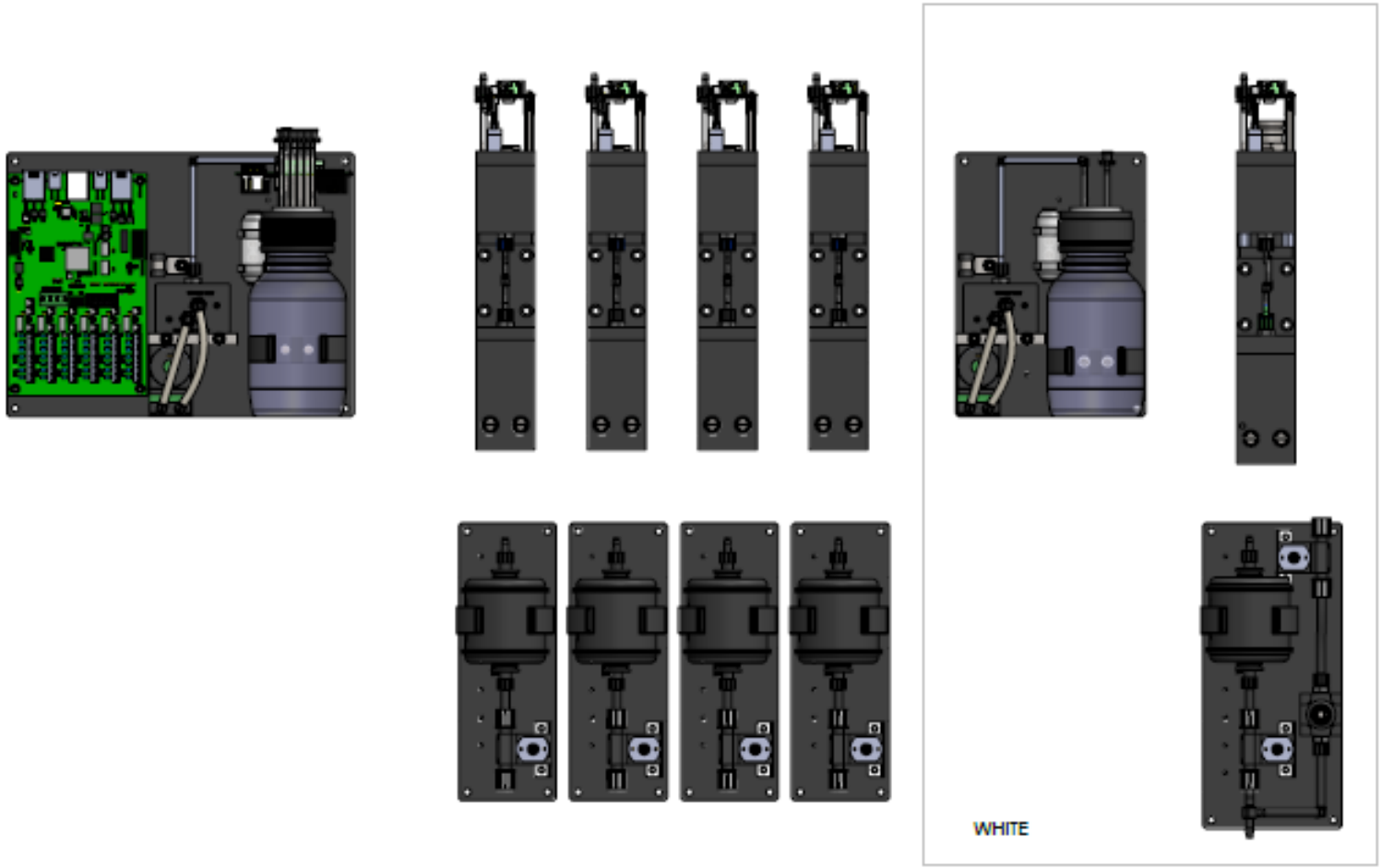
- **Meniscus pressure**
  - Ink pressure inside the printhead
    - Meniscus is formed by a slight negative pressure at the nozzle
- **Air pressure control**
  - Negative air pressures to maintain meniscus pressure of each printhead
  - At different flow rates
  - Scanning XY systems – withstand the acceleration/deceleration of printhead carriage
- **Ink pumping**
  - Control for pumping of ink from bulk ink tank
- **Purging**
  - Positive pressure to the ink in the printhead
    - Low pressure and high pressure purge (required by some printheads)

Basic Requirements

- **Filtration**
  - Minimise chance of particles clogging the nozzles
- **Flow modes**
  - Support for recirculation or no recirculation
- **Degas**
  - Stop air bubbles reaching the printhead/nozzles
  - Avoid air pockets in ink system
- **Heat the ink**
  - For correct operating temperature (printhead dependent)

Pressure Control

- Shared or individual pressure



Example shows shared pressure CMYK and individual pressure White

Image source: GIS

GUI

- **Typical system monitoring requirements**
  - User friendly GUI - system status, ink levels
  - Graphing tools – pressure, pump & solenoid activity etc.

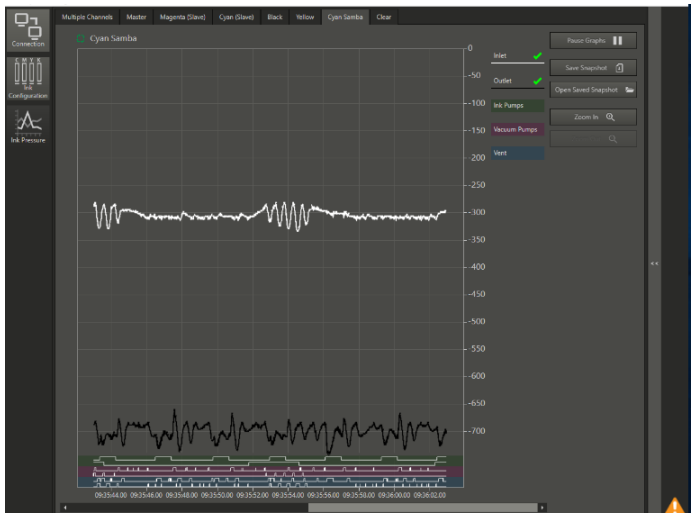
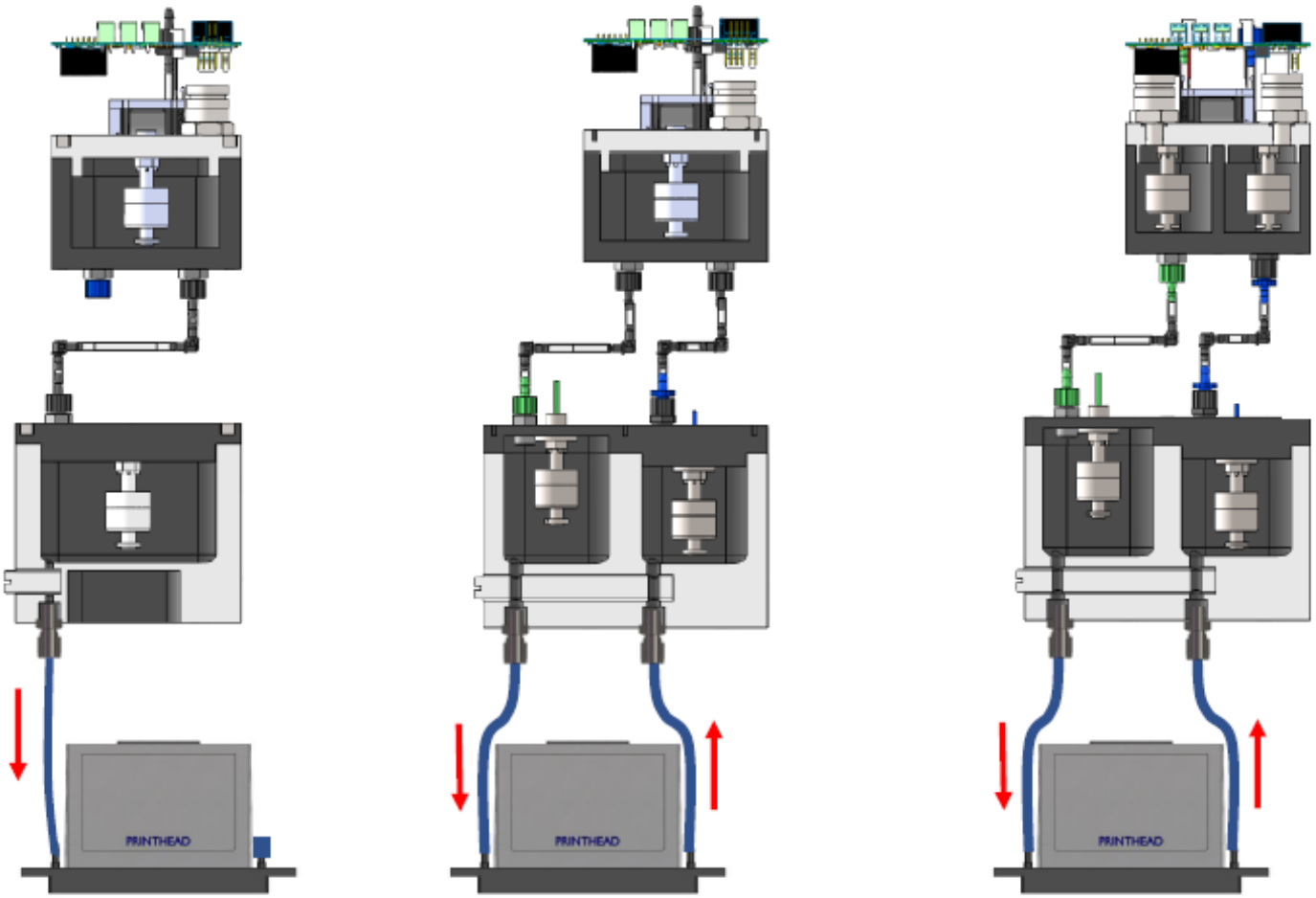


Image source: GIS

Flow Modes



No Flow | Low Flow | Controlled Flow

Image source: GIS

No Flow/End Shooter

- **Basic characteristics**
  - Air pressure range typically 250-500mm between header tank and nozzle plate
  - In this example, negative pressure P (-350mm) applied to balance the positive head of fluid (300mm) and provide a negative meniscus pressure of -50mm at the nozzle plate

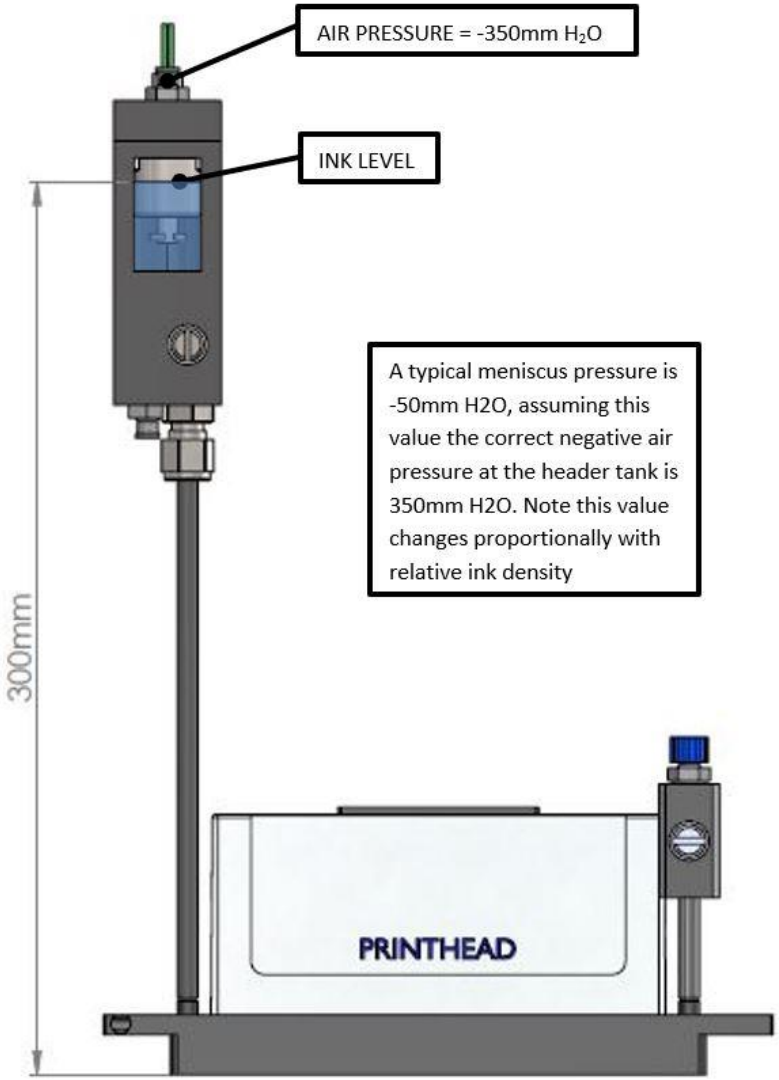


Image source: GIS

Low Flow/End Shooter

- **Basic characteristics**
  - Height difference between the header tanks
  - Same negative air pressure applied to both tanks
  - System constantly tries to level and creates low flow through the printhead

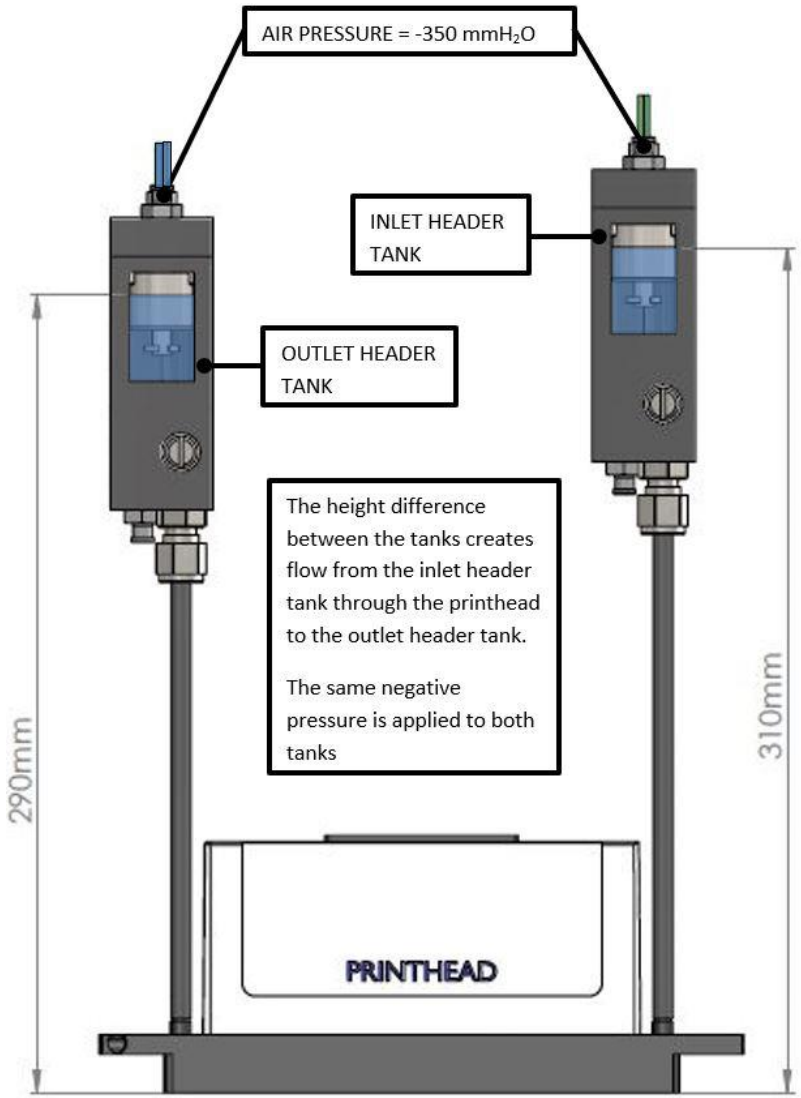


Image source: GIS

Controlled/Adjustable Flow

- **Basic characteristics**
  - Two pressure values assigned
  - Printhead manufacturers tend to specify the pressure difference
  - Differential air pressure creates flow through the printhead
  - Air Pressure[1] and Air Pressure[2] are both adjustable to vary/control the flow rate

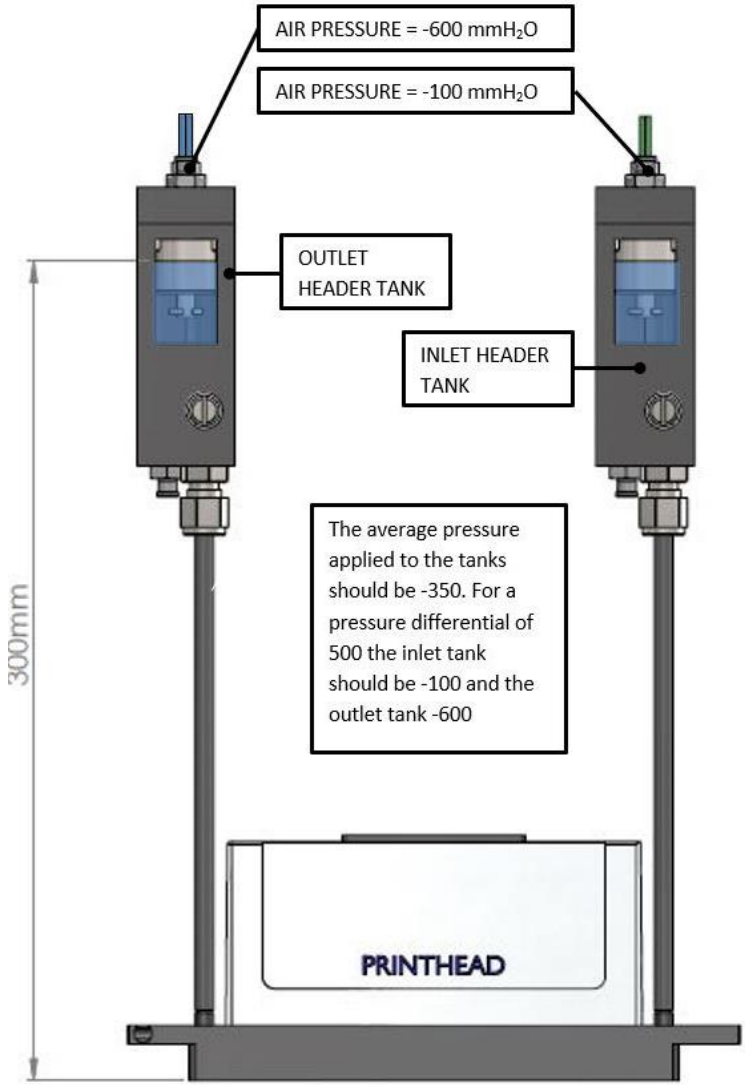


Image source: GIS

Printheads & Flow Modes - examples

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Example Printheads	No Flow	Low Flow	Controlled Flow
Fujifilm Samba G3L/G5L	✗	✗	✓
Fujifilm Starfire SG1024	✗	✗	✓
Fujifilm Sapphire 256	✓	(✓)	✗
Konica Minolta 1024i	✓	(✓)	✗
Kyocera KJ4B-QA/YH	✓	(✓)	✗
Kyocera KJ4A-TA/AA/RH	✓	(✓)	✗
Ricoh MH5441	✓	(✓)	(✓)
TTEC CF1/CF3	✗	✗	✓
Xaar 1003/ 5601	✗	✗	✓

Key

✓ Required

(✓) Optional

Ink/Fluid Requirements

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Ink Type	Typical Ink System Requirements
UV Cure	• Requires heating (most printheads have heaters and/or use heated mounts) • Degassing can be advantageous - best for high frequency/large number of heads. Must be used with care - can make ink over-sensitive to curing
Aqueous	• (Requires) degassing
Oil based	• None special
Solvent	• May require materials compatibility testing
White/ Ceramic	• Require special pumps due to abrasive ink pigment and particle settling
Fluid Deposition/ Functional Fluid/ Ink Development	• Requires materials compatibility testing • Typically requires small volumes due to high value of fluid– may affect header tank design/size

Heating

- **Ink performance varies with temperature**
  - Higher temperature
    - Reduces viscosity
    - Increases evaporation
- **Inks have a recommended operating temperature window (consult you ink supplier)**
- **Temperature most critical at the printhead/jetting**

Mode of Heat	Comment	Pros	Cons
In-line Heaters	• Only work with recirculating systems	• Provide fast and controllable ink heating	• Adds cost
Heated Header Tanks	• Typically used in no flow or low flow systems	• Lower cost than in-line heaters	• Only suitable for low density printing • Temperature control less accurate
Heated Head Plates	• Can be used with all flow modes	• Provides uniform thermal environment • Reduces workload on printhead/ink system heating improving thermal control	• Thermal expansion • Adds cost

Degassing

- **(Required) for aqueous inks**
  - Sometimes not used on small systems to save cost
- **Recommended for some UV inks**
  - Typically on large, high print frequency systems
- **Contactor must be right size for flow rate and compatible with ink**
- **Vacuum must be applied**
  - High vacuum for aqueous ink
  - Lower vacuum for UV ink
    - Risk stripping all oxygen out of the ink and cause curing

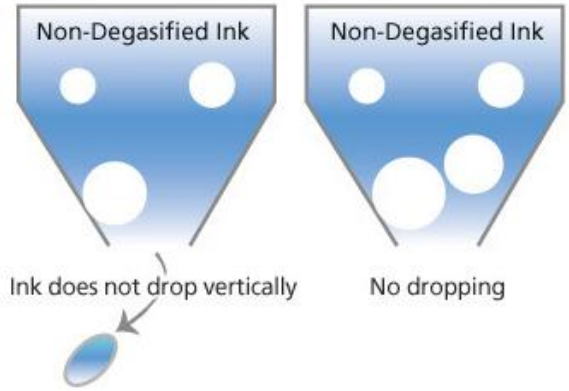


Image source: Separel web site

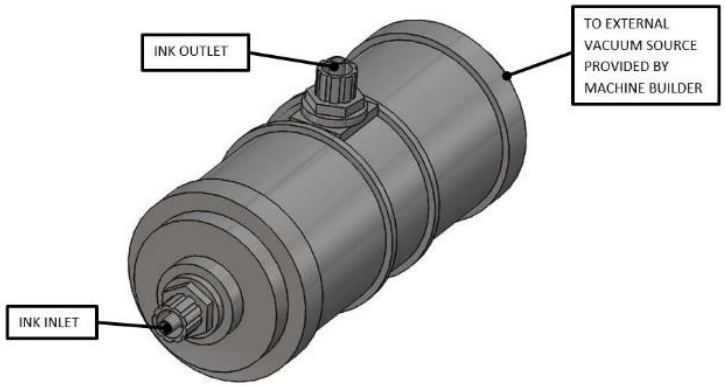
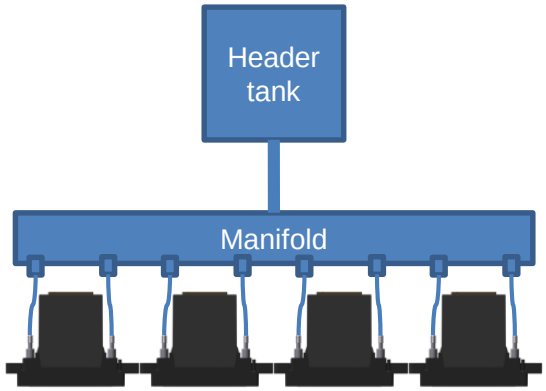
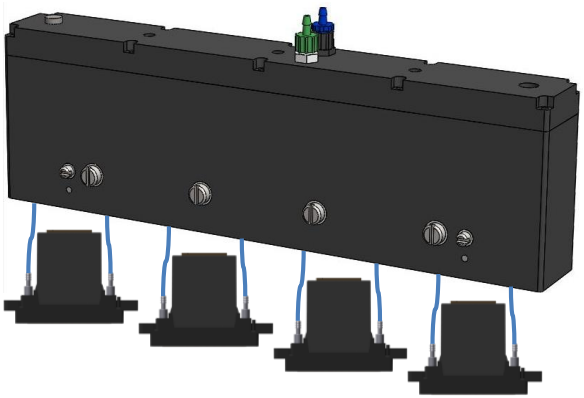


Image source: GIS

Larger Print Bars – Tank Options



- **Manifold system**
  - **Popular design**
  - **Cost efficient to implement**
  - **Can be prone to air traps**
    - Trapped air can sit at top of manifold
  - **Can be difficult to fill**
  - **Extendable**



- **Custom header tanks**
  - **Header tank acts as manifold**
  - **Valve for each printhead**
  - **Equal flow resistance**
  - **Extendable**

Image source: GIS

GIS GLOBAL INKJET SYSTEMS

Typical IDS Issues

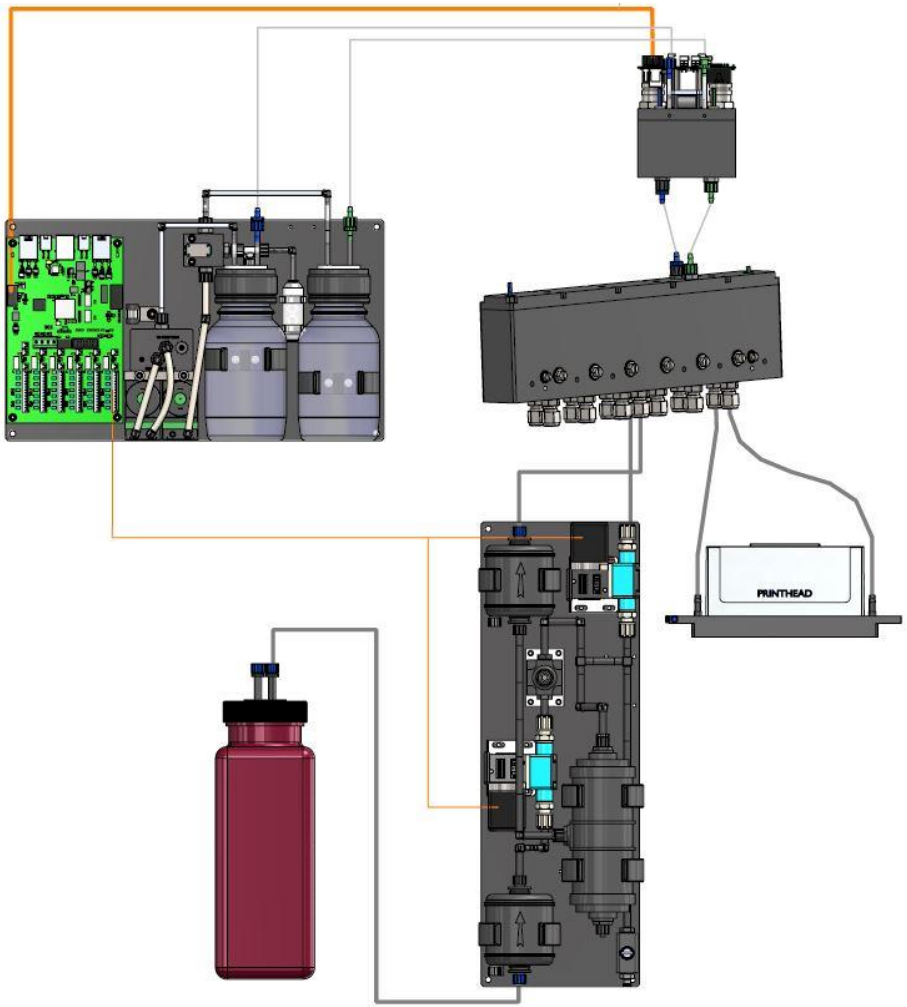


Image source: GIS

Common Issues Attributed to IDS

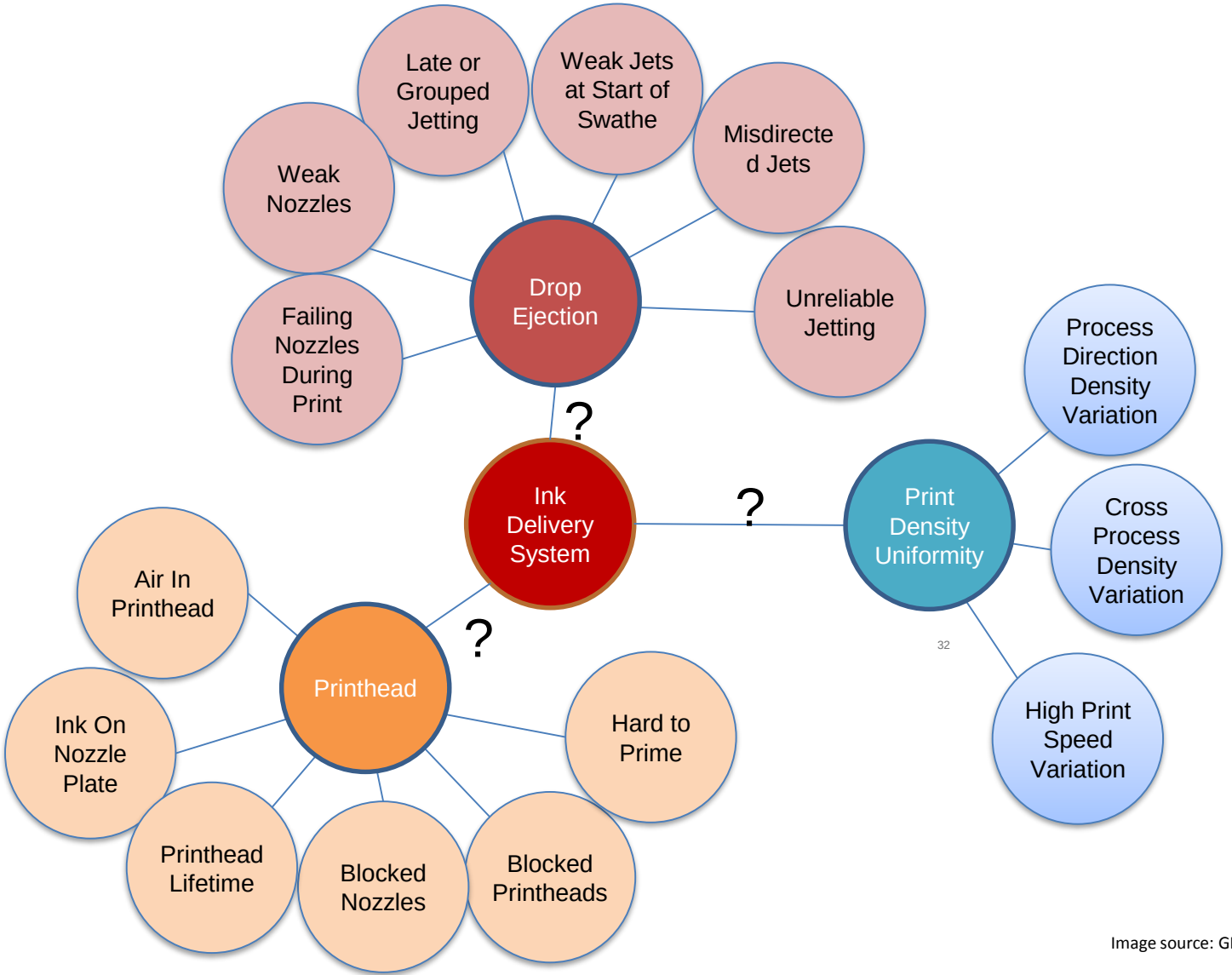


Image source: GIS

Common Issues with Alternative Causes

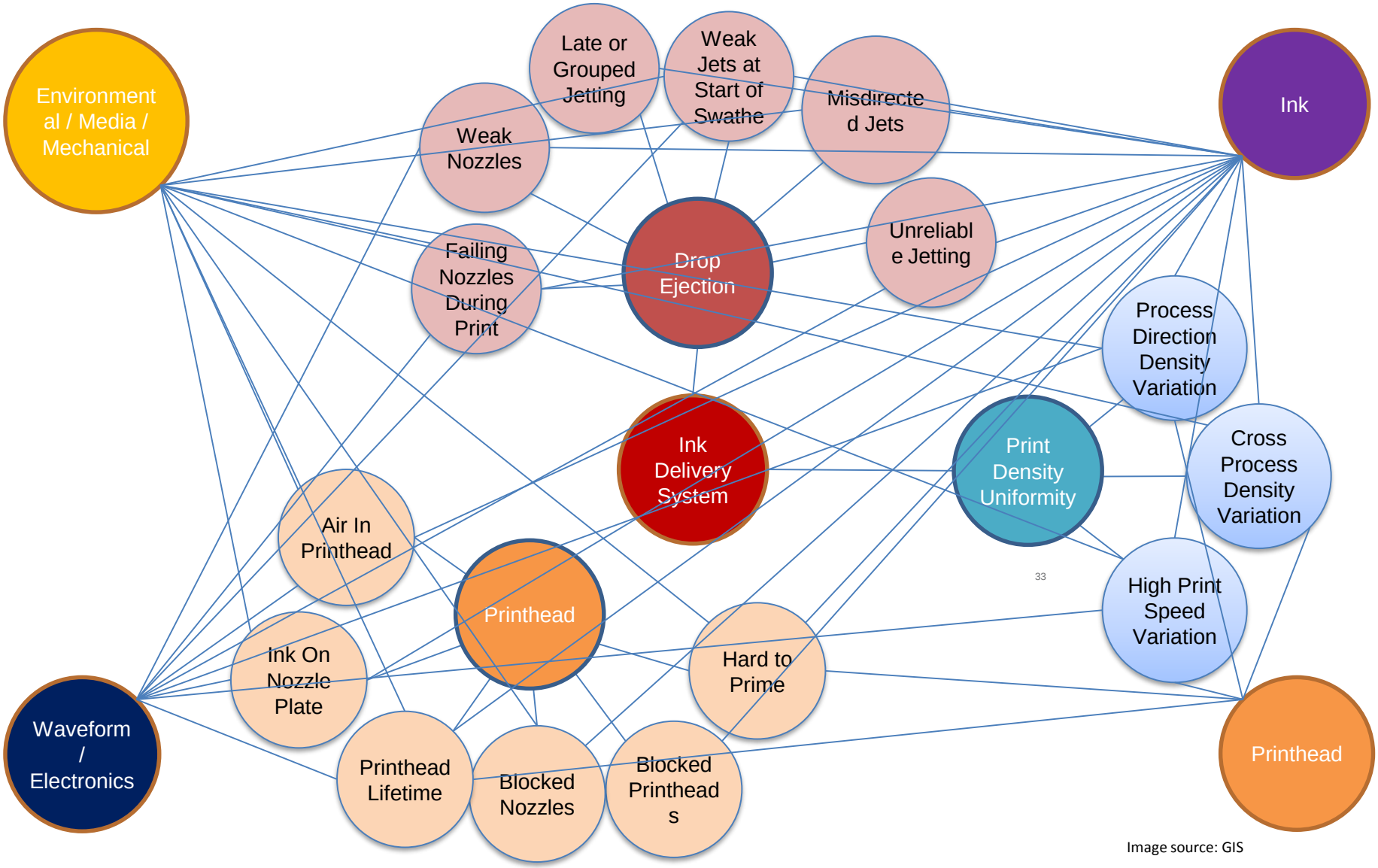


Image source: GIS

Ink Delivery System Summary

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- **Ensure against future problems by careful design and planning**
  - Materials compatibility, correct components, follow ink and printhead manufacturer guidelines etc.
- **Over-specify on prototype**
  - Simplify and cut cost when proven
- **Low flow use with end shooter printheads is growing**
  - No flow for CMYK
  - Low flow for W
- **Recirculating/controlled flow printheads increasing**
  - More demanding for IDS design and implementation

- **Work with an experienced and proven supplier like GIS!**

GIS GLOBAL INKJET SYSTEMS

Suggest 5 minute break here!

Print Quality

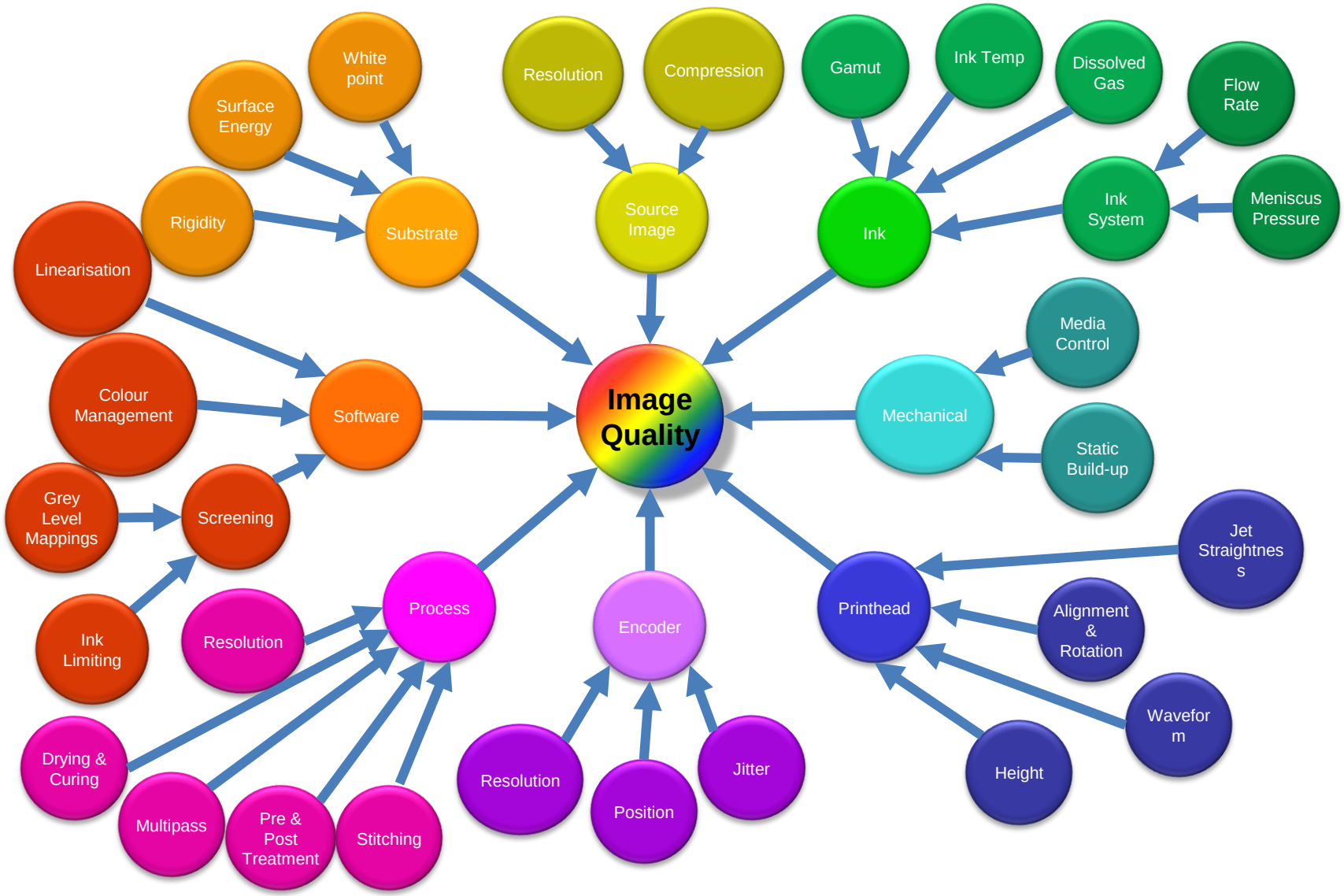
This is a huge topic!

Not enough time to cover everything in detail

The following slides provide just a flavour of some of the issues…..

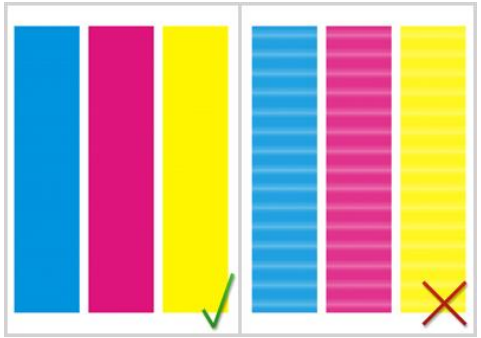
Key message = complete system inter-dependence

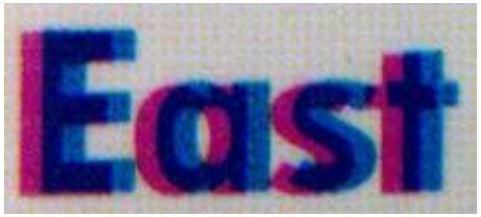
(Some) Factors Affecting Image Quality



Quality Issues (just a few)

- Jetting errors
- Image artefacts
- Resolution too low
- Edge definition
- Grainy images
- Density shift
- Nozzle drop outs
- Wrong colours/gamut
- Missing colours
- Texture/unevenness in areas of solid colour
- Colour stability
- Colour bleed
- Ink supply issues
- Reticulation

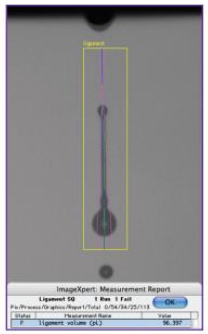




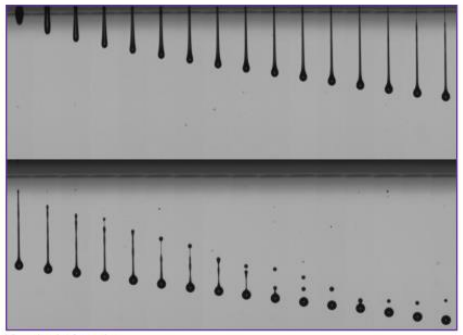
Ink & Substrates

Inks & Substrates

- **It all starts with the ink/fluid**
  - Compatibility
    - Printhead, substrate, print process etc.
  - Characterisation
    - Core formulation (viscosity, surface tension, particle size etc.) through to printability (drop formation, reliability, open time, stability etc.)
- **Established inks/fluids**
  - Waveform, temperature settings are known
- **New ink/fluid**
  - Requires waveform development
  - Often applies to functional fluids



Ligament volume measurement



View droplet formation

Image source: ImageXpert

Ink & Substrates

- **Ink wetting & adhesion**
  - Substrate surface energy vs. ink surface tension

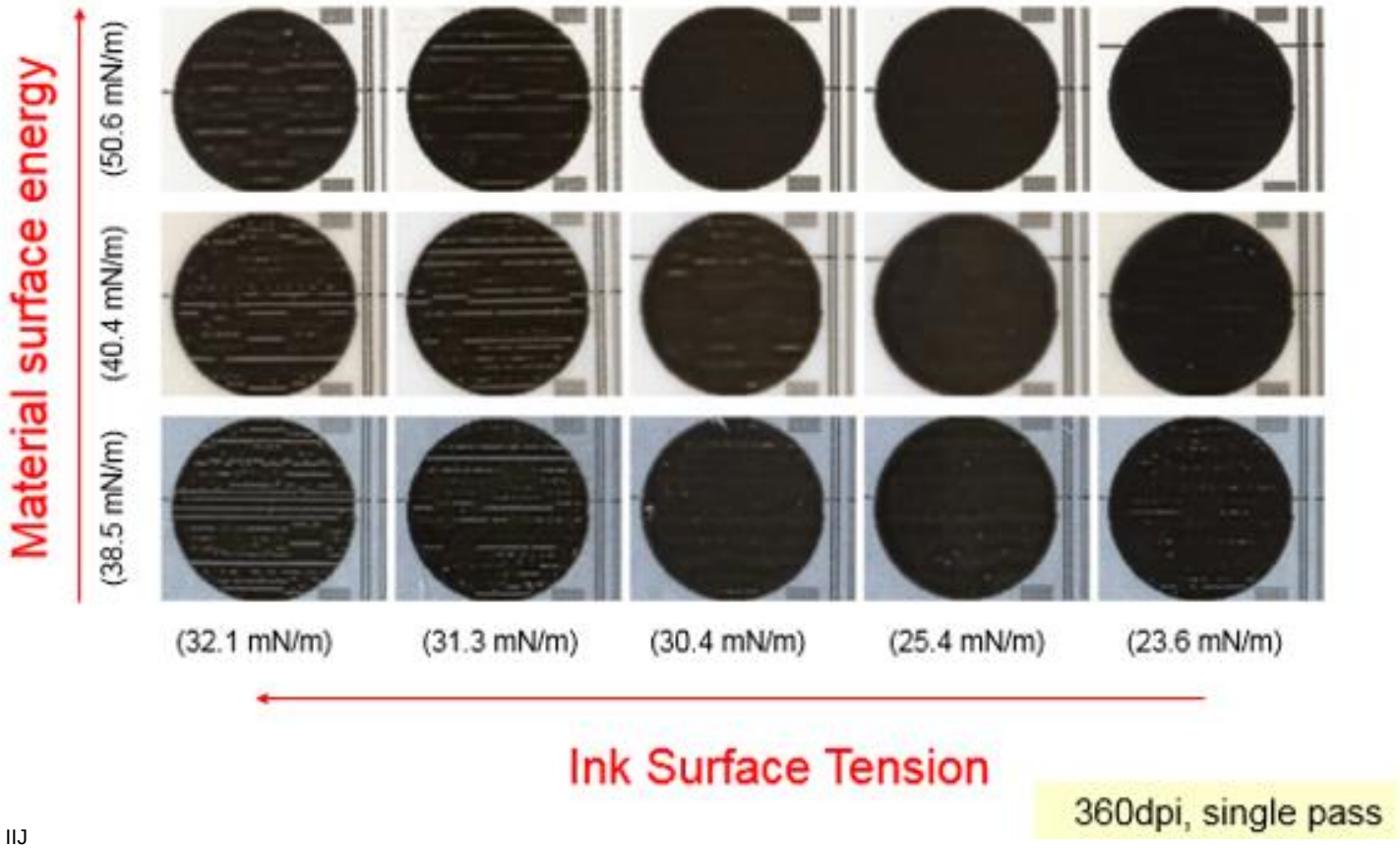


Image courtesy of IIJ

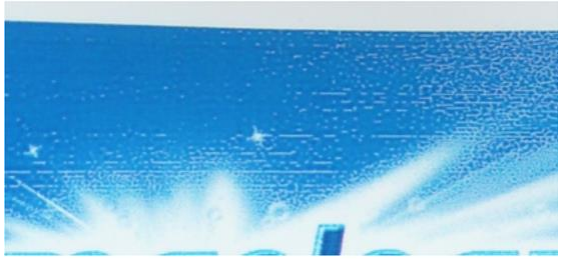
Inks & Substrates

- **Ink wetting & adhesion**
  - Varies from substrate to substrate – and ink to ink

Ink 1 Ink 2 Ink 3

  - Importance of pre-treatment for some substrates
    - Alcohol
    - Flame
    - Corona
    - Plasma
    - Primer

No corona



Corona

Images courtesy of IIJ

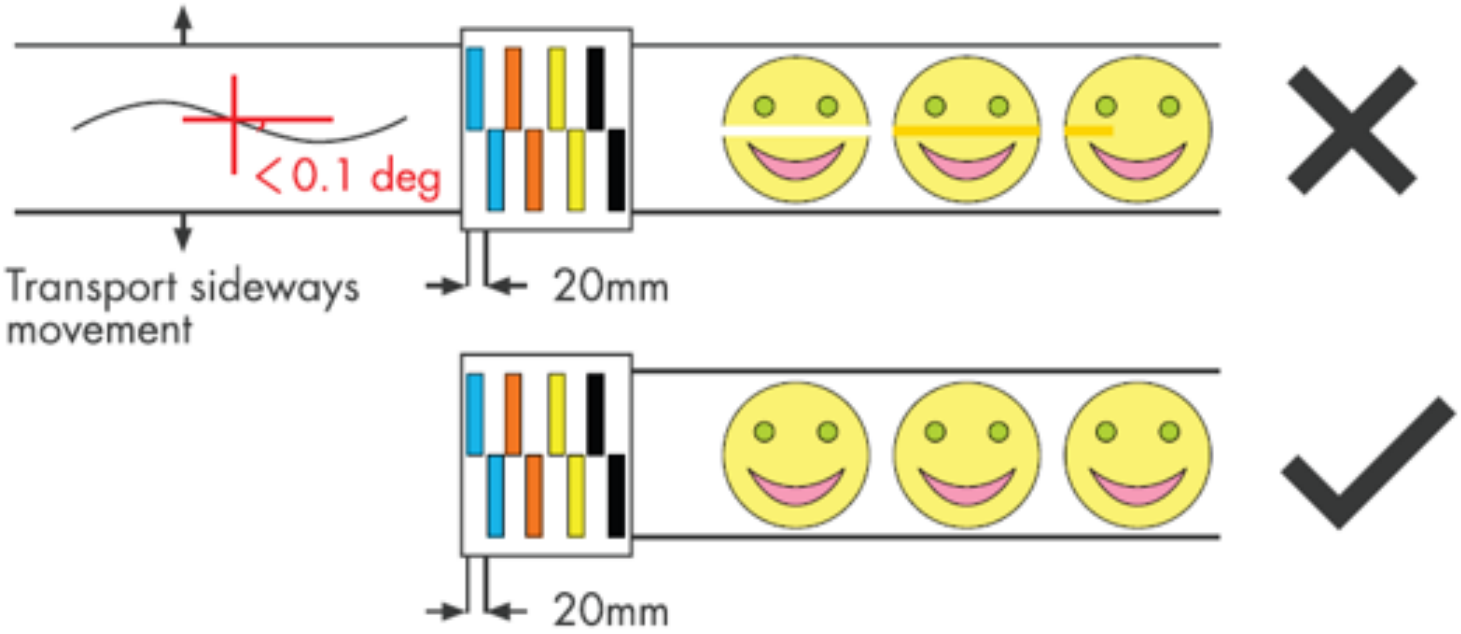
GIS GLOBAL INKJET SYSTEMS

Mechanical
- Encoders & Media Control
- Colour Registration

GIS GLOBAL INKJET SYSTEMS

KONICA MINOLTA

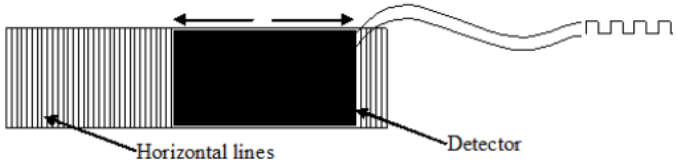
Effect of Accuracy of Movement



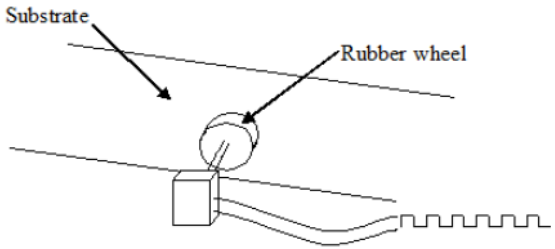
Slide courtesy of IIJ

Encoders

- **Responsible for regulating all of the printing, by determining how much substrate has moved relative to the printhead**
  - One of the most common factors contributing to poor print quality
- **Linear encoders (optical & magnetic)**
  - Signal generated based on number of lines read
    - Detector lifting off the strip
    - Ink/dirt on the optical strip or lens



- **Rotary encoders (rotary & shaft)**
  - Speed of rotation generates the encoder signal
    - Positioning (distance from printheads)
    - Wheel slippage/misalignment
    - Substrate stretching or bunching
    - Resolution



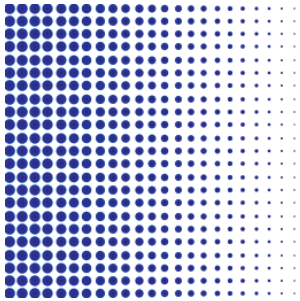
- **Signal noise**
- **Wiring**

Colour Registration

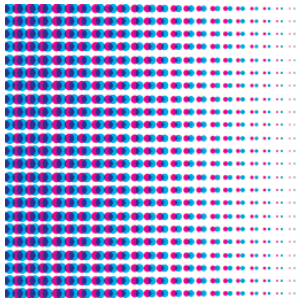
Colour registration is a measure of the accuracy with which two or more colours are aligned with each other

The most common causes of poor colour registration are:-

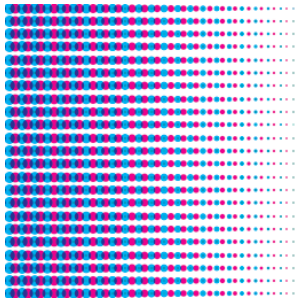
- **System Setup** : The printheads may simply not be aligned mechanically or offset correctly in the electronics / software relative to each other
- **Encoder**: The encoder is not accurately reporting the movement of the media. (e.g. Slippage / Misalignment)
- **Media Control** : The media is stretching, slipping or accelerating
- **Jetting Parameters** : The time of flight of the drops is not the same for all printheads. Typically visible at higher print speeds



Full Dot Overlap



Partial Dot Overlap

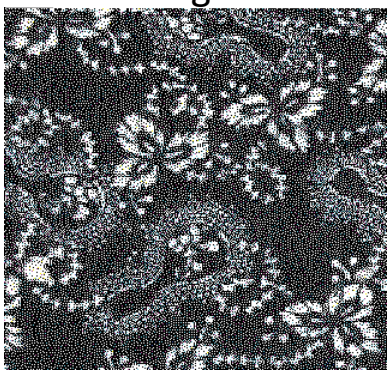


No Dot Overlap

Colour Registration

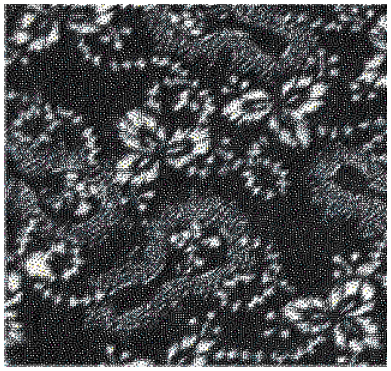
- Colour registration can effect output colour and detail
- Typically there is a reduction in colour gamut and darkening of the image

X & Y nudge

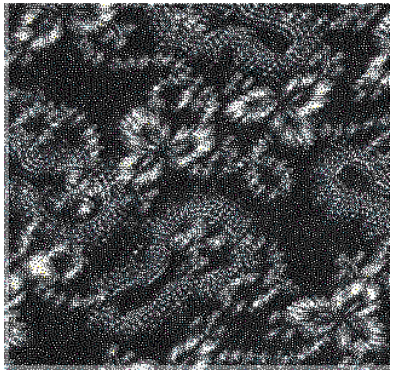


Perfect Alignment

+1,+1 Pixel Nudge

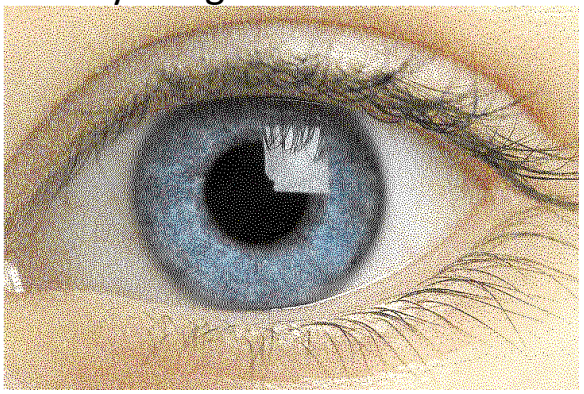


+2,+2 Pixel Nudge

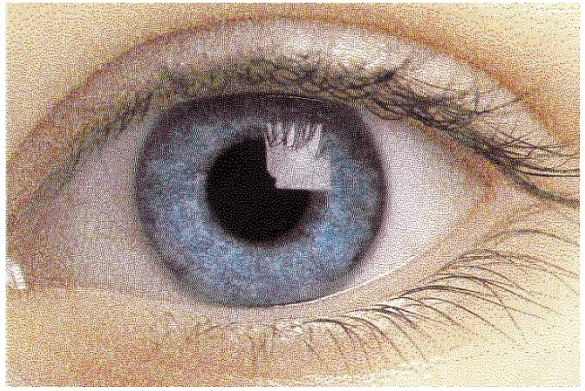


+4,+4 Pixel Nudge

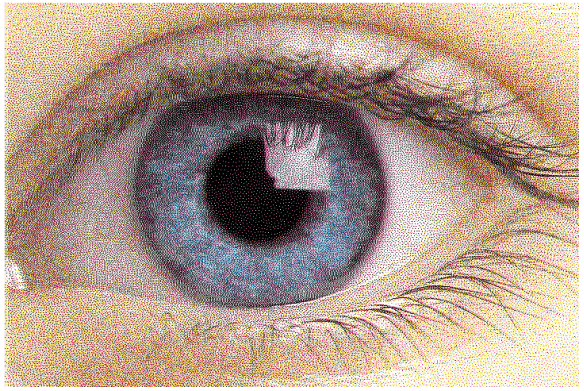
X only nudge



Perfect Alignment



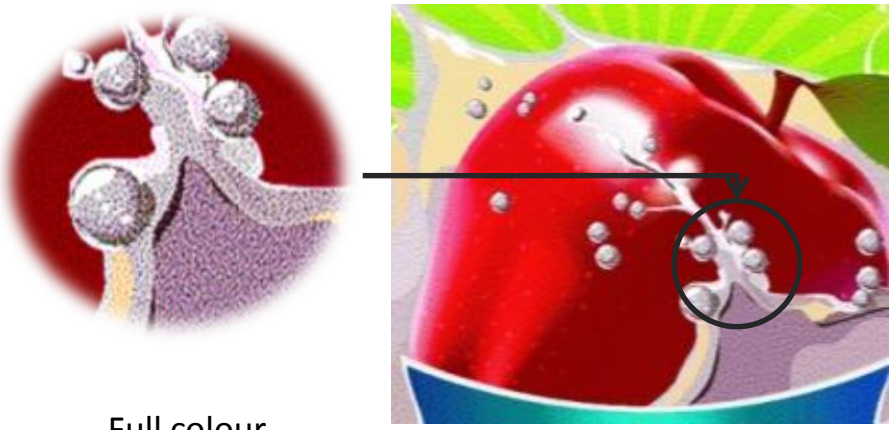
+2,0 Pixel Nudge



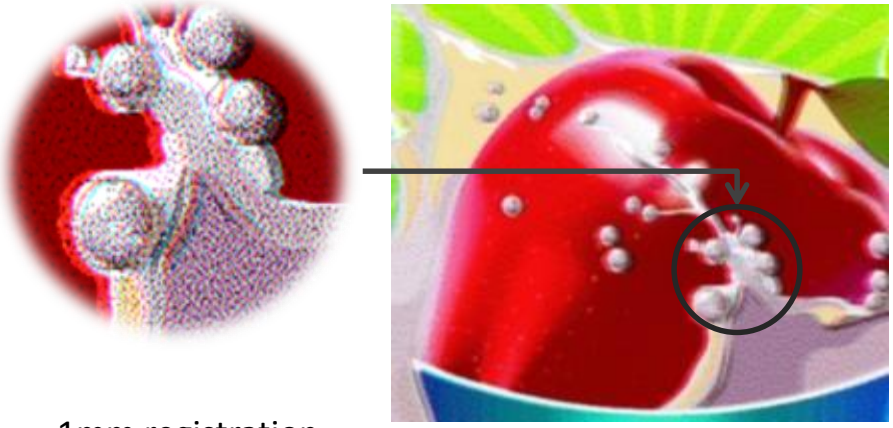
+4,0 Pixel Nudge

Poor Colour Registration Image Effects

- **Images are less clear**
- **Text less readable**
- **Fine detail is lost**
- **Colours are not accurate**
  - Gamut reduced
- **Some images look worse than others**



Full colour registration



1mm registration error in black and cyan

Image source: GIS

GIS GLOBAL INKJET SYSTEMS

Software – Critical Importance in Managing & Maintaining Image Quality

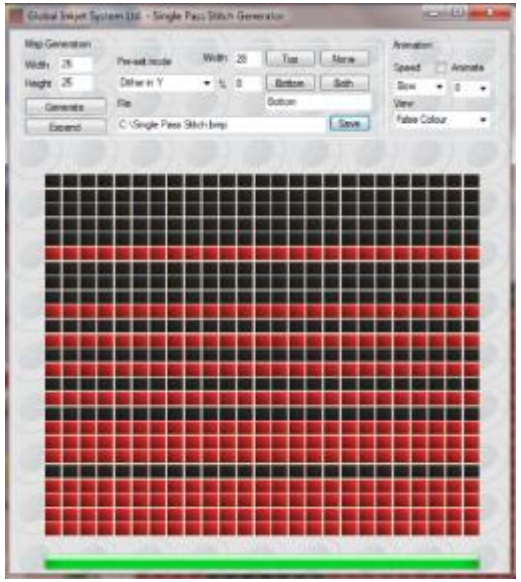
Hard Stitching - Masking

GIS GLOBAL INKJET SYSTEMS

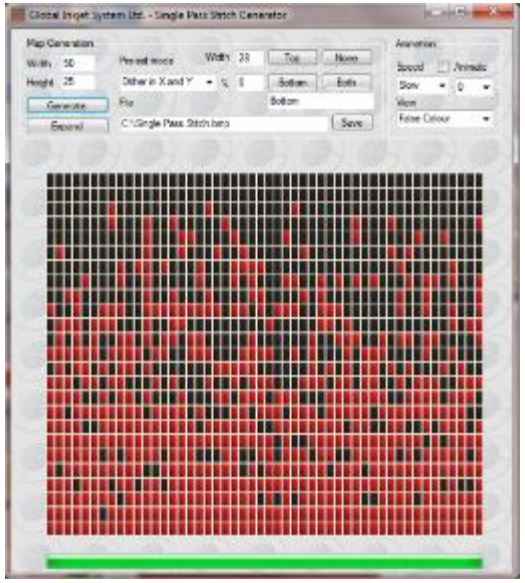
Masking (Hard Stitching)

- 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

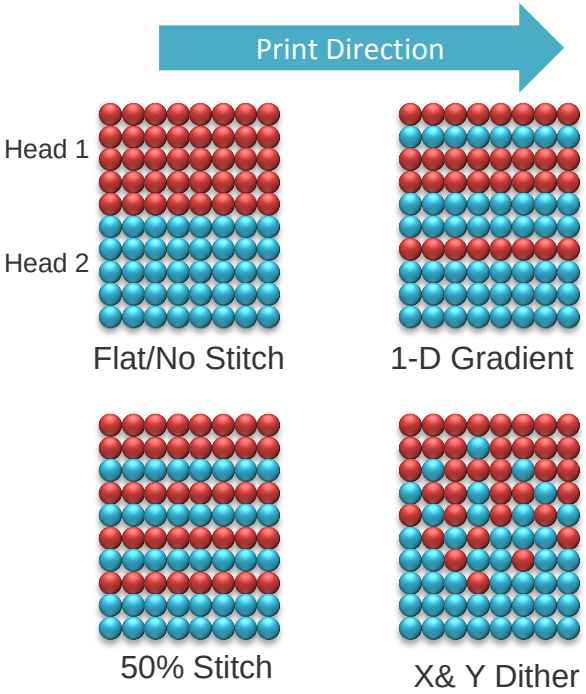


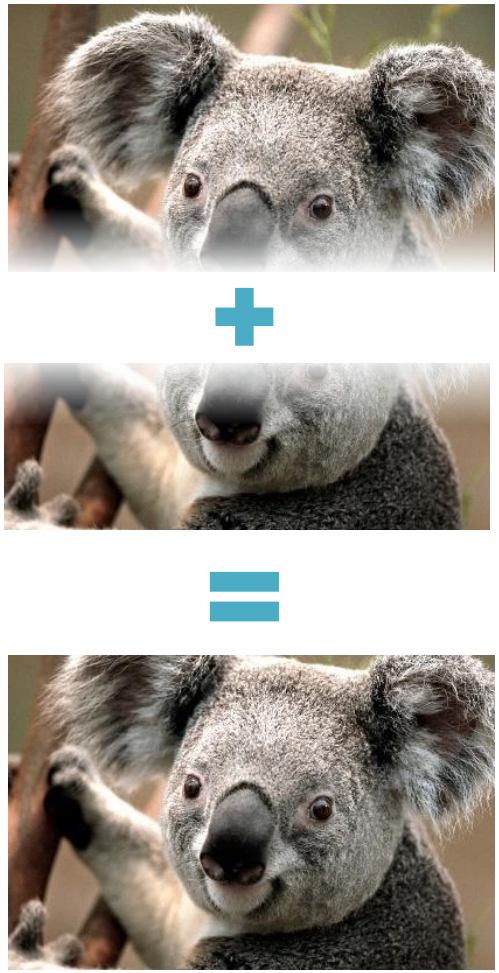
Image source: GIS

Soft Stitching - Greyscale

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



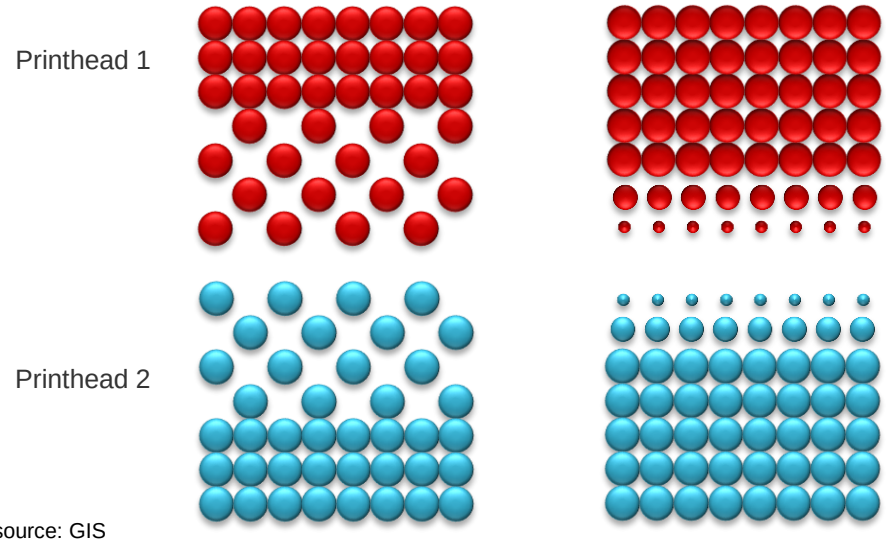


Image source: GIS

Achieving Flat Colours

- **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 Density 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

Digital Printhead Linearization (via image correction)

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Printhead banding

Printhead banding

Printhead banding

Linearized printhead

Image source: GIS

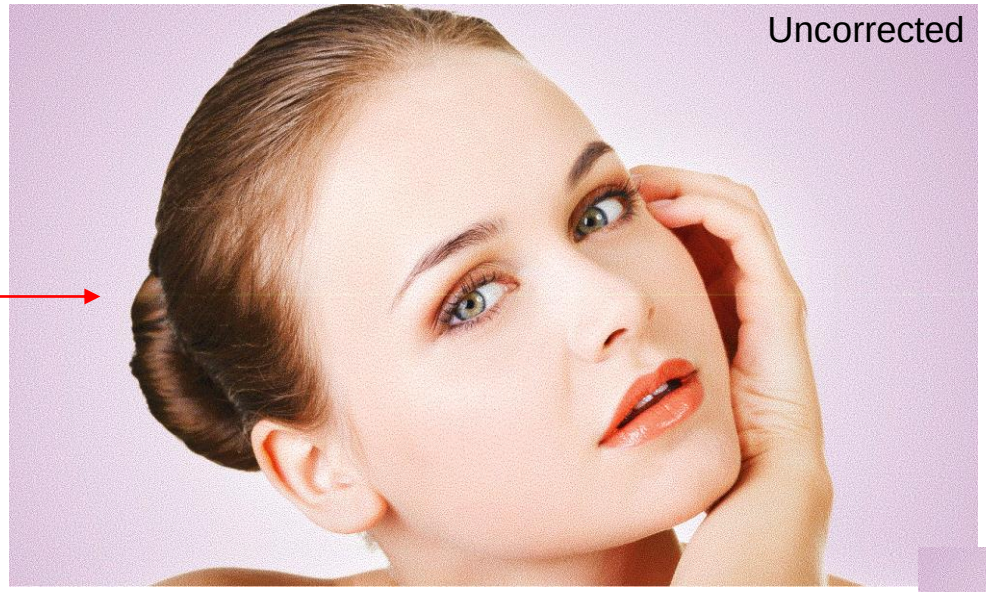
Missing Nozzles

- **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

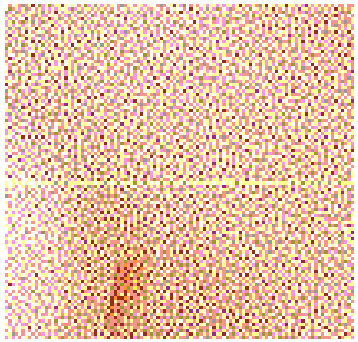
- **Isolated nozzles work best**
  - Clusters of nozzles much more difficult to hide
  - Technology works best where there is some substrate bleed/drop overlap
- **Many different strategies exist using neighbouring nozzles**
  - Correction in contone or screened data
    - GIS believes best results achieved with contone correction
  - 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
- **Numerous patents exist**

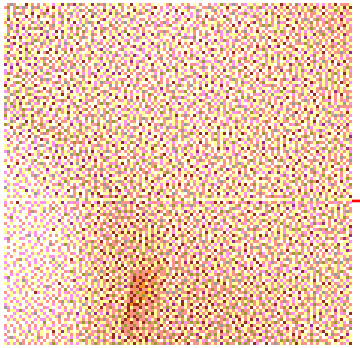
Nozzle Out Compensation



4 Level CMYK

Magenta nozzle out on line 511





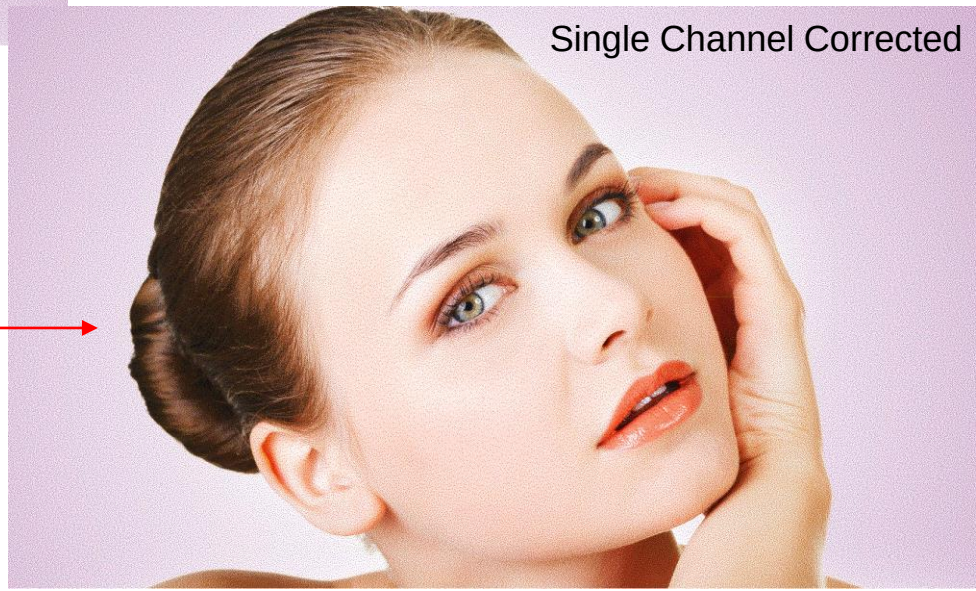


Image source: GIS

Nozzle Out Compensation

Original image | Missing nozzles | Nozzle Out Compensation

Image source: GIS

Challenges of Finishing/Varnishes

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- **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)

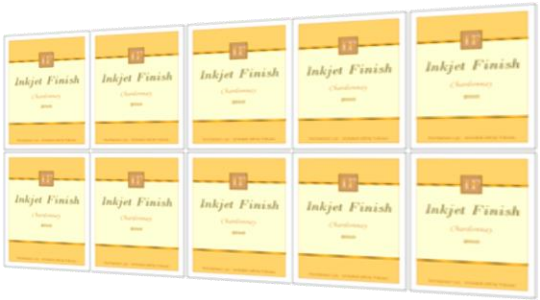
- Product detect (X translation)
- Feeders or software offset (Y translation)

Rotation

- Feeders
- Vision system + fiducials + software

Image source: GIS

Challenges of Finishing/Varnishes

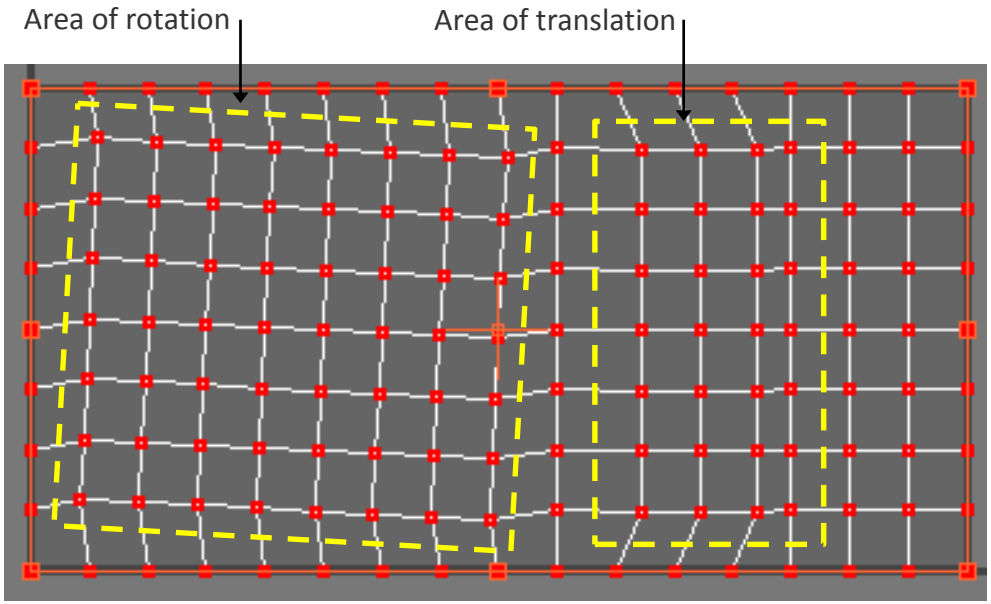


Trapezoid / Skew

- 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

Image source: GIS

GIS GLOBAL INKJET SYSTEMS

Markets and Applications

In this section we will cover:-

- Brief summary of some key and emerging industrial inkjet markets
  - Textile
  - Packaging
  - Product Decoration
  - 3D
  - Materials Deposition
  - etc

GIS | GLOBAL INKJET SYSTEMS

Disclaimer

Global Inkjet Systems supplies inkjet technology and components to 130+ original equipment manufacturers world-wide. As a matter of policy, we do not disclose our customer relationships.

Some of the following slides contain images chosen to illustrate the range of inkjet print systems which are available in the market. The presence, or absence, of any manufacturer's products in these images does not in any way imply a commercial relationship between that manufacturer and GIS.

Textiles

- **Print technologies**
  - Market dominated by rotary screen approx. 65%
  - Flat screen approx. <30%
  - Inkjet penetration still relatively low <5%
- **Several single pass systems now in the market**
  - MS Italy, SPG, Atexco, EFI
- **Inkjet growing, but cost pressures increasing**

Image Source: SPG

Labels

- **EPG - initially set the standard and still very strong**
  - Xeikon (dry toner)
  - HP Indigo (liquid toner)
- **Inkjet**
  - Adoption been relatively slow over many years (but now accelerating strongly)
  - Resolution/speed/print quality issues
  - Timeline development
    - From Xaar 1003 to Fuji Samba
  - Hybrid systems
    - Most narrow web flexo manufacturers have either partnered with a digital OEM or built their own units

Mark Andy – Digital Series
In line with flexo

Folding Carton

- **Analogue – still dominates (flexo/offset)**
- **EPG**
  - Xeikon, HP Indigo, Xerox
- **Inkjet**
  - Adoption been slow (but now accelerating)
  - Many systems on the market
  - Print quality is critical – primary packaging

Heidelberg - Primefire 106 - B1

Konica Minolta KM-1 & KM-C

Fujifilm - Jetpress 720S B2

Landa – S10 – B1

Image source: company web sites

Corrugated

- **Analogue – still dominates (flexo/offset)**
- **Two key sectors**
  - **Pre-print**
    - Printing onto rolls of liner (the top sheet on corrugated)
    - High speed/wide width requirement
    - Single pass
  - **Post-print**
    - Printing onto sheets of converted corrugated
    - Single pass and XY scanning
- **Secondary packaging**
  - 1 or 2 colours
- **Display packaging**
  - Full colour – high quality

HP T1100S – 110” (2.8m) wide
Pre-print system

EFI Nozomi C18000 - sheets 1.8m wide
Post-print system

Image source: company web sites

Flexible

- **Analogue – dominated by CI flexo**
- **High proportion = food packaging**
  - Safety issues
    - Aqueous inks or EB cure
  - High speed requirement
  - Very high print quality requirement
  - Single pass

Landa W10
Fujifilm Samba heads

Uteco – Sapphire Evo
Kodak Stream CIJ

Uteco – Gaia
EB cure

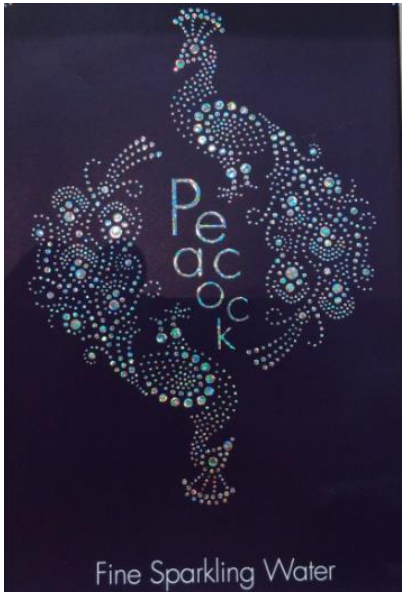
Image source: company web sites

Packaging – Finishing

- **Labels & packaging**
  - Proliferation of units for varnishing, haptic effects, foiling
  - Established players – Scodix, MGI - now many new players
  - Inline systems
    - HP Indigo Gem – inkjet inline with liquid toner
    - Xeikon Fusion – inkjet inline with dry toner

Domino K600i – digital foiling

MGI JETvarnish



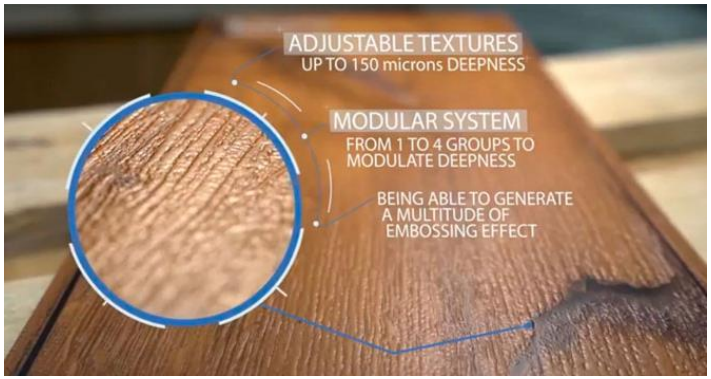
HP Indigo Gem - Spot varnish, tactile & foil

Scodix

Image source: company web sites

Décor

- **Competing against gravure**
- **Laminates/décor paper**
  - Approx. 1.6m wide
  - Water based inks
- **Direct to board**
  - MDF, particle board etc
  - UV and texturing
- **Edge banding**



panels up to 1890 mm

Image source: company web sites

Inkjet Printing Direct to Shape (DTS)

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Inkjet competing against pad printing, rotary screen, dry offset, In-mold label (IML)

Flat & Semi-Flat | **Tubes/Cylinders** | **Cones** | **Tubs**

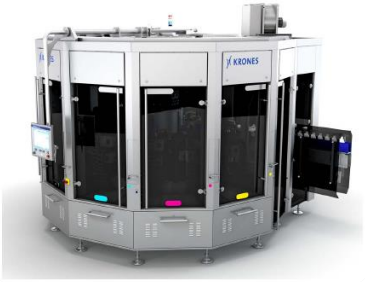

Image source: company web sites

DTS – GIS Curved Surface Software

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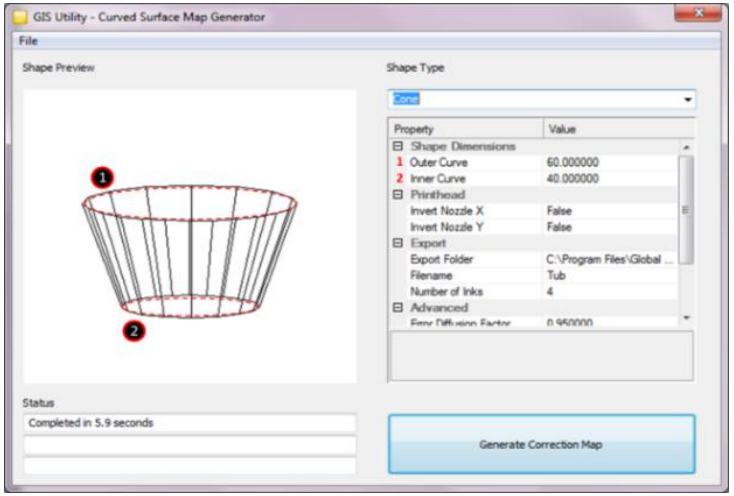

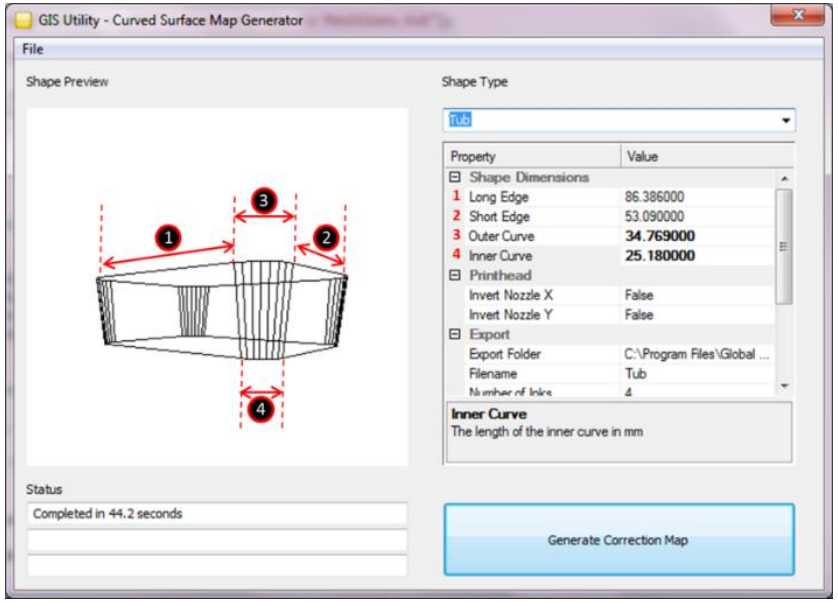

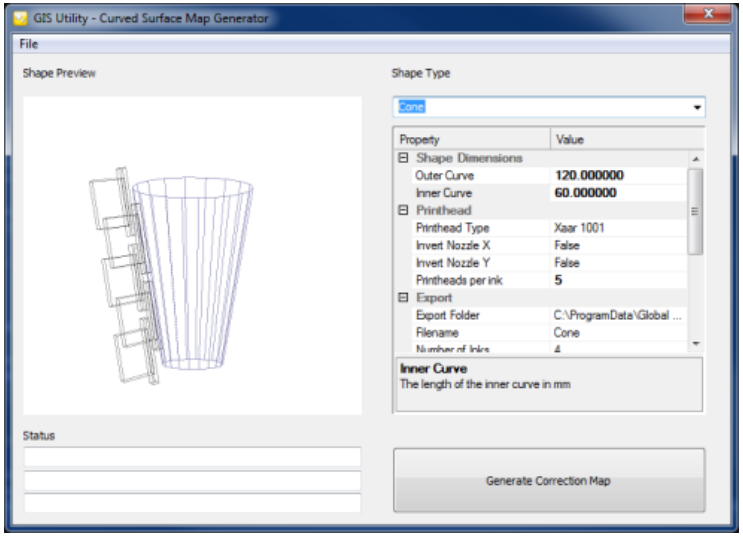

GIS image compensation software

DTS –Inkjet Systems

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- Machines are now installed and in production
- A selection….

Dubuit

Hinterkopf

Wifag Polytype

KHS

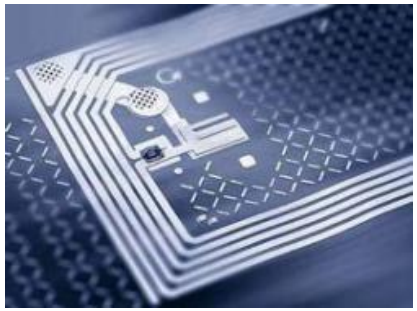
Martinenghi

Image source: company web sites

Inkjet – Materials Deposition

GIS GLOBAL INKJET SYSTEMS

- **Functional Coatings**
  - Textiles
    - Hydrophobic
    - Anti-bacterial
    - Flame-retardant
  - Other products
    - Anti- scratch on mobile phones
- **Display**
  - LCD colour filters
  - OLED
    - Depositing light emitting layer
- **Printed Electronics**
  - Conductives
  - Dielectrics
  - Sensor materials
- **Solar**
  - Organic solar cells (OPV)



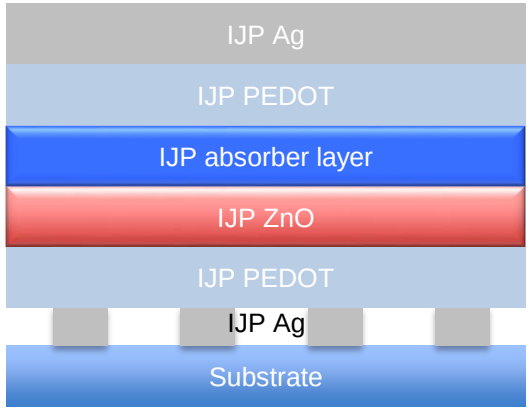


Image source: company web sites

Inkjet - 3D

GIS GLOBAL INKJET SYSTEMS

- Inkjet one of many 3D technologies
  - **Prototypes & Industrial use**
    - Automotive
    - Aerospace
    - Pump & Heavy Industry
    - Art & Design
    - Film & Museum

Image source: Voxeljet

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