Inkjet in Coatings and Complex Shapes
- Technologies & Processes -

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Agenda

- **Brief introduction to GIS**
- **Functional coatings with inkjet**
  - Challenges – and solutions
- **Coating / printing direct to shape**
- **More complex shapes**
  - Some more challenges – and solutions

Image source: GIS

Global Inkjet Systems Ltd

- **Leading independent developer of inkjet technology**
  - Supply inkjet capability to OEM system builders, specialist integrators and end users
  - Support a broad range of inkjet printheads in wide range of applications and industries
- **Based in Cambridge, UK**
  - 12+ years of growth & technology innovation
  - 70+ employees
  - 130+ customers world-wide
  - Support offices in UK, Japan and China





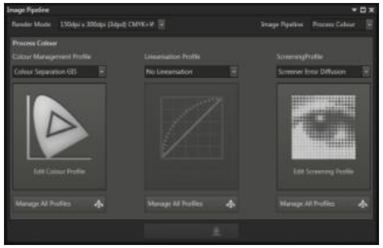
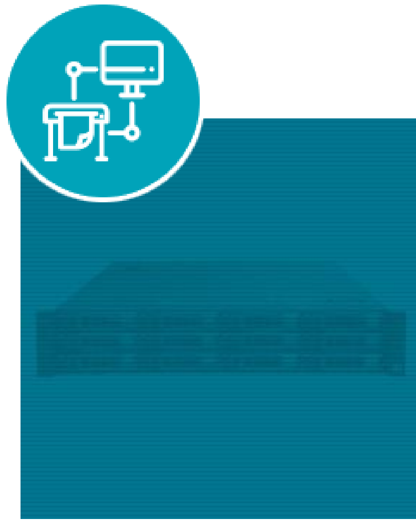



Image source: GIS

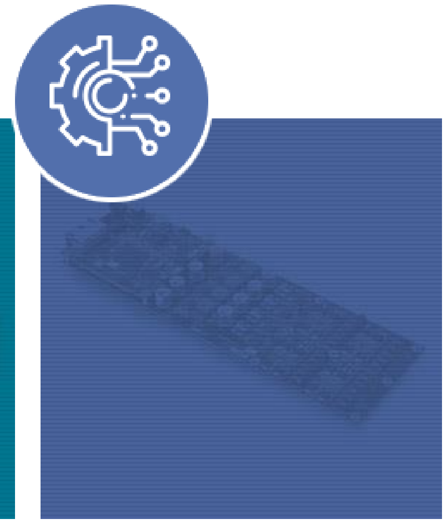
GIS - Product Groups

GIS | GLOBAL INKJET SYSTEMS

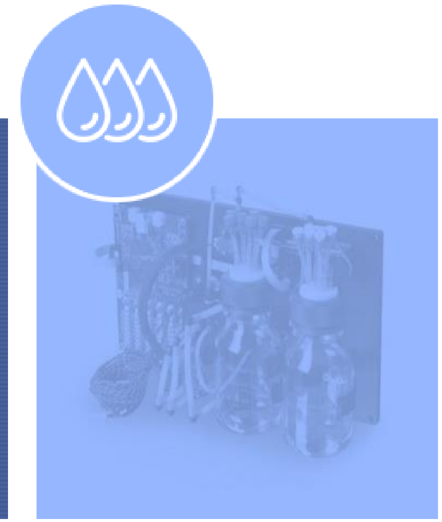
Digital Front End
Atlas® User Interface
Raster Image Processing



Machine Control
Atlas® Server



Print Controllers
Datapath &
Drive Electronics



Ink Delivery Systems
Controlled Temperature,
Pressure and Flow

- **GIS provides key technology to industrial inkjet systems builders, specialist integrators and large end users**
- **From pixels to droplets: we supply technology for the whole data pipeline – from image to print**

GLOBAL INKJET SYSTEMS

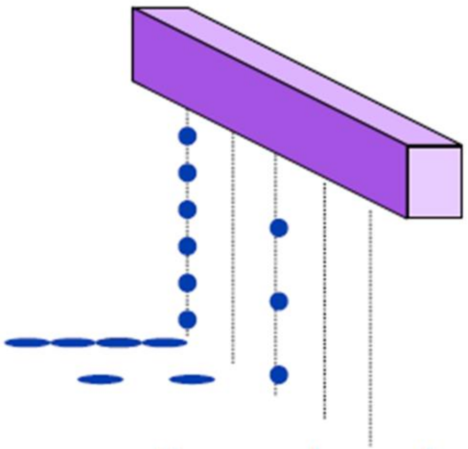
Disclaimer

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.

Inkjet Technology

- **Industrial piezo inkjet printheads**
  - Dominant technology: Drop on demand
  - Drop sizes: 2 – 200 picoLitres
  - Firing rates: 10 – 220kHz
  - Highly integrated: 100s – 1000s of nozzles per head
  - Printheads and variants for many applications



Drop on demand

drops generated only when required

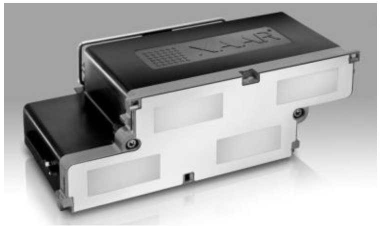


Image source: printhead web site
Diagram source: Pivotal Resources

Inkjet Strengths

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- **Non contact**
- **Additive process**
- **Subtractive process**
- **Broad fluid capability**
  - Aqueous
  - Solvent
  - UV curable inks, resists & adhesives
  - Conductive fluids
  - Jettable polymers & dielectrics
  - Jettable active & passive electronics
  - Acid resist
- **Precise drop formation**
  - Small drops for small features
  - Large drops for coatings/area fill
- **Precise drop location**
- **Conserves expensive materials**
- **Reduces waste**
- **Can reduce cost**
- **High drop production rate capability**
- **Long printhead life**
  - Heavy duty cycle capability
- **Proven reliability in production environments**
- **Inkjet as a partial or complete solution**
- **Integrated into standalone & hybrid manufacturing systems**
- **Highly integrated, modular technology**

Software Solutions

- **Nothing is perfect and inkjet printing / coating is no exception**
- **However, software can compensate for many print quality issues**

- **Intelligent image management**
  - Colour correction
  - Printhead stitch correction
  - Nozzle density correction
  - Nozzle out compensation
  - Geometry correction

Inkjet – Think Graphics – and Beyond Graphics

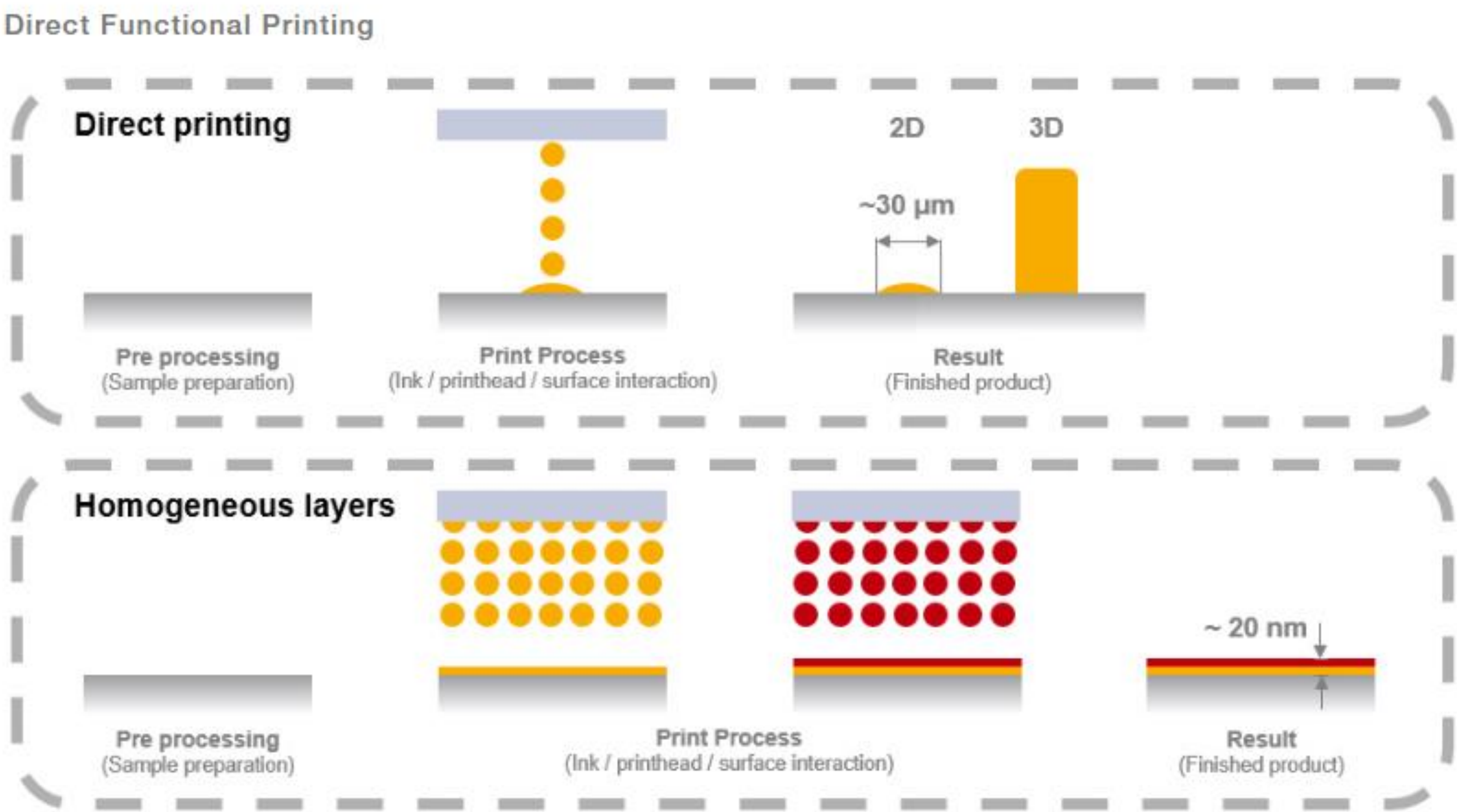


Image source: Meyer Burger

Inkjet – Think Beyond Graphics

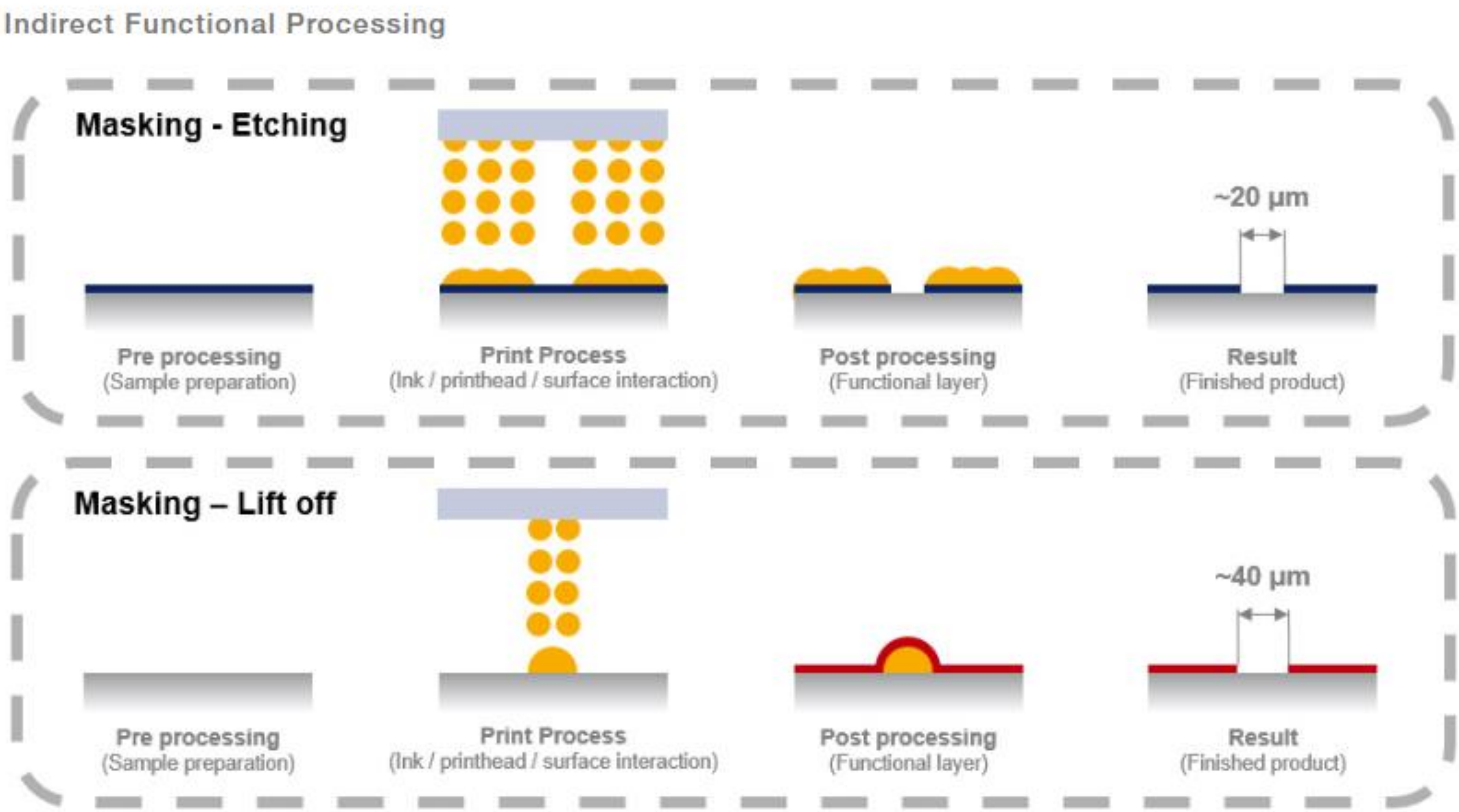
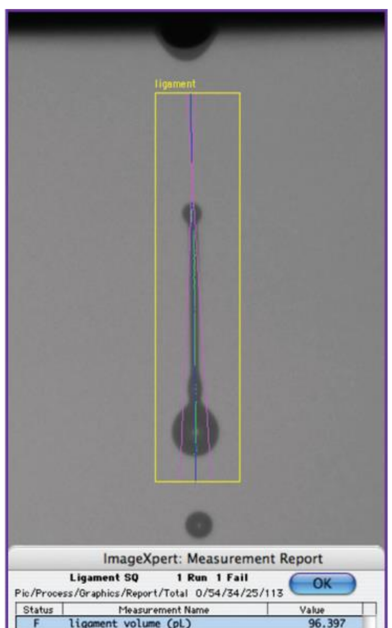


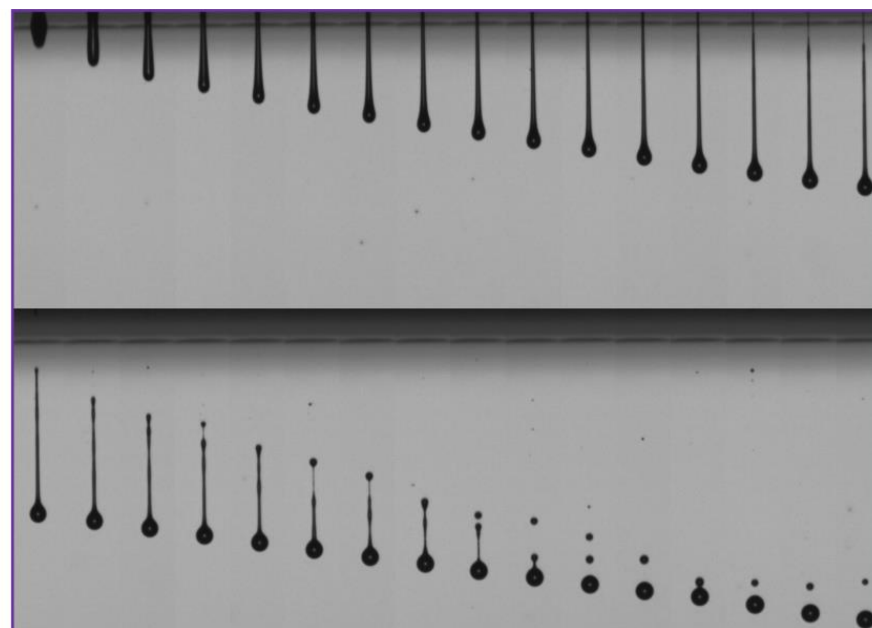
Image source: Meyer Burger

Inkjet Challenges - Jetability

- **Viscosity**
  - Most drop on demand printheads require fluids with viscosities in the range 7-15 centipoise (cps) at jetting temperature
    - Higher viscosity fluids can be heated to reduce viscosity to be jettable
    - Some new printhead developments will enable higher viscosities
  - Opportunities for inkjet to add efficiency and precision drop placement



Ligament volume measurement



View droplet formation

Image source: JetXpert

Inkjet Challenges - Jetability

- **Particulates**
  - Some visual effects in in analogue fluids are achieved using large particles, which would probably block nozzles in inkjet
  - Some of these effects could be potentially achieved instead using digitally controlled patterns
- **Inkjet provides different ways of producing optical effects**
  - Currently lot of activity in commercial print & packaging – same techniques could be applied in functional coatings

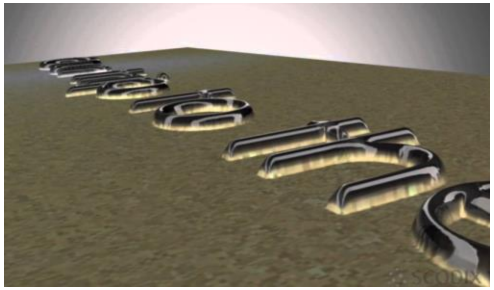
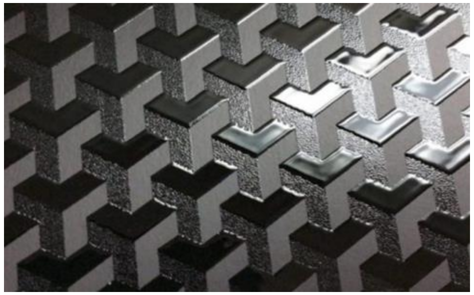




Image Source: Scodix

Inkjet Challenges – Throw Distances

- **Inkjet printers are typically designed to throw ink drops a distance of 1 – 2mm to the surface**
  - This produces sharp, detailed graphics and text – down to 2pt @ 1200dpi
  - And works well even when the head or surface are moving at up to 5m/s relative speed
  - But has created a perception that greater throw distances are a problem
- **In fact, nozzle drop velocities are in the range 5-8m/s**
  - Medium to large drops will travel over 20mm
  - Placement accuracy does degrade with range, so a trade-off must be found
    - Fine detail can be achieved on near-flat surfaces with shorter throw distances
    - Coating coverage can be achieved even in concavities up to ~25mm depth

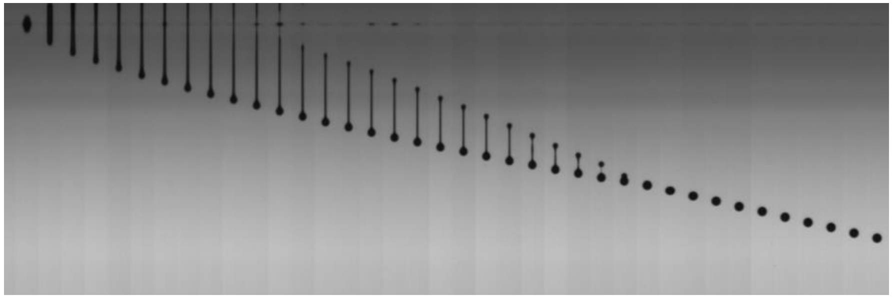


Image Source: ImageXpert

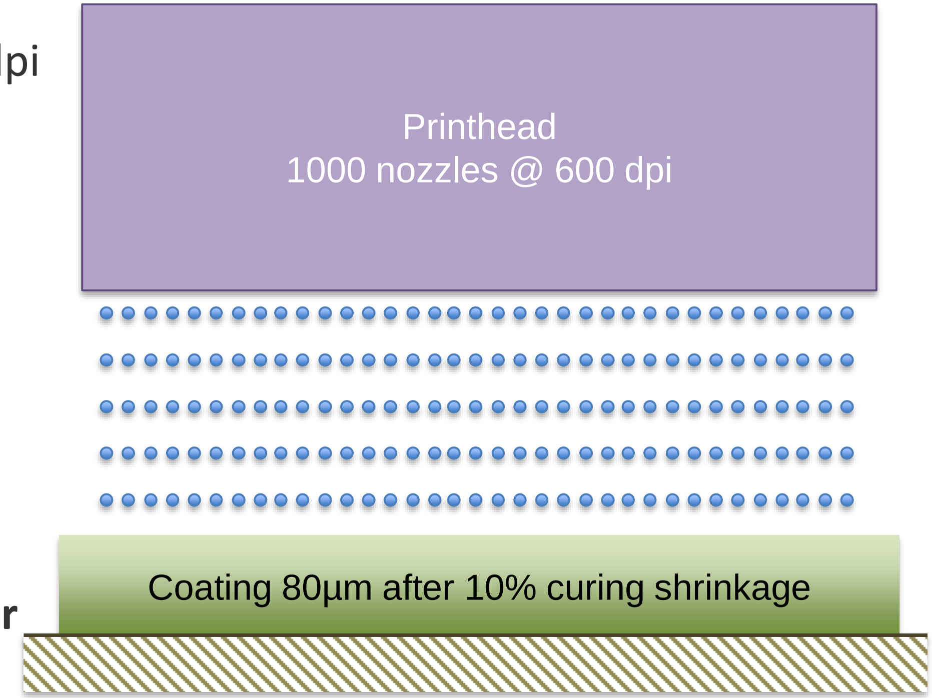
Example: Inkjet Coating vs. Spray Coating

Features	Benefits
Precise drop formation and placement Digital control	High transfer efficiency Fluid cost savings
Drop on demand technology Digital control	No overspray Precision coatings Environmental management cost savings
Digital control	No physical masking required Short run customisation Labour cost savings Time saving
Highly integrated, modular technology	Fluid changes by switching print module

Inkjet Productivity

Coating application example:

- Depositing 80µm layer onto a flat surface
- Medium density head: 1000 nozzles @ 600dpi
- Firing large 160 picoLitre drops @ 20kHz
- Allow 10% for curing shrinkage



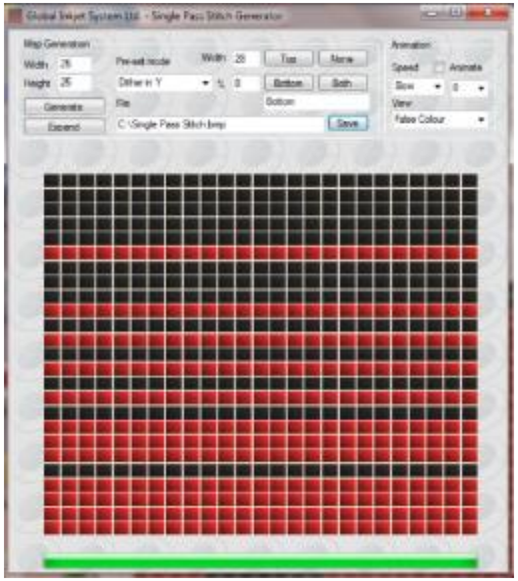
Surface coverage for a single head:

- Head width: 42.3mm
- Print speed: 846mm/s

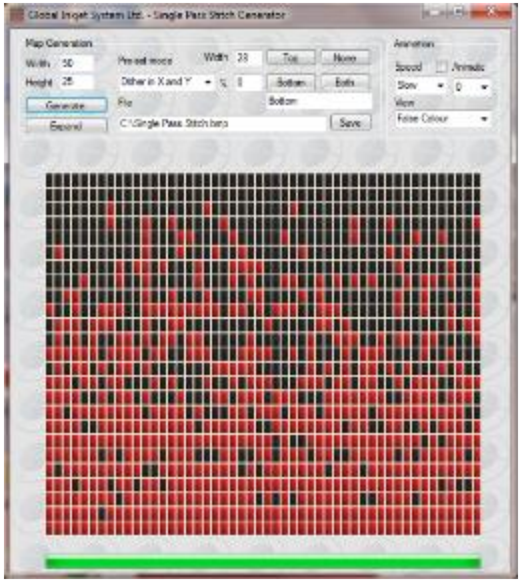
Area covered by single printhead: 129 m^2/hour

Hard Stitching

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



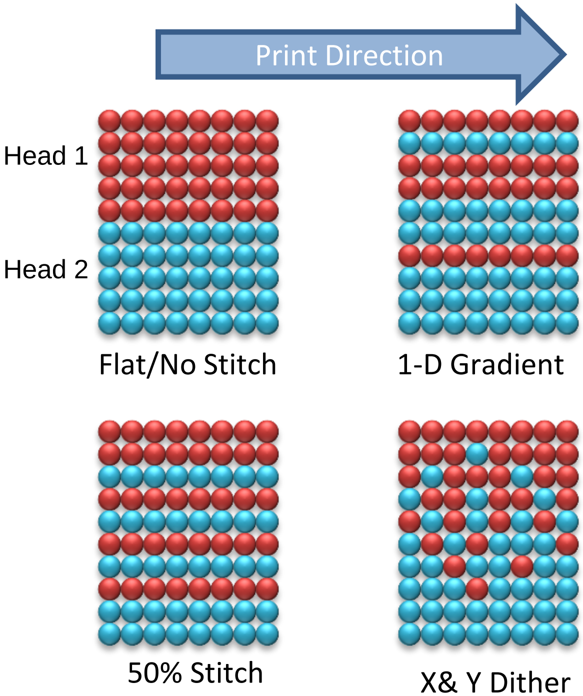
2-D Density



X & Y Dither

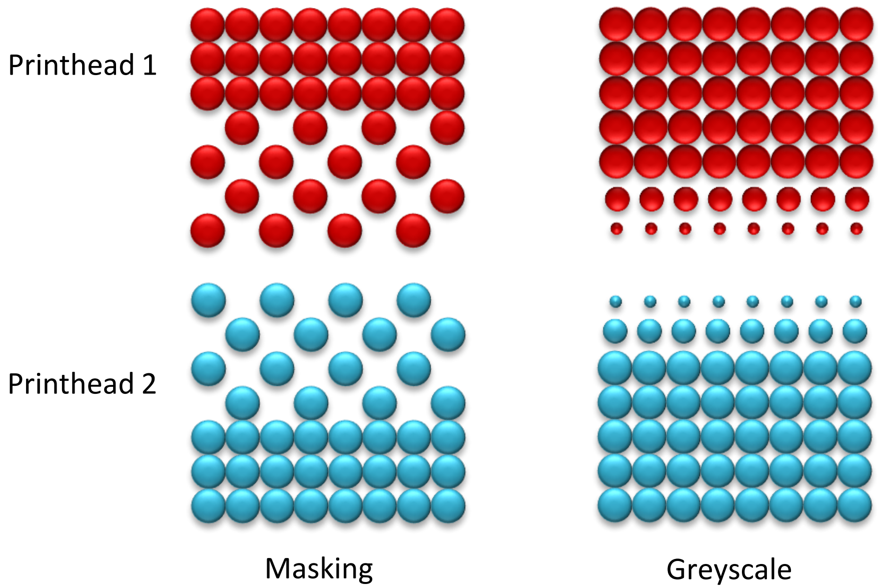
GIS Stitching Tool

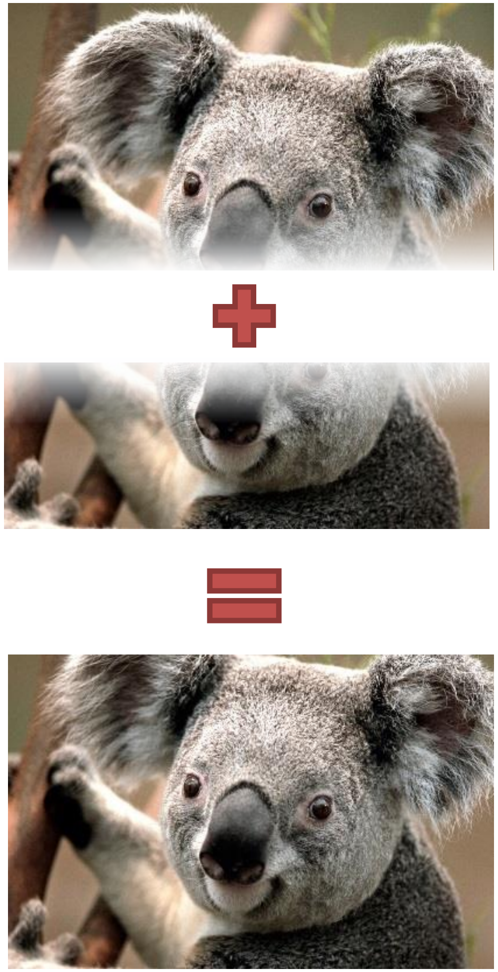
Examples of masking stitches



Greyscale 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**





GIS Stitching Tool

Achieving Uniform Coatings

- **Large areas of solids / flat colours / uniform coatings**
  - Drop volumes not always consistent across printhead
  - “Non-linearity” in drop volume
  - Even small difference can affect final print
  - We want uniformity of drop laydown
  - We need to linearize the printheads
- **Printhead linearization**
  - Electronic/printhead solutions
  - Software solutions

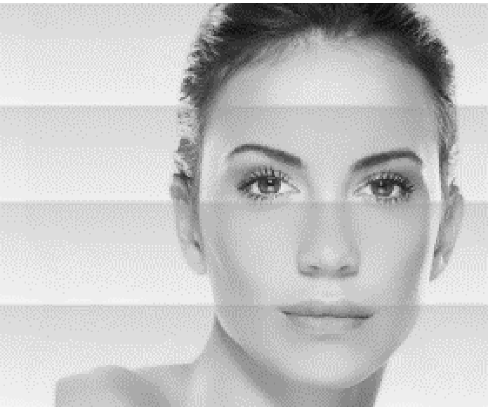
Printhead Density Correction

- **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 in software – 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 banding

Printhead banding

Printhead banding



Digital printhead linearization 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

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Nozzle Out Compensation

- **Many different strategies exist using neighbouring nozzles**
  - Correction in contone or screened data
  - 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
- **Isolated nozzles work best**
  - Clusters of nozzles much more difficult to hide
  - Technology works best where there is some substrate bleed/drop overlap
- **Helps disguise/makes the missing nozzle less visible**
  - Less white space

Inkjet – Direct to Shape

- **Not everything we want to decorate or coat is flat**
- **Tubes, cones, tubs - now well established technology**
  - Many systems – low & high production
  - Glass, plastics, aluminium
- **Cones & tubs – require correction in software**

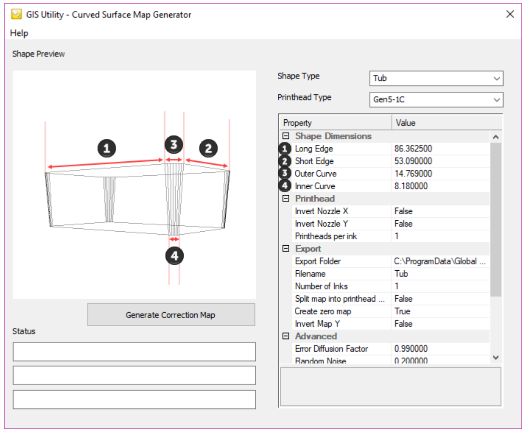
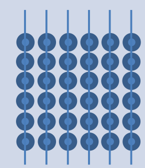
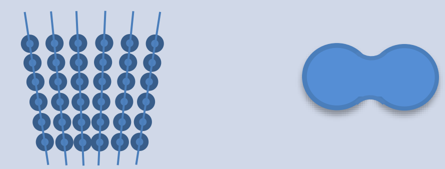
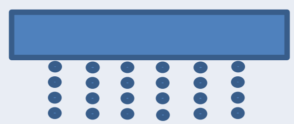
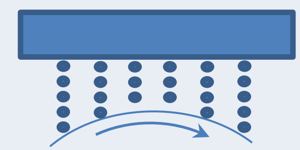
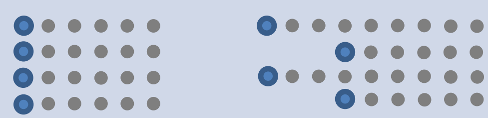
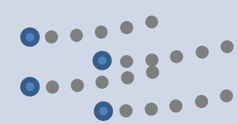


Image source: GIS software, SMT Digital, KHS, Till, Martinenghi, Wifag

Inkjet Challenges – Complex Curved Surfaces

	Flat Surfaces	Curved Surfaces
Density Correction		
Throw Distance & Flight Time		
Nozzle Alignment & Interleaving		
Screening		

More Complex Shapes

- **Many complex shapes have eluded inkjet printing & coating**
- **Analogue technologies dominate**
- **Inkjet moving from partial to full coverage printing of any object**

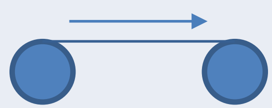
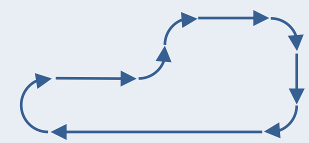
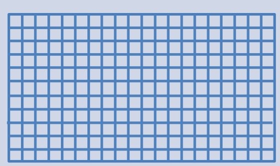
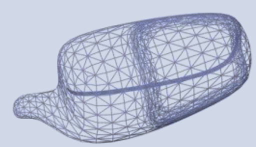
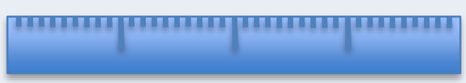




Photo credit: © Upper Austrian Research, Hartwig Zörgl

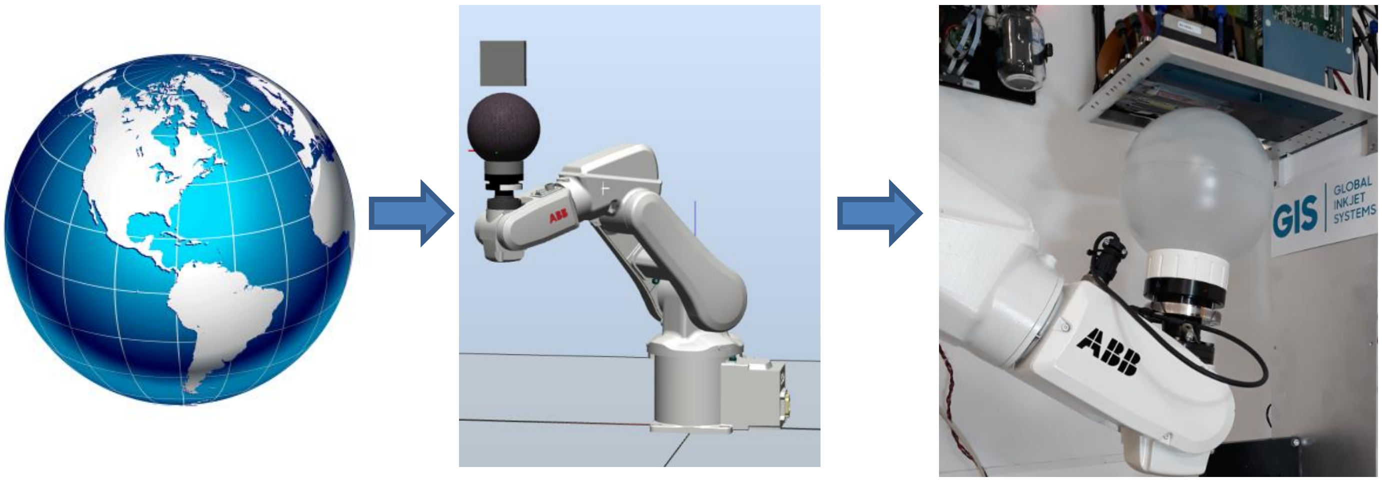
Other images from YouTube, Airbus & Ritzi (Heidelberg)

Inkjet Challenges – Navigation & Motion Control

	Flat Surfaces	Curved Surfaces
Geometry	2 Dimensions 2 Degrees of Freedom	3 Dimensions 6 Degrees of Freedom
Print Path		
Shape Data		
Motion Control		

From Concept To Reality

- **Starting with a sphere**
- **Using a robot to position the shape under the printheads**
- **We built a test print rig**



Mesh & Texture

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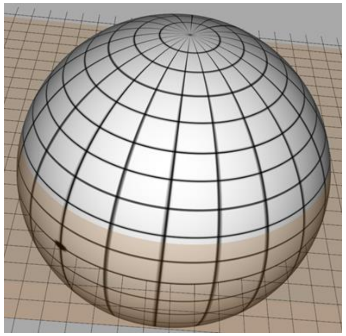
3D Mesh



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Texture

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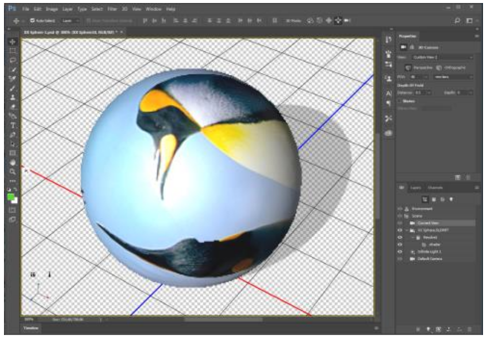
- **Many tools available for wrapping**
  - Well established technologies from gaming, augmented reality industries, etc.
  - Many different ways to wrap, edit directly on to 3D surfaces
  - Result is expressed as a texture map



Print Path

- **Design a print path**
  - Taking into account the constraints of the object to be printed, inkjet printhead, capability of the robot
  - Currently we do this manually, which is appropriate for most manufacturing applications, but there is research towards automation

Latitude **Spiral** **Other**

Positioning Accuracy

Industrial robots have sufficient accuracy for many industrial applications …

… but printing requirements are tight

- Typical industrial robots can achieve absolute pose accuracy with calibration of 200-500 µm
- Inkjet printing requirements for graphics are typically 5-10x finer, but not so precise for coating
- Robot repeatability is better than absolute accuracy, so further calibration is possible

Image source: ABB and Fanuc

Shape Variation

All manufactured objects have tolerances
- E.g. Polypropylene sphere
- Inexpensive consumer product

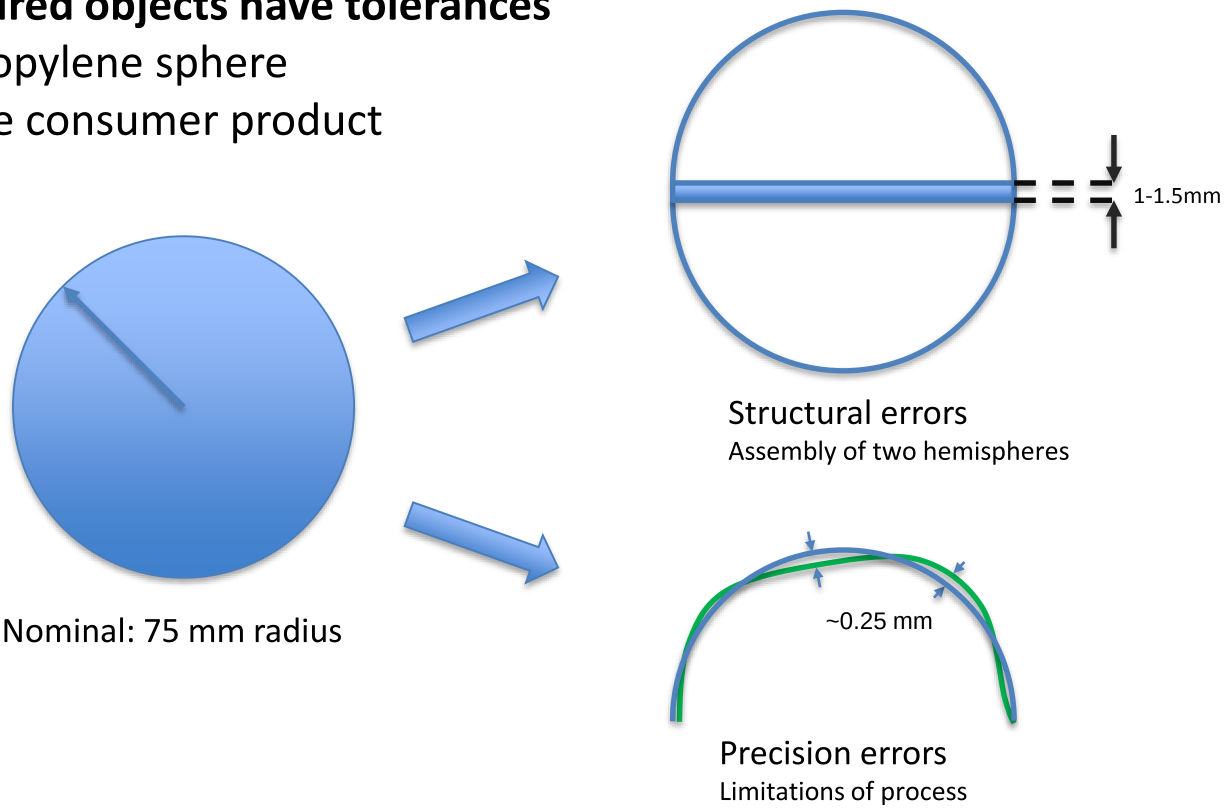


Image source: GIS

Stitching

- **Stitching is a key area where inaccuracies will show**
  - Positioning errors cause gaps or overlaps, familiar from 2D printing

- **Careful control is required of multiple factors:**
  - Accuracy of transport
  - Print synchronisation
  - Variation of the target shape from nominal dimensions

Image source: GIS

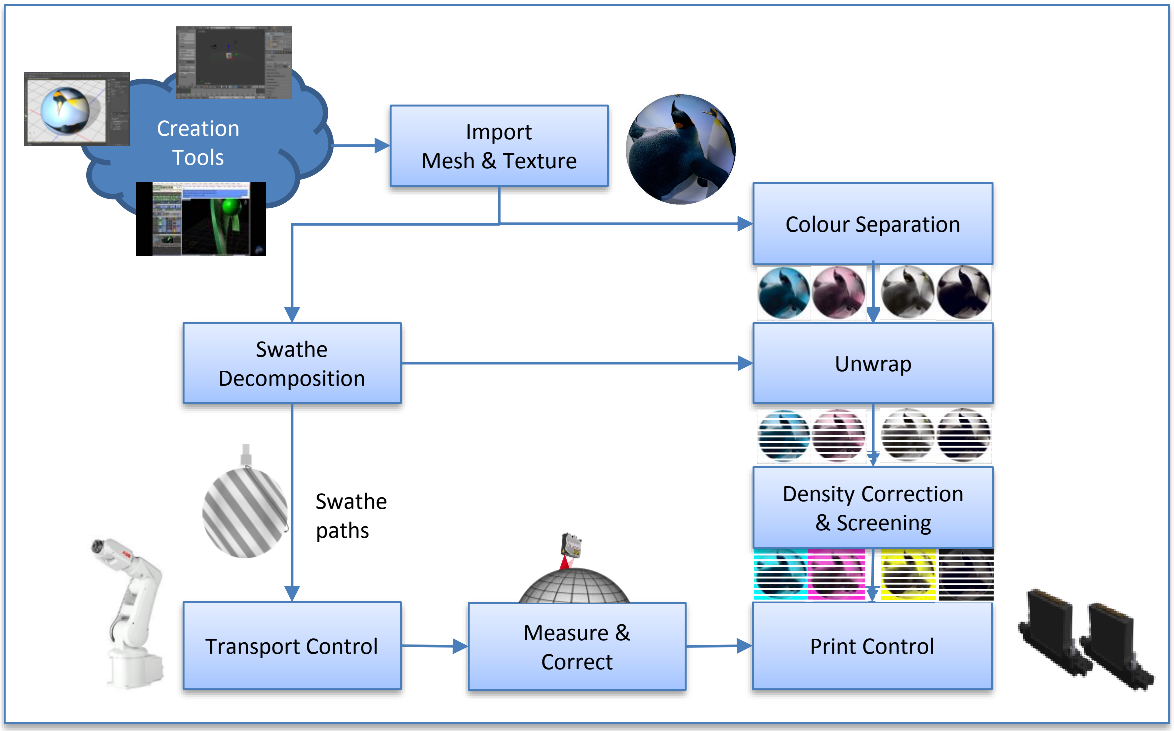
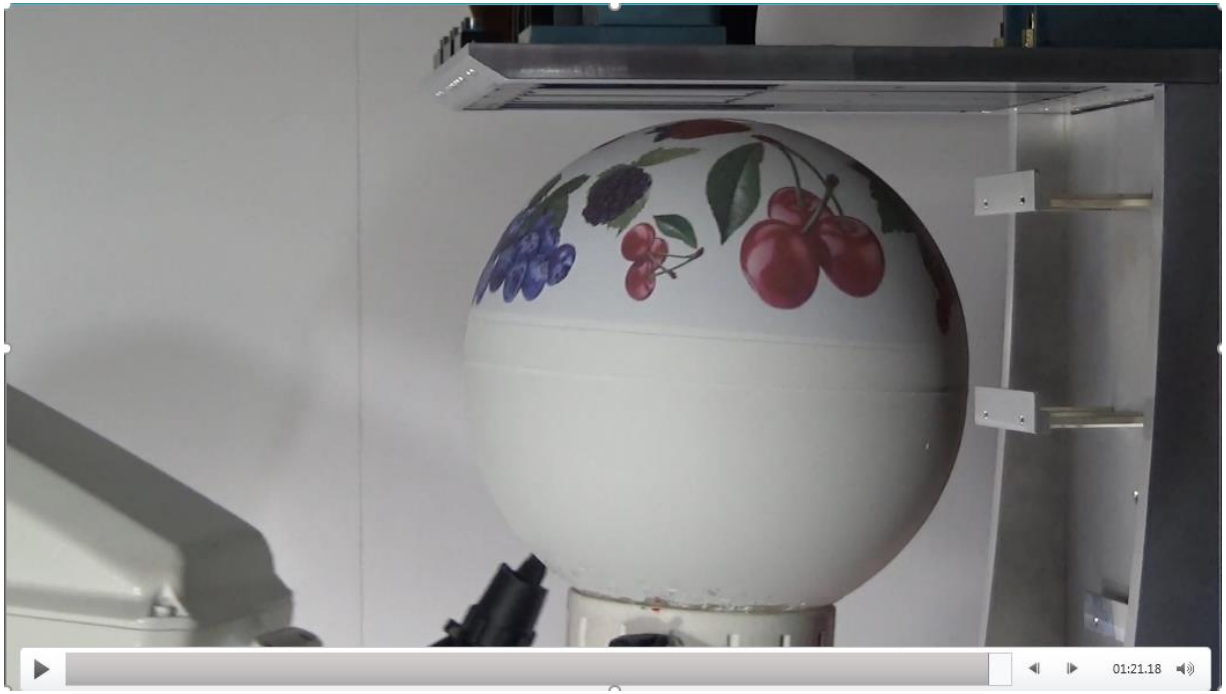


Image source: GIS

Video



Result: a printed polypropylene spheroid

- CMYK 1200 dpi
- Latitude swathes
- 300dpi native x 4 interleave

Summary - Implications & Opportunities

- **Inkjet already being used in many functional coating applications**
  - Decorative & functional
- **Advances in printhead technologies, software and fluids continues**
  - Some highly viscous fluids remain a challenge
  - Ink jettable fluids - key to unlocking more applications
- **Inkjet no longer constrained to flat surfaces**
- **Great potential for further usage**

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