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Industrial Inkjet for Coating and Decoration of Automotive Surfaces

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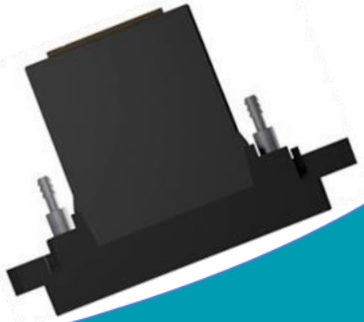
Disclaimer

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.

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.

Agenda

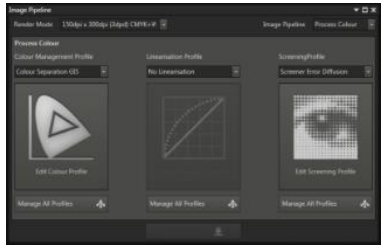
- **Brief Introduction to Global Inkjet Systems (GIS)**
- **Industrial Inkjet**
  - Busting the myths!
  - What inkjet can really achieve in production environments
- **Challenges of Automotive Surfaces**
- **Printing or Coating Complex Curved Surfaces**
  - Like a dashboard or a wing mirror…or even a complete car?



Global Inkjet Systems Ltd

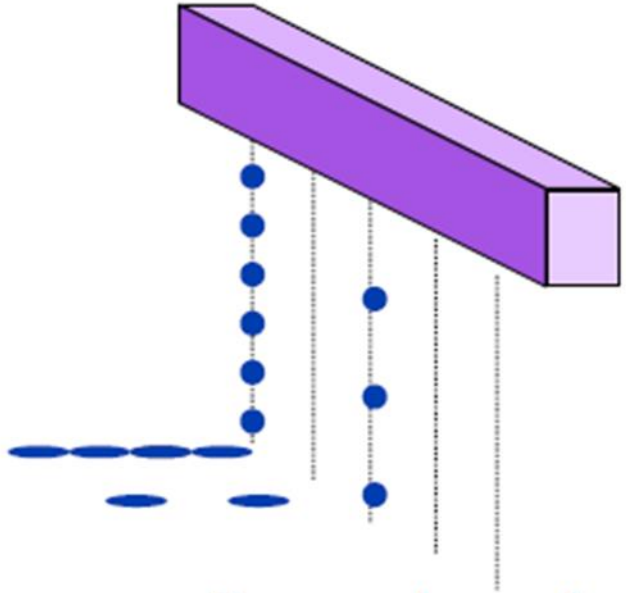
- **Leading independent developer of inkjet technology**
  - Supply inkjet capability to OEM system builders, specialist integrators and end users
  - Support a broad range of inkjet printheads in wide range of applications and industries

- **Based in Cambridge, UK**
  - 12 years of growth & technology innovation
  - 70 employees
  - 130+ customers world-wide
  - Support offices in UK, Japan and China



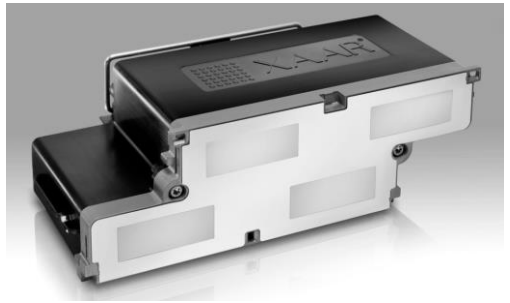
Inkjet Technology

- **Industrial 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

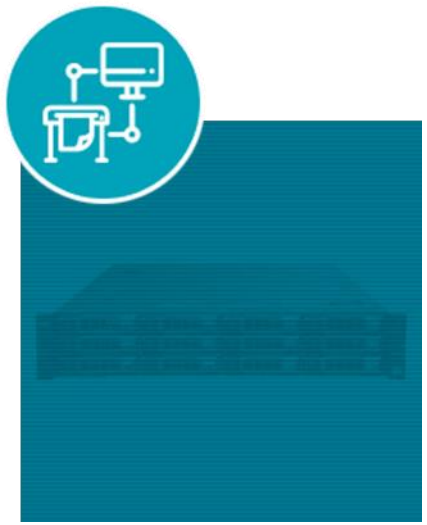


Inkjet Strengths

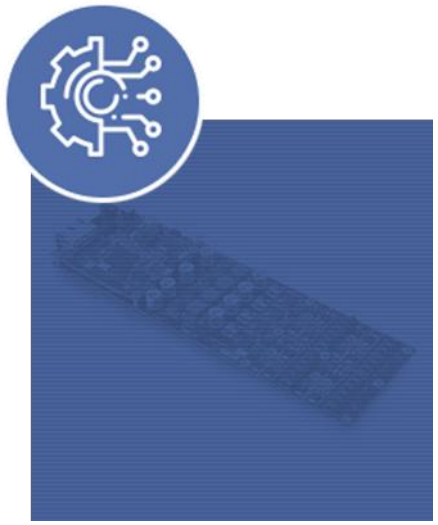
- **Non contact**
- **Additive process**
- **Subtractive process**
- **Broad fluid capability**
  - UV curable inks, resists & adhesives
  - Conductive fluids
  - Jettable polymers & dielectrics
  - Jettable active & passive electronics
  - Acid resist
- **Precise drop formation**
  - Small drops for small features
  - Large drops for coatings/area fill
- **Precise drop location**
- **Conserves expensive materials**
- **Reduces 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**

GIS - Product Groups

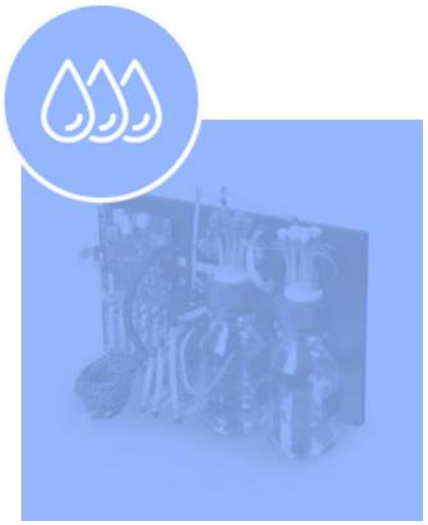
Digital Front End
Atlas® User Interface
Raster Image Processing



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**

Inkjet in Production

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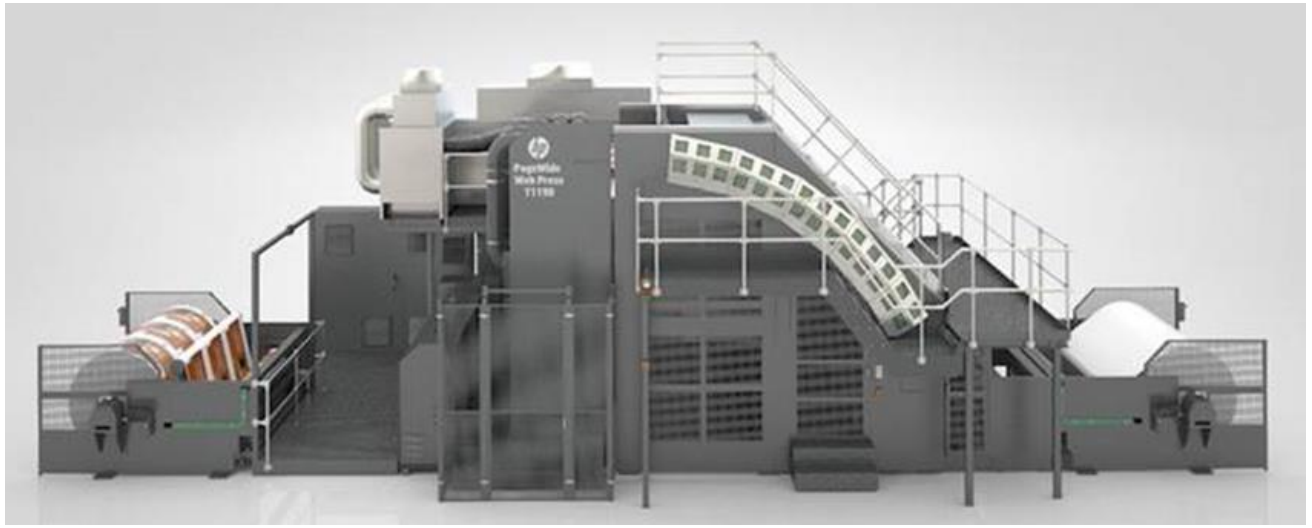
Not this …

Image source: HP

Inkjet in Production – Big Presses



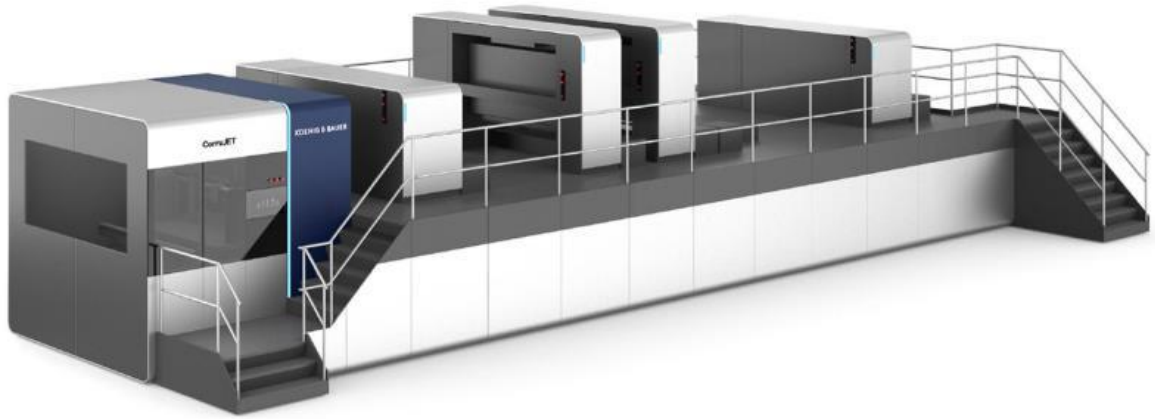
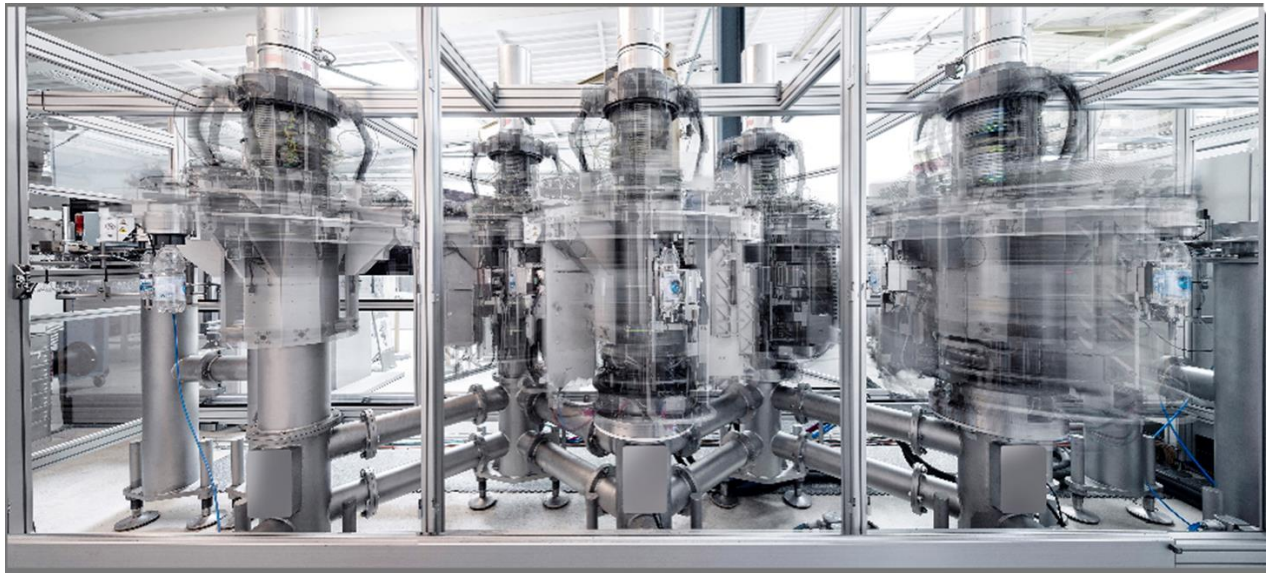


Image source: Inca Digital, HP, KBA, KHS



Inkjet – Think Graphics – and Beyond Graphics

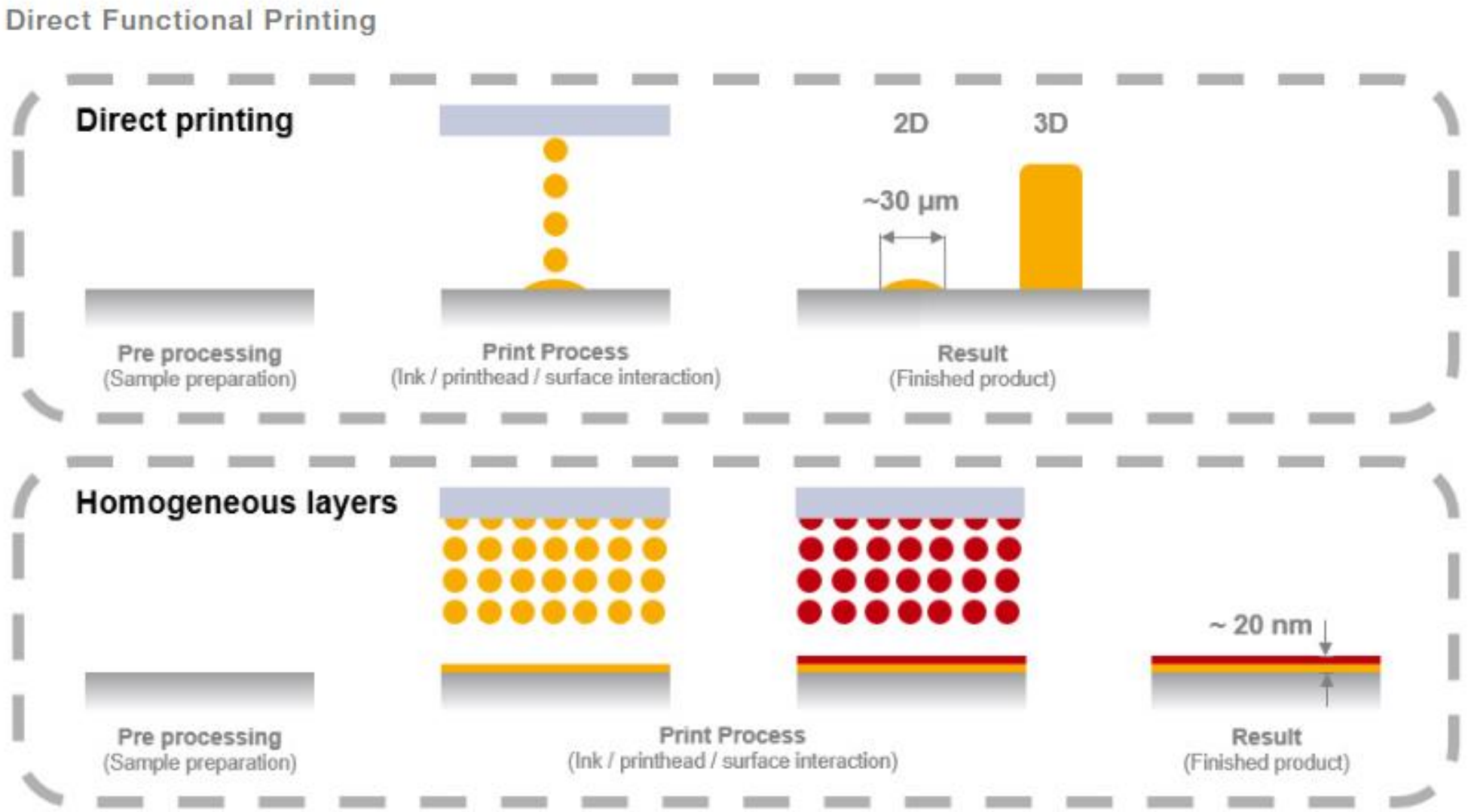


Image source: Meyer Burger

Inkjet – Think Beyond Graphics

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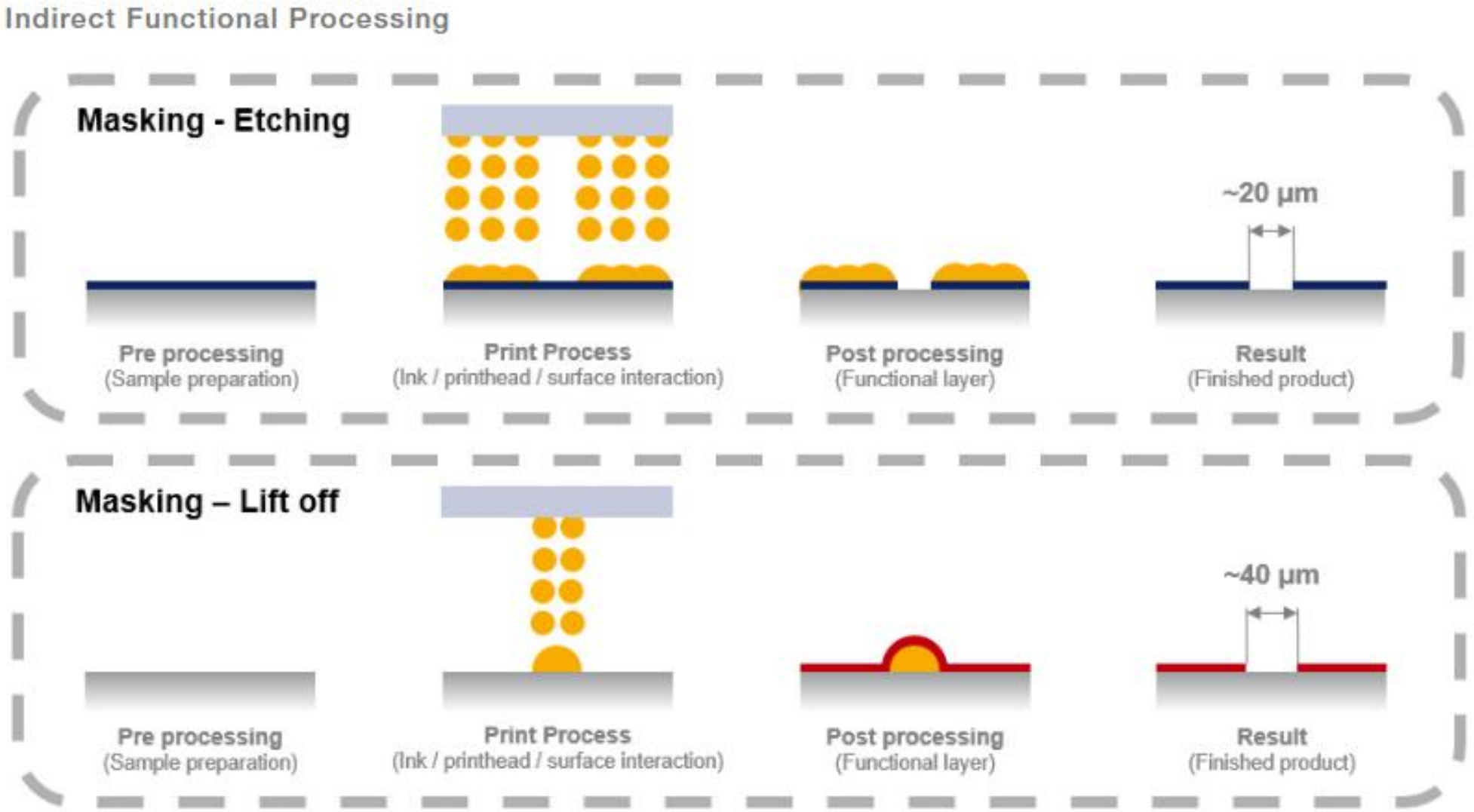

Image source: Meyer Burger

Inkjet Markets – Coding and Marking

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Non-impact gave inkjet a market breakthrough

Now key technology in Track & Trace

Image source: Domino, Codemark, Pryor Technology, Planet Group

Inkjet Markets - Ceramics

Image Source: System Italy

Inkjet now dominates ceramic tile production

That floor looks like stone

- but it isn’t

Inkjet Markets - Textiles

Image Source: SPG

Digital print for textiles has reduced minimum viable print run lengths and shortened turnaround times

Image Source: Seiko Epson Corporation

Inkjet Markets – Automotive Textiles

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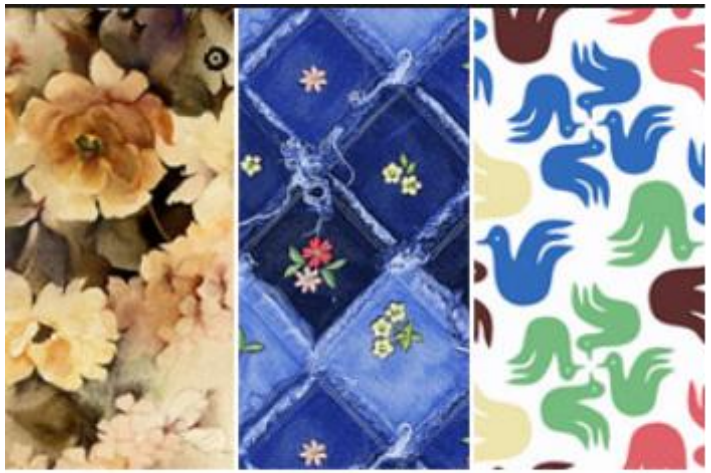


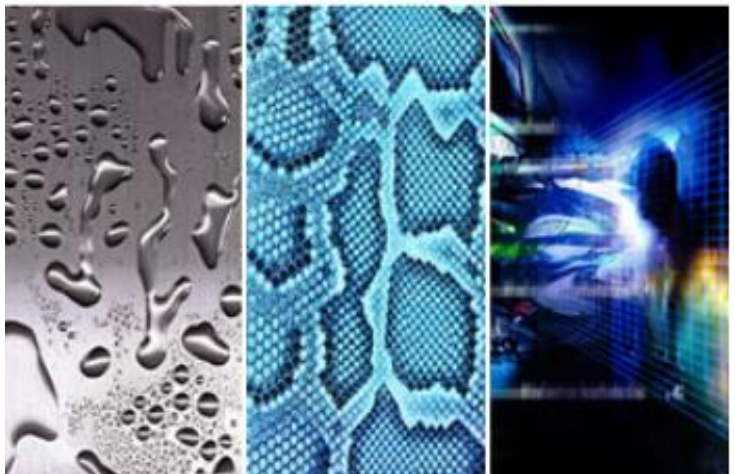


Image Sources: Mimaki, Seiren

Inkjet Markets - Décor

Graphics and textures for all kinds of decorative products: wall coverings, edge banding, flooring, doors, window frames, furniture…

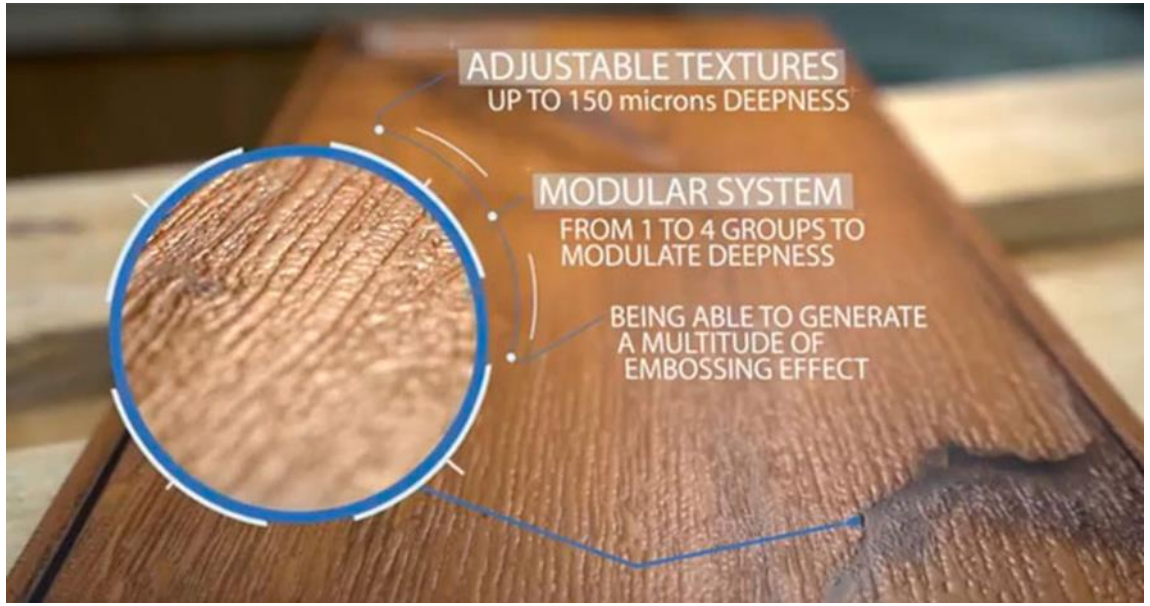
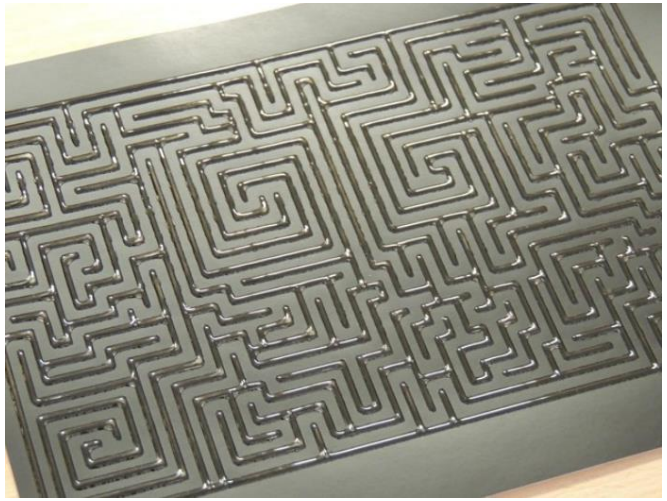
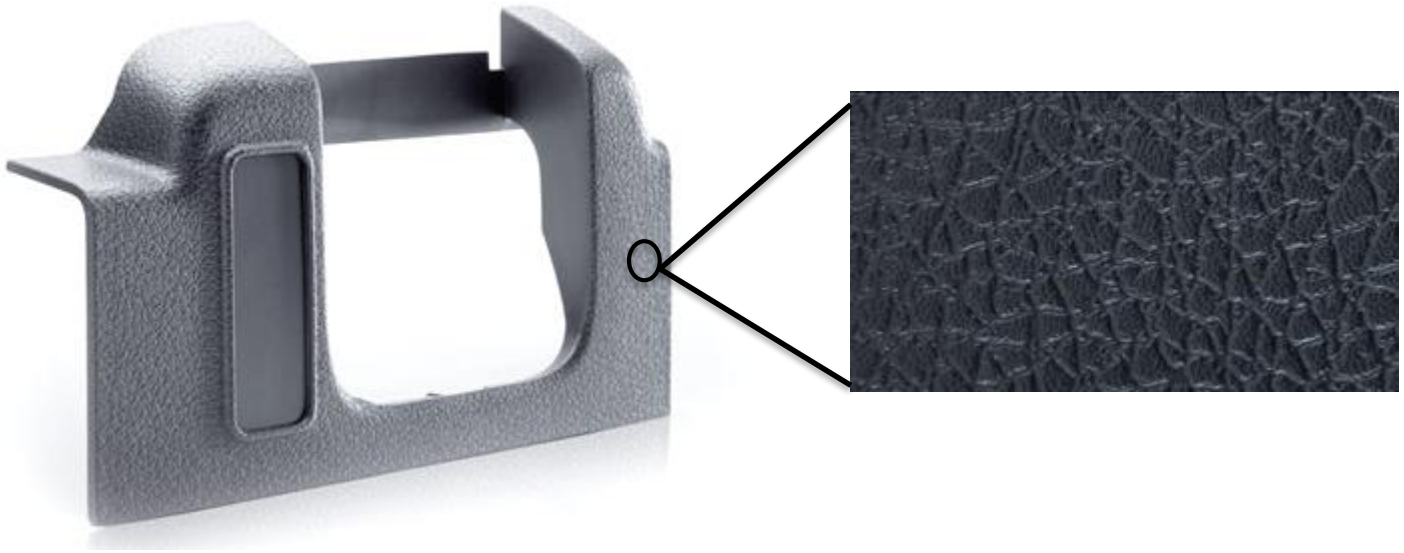


Image Sources: Hymmen, Cefla, Interprint

Inkjet Markets – Texturing

- **Tactile effects**
  - Additive
    - High laydown effects
  - Subtractive
    - Ink-jetted acid resist





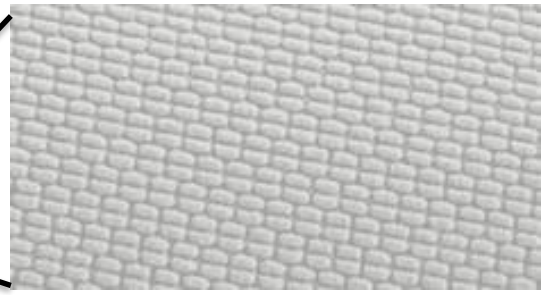
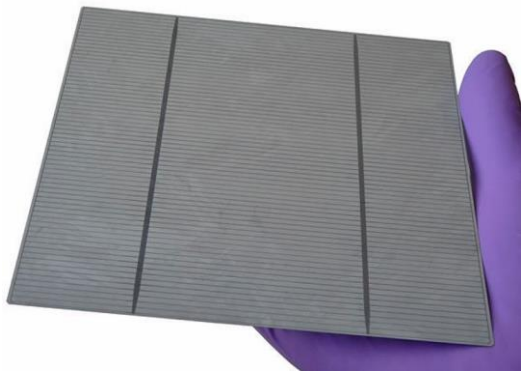


Image source: Ikonics, Kuei, Komfi

Inkjet Markets – Printed Electronics

- **Display**
  - LCD colour filters
  - OLED
    - Depositing light emitting layer
  - Encapsulation layers
- **Photovoltaics**
- **Other**
  - Jetting conductive tracks
  - Solder mask

Increasingly moving towards flexibles



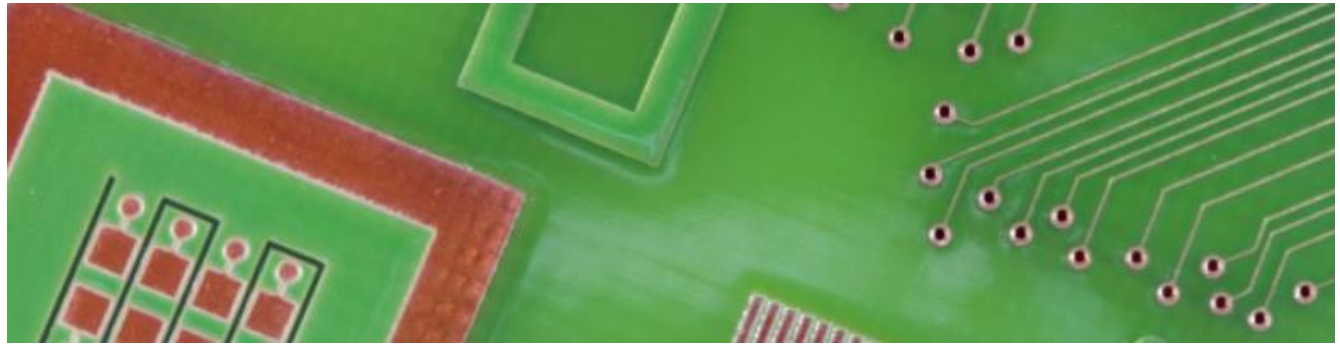


Image source: Kateeva, Meyer Burger

Inkjet Markets – 3D

- **Inkjet one of many 3D technologies**
  - Concept & functional prototypes and Industrial use
    - Automotive
    - Aerospace
    - Pump & Heavy Industry
    - Art & Design
    - Film & Museum
  - Production example - Binderjet
    - Powder can be
      - Sand for industrial casting moulds
      - Metal, subsequently sintered
      - Ceramics: silicon carbide or aluminium oxide

Image source: Voxeljet, Stratasys, Hoganas, Schunk

Inkjet Markets – Direct to Shape

- **Tubes, cones, tubs**
- **Tubes – now well established technology**
  - Many systems – low & high production
  - Glass, plastics, aluminium
- **Cones & tubs – require correction in software**

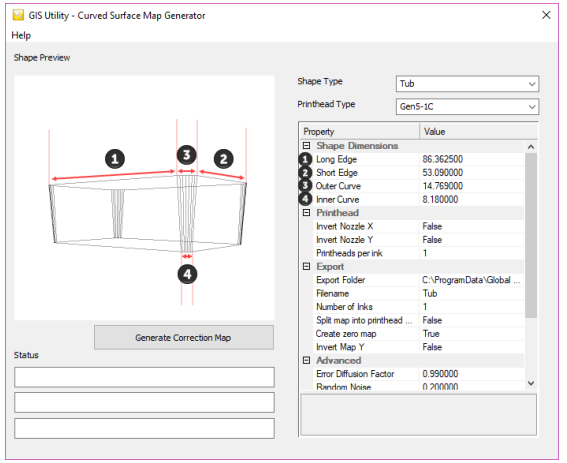


Image source: GIS software, SMT Digital, KHS, Till, Martinenghi

More Complex Shapes

- **Many complex shapes have eluded inkjet printing & coating**
- **Analogue technologies dominate - even when some processes are inefficient and wasteful of materials**
- **Inkjet moving from partial to full coverage printing of any object**

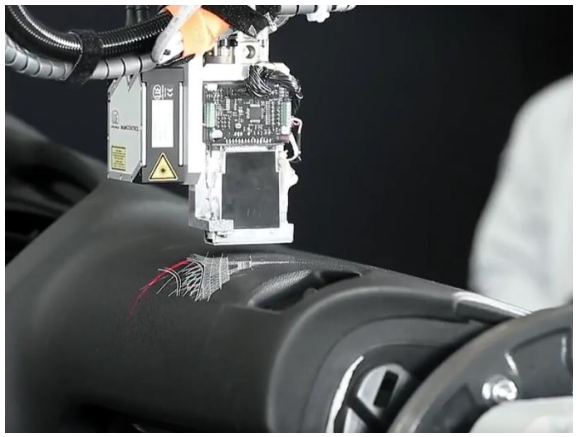
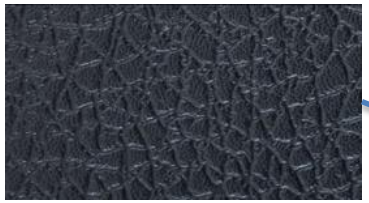


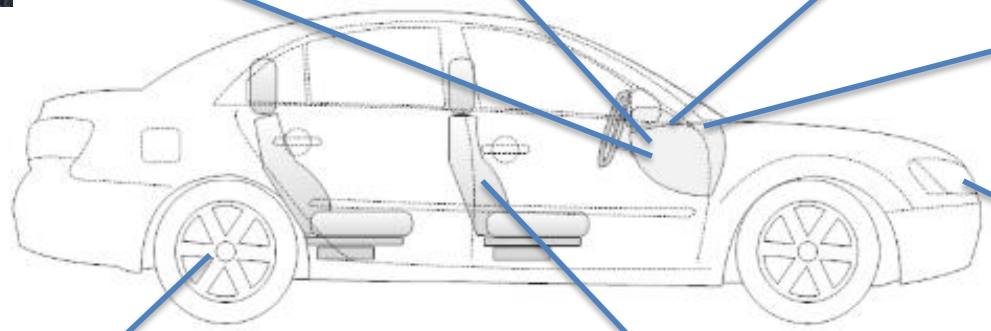
Photo credit: © Upper Austrian Research, Hartwig Zörgl

Other images from YouTube, Airbus & Ritzi (Heidelberg)

Inkjet & Automotive Surfaces – so far

Some examples:-





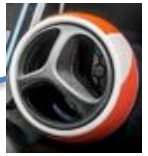


Image Source: Momentive, Borbet, Ritzi, Nakan, Seiren, Ikonics

Inkjet for Automotive Surfaces

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	Graphic painting/coating without physical masking Short run customisation Labour cost savings
Highly integrated, modular technology	Fluid changes by switching print module Support wider range of colours for decorative applications

Inkjet Productivity

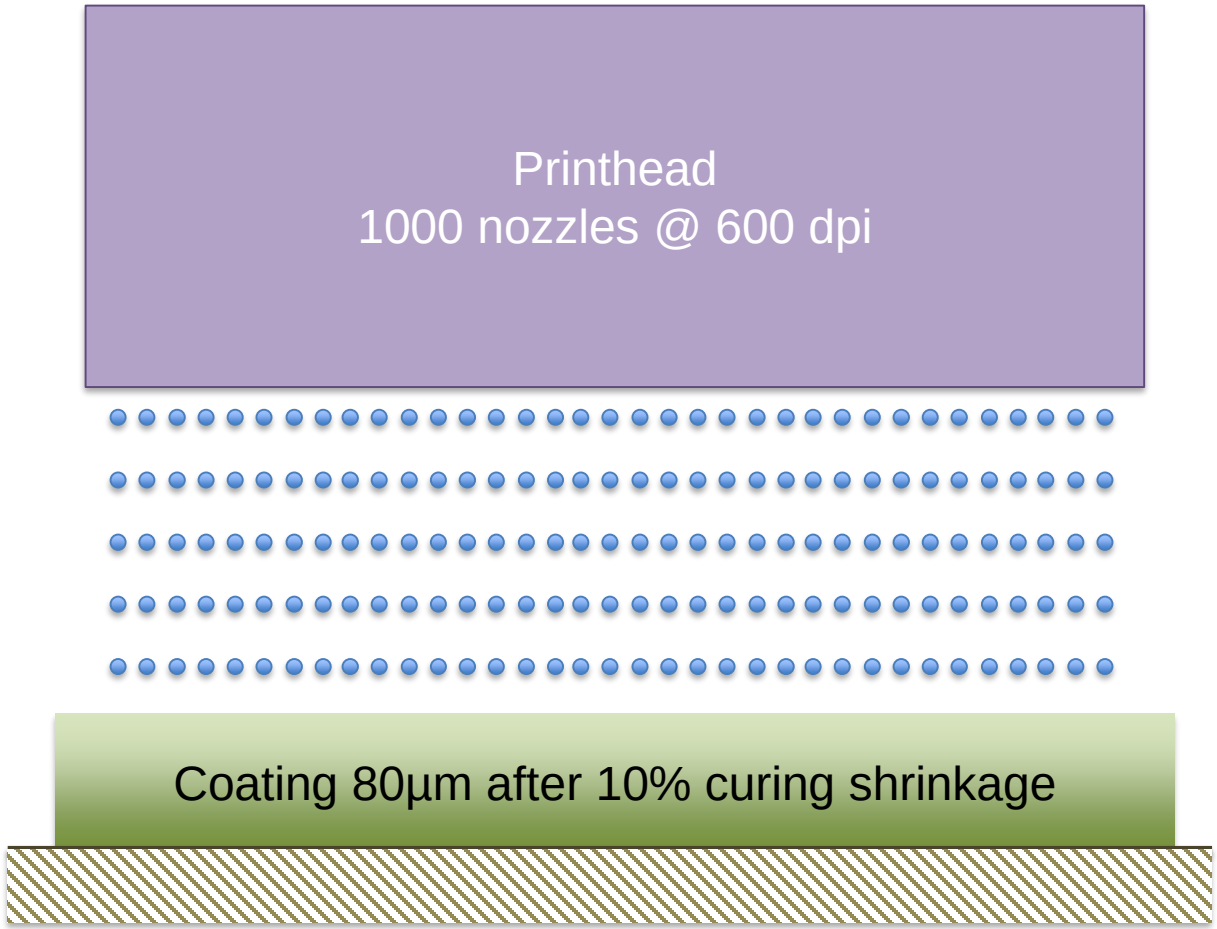
Coating application:

- 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:

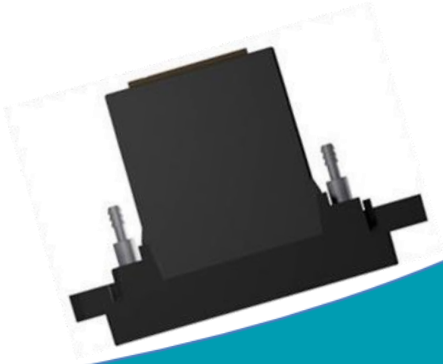
- Head width: 42.3mm
- Print speed: 846mm/s

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



Inkjet Challenges

- **We also have some challenges**
  - Jettability
    - What fluids can we handle?
  - Throw Distances
    - Where can we jet them?
  - Complex Curved Surfaces
    - How do we adapt?
  - Navigation & Motion control
    - Where are we?



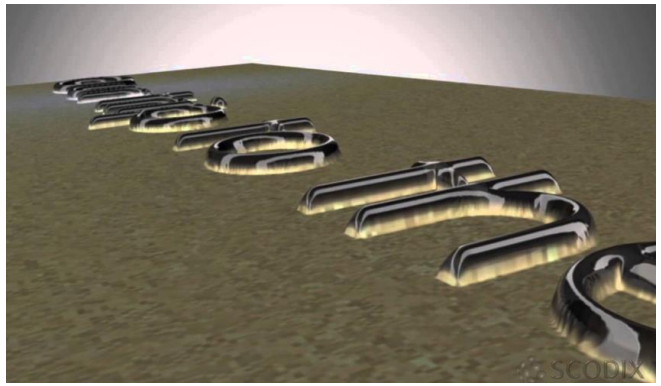
Inkjet Challenges - Jettability

- **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
  - Automotive paints – viscosity challenging for inkjet
  - Automotive hardcoats – can be as low as 10cps
    - E.g. Momentive SilFORT
  - Opportunities for inkjet to add efficiency and precision drop placement

Image Source: Momentive SilFORT Hardcoats, Easypaintrobot.com

Inkjet Challenges - Jettability

- **Particulates**
  - Some visual effects in automotive paints are achieved using large particles, which would probably cause problems blocking nozzles
  - These effects could be achieved instead using digitally controlled patterns
- **Inkjet provides different way of producing optical effects**
  - Currently lot of activity in commercial print & packaging – same techniques could be applied in automotive coatings



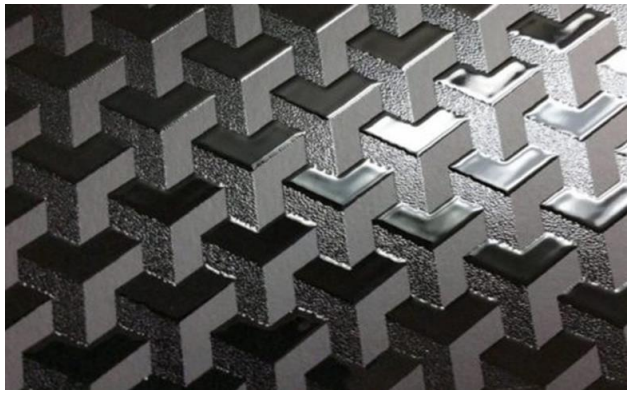
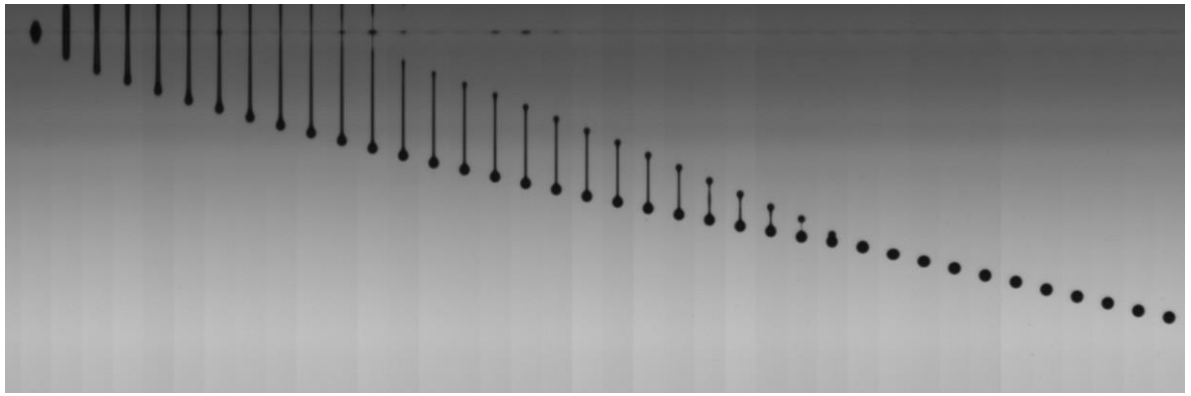



Image Source: Scodix

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



Inkjet Challenges – Complex Curved Surfaces

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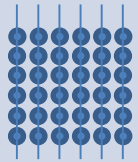
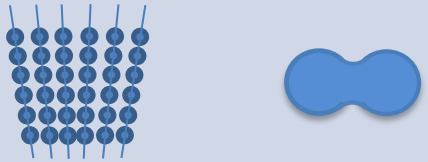
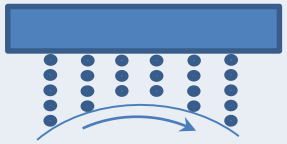
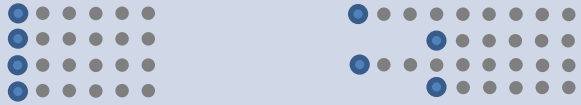
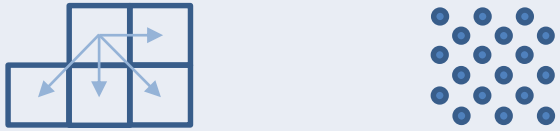
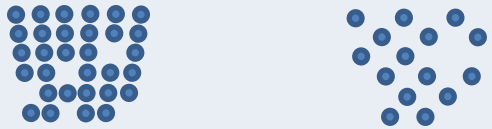
	Flat Surfaces	Curved Surfaces
Density Correction		
Throw Distance & Flight Time		
Nozzle Alignment & Interleaving		
Screening		

Inkjet Challenges – Navigation & Motion Control

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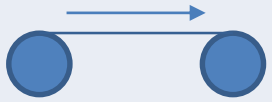
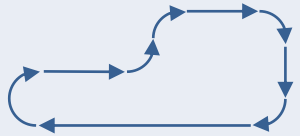
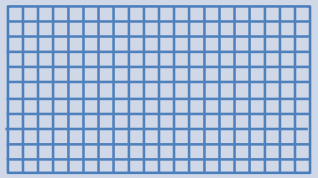
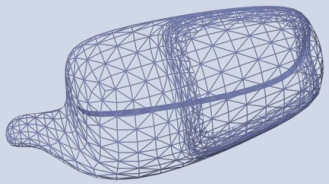
	Flat Surfaces	Curved Surfaces
Geometry	2 Dimensions 2 Degrees of Freedom	3 Dimensions 6 Degrees of Freedom
Print Path		
Shape Data		
Motion Control		

From Concept To Reality – Sphere Printer

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

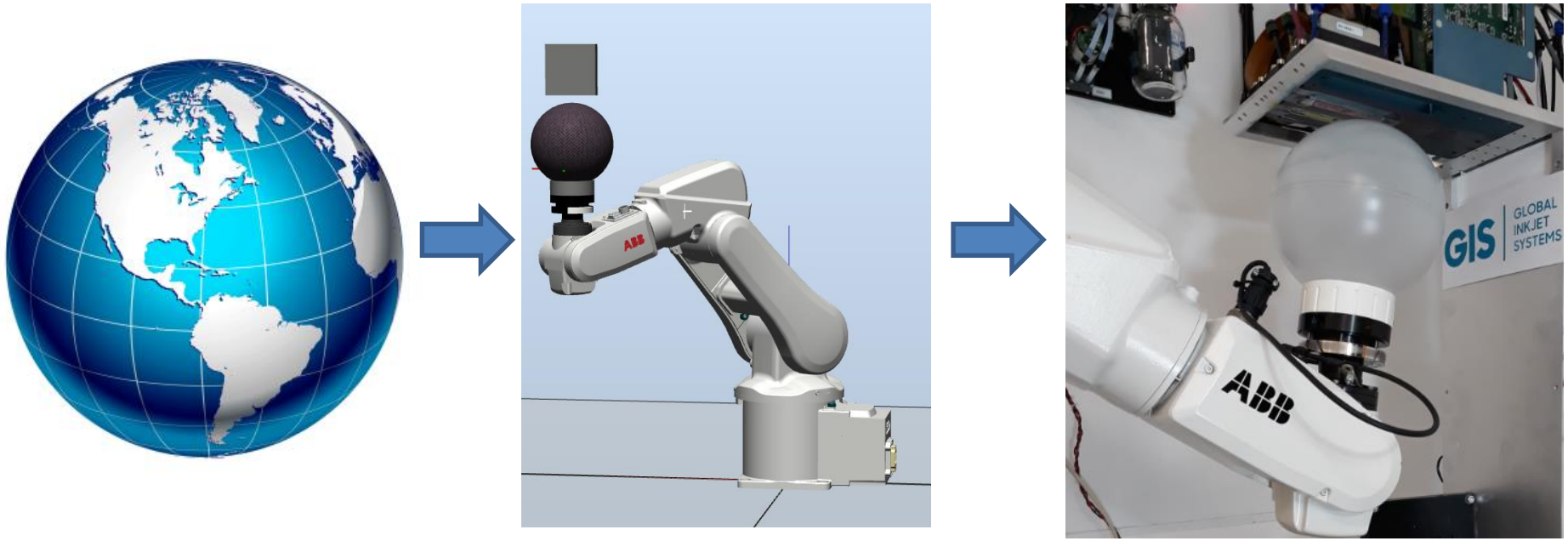


Image source: GIS

Sphere Printer - Workflow

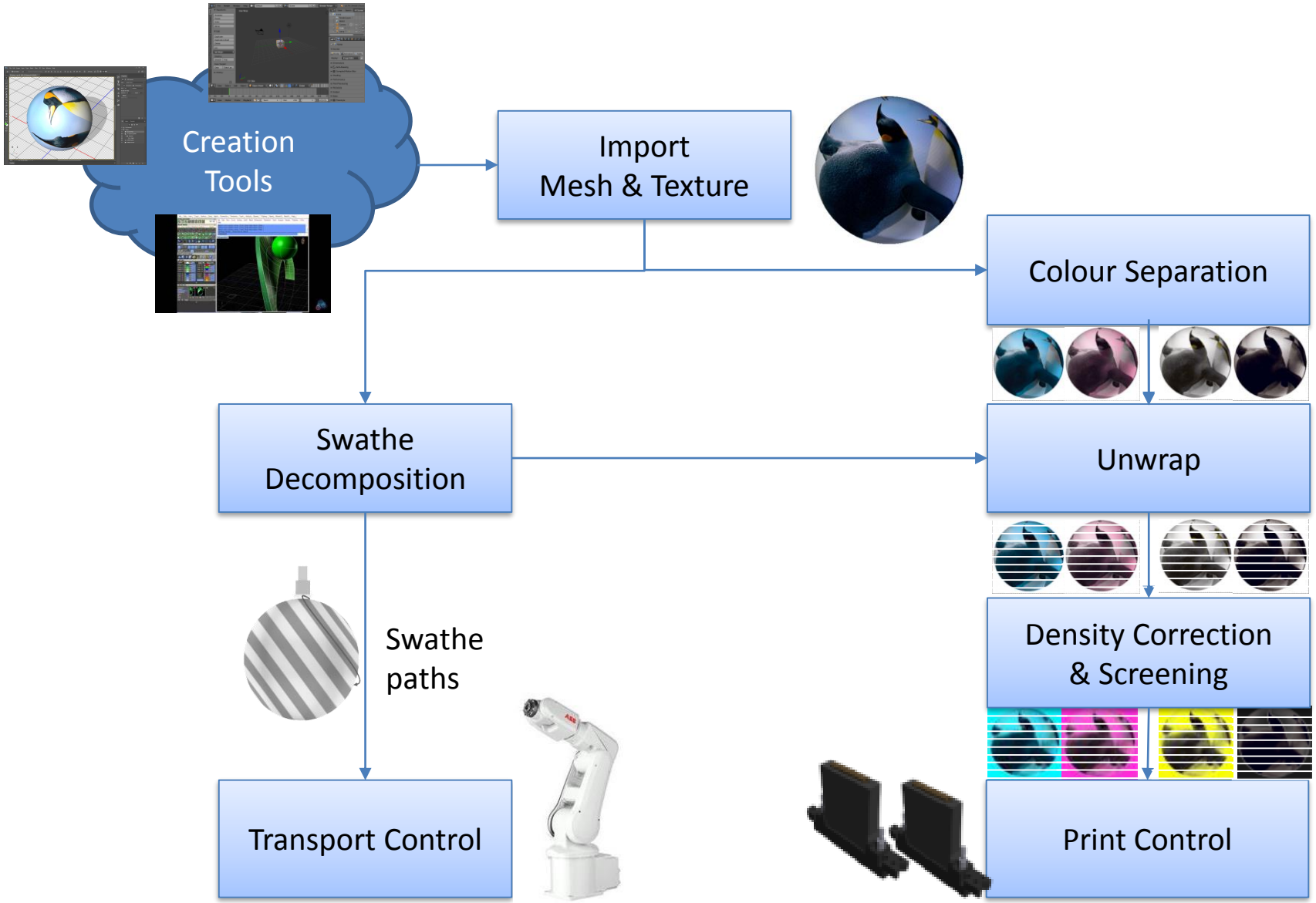
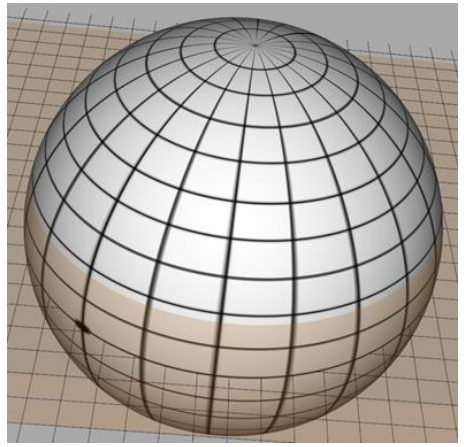


Image source: GIS

Sphere Printer – Mesh & Texture

3D Mesh



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Texture

=

- **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

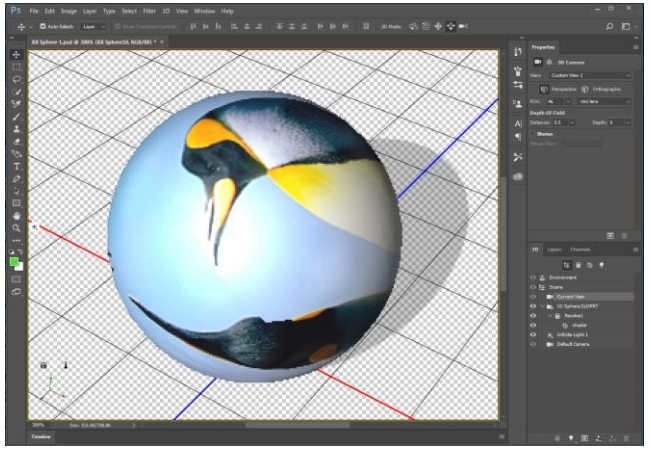


Image source: GIS

Sphere Printer – 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

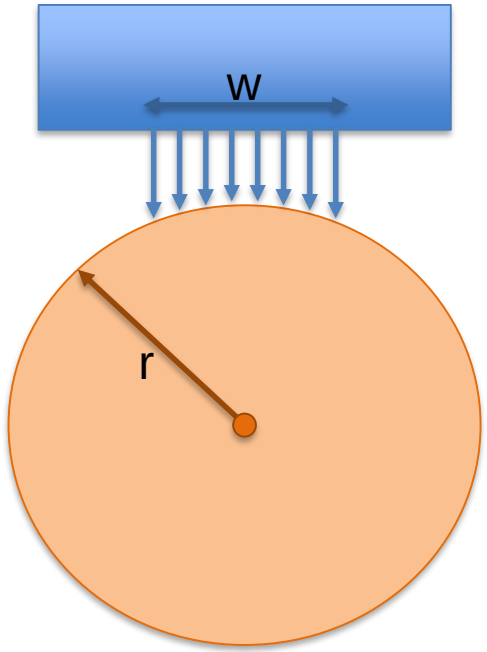
Spiral

Other

Image source: GIS

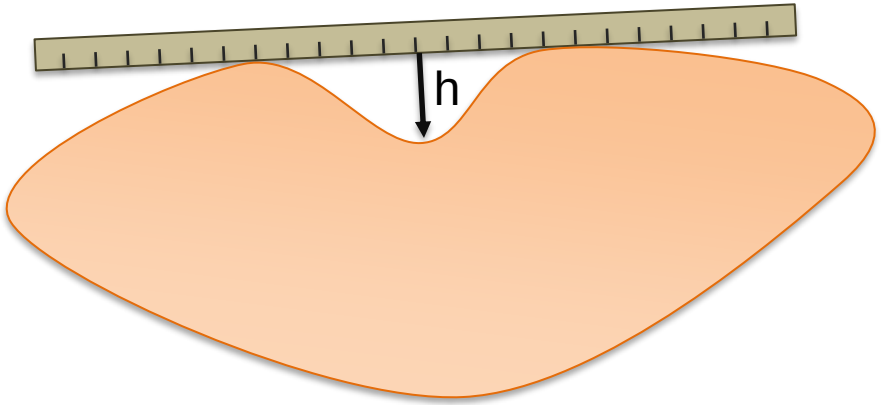
Sphere Printer – Print Geometry

At printhead scale and below: convex or near-convex shapes



Convex

$r >\approx w$

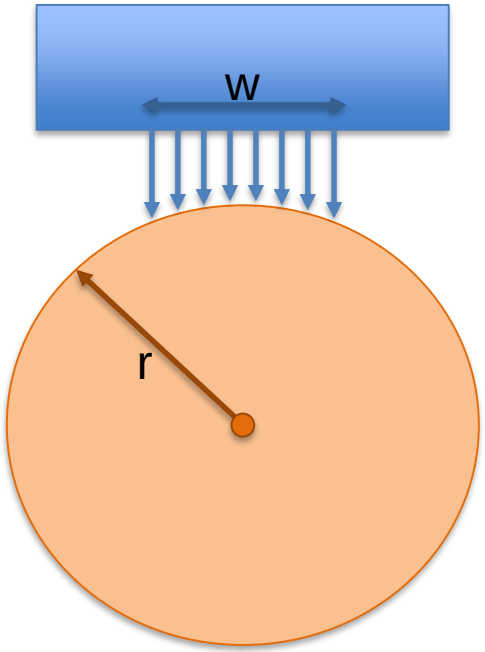


Near-convex

$h < h_{max}$

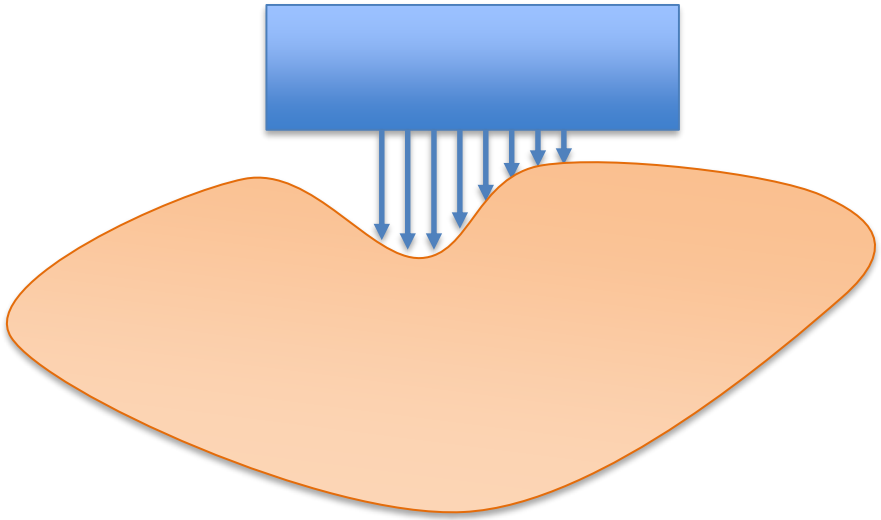
Sphere Printer – Print Geometry

At printhead scale and below: convex or near-convex shapes



Convex

$r >\approx w$

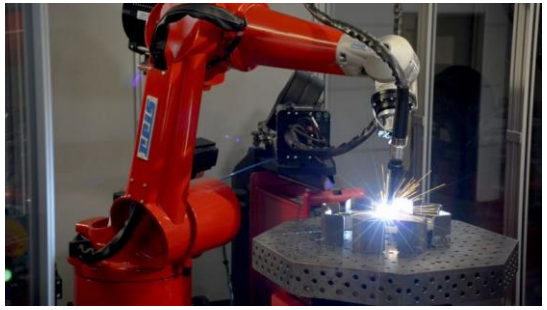


Near-convex

$h < h_{max}$

Sphere Printer – Positioning Accuracy

Industrial robots have sufficient accuracy for many industrial applications …



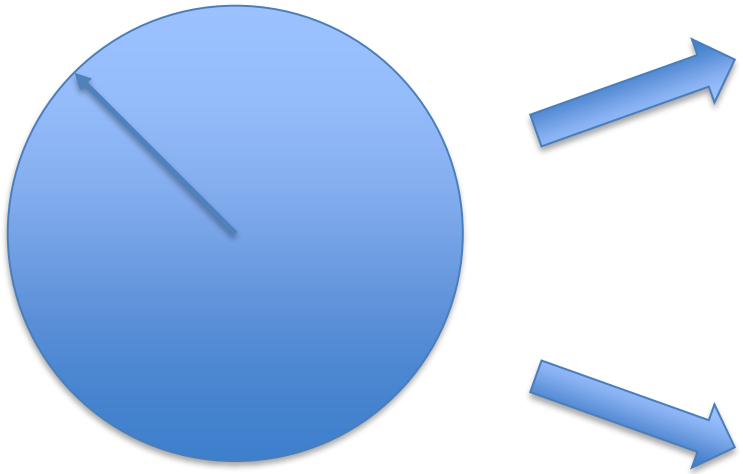
… but printing requirements are tight

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

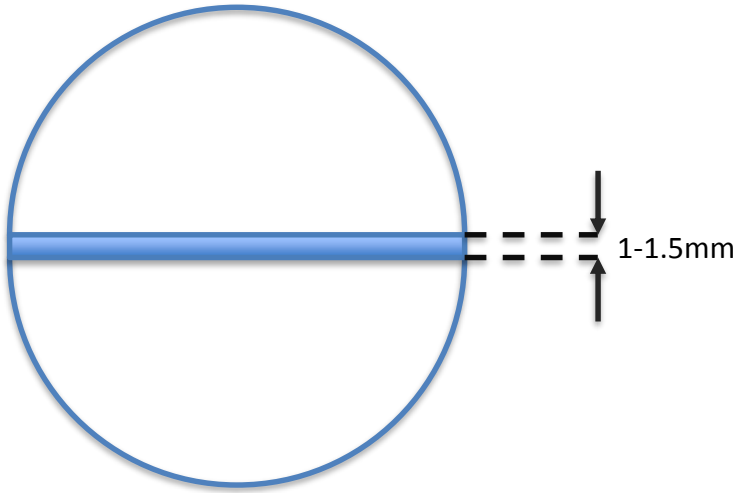
Sphere Printer – Shape Variation

All manufactured objects have tolerances

- E.g. Polypropylene sphere
- Inexpensive consumer product

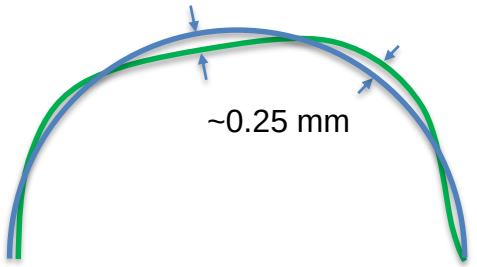


Nominal: 75 mm radius



Structural errors

Assembly of two hemispheres



Precision errors

Limitations of process

Image source: GIS

Sphere Printer - Stitching

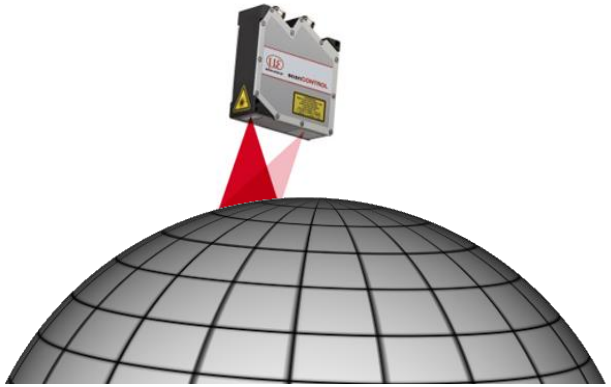
- **Stitching is a key area where inaccuracies will show**
  - Positioning errors cause gaps or overlaps, familiar from 2D printing

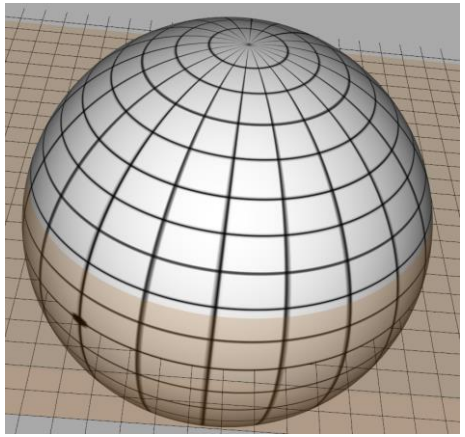
- **Careful control is required of multiple factors:**
  - Accuracy of transport, especially robots near to singularities
  - Print synchronisation
  - Variation of the target shape from nominal dimensions

Image source: GIS

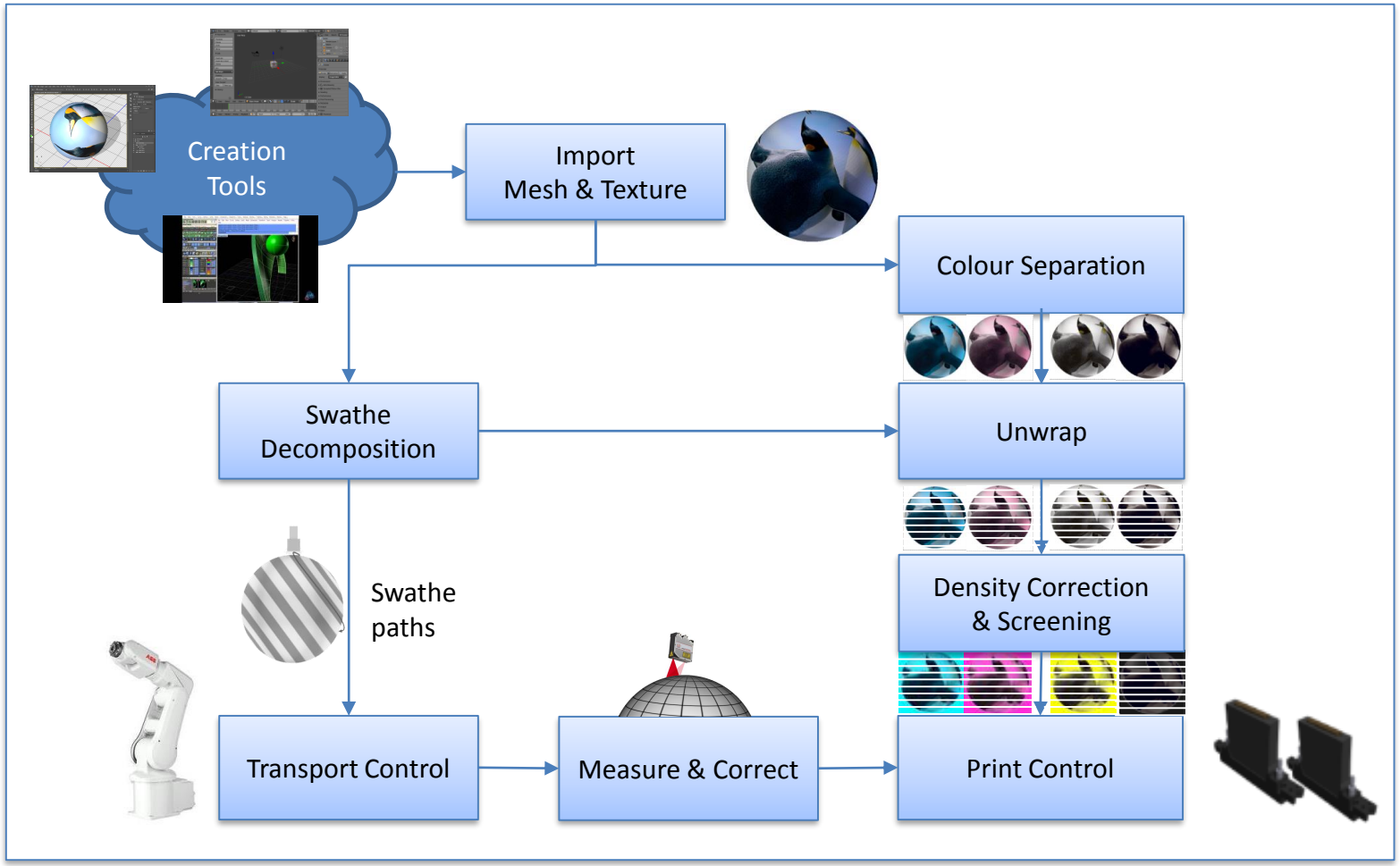
Sphere Printer – Shape Variation Compensation

- **Measure the target shape accurately**
  - Mechanical profile gauges
    - Adequate, but rather slow
    - Contact with target shape may be a problem
  - Laser triangulation sensors
    - Resolutions down to ~1 µm, sample rates 1-100kHz
    - Non-contact
- **Apply measurements as corrections to the mesh model**
  - For per unit variations this can be done as a late stage correction
  - Output adjusted swathe data





Sphere Printer – Apply the Workflow



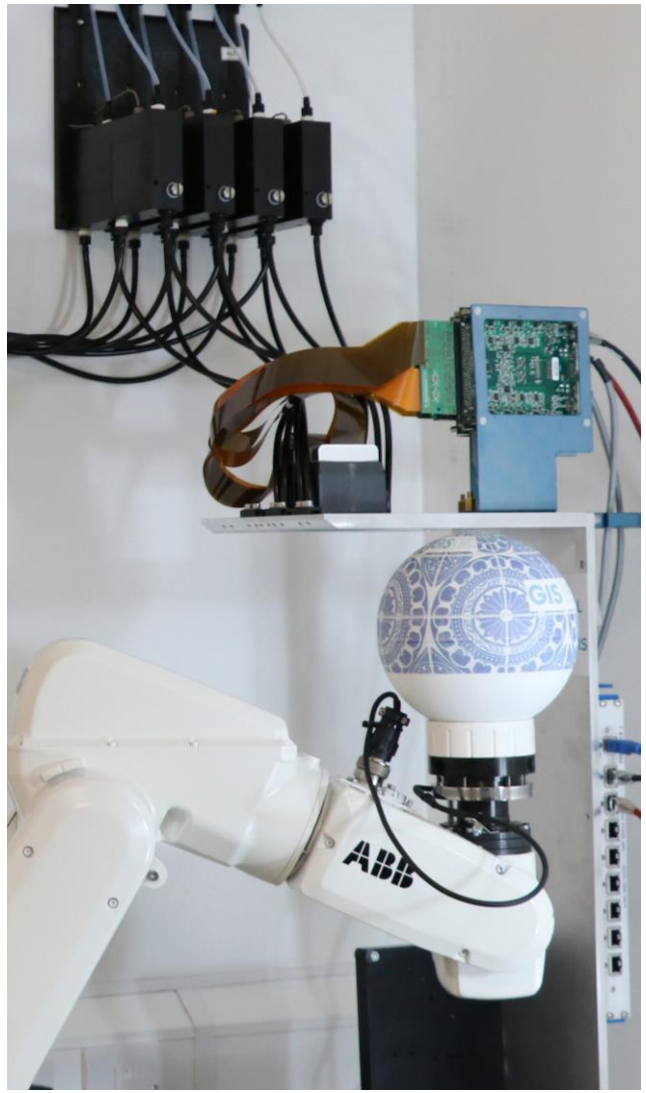


Image source: GIS

Sphere Printer – The Movie

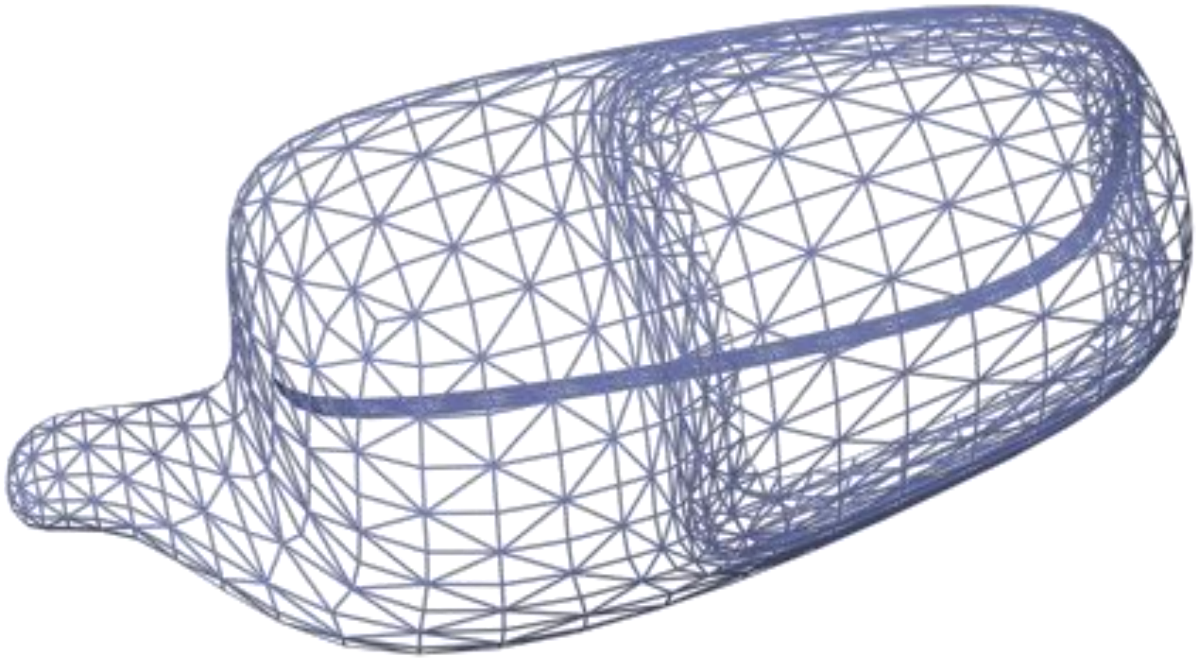
Sphere Printer - Summary

Result: a printed polypropylene spheroid

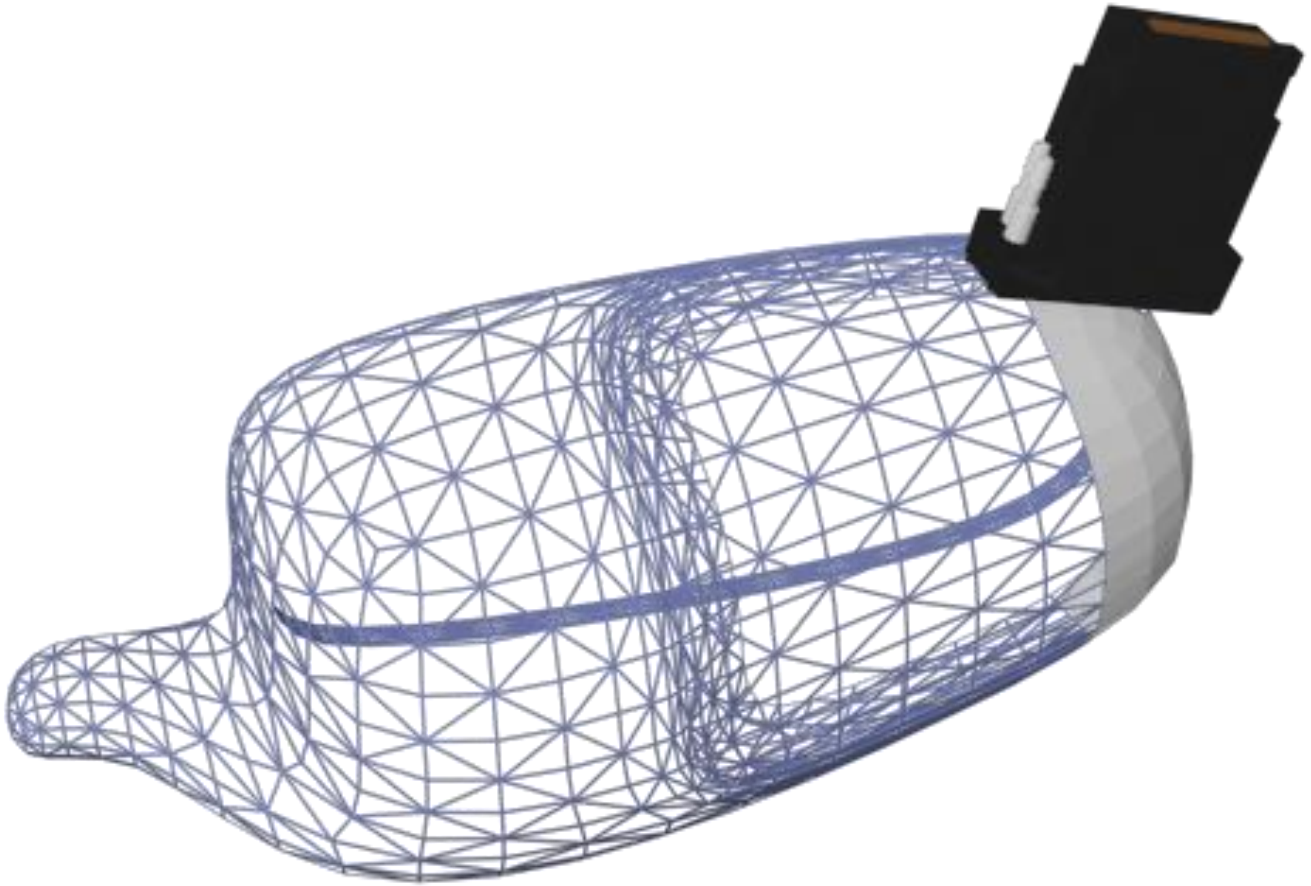
- CMYK 1200 dpi
- Latitude swathes, 18^{o} high, covering the top hemisphere
- 300dpi native; x 4 interleave

Image source: GIS

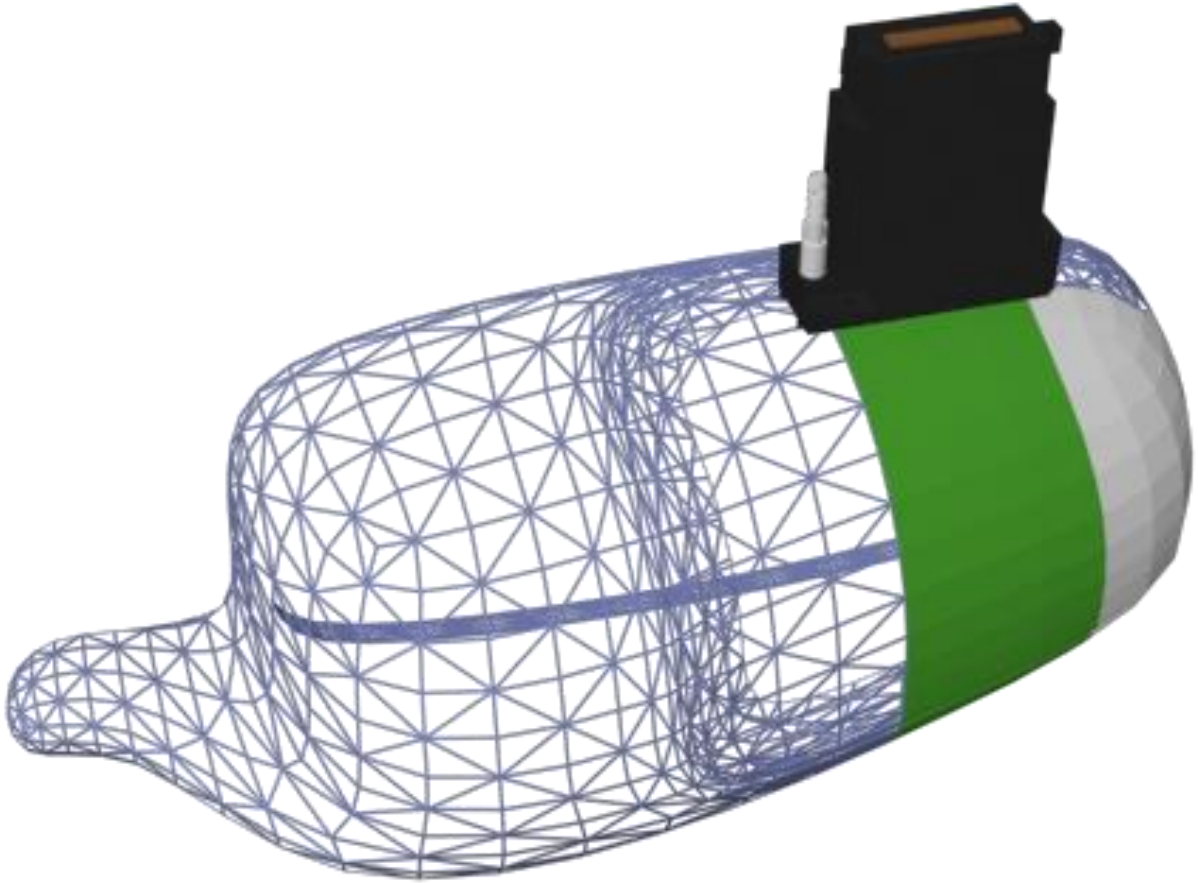
Simulated Print Sequence



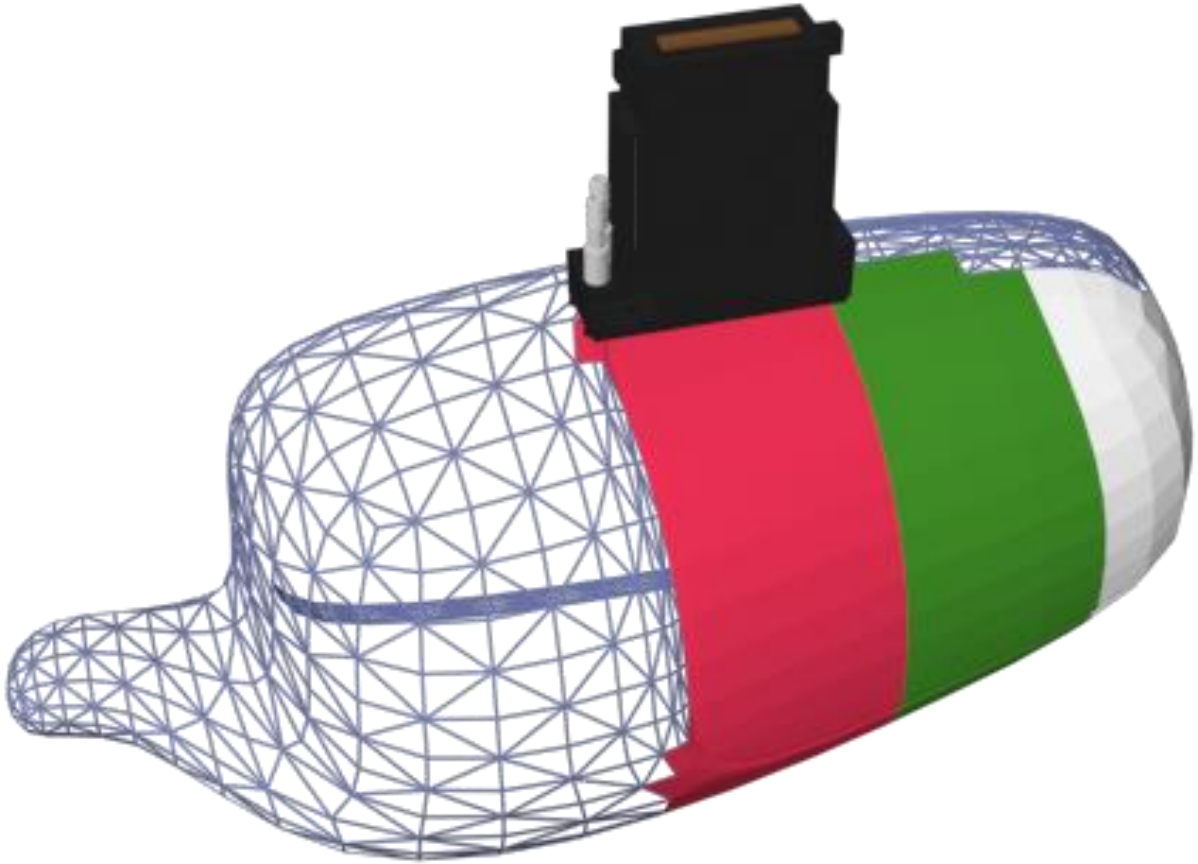
Simulated Print Sequence



Simulated Print Sequence



Simulated Print Sequence



Simulated Print Sequence

Implications & Opportunities

- **Inkjet already being used in automotive production**
  - Decorative & functional
- **Advances in printhead technologies, software and fluids**
- **No longer constrained to flat surfaces**
- **Some highly viscous fluids remain a challenge**
  - Thinking differently can provide solutions
- **Great potential for further usage**

Thank you – Any Questions?

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