

Korean Fluid Machinery Association

Inkjet printhead design & analysis using CoventorWare™

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Inkjet printing market

NEXUS 2002

Alcortec
 SpectraJet
 Bionics diagnostics
 Ocular Ink
 Hoescht Ink
 Hwaet accelerators
 BIOC leads
 Kodak's heads

Forecast Revenues for Microfluidics Devices (\$ in billions)

Source: B-Scan/MSA, SPA

Compound Annual Growth Rate (CAGR) of 10.3% from \$1.7 billion in 2003, to more than \$2.7 billion in 2008

Inkjet printing remains the dominant source of revenue and unit shipments for this unique MEMS category.

Canon SHARP
 brother EPSON[®] LEXMARK
Lexmark for printing. The best.
 HITACHI
HITACHI for printing. The best.
 Olivetti
 Exonmob
 Agilent THE EXCITING COMPANY
 Packard
 AstarZeneca
 Valpar
 Tektronix

Technology tree

Continuous Binary Deflection Elmer Image Drop-on-Demand	Thermal Rod-shape Hewlett-Packard Olivetti Lexmark	Multiple Deflection Videojet Domino Anijet Linx	Hertz Hts Graphics	Microdot Hitachi	Piezoelectric Squeeze tube Siemens Geudt	Electrostatic Meristahlis Tokyo Electric NEC	Acoustic Xerox	Band mode Tektronix Sharp Epson On Target Tech.	Push mode Dataproducts Epson Trident	Shear mode Spocita Xaar Nu-Kole Brother Pihonab Tech. Topas Tech.
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Inkjet Design Issues


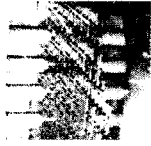


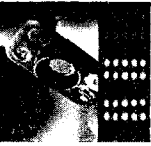
Design Issue	Questions to Ask
Chamber Refill	<ul style="list-style-type: none"> How does fluid mass affect refill time? What is the effect of design of the resistor to the reservoir?
Meniscus Oscillations	<ul style="list-style-type: none"> Do secondary droplets form? How does the meniscus oscillation affect the actuator response? How quickly can another drop be formed?
Nozzle Cross-Talk	<ul style="list-style-type: none"> Does firing one nozzle affect a neighboring nozzle?
Nozzle Geometry	<ul style="list-style-type: none"> How do I get a clean droplet? What is the effect of nozzle shape?
Manufacturing Variations	<ul style="list-style-type: none"> What effect do manufacturing tolerances have on the design? What are the critical parameters of the design?
Actuator Design	<ul style="list-style-type: none"> What is the most efficient actuation methodology? What is the most efficient power wave form? What is the best size and position for the actuator?
Ink Properties	<ul style="list-style-type: none"> What is the effect of ink viscosity and surface tension? What is the effect of temperature?

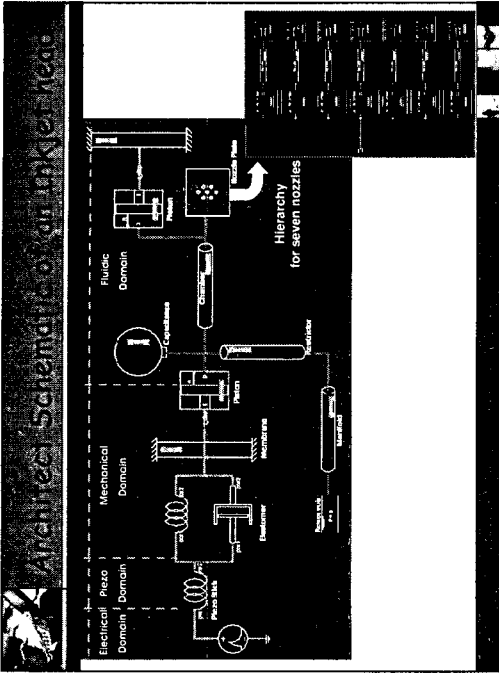
Applications

Market/Applications	Key player
<ul style="list-style-type: none"> Small office/home office 	<ul style="list-style-type: none"> Hewlett-Packard, Canon, Epson
<ul style="list-style-type: none"> Office network Graphic arts Industrial/special marking Large format 	<ul style="list-style-type: none"> Samsung, Hewlett-Packard, Ricoh, Konica, Epson Indigo, Xerox, Image, Willet ColorSpan, Epson, Hewlett-Packard, Linmark, Epson
<ul style="list-style-type: none"> Home photo 	<ul style="list-style-type: none"> Hewlett-Packard, Canon, Epson
<ul style="list-style-type: none"> Multifunction Digital color press Grand format 	<ul style="list-style-type: none"> Hewlett-Packard, Canon Sales, ACS, Tektronix Global, Xerox, Nitro, ColorSpan, Mutoh
<ul style="list-style-type: none"> Textile Medical imaging 3D printing 	<ul style="list-style-type: none"> Canon, Samsung, Xerox, Toner Medical Imaging Diagnostic Systems, Corp.

Component-Water Cell

Components	Use and Physics Modeled	Design Issues Addressed
Architect	System modeling environment with pre-characterized library of system components for inkjet systems	<ul style="list-style-type: none"> Chamber Refill Meniscus Oscillations Nozzle cross-talk Controller design Design parameter sensitivity Manufacturing Variations
Designer	Geometry creation	<ul style="list-style-type: none"> Mask layout, process description, solid model creation
DropSim	3D modeling of droplet ejection process	<ul style="list-style-type: none"> Nozzle Geometry Actuator Design
BubbleSim	3D modeling of bubble growth for thermal inkjets	<ul style="list-style-type: none"> Actuation Design Bubble Generation & Growth Process
MemMech	3D modeling of fluid flow, heat transfer, and structural deformation	<ul style="list-style-type: none"> Nozzle Cross-Talk Ink Properties, thermal effects Actuator design
Integrator	Create system component models from 3D models	<ul style="list-style-type: none"> Chamber Refill Meniscus Oscillation

 <p>Philips: OLED displays</p>	 <p>IBM Zurich: Nanomechanical sensor</p>	 <p>Microarray</p>
 <p>Two-antibody diagnostic assay - Abbot TestPack™ - continuous inkjet printed</p>	 <p>Disposable diagnostic test Boehringer MicroSpot™</p>	

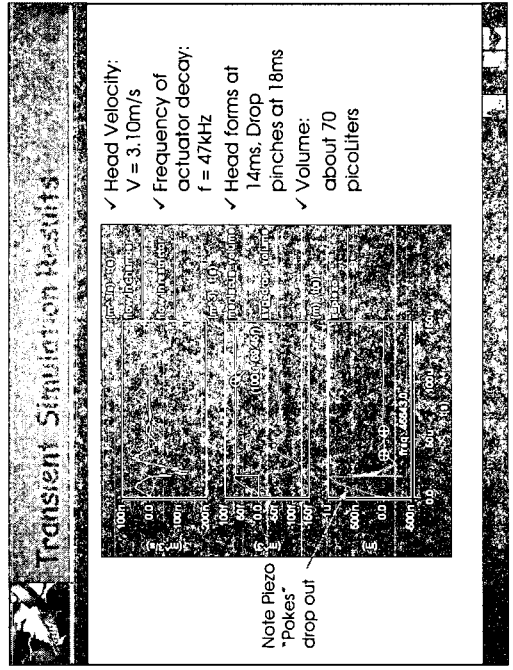
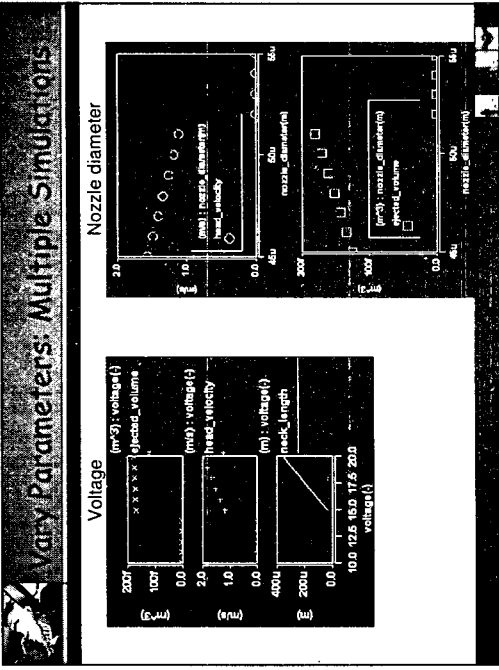


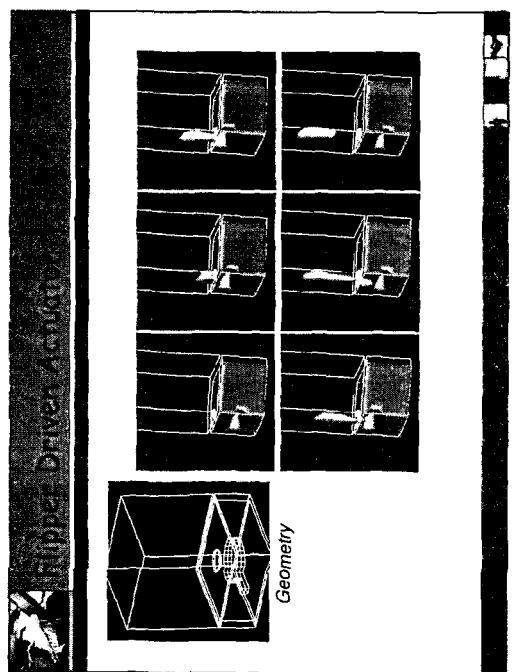
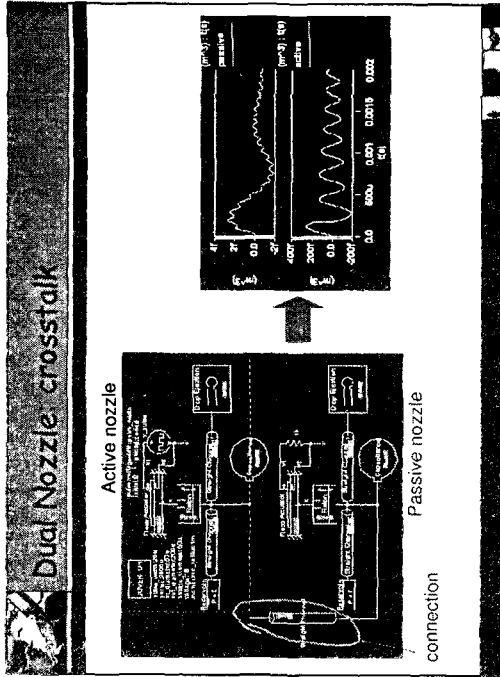
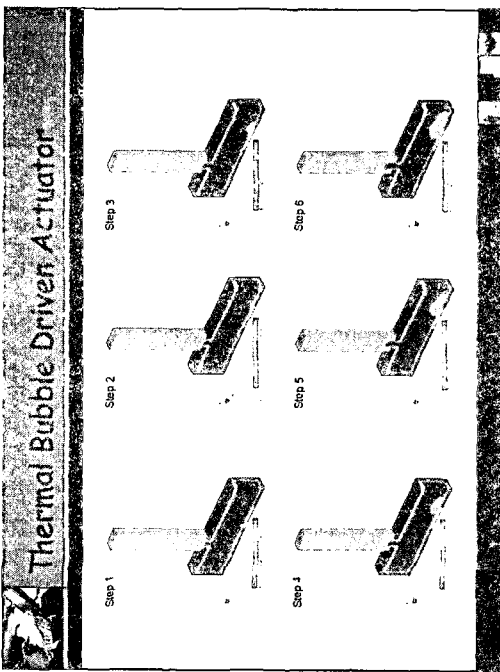
Sensitivity Analysis

Nominal Value = 8.0791

Increase	Part Type	Parameter	Value	Sensitivity	Dev-elm
100%	7.64	...
100%	4.36	...
100%	3.69	...
100%	2.19	...
100%	1.75	...
100%	1.60	...
100%	1.19	...
100%	0.96	...
100%	0.94	...
100%	0.88	...
100%	0.86	...
100%	0.75	...
100%	0.69	...
100%	0.68	...
100%	0.56	...
100%	0.54	...
100%	0.51	...
100%	0.47	...
100%	0.43	...
100%	0.40	...
100%	0.38	...
100%	0.35	...
100%	0.34	...
100%	0.33	...
100%	0.32	...
100%	0.31	...
100%	0.30	...
100%	0.29	...
100%	0.28	...
100%	0.27	...
100%	0.26	...
100%	0.25	...
100%	0.24	...
100%	0.23	...
100%	0.22	...
100%	0.21	...
100%	0.20	...
100%	0.19	...
100%	0.18	...
100%	0.17	...
100%	0.16	...
100%	0.15	...
100%	0.14	...
100%	0.13	...
100%	0.12	...
100%	0.11	...
100%	0.10	...
100%	0.09	...
100%	0.08	...
100%	0.07	...
100%	0.06	...
100%	0.05	...
100%	0.04	...
100%	0.03	...
100%	0.02	...
100%	0.01	...

Annotations: "Most influential parameters to the drop velocity" points to the top of the table. "Parameters that don't affect result" points to the bottom of the table.

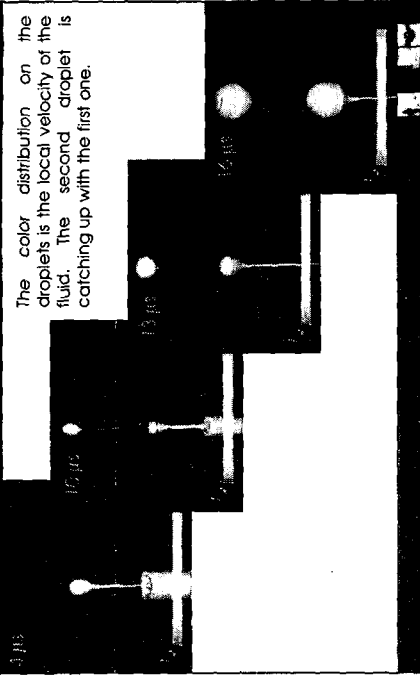




- ✓ Finite Difference Method (FDM) combined with Volume of Fluid (VOF) approach best way to simulate droplet breakup
- ✓ Can simulate in 3D—details any kind of inkjet physics including
 - Pressure driven flow
 - Two phase (gas/liquid) flows with surface tension and contact angle effects
 - Heat transfer
 - Piezoelectric actuation
 - Variable fluid properties
 - Structural Deformation
 - Fluid Structure Interaction

Multiple Droplet Ejection

The color distribution on the droplets is the local velocity of the fluid. The second droplet is catching up with the first one.



Take-Away Messages about Coventor Vio

- ✓ Provides the only complete end-to-end design methodology for MEMS today
- ✓ Works with best-of-breed EDA tools such as Cadence and Synopsys
- ✓ Can be flexibly configured to suit customer preferences – an entire end-to-end flow or specific targeted products
- ✓ New products such as EM3DS, MEMulator, and enhanced Saber for Architect
- ✓ Product is industrial strength
 - Battle tested with 200 commercial customers
 - Over 2000 university seats in use today
 - Used by Coventor in dozens of successful professional services programs
- ✓ The best-in-class solution