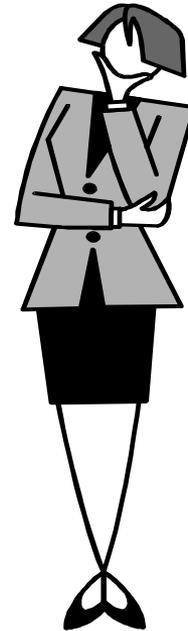


IMI 7th ANNUAL INK JET PRINTING CONFERENCE
APRIL 29-MAY 1, 1998

**THERMAL (TIJ) OR PIEZO?,
WHO CARES?**

Rob Beeson
Hewlett Packard Company

WHAT ABOUT A PRINTER PURCHASE?



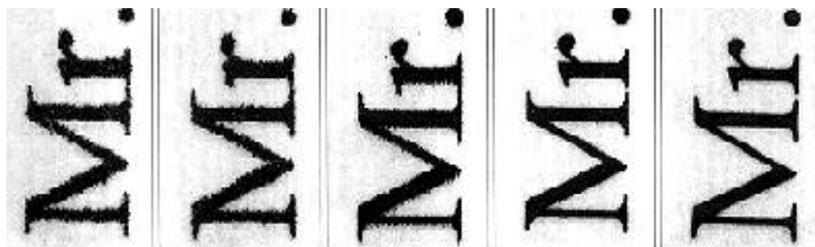
- * TEXT/GRAPHICS PQ?
- * PRINT SPEED?
- * POP (MFG COST)?
- * IMAGE QUALITY?
- * COST OF OWNERSHIP (RELIABILITY)?

The choice of engine probably doesn't matter, but above mentioned attributes certainly do!

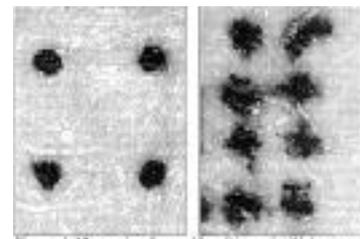
Let's examine each attribute to make a choice...

TEXT PRINT QUALITY:

- The “HARDCOPY OBSERVER” rates best pq on plain papers are from printers (two different brands) with pigmented black inks - both are TIJ.
- If piezo has more ink independence, why aren't pigments used for the black colorant?
- TIJ has also introduced pigments in large format market for excellent outdoor performance.
- Key elements for good pq are optical density, edge sharpness, and dot size/placement - dots per inch (dpi) is only one part.



DYE TIJ DYE PIEZO PIG TIJ PIG TIJ LASER

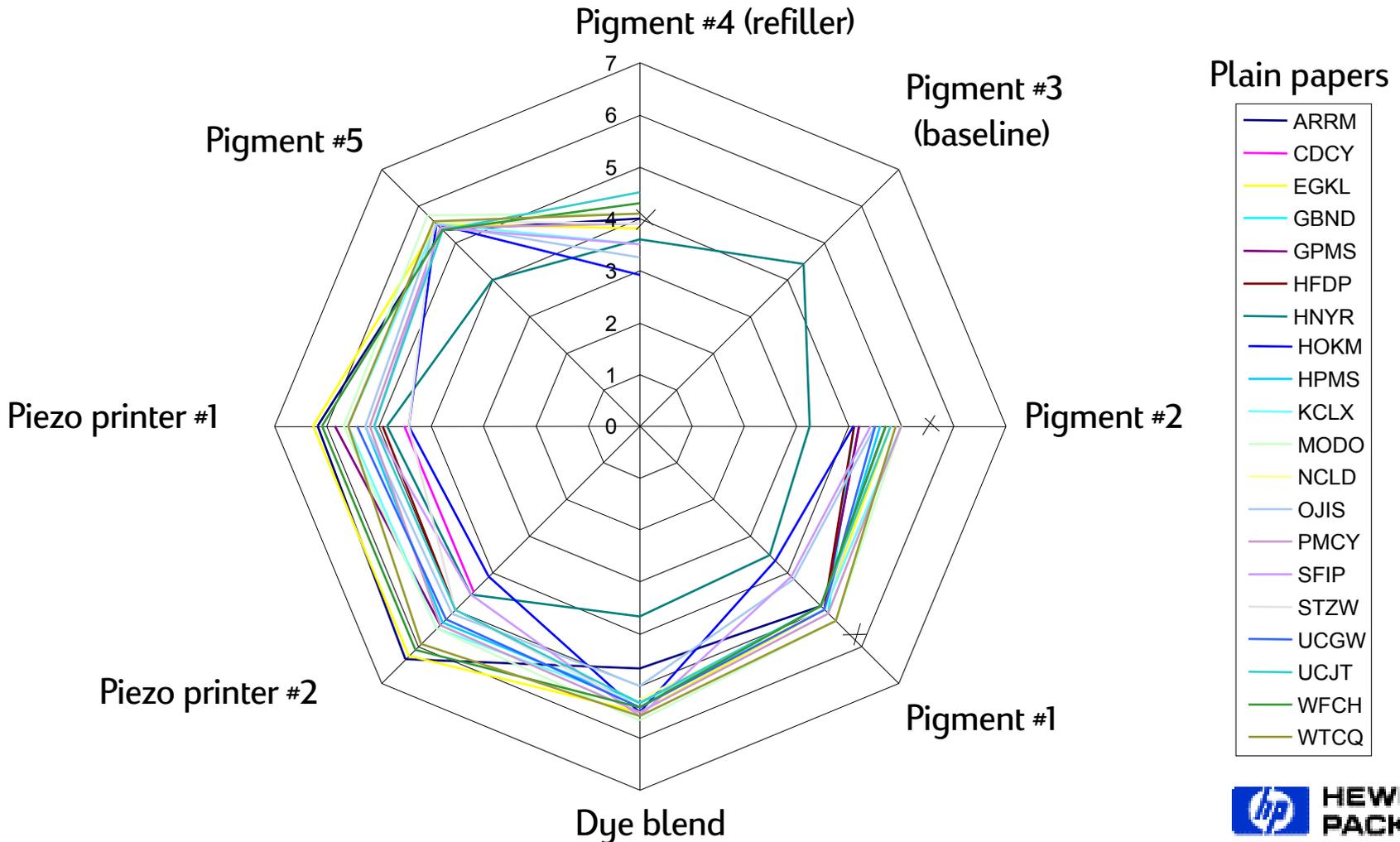


PIG TIJ PIEZO

“Who goes splat”
(225 X)

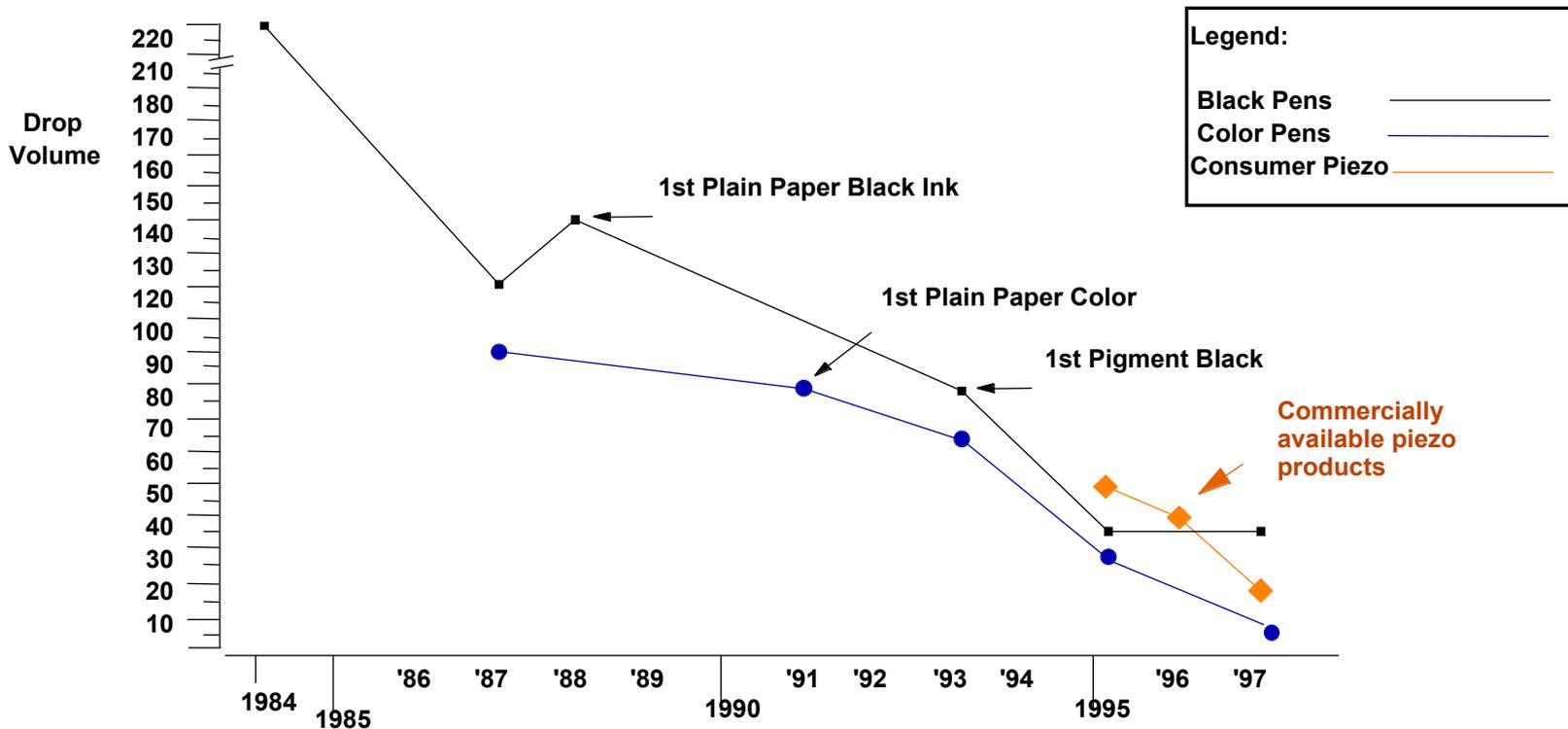
PRINT QUALITY (CONT)

PQ SCORES FOR VARIOUS INKS IN DESKTOP PIEZO PRINTER



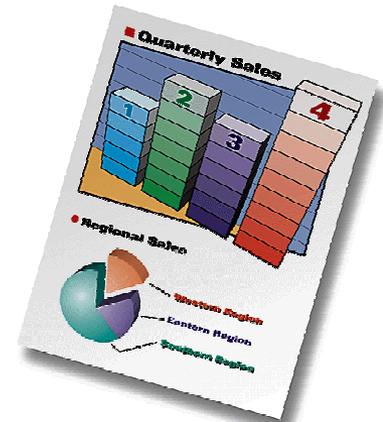
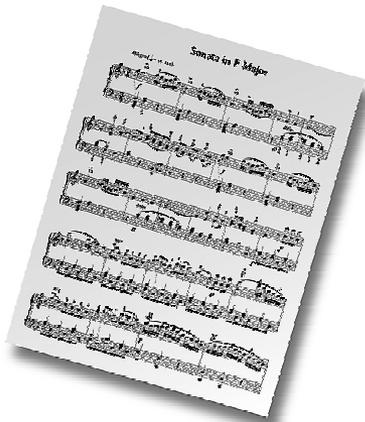
PRINT QUALITY (CONT)

- Small dots with good ink/media interaction qualities can meet these demanding criteria. TIJ has shown the ability to deliver smaller drops before piezo.



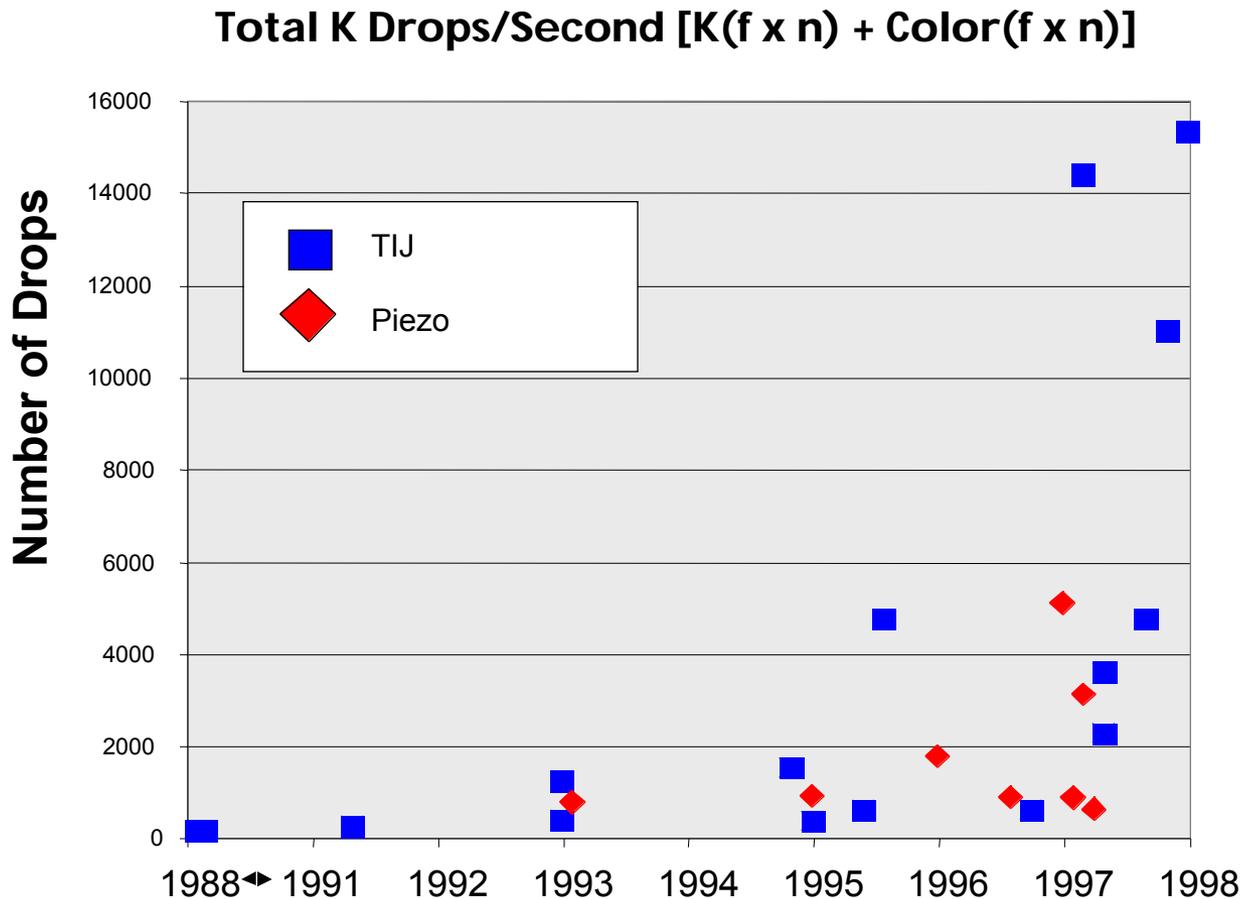
PRINT QUALITY (CONT)

- TIJ is successfully utilizing pigments and is leading the drive toward smaller drop volume.
- **CONCLUSION: TIJ IS SUPERIOR TO PIEZO AND RAPIDLY APPROACHING LASER QUALITY**



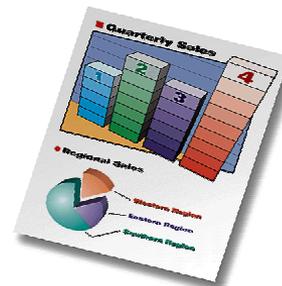
PRINT SPEED

- Upper limit on pq is achievable, but not speed, faster will always be better.
- The print engine contributes to speed by nozzle count, firing frequency, and number dots per pixel.



PRINT SPEED

- TIJ has achieved 600 dpi linear resolution in the printhead scan axis which is adequate for laser quality print in a single pass.
- Piezo's highest single pass resolution per nozzle row is 185 - (popular desktop models are only 90) multiple rows or print passes are required.
- Multiple passes are required, but the margin will increase as drop position accuracy improves.
- If stacking multiple printheads is discounted, and only a unit print engine is considered, TIJ has the advantage.
- **CONCLUSION: PRINT MODES AND QUALITY SETTING LARGELY DETERMINE PRINT SPEEDS - TIJ HAS THE EDGE**

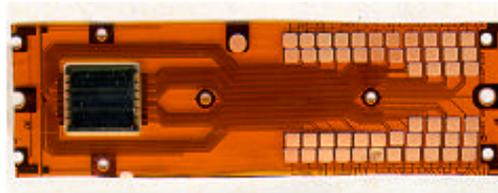


MANUFACTURING COST

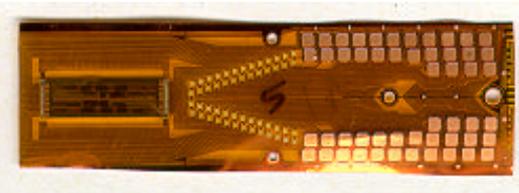
INTEGRATED ELECTRONICS - SYSTEM ADVANTAGE FOR TIJ

TIJ

- Multiplexed addressing for higher throughput and color resolution without excessive system cost and size



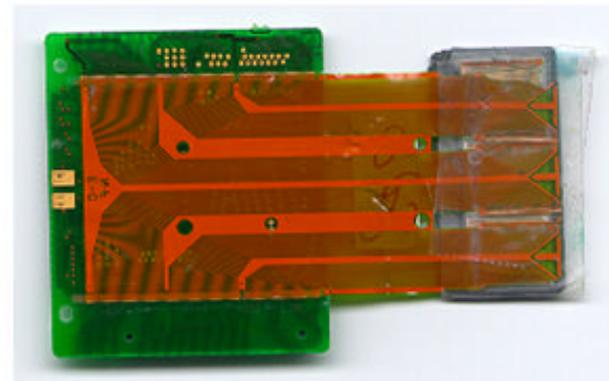
TIJ Color engine
192 nozzles @300 dpi



TIJ Black engine
300 nozzles @600 dpi

PIEZO

- Direct drive electronics with no multiplexing or associated reduction in system complexity

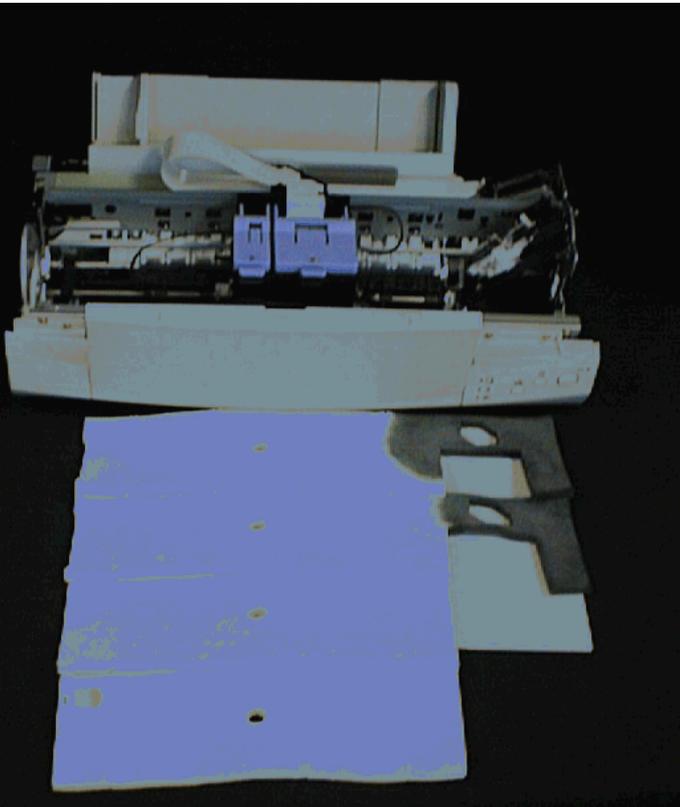


Piezo competitor
192 nozzles @180 dpi

MANUFACTURING COST (CONT)

- Piezo printheads require vacuum pumps and ink absorbent pads to keep nozzles printing reliably.
- TIJ has small absorber and spits to clear nozzles.

Photo of popular piezo printer model

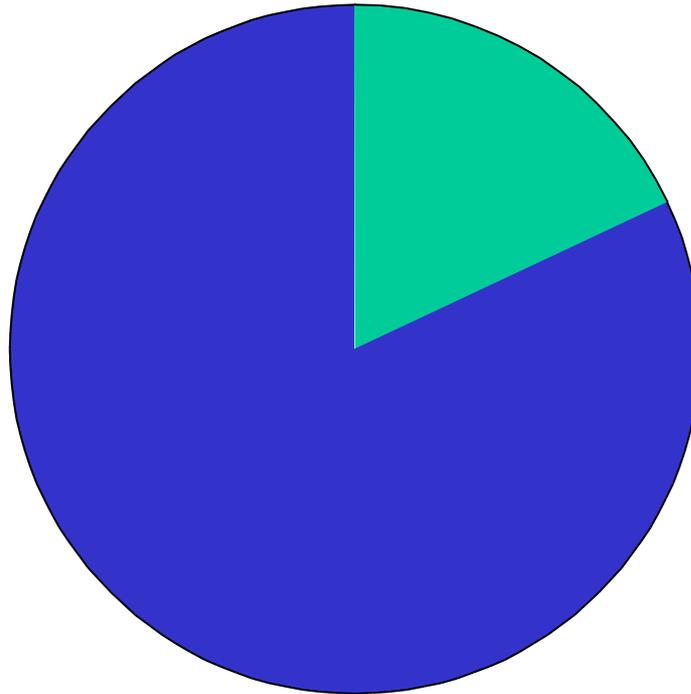


Large amounts of ink are wasted in head servicing to keep air out of the firing chamber.

The absorber is over 50 cubic inches and nearly \$7 of ink is wasted on priming when the printer is first turned on (pigments may be a problem).

MANUFACTURING COST (CONT)

High volume production yields lower unit costs.



■ TIJ
■ PIEZO

Worldwide total inkjet sales is approximately 100 million units

MANUFACTURING COST SUMMARY

- TIJ products need less pumping overhead.
- Monolithic integration of drop generators and drive electronics.
- High volume manufacturing significantly reduces manufacturing costs.
- **CONCLUSION: TIJ IS LOWER COST**

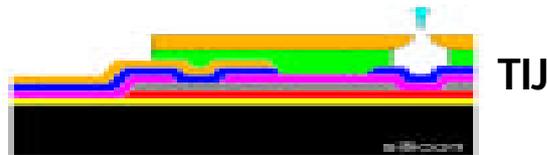


IMAGE QUALITY

- Rapidly becoming more important for consumers.
- Key is accurately delivering a high rate of very small drops per pixel on demand.
- Want to make individual drops disappear.
- DPI is a useless metric because the meaning isn't clear and it has been used unwisely.
- DPI “looks good on the box” however - it can sell products.
- Dot size (drop volume) is very useful (but not all inclusive), however.

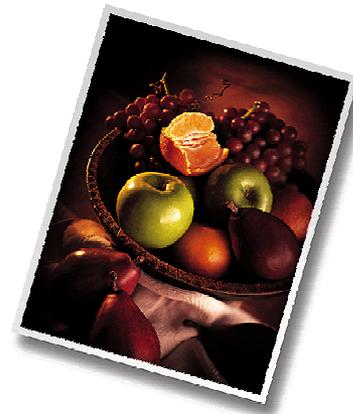
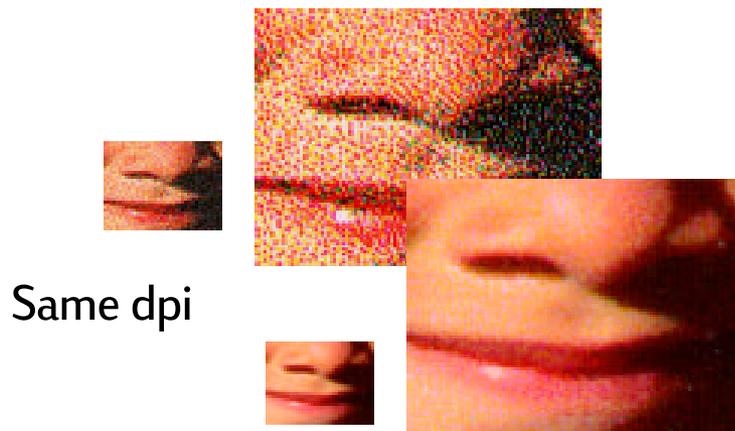
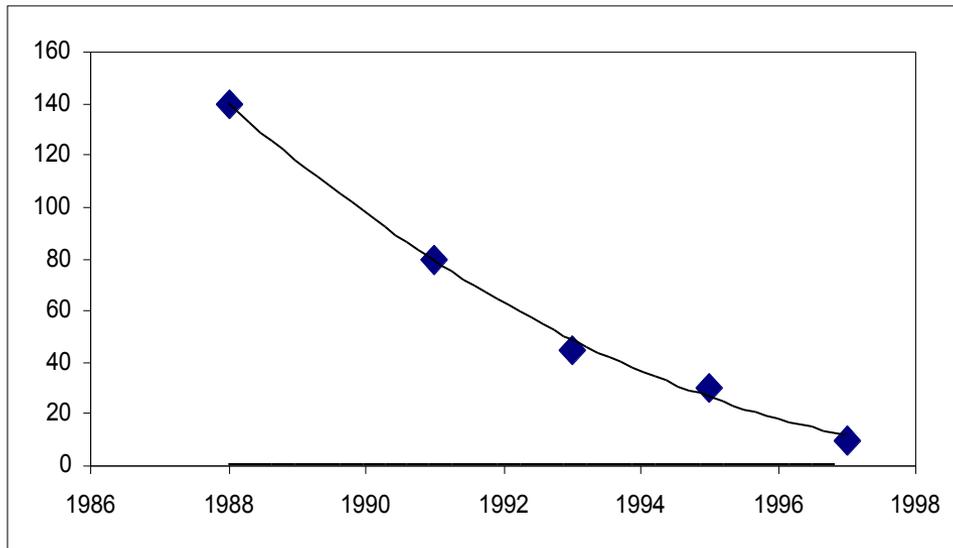
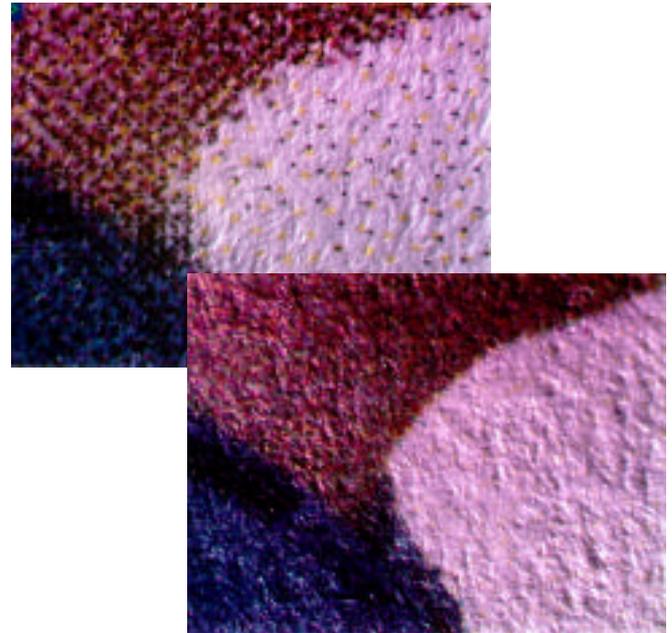


IMAGE QUALITY (CONT)



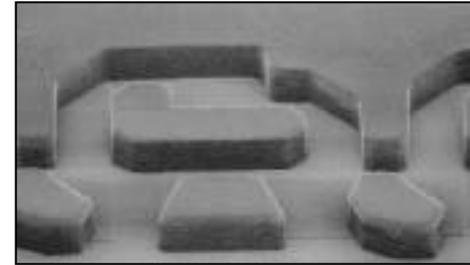
TIJ drop volume vs. time



Higher image quality and better image reproduction on a variety of media.

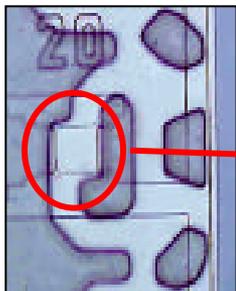
IMAGE QUALITY (CONT)

- Firing chamber geometry
 - Reduced dimensions.
 - Smaller drop volumes ejected.
 - Enables higher nozzle packing density.
- Drop ejection frequency
 - Increased frequency.
 - Less energy required per drop.
 - Improved system efficiency.
- Integrated electronics
 - Print head integration on silicon allows integration of both power electronics and per-nozzle interconnect.
 - Enables higher throughput and color image quality without excessive system cost and size.

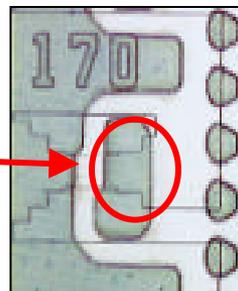


30 pl drop vol

10 pl

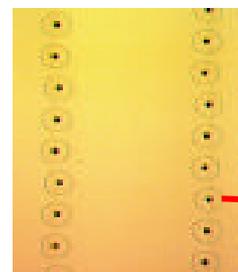


Smaller heater
Smaller firing chamber



30 pl nozzle plate

10 pl



Smaller nozzle

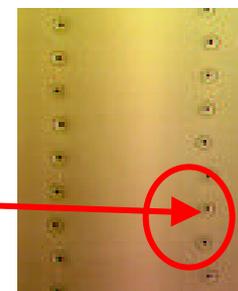


IMAGE QUALITY (CONT)

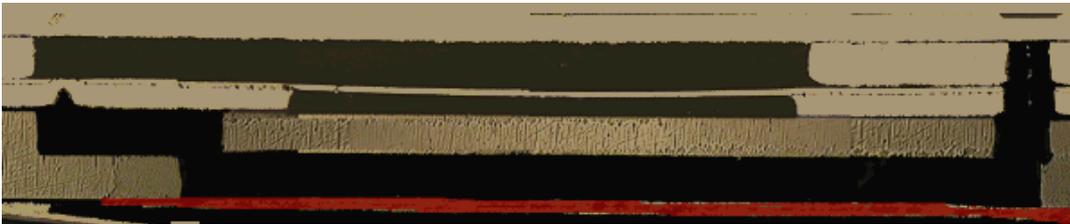
Firing chamber geometry

- Reducing firing chamber dimensions enables higher nozzle packing density.
- Firing chamber volume to drop volume ratio smaller for TIJ than piezo - can approach 2:1 for TIJ.
- Distinct TIJ technology advantage - reduces cost and system complexity.
- Note the scaled cross-section photos

TIJ - 12 kHz, 30 pl



Piezo - 7 kHz, 30 pl

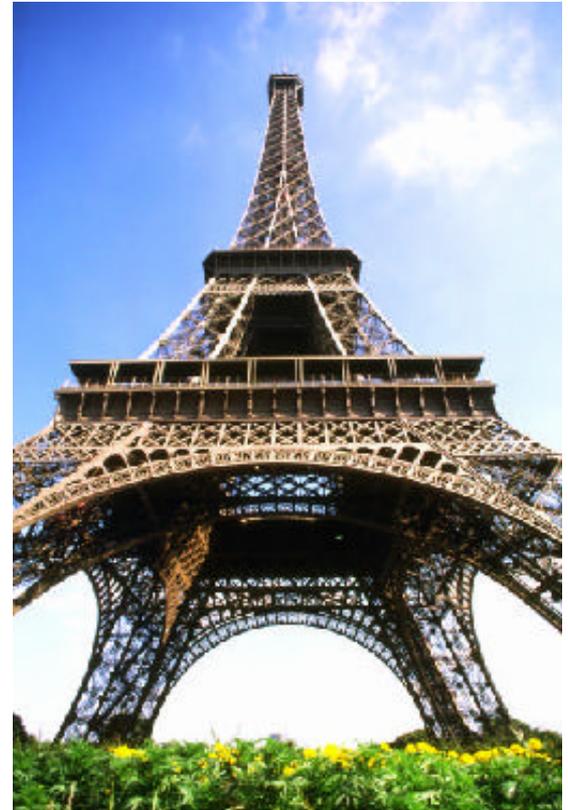
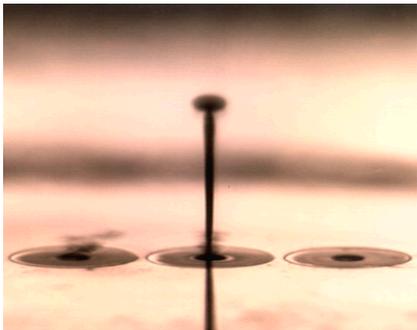


Piezo chamber length = 19 X TIJ, face area = 248 X TIJ

IMAGE QUALITY (CONT)

Firing chamber geometry

- Nozzle plates electroformed metal or laser-defined orifice layer integrated with flex circuit.
- Tight bore control for dimensional control
- Process control for straight shooting of well-formed small drops.



**CONCLUSION: TIJ DELIVERS
BETTER IMAGE QUALITY**

COST OF OWNERSHIP

- Some TIJ products have replaceable ink supplies.
- TIJ engines have been used with replaceable ink supplies in large format printers for years.
- Piezo has made strong claims of achieving better printhead reliability, but have suffered field reliability problems.
- Recent test results on piezo products do not support long life claims.

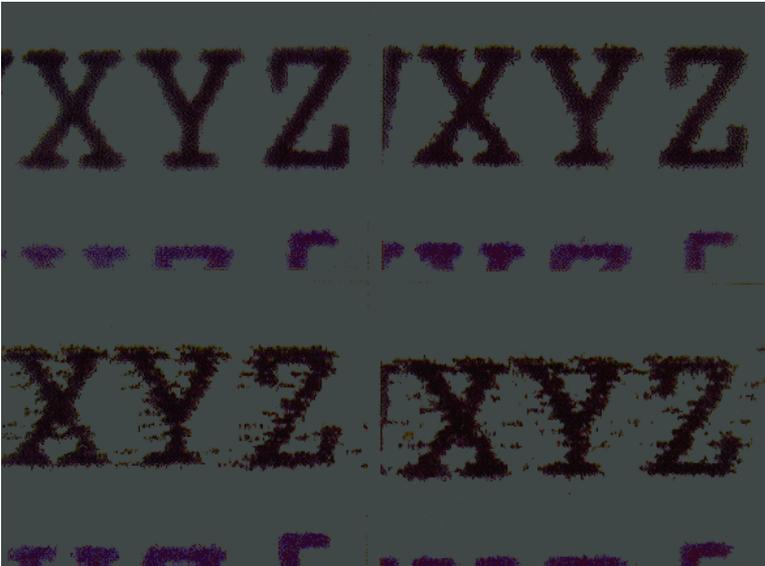


COST OF OWNERSHIP (CONT)

(Reliability)

Testing two billion dots per nozzle claim
on a popular desktop piezo printer.

20 Megadrops



481 Megadrops

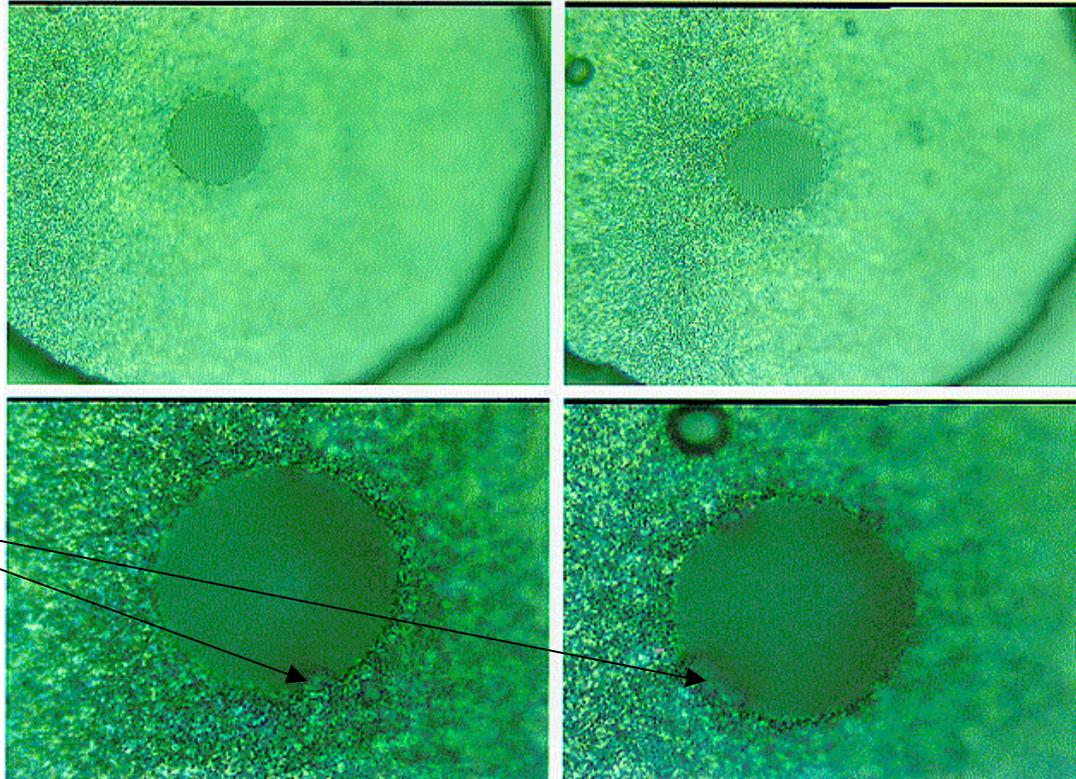
881 Megadrops

1281 Megadrops

Text was unacceptable less than 1/4 through test.

COST OF OWNERSHIP (CONT)

(Reliability)



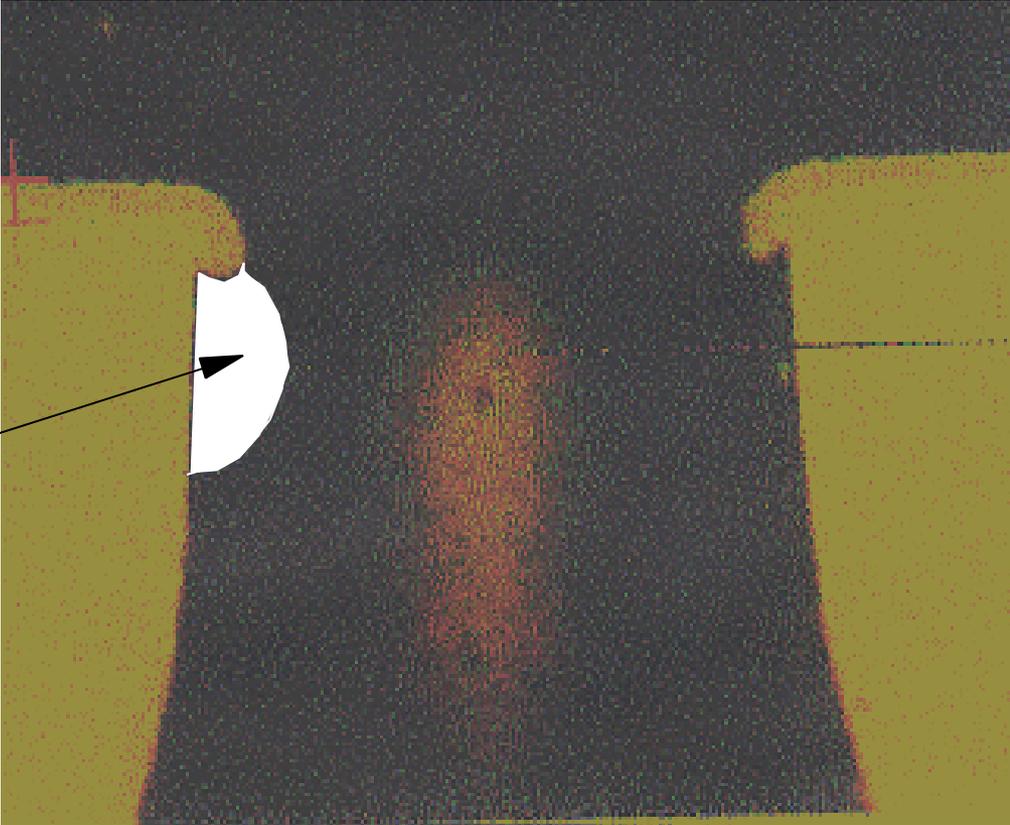
Bubbles

Top two nozzles normal, bottom two have air bubbles in nozzle that can't be primed and misdirect ink droplets being jetted.

COST OF OWNERSHIP (CONT)

(Reliability)

NOZZLE CROSS SECTION



2 micron
Teflon

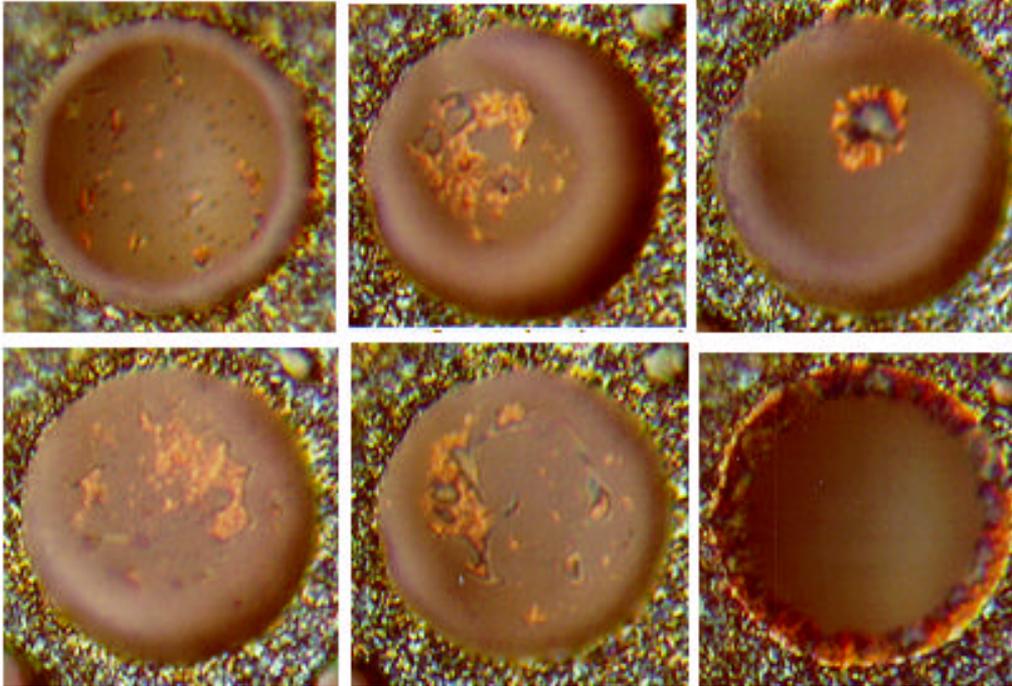
(SCHEMATIC)
AIR POCKET

POCKET GROWS, DEFLECTS
DROP AND IS EVENTUALLY
DISLODGED RESTORING
NORMAL OPERATION

COST OF OWNERSHIP (CONT)

(Reliability)

Low usage testing of a popular desktop piezo printer.



Crusted nozzles

Normal nozzle

New printer was tested and stored for 55 days, then primed and print tested.

Results: five black nozzles were inoperable.

Microscopic examination showed ink had formed a crust that couldn't be primed and print quality was unacceptable.

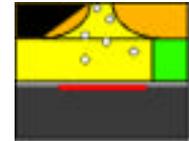
COST OF OWNERSHIP (CONT)

(Reliability)

Air management - system advantage for TIJ

Inkjet systems trap air bubbles in ink

- Air absorbs into ink at the nozzle tip (meniscus)
- Gas creation due to superheating ink - TIJ
- Piezo's mechanical oscillations drive gas out of solution - inadvertent nucleation sites in firing chamber also trap bubbles



TIJ



PIEZO

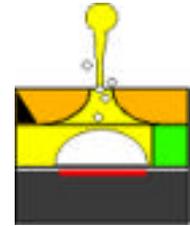
COST OF OWNERSHIP (CONT)

(Reliability)

Air management - system advantage for TIJ

System implications different for TIJ and piezo

- TIJ drop ejection integrity not sensitive to small bubbles in firing chamber
- TIJ has natural release mechanism - controlled flushing action
- Piezo mechanical stability is very sensitive to small air bubbles - like brake system in automobile
- Piezo relies on wasteful flushing of the system with ink to purge trapped air



TIJ



PIEZO

CONCLUSION: SIMILAR SUPPLY COSTS AND RELIABILITY ISSUES WITH PIEZO MAKE THIS EQUAL

SUMMARY



TIJ

PIEZO

TEXT/GRAPHICS PQ



PRINT SPEED



MANUFACTURING COST

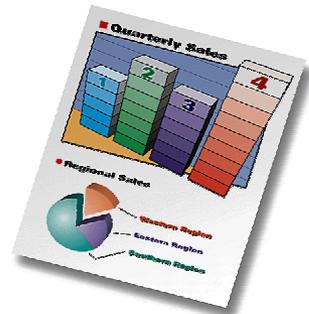


IMAGE QUALITY



COST OF OWNERSHIP

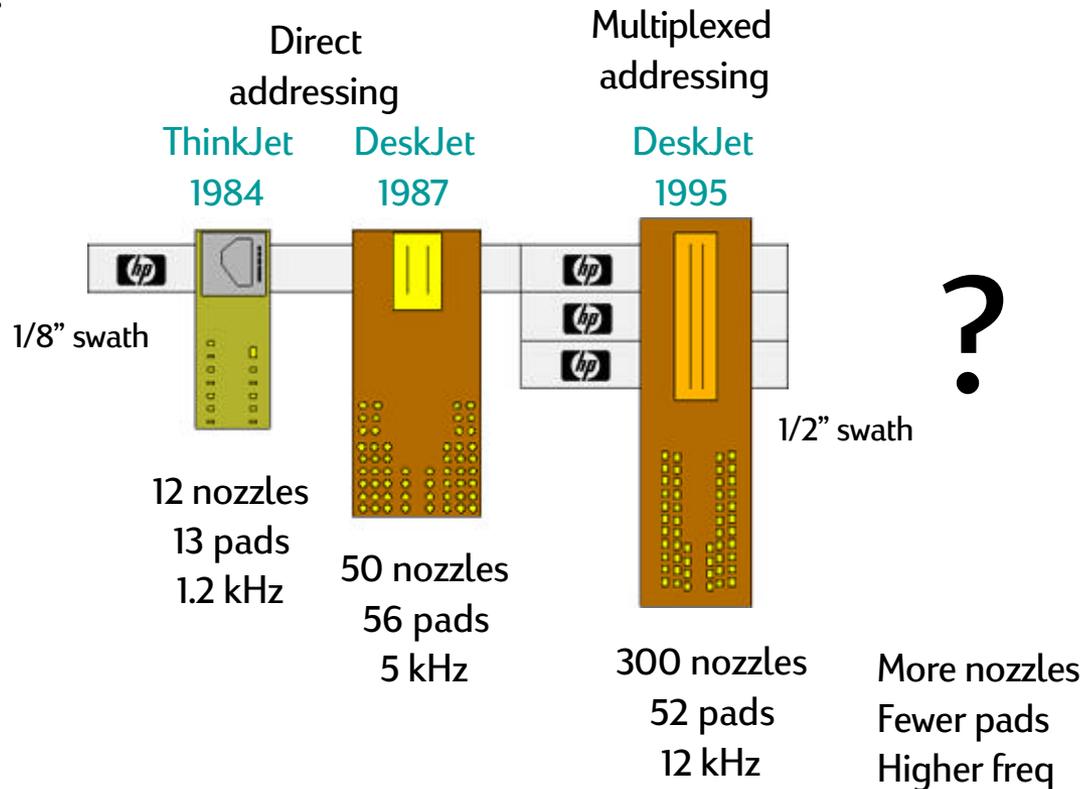
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THE FUTURE OF TIJ

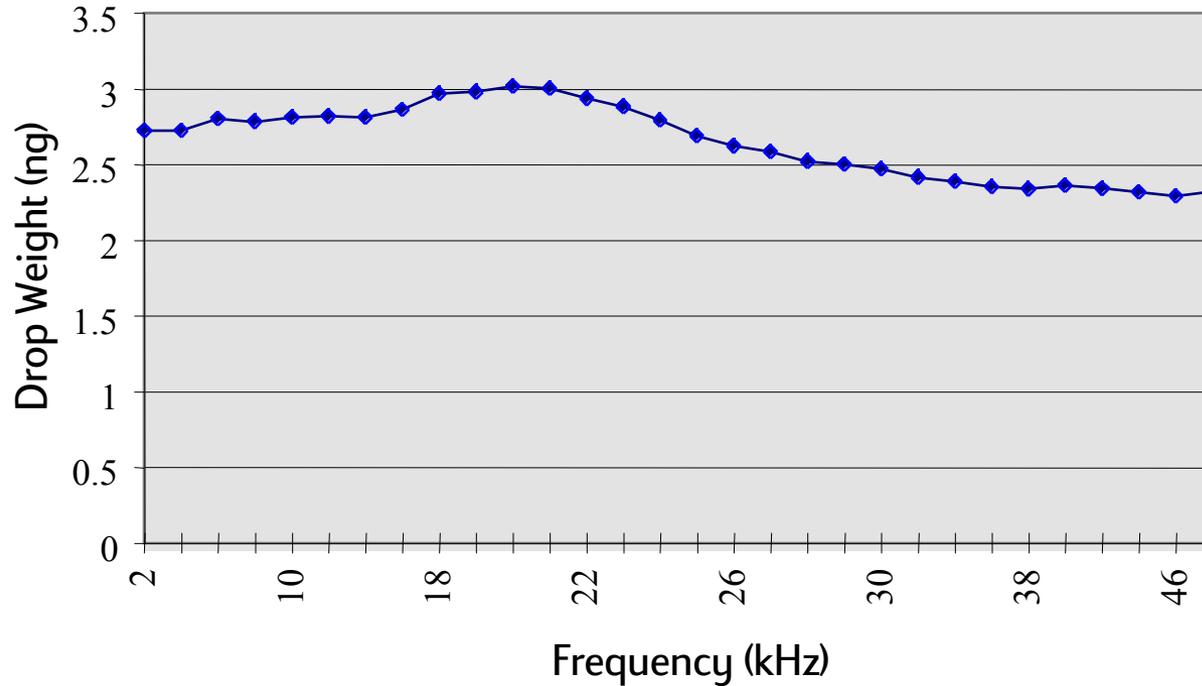
Integrated electronics allows:

- Print heads to be built with fewer electrical connections by utilizing multiplexed addressing.
- Novel interconnect technology with TAB finger bonded to print head silicon.
- Higher throughput and color resolution without excessive system cost and size.



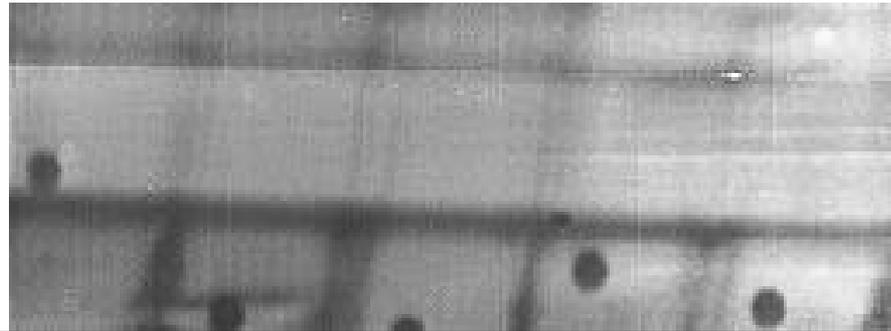
THE FUTURE OF TIJ (CONT)

Drop wt (vol) of an experimental pen.



THE FUTURE OF TIJ (CONT)

2 Picoliter Drops in Flight



Nozzle Plate Plane



THE TAKEAWAY SLIDE



- Small drops are the key printhead technology to superior print and image quality.
- TIJ is leading piezo in achieving these small drops and the gap is expected to widen.
- Monolithic integration of drive electronics with drop generator will favor TIJ in quality and cost in the foreseeable future.
- Clearly the choice is...**TIJ**