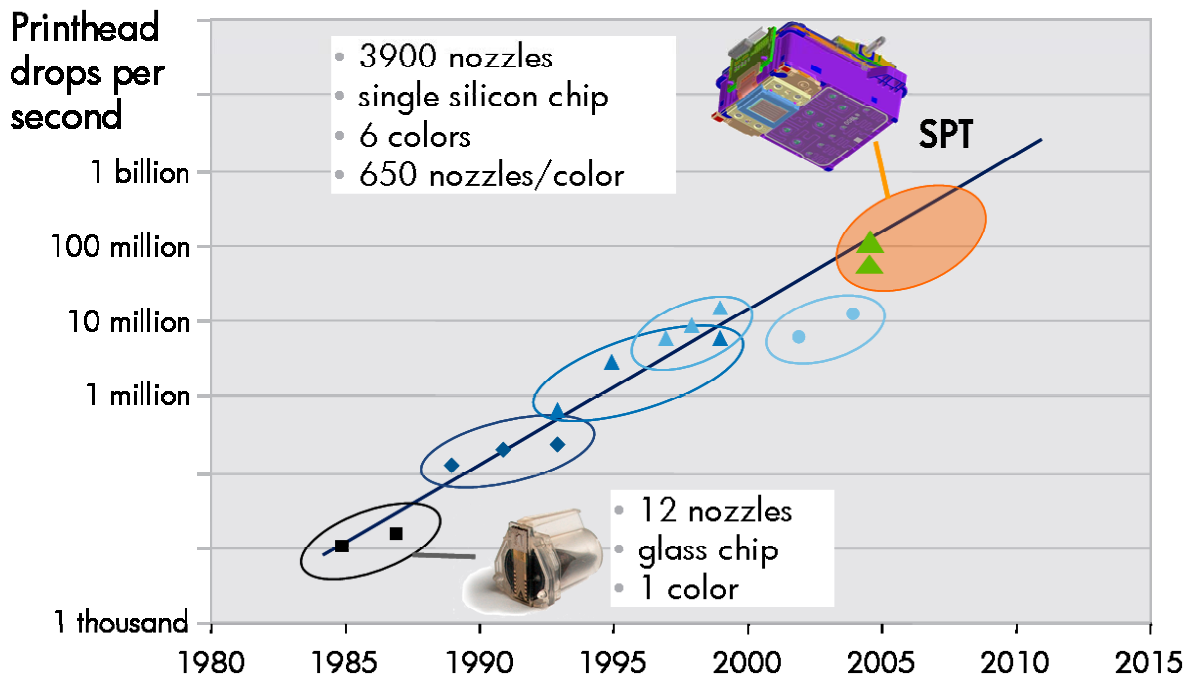


# Scalable Printing Technology

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Since the introduction of HP's first inkjet printer in 1985, HP innovation has doubled inkjet printing performance every 18 months. This extraordinary achievement was accomplished with printers equipped with more nozzles per color, each producing more drops per second, and printing with more colors of ink. Each new printhead generation delivered print quality advances, requiring smaller drops with improved placement accuracy. These trends placed ever-greater demands on printhead design, materials, and fabrication precision.



About five years ago, HP engineers and scientists looked into the future of inkjet printing. They recognized that breakthrough technologies were needed so that HP could continue to deliver printing solutions with industry-leading performance. HP engineers took inkjet printing back to the drawing board and developed new writing systems, inks, printhead materials, and fabrication processes.

After a \$1.4 billion investment in R&D and Manufacturing, HP introduced Scalable Printing Technology. Scalable Printing Technology enables HP to develop future generations of writing systems with printing speeds, quality, reliability, and design flexibility far beyond what could be achieved with previous designs. The flexibility Scalable Printing Technology offers in product design and reduced time-to-market will allow HP to compete even more effectively in maturing low-end printing markets and to enter new, higher-value printing markets in the office, retail photo, commercial and industrial printing, and other emerging opportunities.

HP's effort to develop Scalable Printing Technology represented a major commitment to the future of printing and delivering on customer needs. In the process of developing new products for 2005, over 40 patents were issued to HP on printhead and ink delivery system technology.

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## ***Technology scalable to markets and user needs***

When developing new consumer and commercial printing products, there are many vectors to consider for investment and innovation:

- Technology flexibility to enter new markets with innovative products
- Printing speed
- Product cost
- Cost-per-page
- Image quality
- Ink formulations for different performance attributes
- Ink delivery systems
- Print durability, fade-resistance, and water-fastness
- Time-to-market for new products

Technology that is scalable allows HP engineers to meet more user needs in a single product by allowing designs to advance on one or more vectors much farther than before. In addition, entirely new products can be built to serve new markets whose needs could not be met with previous solutions.

Scalable Printing Technology allows HP to put more nozzles spaced closer together on a printhead. Introduced in Fall 2005, the HP Photosmart 8250 printer (\$199<sup>1</sup> and HP Photosmart 3000 All-in-One series (\$299/\$399<sup>1</sup>) offer 3900 nozzles on a single Scalable Printing Technology printhead: 650 per color, six colors, and densely-packed nozzles spaced at 1200 per inch. These are currently the "world's fastest photo printers"<sup>2</sup> producing a 4 X 6 inch print as fast as 14 seconds. The HP Officejet Pro K550 (\$199<sup>1</sup>) uses two Scalable Printing Technology printheads, each with two ink colors and 1056 nozzles per color. At up to 10 color pages per minute<sup>3</sup> (laser-quality speed "LQS"), the HP Officejet Pro K550 is twice as fast as personal color laser printers.

One aspect of *scalability* is the capability to build larger printheads with more nozzles while still maintaining sub-micron assembly precision for every nozzle. "Larger" means both wider print swaths and more columns of nozzles on a single printhead. With each nozzle column offering the option for a different color, type, and drop volume of ink, HP customers benefit from new levels of speed, print quality, and versatility in printer designs. For example, with Scalable Printing Technology, additional columns of nozzles can be added to the printhead to precisely deliver other components that work with the inks to improve print quality and durability.

Scalable Printing Technology also allows a wide range of drop volumes for different applications from ultra-small (1pl) for photoprinting applications to large (15pl and more) for high-speed commercial printing.

*Scalable* means more than just larger and higher-performance printheads: Scalable Printing Technology innovations extend across all elements of inkjet writing systems. HP ink-based printers serve many markets and customer needs. From portable photo printers and desktop All-in-Ones for home users to office-class workgroup printers and large format graphics printers for commercial applications. Each product segment has different requirements for media, inks, and the ink delivery

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<sup>1</sup> Estimated US street price, actual price may vary.

<sup>2</sup> Speed comparisons in default and fastest modes, when printing from a computer, based upon HP internal testing of comparable consumer photo printing products available as of April 2005

<sup>3</sup> Compared to color laser printers under \$500. Laser Quality Speed is an HP measurement method representing the print speed of typical office documents in default mode; compared to published color speeds by laser manufacturers as of May, 2005.

system, and these requirements can be met by employing the breadth of technologies included within Scalable Printing Technology.

Scalable Printing Technology innovation includes new ink and media formulations for higher-speed photo printing and improved durability and water-fastness. Scalable Printing Technology ink delivery systems offer enhanced printing reliability, and optimization of the ink delivery system to meet the needs of personal, business, and commercial/industrial applications.

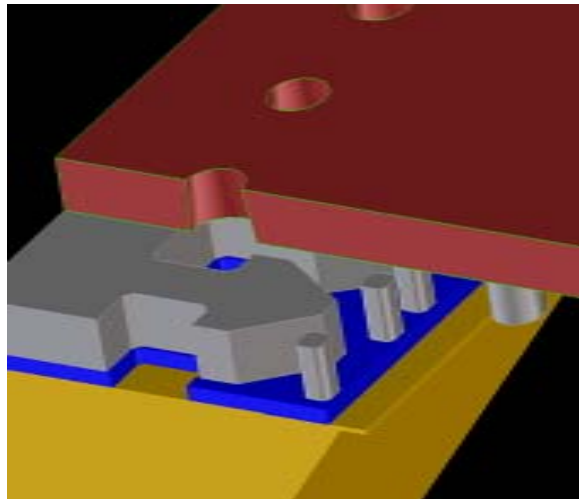
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## ***Breakthroughs in printhead materials and fabrication***

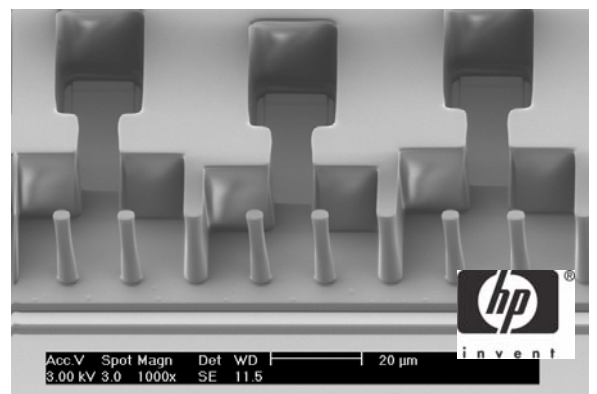
Beginning with its first inkjet printer in 1984, HP has used photolithographic processes in printhead manufacturing. Photolithography defines the incredibly tiny structures in an HP inkjet printhead by exposing light-sensitive materials through the same kind of photographic masks used in integrated circuit fabrication. Once exposed, these materials are chemically-processed to “develop” structures like chambers for the drop generator, nozzles, and features that block particles from entering the drop generators. Individually, these components can be made to sub-micron accuracy.

Before Scalable Printing Technology, parts of the printhead were produced separately and then aligned and assembled onto a silicon wafer containing the printhead electronics. It is the assembly of these precision parts from different processes that is the challenge, and some practical limits have been reached with earlier technologies. While these technologies meet the needs of current applications, their limitations affect how much farther they could be developed to deliver smaller features, better drop control, more nozzles, and larger printheads meeting the speed, image quality, and reliability needs of future applications.

With Scalable Printing Technology, the entire printhead is built using photolithography to maintain sub-micron feature definitions and alignment throughout the entire structure. Precisedefinition of ink passages, chambers, and nozzles optimizes drop ejection performance resulting in higher frequency operation and less variation in drop volume, drop speed, and drop trajectory. Precise drop ejection delivers consistently high print quality and enables faster printing speeds. With Scalable Printing Technology’s ability to define very fine structures, HP engineers can build printheads that are very particle- and bubble-tolerant using small features (“pillars”) in the ink feed path. These act as filters to prevent particles and bubbles from entering the printhead. This is important for reliable operation of a long-life printhead, especially as chambers and ink channels get even smaller for 1-2pl drops.



*CAD model of an Scalable Printing Technology Drop Generator showing the Silicon substrate (gold), “Primer” layer (blue), Drop Generator chamber walls (gray), Nozzle Plate (red). Note the Pillars providing a barrier to particles entering the drop generator.*



*Scanning Electron Microscope view of Drop Generator chamber walls and Pillars showing the precision fabrication possible with Scalable Printing Technology.*

Earlier generations of inkjet printheads used different materials and adhesives to form drop generators and nozzles, the printhead's "fluidic layers". Scalable Printing Technology offers a significant simplification by forming fluidic layers from a single material, applied in different process steps as both a liquid and a dry-film. This material is very robust and maintains its structural and dimensional properties under long-term exposure to ink. Because the fluidic layers are made from the same material, they can better match the silicon substrate's dimensional change with temperature. Especially for large arrays of nozzles, this lowers thermally-induced stresses and extends printhead life. With more robust materials and assembly, Scalable Printing Technology printheads may last the life of the printer in applications such as home photo printing. In others, especially in business and commercial printing, Scalable Printing Technology printheads last longer than previous generations, requiring fewer interventions for printhead replacement.

The silicon substrate for HP thermal inkjet printheads incorporates integrated circuits that process input and output signals, store printhead type and use data, manage power, control the drop generators, and measure printhead temperature. Scalable Printing Technology's *1-micron CMOS process* offers high density electronic circuits, and that means more signal processing and functionality on the printhead, fewer electrical interconnections, and higher reliability. For example, the 3900 nozzle Scalable Printing Technology printhead used in HP's new Photosmart printers discussed above can be controlled with only 24 power and signal connections. Fewer connections make the electrical interface to the printer more compact and reliable. In contrast, HP's previously most advanced single-use print cartridge (HP 96<sup>4</sup>) introduced in 2004 before Scalable Printing Technology used 31 connections to control 672 nozzles. Scalable Printing Technology's *modular printhead electronics* and design rules provide HP printhead engineers with a "tool kit" for creating optimized, proven designs that match printhead features and performance to market needs and printer price points. This means shorter development times for new printheads and the entire printing system.

Combining advanced fluidic and electronic designs made possible by Scalable Printing Technology, new generations of HP printheads can produce up to 48,000 drops per second per nozzle. More drops per second from each nozzle and more nozzles translates into faster printing speeds for photos and documents.

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## ***Breakthroughs in performance and ease-of-use***

While a cornerstone of Scalable Printing Technology is printhead design and fabrication, Scalable Printing Technology innovation extends to HP's entire printing solution. A high-performance, robust printhead is the starting point, and it is a key enabler for innovation and performance improvements throughout the entire system.

While the user may not even know there's a Scalable Printing Technology printhead at the heart of the printer, inks and the ink delivery system are key elements of the printing solution that affect quality and ease-of-use: the user sees the quality and durability of the printed output, and managing consumables is an important element in usability and cost.

Serving many markets and applications, HP printers are optimized for different customer needs for cost per page, quality, speed, media versatility, and format. Ink design is one way HP meets those needs. Over the past 20 years, HP has introduced more than 100 ink formulations. Looking to the future, ink design is critical to meeting our goals for durability and fastness, dry-time, and image

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<sup>4</sup> Also the HP 339 print cartridge.

quality. HP offers dye and pigment inks with increasing levels of performance with every new generation of products. HP Vivera inks used in Scalable Printing Technology home photoprinters provide the wide color gamut, brilliant saturation, durability, and fade-resistance customers expect from HP Vivera inks. And, HP inks are designed as a system with HP media, print modes, and for compatibility with materials in the printhead, printhead service station, and ink delivery system for printer reliability.

Scalable Printing Technology was specifically engineered for flexibility in ink formulation. Going forward, Scalable Printing Technology designs and materials will give HP a significant advantage in developing and introducing new ink formulations that meet customer needs.

With Scalable Printing Technology, HP can easily add columns of nozzles on a single printhead for matte and gloss blacks, grays, and more colors to not only meet aggressive imaging performance goals set by our color scientists, but also the needs of our most demanding customers.

The materials used in HP's Scalable Printing Technology printheads give our ink designers more flexibility in future ink design with less development time and redesign to accommodate new inks. By eliminating many adhesives and using chemically robust materials, printhead and ink designs can be rapidly optimized with fewer constraints. Both dye and pigment inks can be used on the same piece of silicon with the drop generator design, drop volumes, and ejection energy optimized for each ink.

An important part of Scalable Printing Technology involves innovations in the printer's ink delivery systems and ink supplies. These innovations make HP printers easier to use and printing more economical in highly-competitive markets. For example, easily selectable color-coded HP 02 ink cartridges conveniently load into the front of the printer, and are based on designs that use less plastics and packaging materials to make printing more environmentally-friendly.

Within HP's new Photosmart 8250 and 3000-series All-in-One printers Scalable Printing Technology innovations include "Guaranteed Page Completion" and "Active Air Management." With "Guaranteed Page Completion", HP engineers designed the ink delivery system so that the printer does not run out of ink in the middle of a page. If the print carriage's on-board ink supply cannot print the next page at maximum density for any color, then the ink supplies are recharged from the ink cartridges. And, an empty ink cartridge is replaced at this point before the printer resumes printing. This helps to avoid reprinting the page and wasting ink, paper, and time.

"Active Air Management" is an SPT ink delivery system innovation that effectively reduces accumulation of air bubbles in the printhead's ink supply. Under some conditions, air bubbles may restrict the flow of ink into an inkjet printhead or even cause some nozzles to fail to eject a drop. For most inkjet printers, ink is consumed when a service cycle is needed to purge air bubbles. But, Active Air Management minimizes ink consumption when purging air bubbles because the ink and air are separated and then the ink is reused for printing.

Scalable Printing Technology ink delivery system innovations will be seen in a wide range of products targeted for different levels of user intervention: large ink supplies for high monthly print volumes and unattended operation, smaller supplies for compact desktop printers.

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## Conclusion

HP looked into the future of printing and reinvented inkjet with Scalable Printing Technology. Combining new printhead materials, fluidic and electronic designs, fabrication methods, inks, and ink delivery systems, Scalable Printing Technology enables HP writing system engineers to extend HP's leadership in current imaging markets and to enter new ones with products, features, and performance that previously could only be imagined.