Final Report

Comparative Study: *Hewlett-Packard Business Inkjet 2300dtn* *vs.* Konica Minolta magicolor 2300DL

The *SpencerLab* Digital Color Laboratory, a division of Spencer & Associates Publishing, Ltd, has conducted independent testing and comparative evaluation of ***Throughput Speed Performance, Ink/Toner Yield*** *with resultant* ***Cost-per-Print,*** and ***Print Quality*** of the HEWLETT-PACKARD BUSINESS INKJET 2300DTN (BIJ 2300) color inkjet printer and the KONICA MINOLTA MAGICOLOR 2300DL (magicolor 2300) color laser printer.

Testing was performed utilizing a variety of real-world representative documents, including professional office word processing and desktop publishing applications from the *SpencerLab* Printer Test Suite[1] and HP-supplied documents.

Throughput Speed Performance test results show that the BIJ 2300 was able to produce a typical monochrome office document more quickly than the magicolor 2300; the BIJ 2300 was faster than the competitive printer on two of the three office documents tested.

Cost-per-Print results show that all tested office documents are less expensive when produced on the BIJ 2300 than on the magicolor 2300, the magicolor 2300 ranging from 7% to 34% more expensive in the U.S. market and 35% to 76% more expensive in the European market.

Print Quality of the BIJ 2300 surpasses that of the magicolor 2300 in most print attributes, including Color Text, Color Lines, Tints, Blends, and Image rendition. Images on the BIJ 2300 offer realistic color reproduction, excellent richness, sharpness, detail and smoothness. Areas of relative weakness include Black Text and Line rendition when using plain paper driver settings.

The *SpencerLab* Digital Color Laboratory is an independent test laboratory with a broad base of industry clients. Although this comparative study was commissioned by Hewlett-Packard Company, *SpencerLab* believes these results maintain its reputation for the integrity of its procedures and analyses. Results stated herein are based upon direct testing by *SpencerLab* personnel of actual products believed to be representative.

[1] The *SpencerLab* Printer Test Suite, now in ßeta, is an extension of Spencer & Associates' *Color Hardcopy Quality Factors* test suite, a de facto industry standard since 1990.

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Throughput Speed Performance

Methodology

Three test document files were selected to represent an appropriate range of office user applications for this class of color office printers. One monochrome file was used as supplied by HP after review; one was color file was supplied by HP and *spencerized*[2]; and the other color file was selected from the *SpencerLab* Printer Test Suite:

- *Monochrome Dignissimas* (Microsoft Word 2003) – black text with four-column grayscale chart, HP-supplied document, 1-page
- *SpencerLab Greenland* (Microsoft Word 2003) – compound color text, color graphics and images in report format; *spencerized* HP document, 1-page
- *Newsletter* (Adobe Acrobat 5.0) – mixed text, color graphics and photograph; *SpencerLab* document, 1-page

All time measurements begin with the request-to-PRINT. The TOTAL PRINT TIME measurement or LAST PAGE OUT time (when the last page drops into the output tray, also known as "Click-to-Clunk") is augmented by measurements of APPLICATION RELEASE and WORKSTATION RELEASE, and ENGINE START (a perceptible sound or mechanical action) time.

Directly impacting user workflow, APPLICATION and WORKSTATION RELEASE times allow the user to resume working, and their workstation to return to full processing power, respectively. ENGINE START time provides important feedback to the user – that the print request has progressed to physical printing. All timings are recorded for each test document over several iterations to assure accurate results within one percent plus/minus one second.

Since different print modes are available on each printer, a focused print quality evaluation was performed to establish comparable output quality levels for each file. Based on results of this comparison, throughput tests were performed in the modes noted on the following Table. Latest drivers were downloaded from the respective manufacturer websites; at the time of testing, HP 60.32.46.0 and KM 1.4.411.0 driver versions were utilized.

THROUGHPUT MODES	HP BIJ 2300dtn	KM magicolor 2300DL
Monochrome Dignissimas	PRINT QUALITY: NORMAL COLOR OPTIONS: PRINT IN GRAYSCALE, BLACK INK ONLY	RESOLUTION: 1200 x 600 COLOR: B/W ON
SpencerLab Greenland	PRINT QUALITY: NORMAL	RESOLUTION: 1200 x 600
Newsletter	PRINT QUALITY: NORMAL	RESOLUTION: 1200 x 600

Throughput speed performance testing of the BIJ 2300 and the magicolor 2300 utilized a client/print server configuration on an isolated local area network. The client workstation was a 2.2 GHz Dell Dimension 4500 Pentium 4 with a 19.1 GB hard drive and 512 MB RAM running Windows XP; it was connected to the print server via 100BaseT through a 10/100BaseT switch. The print server, a 2.0 GHz Dell Dimension 4500 Pentium 4, with a 10.0 GB hard drive and 512 MB RAM running Windows XP, was connected via 10/100BaseT Ethernet, one-at-a-time, to the tested printers.

[2] *Spencerizing* is our proprietary document optimization process, used by more than a half-dozen major industry clients.

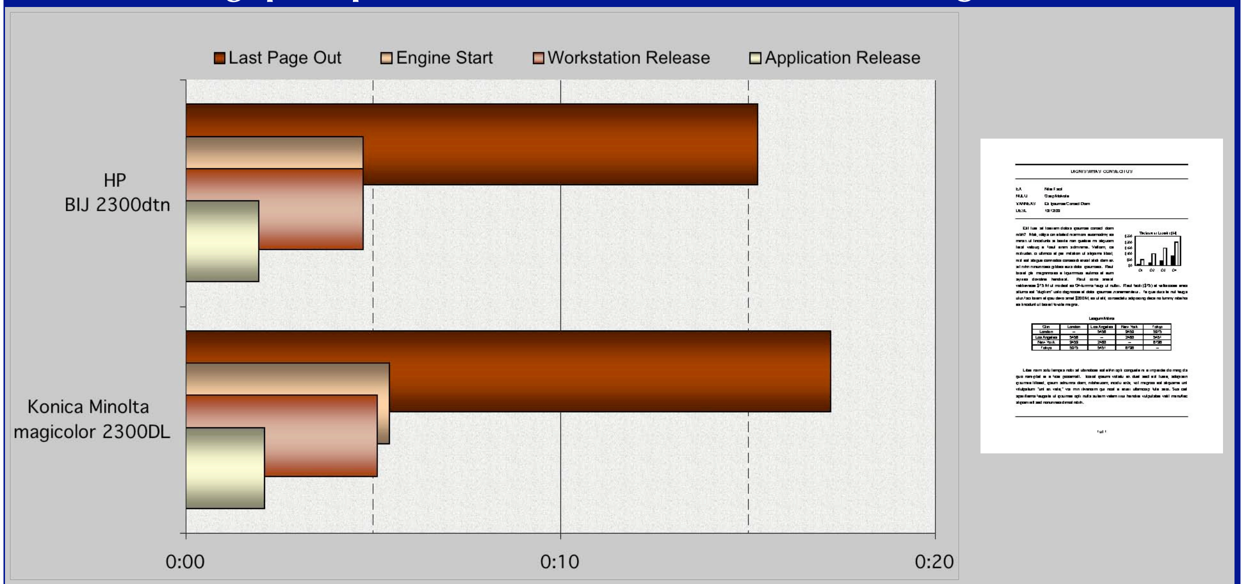
Throughput Speed Performance Testing Results

The BIJ 2300 was faster than the magicolor 2300 on two out of the three office documents tested. The results of the Throughput Speed testing for the individual test files follow.

"Monochrome Dignissimas"

On this 1-page, monochrome test file, the TOTAL PRINT TIME (LAST PAGE OUT) of the BIJ 2300 was 15.3[3] seconds, 11% faster than the magicolor 2300, which took 17.2 seconds.

Throughput Speed Performance – *Monochrome Dignissimas*



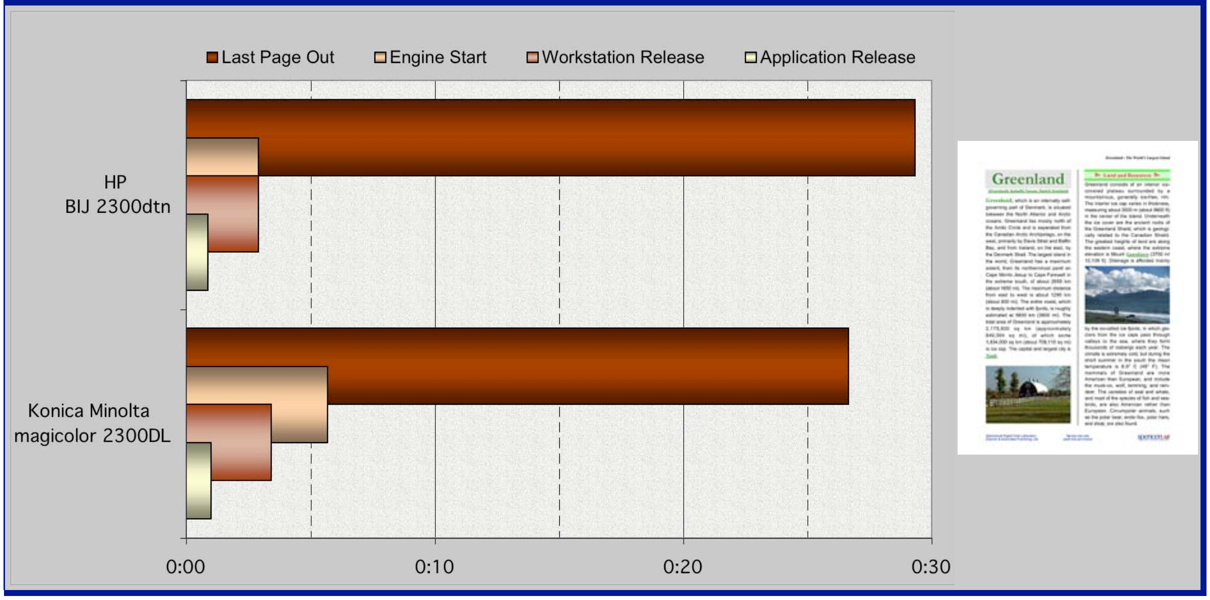
APPLICATION RELEASE for the printers was within 0.2 seconds, with the BIJ 2300 at 1.9 seconds and the magicolor 2300 at 2.1 seconds. WORKSTATION RELEASE on the BIJ 2300 occurred simultaneously with its ENGINE START at 4.7 seconds, faster than both the WORKSTATION RELEASE and ENGINE START of the magicolor 2300 at 5.1 seconds and 5.4 seconds, respectively.

"SpencerLab Greenland"

On this single page color test document, the 29.3 second TOTAL PRINT TIME of BIJ 2300 was slower than the 26.6 second time of the magicolor 2300. APPLICATION RELEASE on the BIJ 2300 (.9 second) and magicolor 2300 (1 second) was within a very tight range. Again, the WORKSTATION RELEASE and ENGINE START were simultaneous on the BIJ 2300 at 2.9 seconds, as compared to 3.4 seconds and 5.7 seconds, respectively, on the magicolor 2300. Although the ENGINE START on the BIJ 2300 was twice as fast as the magicolor 2300, the benefit was lost due to a 5.5 second slower mechanical printing time on the BIJ 2300.

3 Times are denoted as min:sec.tenths, min:sec, or sec.tenths.

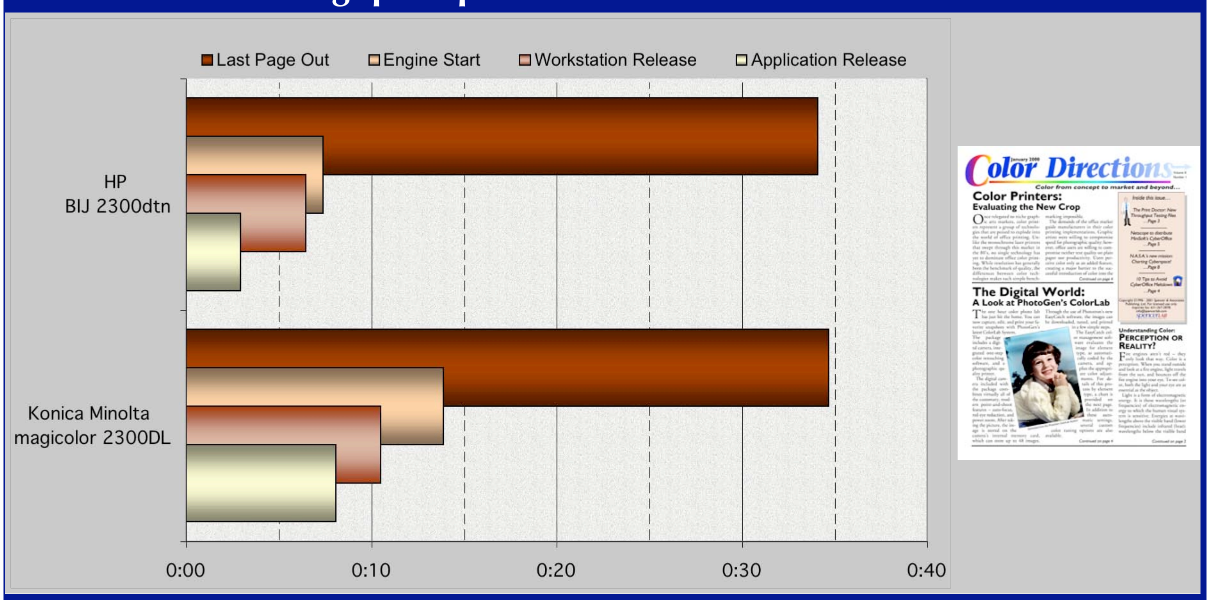
Throughput Speed Performance – *SpencerLab* Greenland



"Newsletter"

On the *Newsletter* file, the BIJ 2300 had the faster TOTAL PRINT TIME of 34.1 seconds, edging out the magicolor 2300 at 34.7 seconds. APPLICATION RELEASE on the BIJ 2300 (2.9 seconds) was more than 2.5 times faster than the magicolor 2300 (8.1 seconds).

Throughput Speed Performance – *Newsletter*



Again, while the WORKSTATION RELEASE (6.4 seconds) and ENGINE START (7.4 seconds) of the BIJ 2300 were substantially quicker than 10.5 seconds and 13.9 seconds, respectively, on the magicolor 2300, slow mechanical printing time of the BIJ 2300 allowed magicolor 2300 to reduce the overall deficit to within 0.6 seconds.

Ink/Toner Yield and **Cost-per-Print**

Methodology

As before, three test document files were selected to represent an appropriate range of office user applications for this class of color office printers. One monochrome file was used as supplied by HP after review; one was color file was supplied by HP and *spencerized*[4]; and the other color file was selected from the *SpencerLab* Printer Test Suite:

- *Monochrome Dignissimas* – black text with four-column grayscale chart, HP-supplied document
- *SpencerLab Greenland* – compound color text, color graphics and images in report format; *spencerized* HP document
- *Newsletter* – mixed text, color graphics and photograph; *SpencerLab* document

The primary method of determining Cost-per-Print is based upon a determination of the number of copies of a test document that can be printed by the black and color ink/toner cartridges. Testing for this Ink/Toner Yield determination is repeated over multiple cartridges to assure consistency. Once an average number of Prints-per-Cartridge yield is established for black and for each color, the cost of each cartridge is divided by this result to calculate the black and color component costs. For this analysis, Manufacturer Suggest Retail Prices (MSRPs) for cartridges were obtained from manufacturer U.S. and European[5] websites. These component costs for each ink/toner color are then summed to obtain the total ink/toner Cost-per-Print for each of the test documents.

In order to determine when it is appropriate to replace a cartridge (end-of-life), the print quality is continuously monitored. A cartridge is judged to be at end-of-life at the earlier of an INK/TONER OUT signal on the control panel or when test prints show visible defects attributable to ink/toner supply[6]. Both printers in this test contain individual color component ink/toner tanks. Cartridges are replaced at their end-of-life and tests are re-run until sufficient, consistent data is acquired.

This testing utilized a 1.6 GHz, Pentium 4 workstation with a 30 GB hard drive and 640 MB RAM running Windows XP; printers were network connected. Latest drivers were downloaded from the respective manufacturer websites. At the time of testing, HP 60.32.46.0 and KM 1.4.411.0 driver versions were utilized[7]. All test files are in PDF format printed through Adobe Acrobat 5.

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4 *Spencerizing* is our proprietary document optimization process, used by more than a half-dozen major industry clients.

5 European pricing (without VAT) obtained from HP France and Konica Minolta Europe websites.

6 The magicolor 2300 sometimes displayed print quality degradation before a TONER OUT signal was received, and in some instances the control panel at this juncture displayed 30% cartridge life remaining. These incidents were not limited to one magicolor 2300 printer; a second magicolor 2300 also presented the same issue. KM technical support was contacted but was not previously knowledgeable of this issue.

7 A recently updated magicolor 2300 driver increases output print quality, however not up to the quality level of the BIJ 2300; however, the QMS Cost-per-Print would correspondingly increase, furthering the HP advantage.

COST-PER-PRINT MODES	HP BIJ 2300dtn	KM magicolor 2300DL
Monochrome Dignissimas	PRINT QUALITY: NORMAL COLOR OPTIONS: PRINT IN GRAYSCALE, BLACK INK ONLY	RESOLUTION: 1200 X 600 COLOR: B/W ON
SpencerLab Greenland	PRINT QUALITY: NORMAL	RESOLUTION: 1200 X 600
Newsletter	PRINT QUALITY: BEST	RESOLUTION: 2400 X 600

Since the print modes available on each printer are different, a limited print quality evaluation was performed to determine comparable output quality levels for each file. Accordingly, samples from applications often used to produce graphics output were tested at higher quality levels than those applications used primarily for text with incidental graphics. Based on the results of this comparison, cost-per-print tests were performed. Modes were as noted on the chart below; if not otherwise noted, printers' defaults were used.

U.S. Currency

Cartridge Costs

Manufacturer list prices of cartridges in US$, as of March 2004:

CARTRIDGE COSTS	HP BIJ 2300dtn	KM magicolor 2300DL
Color Cartridges	**$33.99**	**$69.00**
Black Cartridge	**$33.99**	**$79.00**

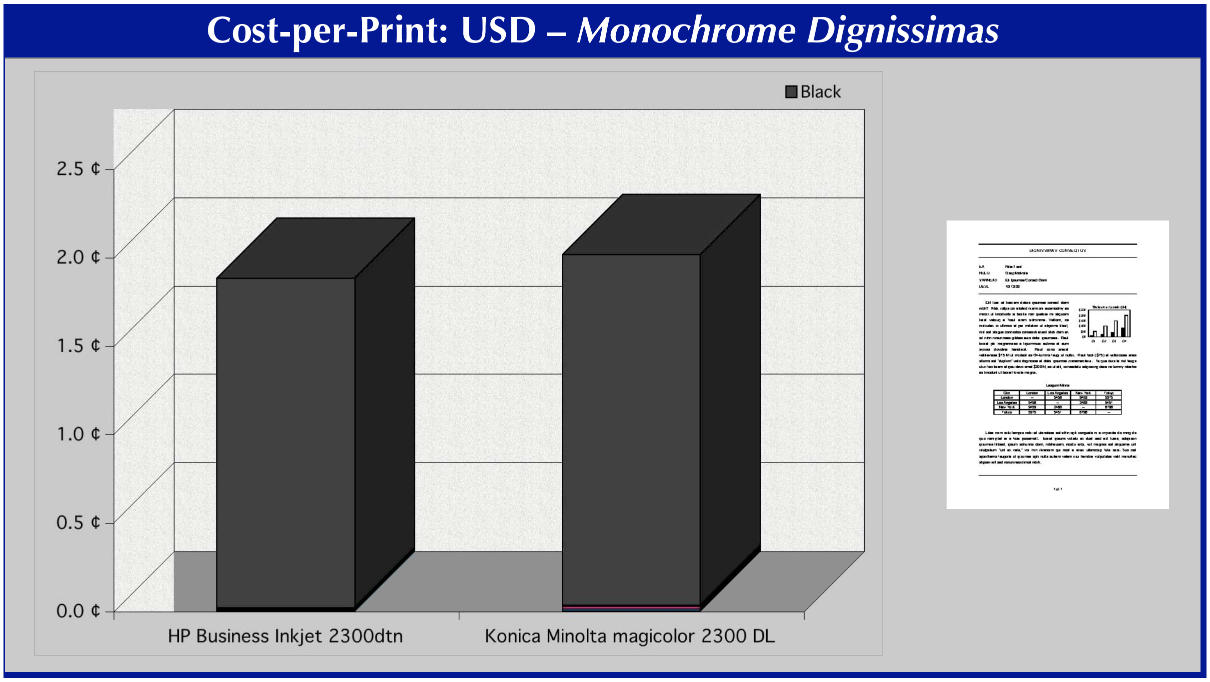
Test Results and Analysis

The Cost-per-Print of the BIJ 2300 is lower than that of the magicolor 2300 on all tested documents, with the magicolor 2300 ranging from 7% to 34% more expensive. The overall results of *SpencerLab's* Cost-per-Print analysis are summarized in the following table. Results include the costs for black and component color inks/toners; media is not included.

COST-PER-PRINT	HP BIJ 2300dtn	KM magicolor 2300DL
Monochrome Dignissimas	**1.88¢**	**2.02¢**
SpencerLab Greenland	**7.17¢**	**9.07¢**
Newsletter	**5.40¢**	**7.22¢**

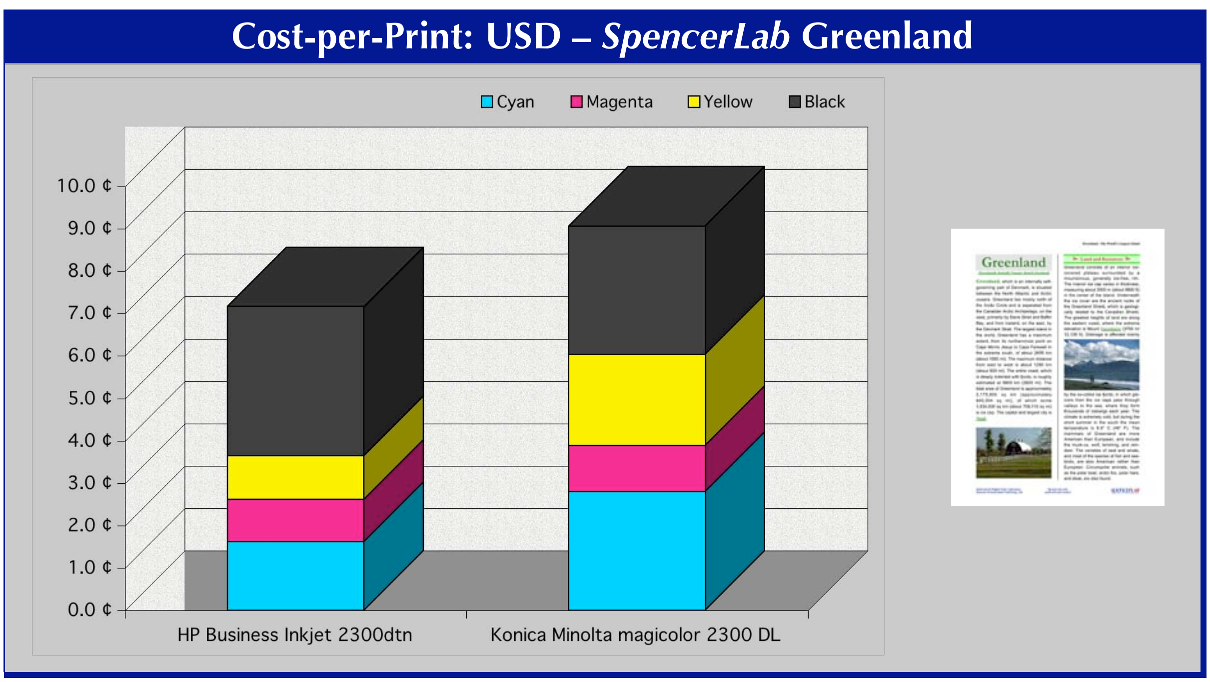
The results of the ink/toner Cost-per-Print analysis for the three individual test files follow.

"Monochrome Dignissimas"



The BIJ 2300 produces this monochrome letter document at 1.88¢ per print; output on the magicolor 2300 costs over 2¢ per print (2.02¢), 7% more expensive than the BIJ 2300.

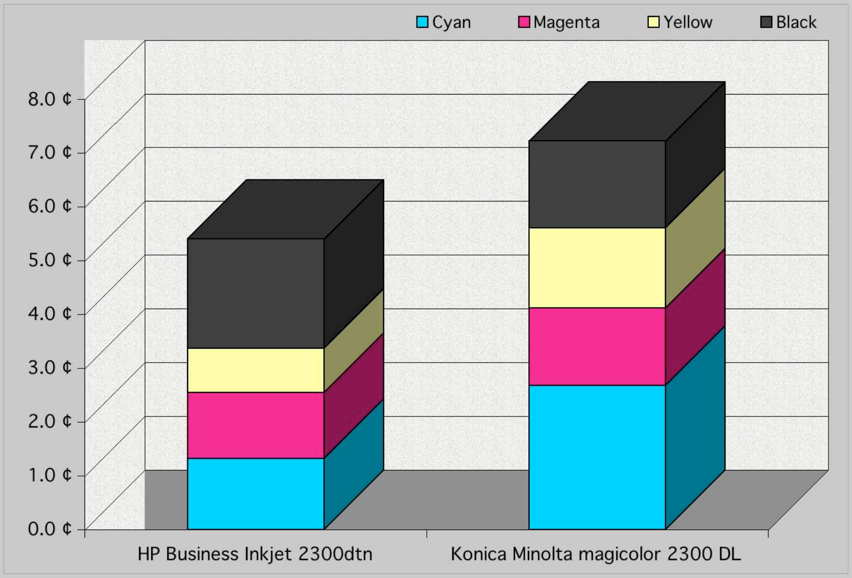
"*SpencerLab* Greenland"



On the *SpencerLab Greenland* text and color graphics test document, the BIJ 2300 cost-per-print is 7.17¢; the magicolor 2300 is 27% more expensive, at 9.07¢ per page.

"Newsletter"

Cost-per-Print: USD – Newsletter



The BIJ 2300 is 5.4¢ per print for the *Newsletter* test document, while the magicolor 2300 is 34% more expensive at 7.22¢ per print.

Euro Currency

Cartridge Costs

Manufacturer list prices of cartridges in Euro (€), as of April 2004:

CARTRIDGE COSTS	HP BIJ 2300dtn	KM magicolor 2300DL
Color Cartridges	€28.74	€78.00
Black Cartridge	€28.74	€84.00

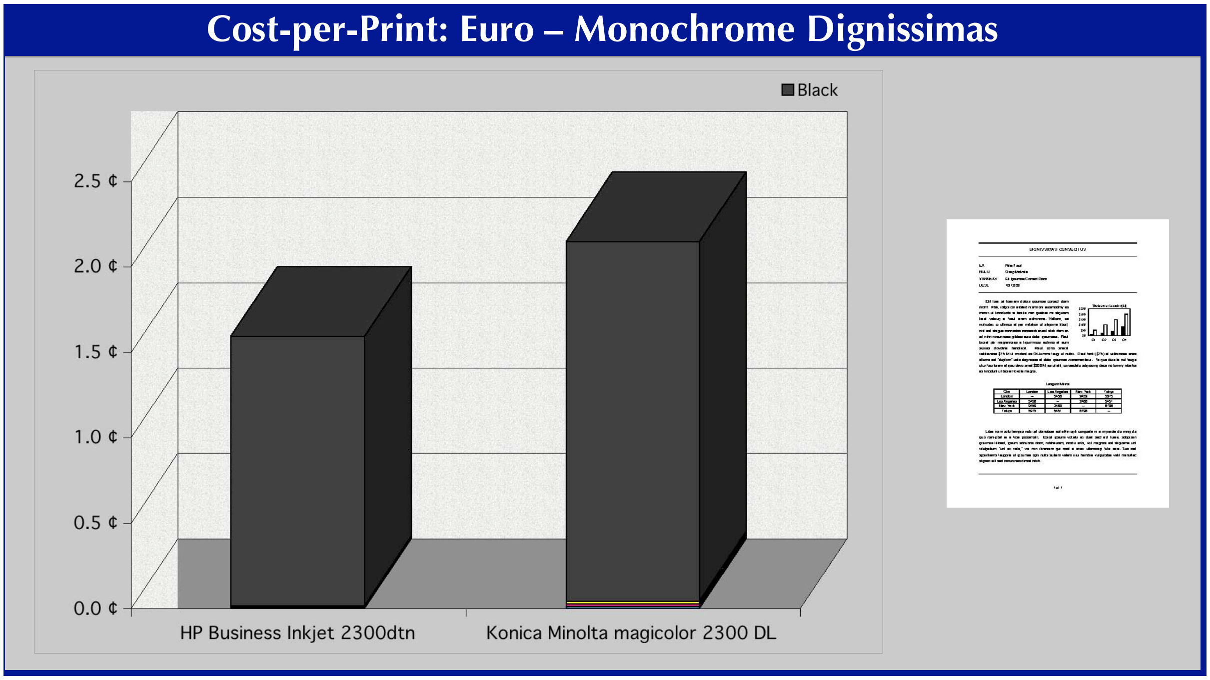
Test Results and Analysis

The Cost-per-Print of the BIJ 2300 is significantly lower than that of the magicolor 2300 on all tested documents, with the magicolor 2300 ranging from 35% to 76% more expensive. The overall results of *SpencerLab's* Cost-per-Print analysis are summarized in the following table. Results include the costs for black and component color inks/toners; media is not included.

COST-PER-PRINT (EUROS)	HP BIJ 2300dtn	KM magicolor 2300DL
Monochrome Dignissimas	1.59 ¢	2.15 ¢
SpencerLab Greenland	6.06 ¢	10.04 ¢
Newsletter	4.57 ¢	8.06 ¢

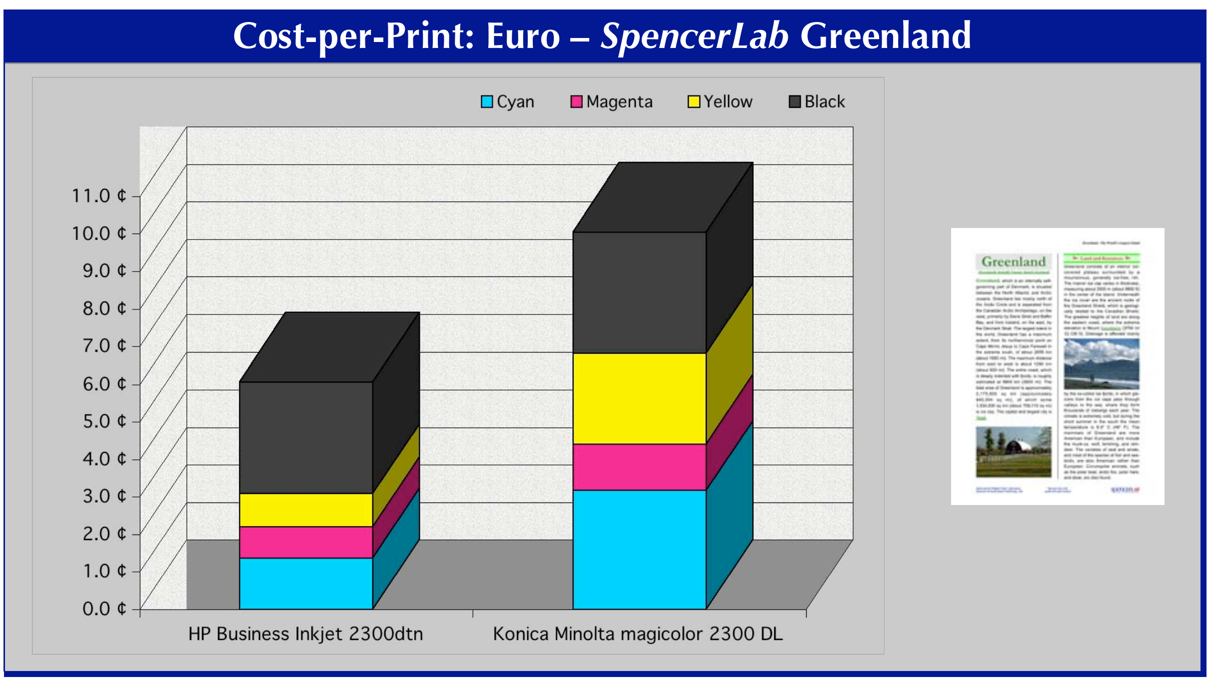
The results of the ink/toner Cost-per-Print analysis for the three individual test files follow.

"Monochrome Dignissimas"



The BIJ 2300 output costs €1.59 per print on this monochrome letter document; output on the magicolor 2300 is 35% more expensive, at €2.15 per print.

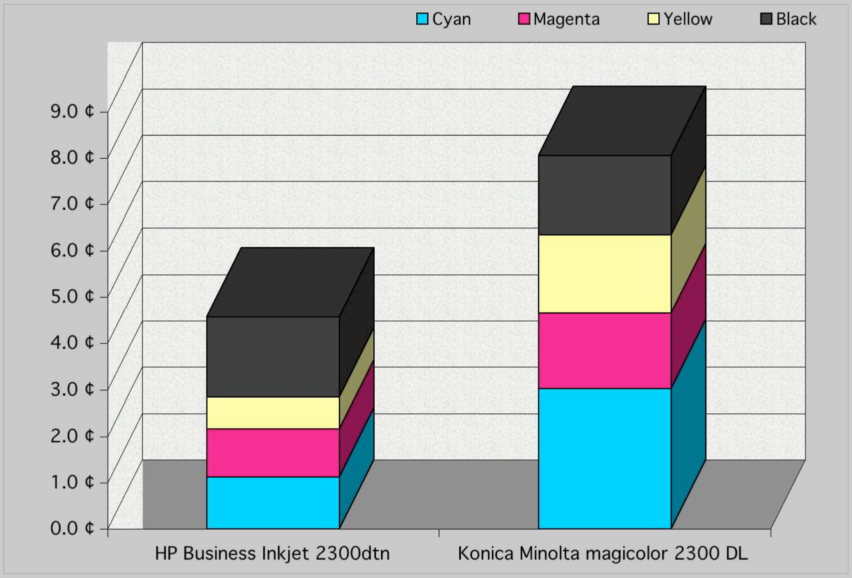
"SpencerLab Greenland*"*



On the *SpencerLab Greenland* text and color graphics test document, the BIJ 2300 cost-per-print is €6.06; the magicolor 2300, at €10.04 per page, is 66% more expensive.

"Newsletter"

Cost-per-Print: Euro – *Newsletter*



The BIJ 2300 produces the *Newsletter* test document at €4.57 per print, while the magicolor 2300 is 76% more expensive, at €8.06 per print.

Prints-between-Interventions

Methodology

The greater the number of Prints-between-Interventions, the less a user must interact with the printer. As noted in the above discussion of Cost-per-Print test and analysis, that methodology is based upon determining the number of prints of a test document that can be imaged by the black and color ink/toner cartridges, or Prints-per-Cartridge. Since an operator Intervention is required to change a cartridge every time it reaches end-of-life, the Prints-per-Cartridge data may be used to estimate an upper bound on the number of Prints-between-Interventions. That is, additional Interventions for other reasons (such as printhead or drum replacement, paper jam) may lower the average number of prints between them, but at the minimum Interventions are required for ink/toner cartridge replacements.

The Prints-per-Cartridge data for the black and color may be combined to calculate the minimum bound on Interventions as follows:

$$\text{Prints-between-Interventions}_{Average} = (\text{Prints-per-Cartridge}_{Black}^{-1} + \text{Prints-per-Cartridge}_{Color}^{-1})^{-1}$$

Test Results and Analysis

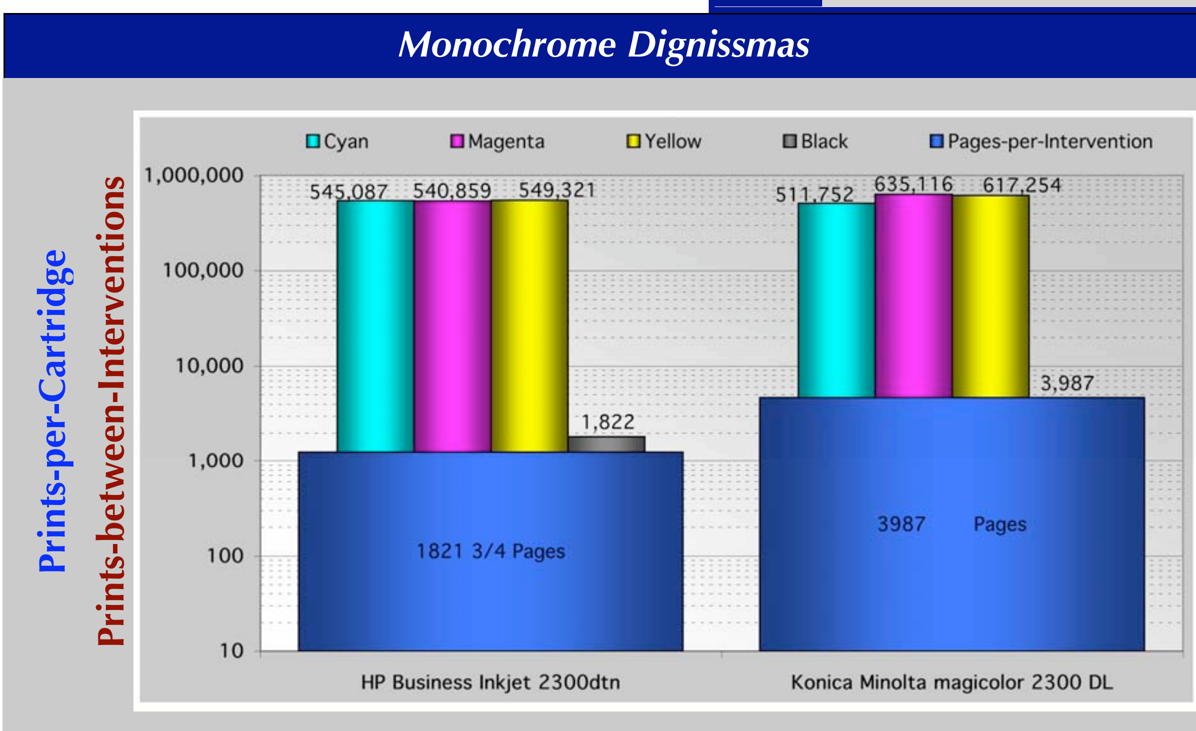
The BIJ 2300 registered lower average number of Prints-between-Interventions due to cartridge changes in all document tests, both monochrome and color – due in part to the toner volume of the magicolor 2300 cartridges.

The results of Prints-per-Cartridge tests and the average Prints-between-Intervention calculations are summarized in the table on the right. This data for Prints-per-Cartridge and the upper resultant bound on the number of Prints-between-Interventions are shown graphically for each test document below.

	Average Prints -between-Interventions	Prints-per-Cartridge Color		Black
Monochrome Dignissmas				
HP BIJ 2300dtn	**1822**	Cyan	545087	1822
		Magenta	540859	
		Yellow	549321	
KM magi-color 2300DL	**3987**	Cyan	511752	3987
		Magenta	635116	
		Yellow	617254	
SpencerLab Greenland				
HP BIJ 2300dtn	**823**	Cyan	2103	966
		Magenta	3413	
		Yellow	3287	
KM magi-color 2300DL	**1519**	Cyan	2463	2603
		Magenta	6307	
		Yellow	3234	
Newsletter				
HP BIJ 2300dtn	**1197**	Cyan	2569	1671
		Magenta	2775	
		Yellow	4160	
KM magi-color 2300DL	**1882**	Cyan	2580	4886
		Magenta	4767	
		Yellow	4648	

"Monochrome Dignissmas"

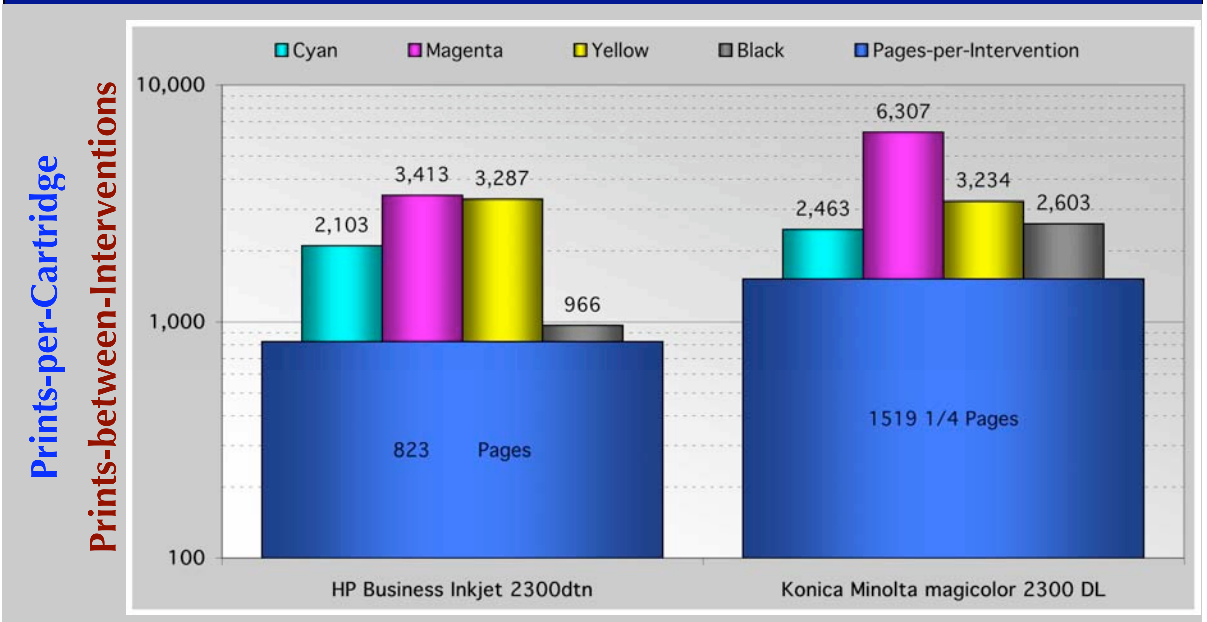
At an estimated average bound of 1,822 Prints-between-Interventions when printing the *Monochrome Dignissmas* file, the BIJ 2300 required interventions to change a print cartridge over twice as often as the magicolor 2300. Correspondingly, the BIJ 2300 requires 0.55 Interventions per 1000 prints, while the magicolor 2300 requires only 0.25. The higher Black page yield per cartridge of the magicolor 2300 contributed significantly to its lower number of user Interventions when printing a monochrome document such as this.



"SpencerLab Greenland"

At an estimated bound of 823 Prints-between-Interventions when printing the *SpencerLab Greenland* file test document, the BIJ 2300 requires an Intervention to change a print cartridge 1.85 times more often than the magicolor 2300, which requires Intervention at an estimated bound of 1519 pages. Correspondingly, the BIJ 2300 requires 1.22 Interventions per 1000 prints, while the magicolor 2300 requires only 0.66.

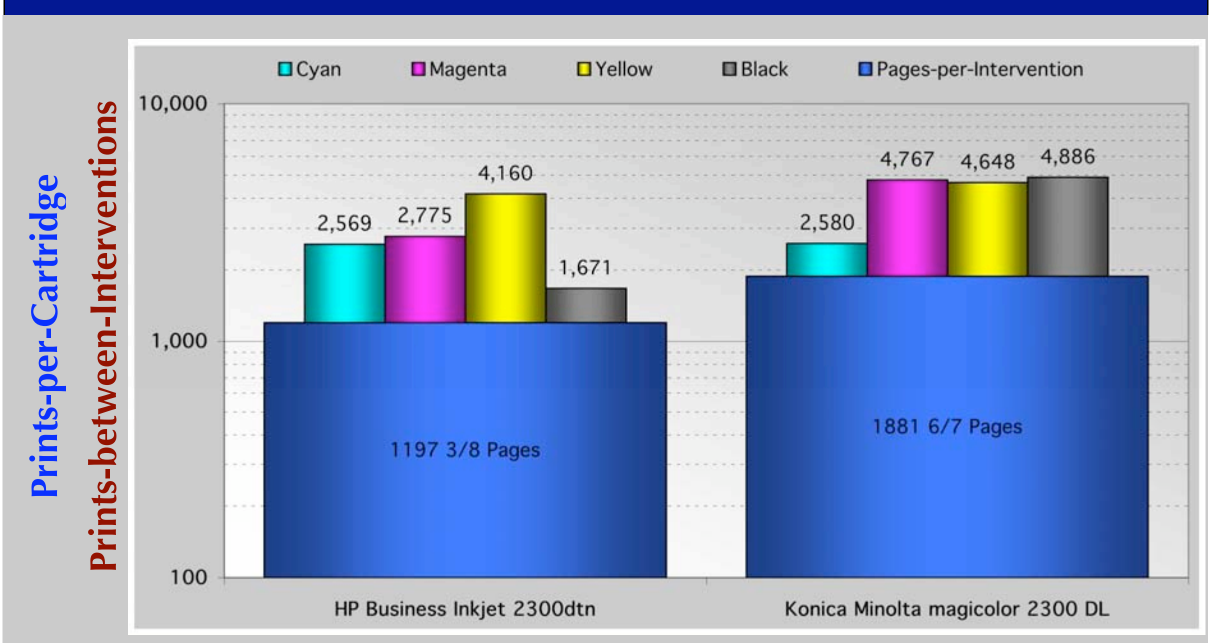
SpencerLab Greenland



"Newsletter"

At an estimated bound of 1197 Prints-between-Interventions when printing the *Newsletter* test document, the BIJ 2300 requires an Intervention to change a print cartridge over 1.5 times more often than the magicolor 2300. The magicolor 2300 requires Intervention at an estimated bound of 1882 pages. Correspondingly, the BIJ 2300 requires 0.84 Interventions per 1000 prints, while the magicolor 2300 requires only 0.53.

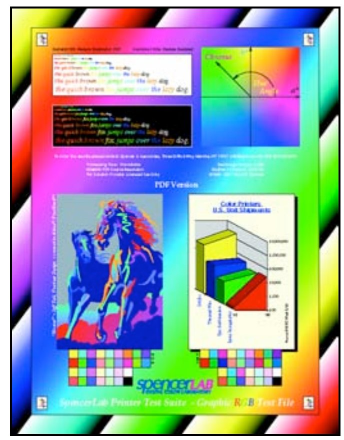
Newsletter



Print Quality Analysis

Methodology

A range of test documents from the *SpencerLab* Printer Test Suite was printed on each of the printers in a range of print modes, after printer setup and alignment. These test documents included current versions of the *Color Spectrum, Graphic,* and *Graphic RGB* programs (originally developed as part of the *Color Hardcopy Quality Factors* study series). Also included was the *Enhanced Graphic* PostScript program (originally developed as part of the *Hardcopy Quality Enhancement* study) and a range of images and application test documents from the suite, covering a variety of printing requirements. Print Quality was analyzed by element type (*e.g.*, Black, Color and Reverse Text, Lines, Tints and Blends, and Images) across these test documents. A single printer of each manufacturer was used in analysis and was assumed to be representative[8].



Test Results and Analysis

HP BIJ 2300 print quality surpasses that of the QMS magicolor 2300 in the areas of Color Text, Color Lines, Tints, Blends, and Images. Black Text and Lines on BIJ 2300 are produced well, but appear a bit jagged when compared to magicolor 2300 output. Photographic Images on the BIJ 2300 offer realistic color reproduction, excellent richness, sharpness, detail and smoothness. Areas for improvement might include Black Text and Line rendition on plain paper.

Text

Reflecting their different print quality issues, Black, Color, and Reverse Text are discussed in the following sections.

Black Text

Black Text represents the most common use of an office printer, and is primarily comprised of thin, filled solid regions. As the principal vehicle for communicating ideas, text is designed to be very legible while being unobtrusive to the reader. Print quality limita-

[8] At the time of testing the latest available driver versions, HP 60.32.46.0 and KM 1.4.411.0, were downloaded from the respective manufacturer websites and utilized. Since the time that testing was completed, an updated QMS magicolor 2300 driver has been posted on the manufacturer website. This driver revision increases output print quality; however, not up to the quality level of the BIJ 2300.

tions can cause distractions that subtract from the effectiveness of the communication; in the worst case, they can render text illegible.

Because of the limited number of addressable dots with which to render a font character, small text poses the greatest challenge to legibility. Two and 4-point text is often used in situations where legibility is crucial but precise artistic accuracy is not necessary; the sophistication of font design increases at 6 points and larger as the visibility of fine details improves with point size to even the most casual reader.

Uniform character stroke weights and spacing provide uniform "typographic color", the perceived overall darkness of the text. This enhances effective communication when successful, but may detract significantly when distorted and uneven. Font details such as fine serifs, thin strokes, and uniform kerning can easily be lost due to poor reproduction.

Black Text on the BIJ 2300 is legible down to 2-point, with dropouts visible at 4-point, but no visible splatter. Typographic color is even and consistent, with smooth gradations. On plain paper, Black Text is slightly thick with noticeable jaggedness; Black Text produced on HP Premium Paper, offers better smoothness and legibility than that of plain paper.

The magicolor 2300 produces sharp and clear Black Text with smooth edges. Black Text is legible down to 2-point and no visible splatter is present. Dropouts are visible without magnification on 4-point text. Overall, Black Text produced on plain paper is of slightly higher quality than that of the BIJ 2300; on premium paper Black Text produced by both printers is comparable.

Color Text

Color can be used to highlight or emphasize particular words or phrases – improper rendering of such color can shift the emphasis from the key idea to the lack of adequate print quality. Because most colors (all but pure primaries and secondaries) require some halftoning even at full saturation, text quality is often decreased further due to the halftone cell structure.

Color Text on BIJ 2300 is comprised of sharp, clear and legible characters. Screening is excellent, and only slightly visible in tertiary colors such as orange or brown. Text is legible to 2-point on HP Premium Paper, and to 4-point on plain paper. Color Text is uniform, consistent and smooth with even color transitions..

Color Text output on the magicolor 2300 is rendered lighter than on the BIJ 2300, appearing washed out, with decreased legibility – especially Yellow text. Light Gray text has a bluish cast and inconsistent gradations. Graininess and visible screening on Color Text further degrades readability at lower point sizes. Overall, Color Text quality is inferior to that of the BIJ 2300.

Reverse Text

Although less significant than other print attributes for many applications, reverse text represents a specific use that some printers tend to reproduce poorly due to enlarged spot size, toner splatter, and other causes of poor modulation transfer function. Typically, thin lines and fine font fills are dimmed or dropped out completely.

Reverse Text on the BIJ 2300, both Color and Black, is legible down to 4-point size. Minor fill-ins begin at 14-point on plain paper and at 8-point on HP Premium Paper. Reverse Color Text, on HP Premium Glossy Photo Paper in BEST mode, is excellently rendered with superior smoothness and edge sharpness. Reverse Black Text, however, exhibits noticeable fill-ins. Printing Color and Black Text on HP Premium Inkjet Paper delivers slightly higher quality output than that of plain paper printing.

The magicolor 2300 offers excellent Reverse Text production. Reverse Black and Color Text edges are very smooth, resulting in excellent edge sharpness and clarity. Reverses are legible down to 4-point, with minor fill-ins visible under magnification on 10-point characters.

Line Graphics

As a graphical element, lines are critical in representing data, providing visual separation of document sections, and contributing to artistic graphics; in fact, the prevalence of lines in printed material is overwhelming and nearly as common as text. Of these, the most common are vertical and horizontal ruled lines – fortunately the simplest to render on a rectilinear grid. Because of the geometry of such a grid, diagonal lines are subject to an increase in minimum thickness; a printer's ability to maintain line thickness between the thinnest straight and diagonal lines is a tradeoff between offering thinner straight lines or greater uniformity.

While this uniformity issue is often of minor importance for discrete lines of different angles, curved lines require that they do not appear to vary in thickness unintentionally. In transitioning along curved lines from vertical or horizontal orientations to the angles between, many rendering algorithms will create noticeable artifacts that emphasize the jaggedness of the pixel grid.

In addition to width non-uniformity, lines often illustrate deficiencies such as drop out and ghosting, halftoning issues (some halftone algorithms are designed for use over large areas, but also employed in thin line situations), and color registration problems perpendicular to the orientation of the line.

The BIJ 2300 produces high quality, sharp, and smooth Color Lines. Reverse Radial patterns produced by the BIJ 2300 are better than those of the magicolor 2300. However, Black Lines are rendered thick and overpowering in comparison to Color Line reproduction; thick Black Line rendition has noticeable jaggedness, resulting in loss of fine details - as in the Mazda Car drawing. Color Lines are sharp with uniform thicknesses, producing clean and crisp Registration Targets and Line drawings that are free from disturbing screening patterns or visible grain. Both Color and Black Lines are better rendered on HP Premium Paper in NORMAL mode than on plain paper settings.

The magicolor 2300 produces clean, sharp and crisp Black Lines of consistent thicknesses. Thin Curved, Radial and Angled Black Lines are rendered well, with some minor stepping and jaggedness. Reverse Radial Lines appear to merge and are not individually visible. Thin Color Lines are produced too lightly and appear as broken, dotted lines. This combined with visible screening, results in a loss of detail - as seen on color Registration Targets and the Mazda Car drawing. Overall, Black Lines on the magicolor 2300 and BIJ 2300 are comparable, whereas the BIJ2300 produces higher quality Color Lines than the magicolor 2300.

Tints and Blends

Reflecting their related print quality issues, Tints and Blends are discussed below.

Tints

Unlike solid printing, tints introduce an increased sensitivity to resolution and mechanical issues. A tint is a large area of a single unsaturated color, such as pink, sky-blue, or brown. Therefore, it is also sensitive to hue color errors.

Traditional screening creates a tradeoff between resolution and the number of available intermediate colors that may be unfavorable. To enhance the number of colors a printer can produce, vendors have often introduced super-pixel dithering over traditional screening – even though this runs some risk of introducing pattern artifacts and moiré effects that can be annoyingly visible. Stochastic screening modulates the placement between high-resolution dots (spatial frequency modulation), minimizing most artifacts; however, this technique requires good color registration and may yield grainy pastels.

The BIJ 2300 renders well-saturated Color Tints that are produced smoother than those of the magicolor 2300. Black Tints, on HP Premium Paper in NORMAL mode, are produced uniformly. A slight magenta cast is seen in light Gray tints. On plain paper, in NORMAL mode, Black Tints exhibit screening and graininess.

On the magicolor 2300, Tints are noticeably less vibrant than those produced by the BIJ 2300. Minor banding is observed, with no mottle. Screening patterns and graininess are visible, particularly in Yellow and light pastel tints.

Blends

Blends are smooth transitions between two or more colors. While incorporating all the issues of tint generation, Blends additionally require an abundance of color levels, smooth transitions between these colors, and perceptual linearity of hue, saturation, and lightness ramps.

Highlights and shadows often deteriorate blend quality. This is due to the difficulties involved in providing accurate differentiation of shades in heavily toned regions, and in providing a sufficient number of pastel shades to smooth the transition to paper white.

Since a majority of print jobs will require a conversion from RGB to CMY, and since user documents in this market segment are increasingly created in RGB, the ability to produce high-quality RGB blends is more important than CMY blends.

The BIJ 2300 produces smooth, saturated and uniform Blends on HP Premium Paper in NORMAL mode. On plain paper, Rainbow Blends on the BIJ 2300 exhibit transitional banding particularly in the Blue and Green regions. On Color Ramps, midtones are lost and highlights drop too quickly. Cyan and Green Color Ramps have harsh highlight-midtone transitions (as on the *Color Spectrum CMYK* file). Monochromatic Blends (on the *Enhanced Black* file) on plain paper in NORMAL mode, display graininess and non-linearities. The 3-D Pie Chart of the *Color Spectrum RGB* file is rendered consistently and smooth, except for some minor rendition issues.

The magicolor 2300 has smooth monochromatic Blends (as seen on the *Enhanced Black* file) at 600x600 and 1200x600 DPI modes. Rainbow Blends are mainly smooth, but some harsh transitions are displayed on Digital Color Supergloss paper at 2400x600

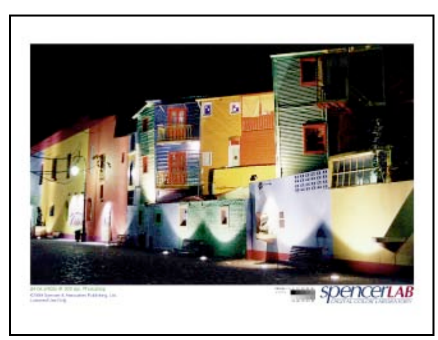
DPI mode. Color Ramps reach 100% saturation too quickly, while midtones and highlights are washed out and exhibit minor transitional banding. Screening and graininess is observed on the 3-D Pie Chart image.

Images

Unlike computer-generated graphics, images are the result of sampled raster data and seamlessly combine the quality elements of graphics, tints, and blends. Because of the wide range of potential subject matter in an image, a printer's ability to produce realistic, high-quality images is extremely difficult, but critical to the user's quality perception; even if only at the time of product selection; therefore, a printer must produce high quality images.

The use of photographic data sources for images leads to a high demand for color fidelity. This includes accurate reproduction of memory colors – those with which users are heuristically familiar – without requiring an original for comparison. Natural greens, sky blues, wood browns, and skin tones represent common memory colors that can tax a printer's color rendering ability due to color gamut restrictions, imprecise color balance, or sub-optimal colorants. Another demand for image color fidelity is matching a color-corrected photograph such as a calibrated image file with an associated profile or in a standardized color space such as sRGB or SWOP. Although sometimes causing conflict, both objectives are important.

High-frequency, high-contrast detail within an image reflects a printer's ability to provide high quality text and graphics. The device resolution is used to carry the high level of fine detail. In areas of little variation (low spatial frequency), process noise and screen artifacts (in the case of non-continuous-tone printers) can be readily apparent. Finally, smoothly varying regions require blend linearity in order to accurately capture the realistic appearance and visual depth of the original.



Images produced by the BIJ 2300 display excellent richness and color fidelity on gloss media, resulting in extremely pleasing and realistic output. Images are smooth, and free from banding, mottle, grain and print artifacts. Skin tones, as in the *Babies* and the *Woman's Headshot* files, have a slight Magenta cast, whereas blue skies and green grass are rendered a bit too Cyan. Superior image sharpness results in faithful rendering of fine details visible in the *Castle* and *Covered Bridge* files. The BIJ 2300 produces images that are of excellent quality, especially from a printer targeted for a typical office environment.

Image output from the magicolor 2300 ranks very poorly, on all image elements, in comparison to BIJ 2300. Images lack vividness and are rendered with a noticeable yellow cast, resulting in dull and lifeless prints. The Yellow cast is extremely prominent on skin tones, as in the *Babies* image and *Woman's Headshot*, and in the grass and sky of the *Covered Bridge* and *Castle* images. Though no print artifacts are present, minor horizontal and vertical banding are noticeable in blue sky regions of the *Castle* and *Isle* images. All images have disturbing graininess and lack highlight and shadow detail. Output appears blurred, resulting in loss of image sharpness and depth - particularly seen on the *Castle* image. Overall, Images on the magicolor 2300 are of significantly lower quality than those produced by the BIJ 2300.

About *spencerLAB*

The *SpencerLab* Digital Color Laboratory is an independent printer evaluation facility that provides services to vendors and corporations for whom color printing is mission-critical. The Laboratory follows strict guidelines in the integrity of both methodology and reporting; vendor-sponsored studies do not guarantee favorable results. SpencerLab has developed industry-standard test software, and performs print quality, throughput speed, ink and toner cartridge yield and cost-per-page/TCO, and ease-of-use analyses for color and monochrome printers in all technology classes, from inkjet and laser printers to digital color presses.

SpencerLab is operated by Spencer & Associates Publishing, Ltd., a premier IT consulting boutique specializing in the application of Digital Color Technology to all aspects of color imaging. For over a dozen years Spencer & Associates has been providing strategic support to manufacturers in product planning, development, and launch. Color printing workflow analysis, print system selection, and usage optimization services are provided to corporate users.

For more information, please contact *SpencerLab* by email at info@spencerlab.com, on the web at www.spencer.com and www.spencerlab.com, by telephone at 1-631-367-6655, or by fax at 1-631-367-2878.

Appendix A: Test Document Coverage Estimates

Page Coverage may be defined as *the percent of the total page* covered by *any color* – which can be comprised of one or more primary inks/toners, or a tint.

Ink/Toner Coverage may be defined as *the sum of the percents of the total page* covered by *each primary ink/toner* – this is normally defined at 100% equivalence; that is, a 10% tint of one ink/toner covering the entire page is equivalent to 10% of the page being covered completely by that ink/toner. Since most colors consist of two or more primary inks/toners, this total may exceed 100% and could theoretically reach 300% (many printers have a 230-250% total ink/toner limitation).

Since many user pages are defined in an RGB color space and ink-printing technologies must use CMYK, a conversion is required. Furthermore, various devices' CMYK inks do not have the same color characteristics, and printer designs balance the optimization between print quality and cost-per-print among pragmatic constraints. Some printers use all four CMYK colors when printing gray tints to reduce individual dot visibility and many printers even alter CMYK files before printing. Additionally, as drop volumes continue to get smaller, the dot gain will tend to also get smaller, and the resultant print coverage will reduce for the same file. Some inkjets have variable droplet sizes, depending upon data and mode; some reduce ink in solid fill areas. Therefore, no two printers will have the same Ink/Toner coverage even when printing from exactly the same original, and the only consistent measure (as the ISO has acknowledged) is the digital coverage of the file.

SpencerLab methodology utilizes such measurement of the digital coverage of the files (*before* aforementioned dot gain). Alternative methodologies may apply different methodologies for coverage calculation, such as measuring the printed page on a particular ink jet printer (or perhaps an average of printers) after dot gain. Individual methodologies may render disparate percentages of total coverage, for the same printed page.

Therefore, an idealized CMYK printer needs to be defined, along with an idealized algorithmic conversion to it. The most prevalent CMYK standard is SWOP, and many printers even try to emulate it. In the following table we have augmented Page Coverage with an estimate of Ink/toner coverage based upon SWOP-based printing with Photoshop algorithmic conversions from sRGB.

Coverage		*Monochrome Dignissimas*	*SpencerLab Greenland*	*Newsletter*
Page Coverage		**4.1%**	**22.0%**	**29.8%**
Ink Coverage	*Cyan*	—	13.2%	4.7%
	Magenta	—	10.3%	5.0%
	Yellow	—	11.5%	4.3%
	Black	4.1%	8.6%	10.0%
	Sum	**4.1%**	**43.6%**	**24.0%**