A 15-Year History of Digital Printing Technology and Print Permanence in the Evolution of Digital Fine Art Photography – From 1991 to 2006

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Abstract

Since digital fine art photography printing began in 1991 with the difficult to operate and costly to maintain $126,000 Iris Graphics Model 3047 inkjet printer using water-soluble cyan, magenta, yellow and black dye-based inks with poor light stability – but which could nevertheless print beautiful large-format photographs from digital files on a wide variety of artists papers, both thick and thin – the industry has seen rapid progress in the development of far lower cost, faster and easier to operate printers. Central to this evolution have been the dual concerns of image permanence and image quality. An increasingly competitive inkjet industry has driven the development of, at first, more stable dye-based inks and ink-specific optimized inkjet media. More recently, piezo and thermal head printers using high-stability, multi-colorant pigmented ink systems from Epson, Hewlett-Packard, and Canon have come to dominate the field. At the same time, in a massive reshaping of the industry, the reduced costs of both printers and computer systems coupled with Adobe Photoshop and other advanced image editing software has made it possible for digital fine art printmaking to move from a small group of specialized providers into the hands of individual photographers and artists – worldwide.[1]

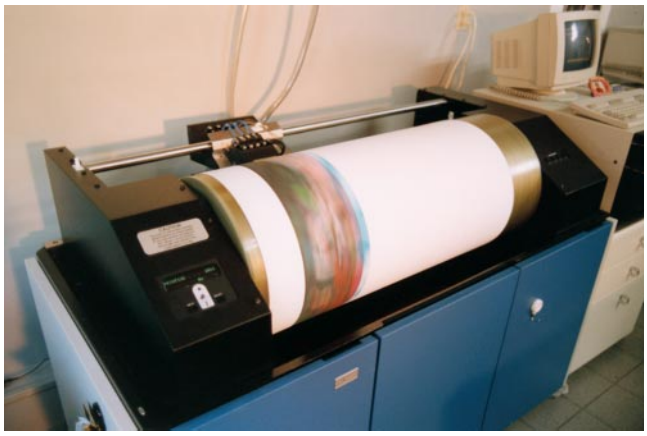
Introduction

Digital printing of fine art photographs – and a broad-based concern about the permanence of digital prints – can be traced to the founding of Nash Editions in Manhattan Beach, California, in 1991. At that time, the only printer capable of producing high-quality, large photographic prints (up to 34x46 inches) on a wide range of papers and canvas was the Iris Graphics Model 3047 inkjet printer made by Iris Graphics, Inc. in Bedford, Massachusetts. The Iris 3047, which had been designed for direct digital graphic arts proofing, was an expensive machine, costing $126,000. As recounted by Steve Boulter, then national sales manager for Iris Graphics: "The 3047 was developed for the Marubeni Corporation of Japan as an eight-up proofer. Hence, the A0 sheet size. The printer was introduced in 1989. I started working for Iris in 1988 and the development activity for the 3047 began shortly after that. Marubeni is kind of like the GE [General Electric Company] of Japan. They are a very large conglomerate and they functioned as a reseller for Iris. They funded the development of the 3047 with about $500,000."[2]

The Iris 3047 was not conceived of nor intended for printing valuable photographs and art reproductions that would be framed and displayed for long periods of time. Because long-term light stability was not of concern in the proofing business, the dye-based ink sets initially available for the printer had poor light stability. Instead, the design goal was to print direct-digital proofs that could match the color gamut and tone scale of the inks used in offset printing; the proofs had only short-term use.

It was rock musician Graham Nash and his concert tour road manager Mac Holbert, both accomplished photographers, who first recognized the potential of the Iris as a fine art printer when, on March 14, 1989, they watched a 3047 printing a color photograph. As Holbert wrote in a one of a series of diary entries: "The digital images are stored on a 1/4-inch recording tape that is inserted into an automatic tape reader. The color and image placement is controlled through a series of menus you access through a digital readout panel on the printer. They printed an image of a bride holding a bouquet of pink roses. Not exactly our type of image.... The print was about 16" x 20" and took about 20 minutes to complete. When the printer stopped spinning and they opened it, both Graham and I got chills. It was astounding! I couldn't believe what I was looking at! The paper they used was a little glossy for my taste, but the technology is there! Steve Boulter mentioned he's been printing painting reproductions on very heavy watercolor paper back in the lab and that had gotten encouraging results. Graham was excited about the prospect of printing a photograph on thick art paper. Graham asked the Iris operator about

A pioneer in the use of high-resolution color ink jet printers in the fine art field is Nash Editions. Located near Los Angeles in Manhattan Beach, California, Nash Editions was founded by British-born Graham Nash of the legendary 1960's rock group Crosby, Stills, Nash & Young. An accomplished photographer and collector, Nash was drawn to the inkjet process as a means of printing photographs that he had scanned and worked on with Adobe Photoshop software on his Apple Macintosh computer. Shown here are Nash Editions staff members (left to right) Jack Duganne, R. Mac Holbert, and Graham Nash. This photograph and the photographs on the following page were taken by the author during a visit to Nash Editions in February 1992, a little over six months after it opened for business. <www.nasheditions.com>



Iris ink jet printers lay down the cyan, magenta, yellow, and black images in a single pass with the print material attached to a rapidly rotating drum. With the cover removed, the leading band of the image printed by the cyan ink jet, which slowly moves across the image from left to right, is clearly visible.

Graham Nash (left) and Jack Duganne detach a completed monochrome print from one of the two Iris Model 3047 ink jet printers at Nash Editions. This photograph is a black-and-white self-portrait of Nash, which he made during the early days of Crosby, Stills, Nash & Young.

Bottles of the water-base inks employed in the Iris ink jet printers. Initially designed for graphic arts proofing, the standard Iris inks have very poor light fading stability. Inks made with dyes having improved light stability for fine art and photography applications started to become available in 1994.

Duganne and Holbert work on an image using Photoshop running on an Apple Macintosh computer with visiting New York City fashion photographer George Holz (center). Prints could be made from scanned transparencies and negatives or directly from a variety of Macintosh and IBM image file formats.

A high-resolution flatbed CCD scanner custom-built by Photometrics, Ltd. was used by Nash Editions to input images from color prints, paintings, and other art work. The scanner could accommodate originals of up to 4x4 feet.

Henry Wilhelm – 1992 (6)

Nash Editions was originally located in this picturesque building, not far from the Los Angeles International Airport.

Table 1 – WIR Display Permanence Ratings for Selected Digital Print Materials 1991–2006[a]

Type of Inkjet Printer/Ink/Paper Combination and Digital Silver-Halide or Digital Silver Dye-Bleach Color Papers Printed with RGB Laser/LED Digital Photo Printers (Year listed is the date stability tests were conducted by Wilhelm Imaging Research, Inc.)	Displayed Prints Framed Under Glass	Displayed Prints Framed With UV Filter
1991 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with Iris ID Inks (4-ink dye-based inkjet prints)		
Arches BFK Heavy Watercolor Paper (uncoated 100% cotton fine art paper)	4 years	4 years
Iris Semi-Matte coated inkjet proofing photo paper	1.4 years	1.8 years
1994 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with Lyson FA Inks (4-ink dye-based inkjet prints)		
Arches BFK Heavy Watercolor Paper (uncoated 100% cotton fine art paper)	14 years	17 years
Iris Semi-Matte coated inkjet proofing photo paper	4 years	5 years
1994 – Durst Lambda 130 digital printer (first large-format RGB laser silver-halide printer)		
Printed with Fujicolor SFA3 Color Negative Paper (silver-halide color prints)	36 years	40 years
Printed with Cibachrome print material (silver dye-bleach color prints)	29 years	33 years
Printed with Kodak Ektacolor Portra II Color Negative Paper (silver-halide color prints)	12 years	12 years
1994 – Epson Stylus Color printer (first "photo-quality" 720 dpi desktop inkjet printer)		
Printed with Epson Inks and Epson Inkjet Paper (4-ink dye-based inkjet prints)	<0.5 years	<0.5 years
1996 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with American Inkjet Corporation "NE" [Nash Editions] inks consisting of AIJ cyan and magenta inks and Lyson FA-I yellow and black inks printed on Somerset Velvet uncoated 100% cotton fine art paper (4-ink dye-based inkjet prints)	22 years	25 years
1997 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with Iris Longevity inks (4-ink dye-based inkjet prints)		
Arches for Iris 100% cotton fine art paper	2 years	– na –
1997 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with Lysonic FA II inks (4-ink dye-based inkjet prints)		
Somerset Velvet uncoated 100% cotton fine art paper	22 years	25 years
Liege Inkjet Fine Art Paper matte-coated fine art paper	2 years	3 years
1997 – Hewlett-Packard PhotoSmart printer (HP's first "photo-quality" desktop inkjet printer)		
Printed with HP PhotoSmart inks and HP PhotoSmart Paper (6-ink dye-based inkjet prints)	6 years	– na –
1998 – Hewlett-Packard DesignJet 2500 and 3500 printers (HP's first pigmented inkjet color printers)		
Printed with HP "UV" inks and matte-coated fine art papers (4-ink pigmented inkjet prints)	>200 years	>250 years
1999 – Roland Hi-Fi Jet printers (Roland's first large-format pigmented inkjet printers)		
Printed with Roland inks and Legion Concorde Rag paper (6-ink pigmented inkjet prints)	125 years	– na –
1999 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with Lysonic i W2 inkset consisting of Lysonic i Cyan #006, i Magenta, i Yellow #005, and i Black (neutral) (4-ink dye-based inkjet prints)		
Lysonic Standard Fine Art Paper matte-coated fine art paper	30 years	– na –
Somerset Enhanced Velvet matte-coated fine art paper	4 years	– na –
2000 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with Iris Equipoise inks (4-ink dye-based inkjet prints)		
Arches Cold Press uncoated 100% cotton fine art paper	34 years	– na –
Somerst Velvet uncoated 100% cotton fine art paper	22 years	– na –
Iris Canvas	17 years	– na –
Lysonic Standard Fine Art Paper matte-coated fine art paper	8 years	– na –
Somerset Enhanced Velvet matte-coated fine art paper	3 years	– na –
2000 – Iris Graphics 3047 printer (introduced in 1989, the first large-format inkjet photo printer)		
Printed with American Ink Jet Pinnacle Gold Iris inks (4-ink dye-based inkjet prints)		
Somerst Velvet uncoated 100% cotton fine art paper	70 years	– na –
Arches for Iris 100% cotton fine art paper	32 years	– na –
Pinnacle Gold Enhanced Watercolor fine art paper	24 years	– na –
UltraStable Canvas	19 years	– na –
2000 – Epson Stylus Photo 870 and 1270 desktop printers ("improved stability" dye-based photo inks)		
Printed with Epson photo inks (6-ink dye-based inkjet prints)		
Epson Matte Paper – Heavyweight (matte-coated paper)	25 years	– na –
Epson Premium Glossy Photo Paper	10 years	– na –
Epson Photo Paper	7 years	– na –

Table 1 – WIR Display Permanence Ratings Continued[(a)]. . . . .

Type of Inkjet Printer/Ink/Paper Combination and Digital Silver-Halide or Digital Silver Dye-Bleach Color Papers Printed with RGB Laser/LED Digital Photo Printers (Year listed is the date stability tests were conducted by Wilhelm Imaging Research, Inc.)	Displayed Prints Framed Under Glass	Displayed Prints Framed With UV Filter
2000 – Epson Stylus Pro 7500, 9500, Stylus Photo P2000 printers (Epson's first pigmented inkjet printers)		
Printed with Epson Archival pigmented inks (6-ink pigmented inkjet prints)		
Epson Premium Luster Photo Paper	>225 years	>250 years
Epson Watercolor Paper – Smooth (matte-coated 100% cotton fine art paper)	>225 years	>250 years
2002 – Hewlett-Packard DesignJet 5000 printer (HP's first 6-ink pigmented inkjet printer)		
Printed with HP "UV" inks and select fine art papers (6-ink pigmented inkjet prints)	>200 years	>250 years
2002 – Epson Stylus Pro 4000, 7600, 9600, Stylus Photo 2200 printers (2-level pigmented black inks)		
Printed with Epson UltraChrome pigmented inks (7-ink pigmented inkjet prints)		
Epson UltraSmooth Fine Art Paper (matte-coated 100% cotton fine art paper)	108 years	175 years
Epson Premium Luster Photo Paper (250)	71 years	165 years
Somerset Velvet for Epson (matte-coated 100% cotton fine art paper)	61 years	125 years
2004 – Durst Lambda, Océ LightJet, and other RGB laser/LED digital printers		
Printed with Fujicolor Crystal Archive color negative paper (silver-halide color prints)	40 years	49 years
Printed with Ilfochrome Classic [Cibachrome] Material (silver dye-bleach color prints)	29 years	33 years
Printed with Kodak Edge Generations color negative paper (silver-halide color prints)	19 years	17 years
2004 – Hewlett-Packard DesignJet 130 printer (HP's first 18x24-inch desktop inkjet photo printer)		
Printed with HP 84/85 inks (6-ink dye-based inkjet prints)		
HP Premium Plus Photo Paper and other HP swellable RC-base photo papers	82 years	100 years
2004 – Canon i9900 and (in 2005) **PIXMA iP8500 printers** (Canon's first 8-ink desktop inkjet printers)		
Printed with Canon ChromaPLUS inks (8-ink dye-based inkjet prints)		
Canon Matte Photo Paper MP-101 [see Note B below]	10 years	12 years
Canon Photo Paper Pro PR-101 (glossy) [see Note B below]	6 years	8 years
2004 – Epson Stylus Photo R800 and (in 2005) **R1800 printers** (first use of clear "gloss-optimizer" ink)		
Printed with Epson UltraChrome Hi-Gloss pigmented inks (7-ink pigmented inkjet prints)		
Epson Watercolor Paper – Radiant White (matte-coated fine art paper)	200 years	>250 years
Epson Premium Glossy Photo Paper Paper	104 years	>175 years
Epson Premium Luster Photo Paper	64 years	>150 years
2005 – Hewlett-Packard Photosmart 8750 desktop printer (HP's first 9-ink inkjet printer)		
Printed with HP Vivera inks (9-ink dye-based inkjet prints)		
HP Premium Plus Photo Paper and other HP swellable RC-base photo papers	108 years	140 years
2005 – Epson Stylus Pro 4800, 7800, 9800, Stylus Photo R2400 printers (3-level pigmented black inks)		
Printed with Epson UltraChrome K3 pigmented inks (8-ink pigmented inkjet prints)		
Epson UltraSmooth Fine Art Paper (matte-coated 100% cotton fine art paper)	108 years	175 years
Epson Premium Luster Photo Paper (250)	71 years	165 years
Somerset Velvet for Epson (matte-coated 100% cotton fine art paper)	61 years	125 years
2006 – Canon PIXMA Pro9500 printer (Canon's first 10-ink desktop pigmented inkjet printer)		
Printed with Canon Lucia pigmented inks (9-ink pigmented inkjet prints)		
Canon Fine Art Photo Rag Paper and select other Canon matte-coated fine art papers	>100 years	>150 years
Canon Luster Photo Paper, Canon Photo Paper Pro, and select other Canon photo papers	>100 years	>150 years
2006 – HP Photosmart Pro B9180 printer (HP's first 8-ink desktop pigmented inkjet printer)		
Printed with HP Vivera Pigment inks (8-ink [7-inks w/ glossy papers] pigmented inkjet prints)		
HP Advanced Photo Paper Glossy (improved version with 10.5 mil paper thickness)	>230 years	>230 years
HP Photo Matte Paper (matte-coated fine art paper)	>230 years	>230 years
HP Hahnumühle Smooth Fine Art Paper (matte-coated fine art paper)	>230 years	>230 years
2006 – Canon imagePROGRAF iPF5000 and iPF9000 printers (Canon's first 12-ink inkjet printers)		
Printed with Canon Lucia pigmented inks (11-ink pigmented inkjet prints)		
Canon Fine Art Photo Rag Paper and select other Canon matte-coated fine art papers	>100 years	>150 years
Canon Luster Photo Paper, Canon Photo Paper Pro, and select other Canon photo papers	>100 years	>150 years

(a) The WIR Display Permanence Ratings given here were derived from accelerated glass-filtered cool white fluorescent light fading tests conducted at 24°C (75°F) and 60% relative humidity and are based on the "standard" indoor display condition of 450 lux for 12 hours per day employed by Wilhelm Imaging Research, Inc. Illumination conditions in homes, offices, and galleries do vary, however, and color images will last longer when displayed under lower light levels; likewise, the life of prints will be shortened when displayed under illumination that is more intense than 450 lux. The predictions given here are the years of display required for the changes in color balance, and/or staining specified in the visually-weighted WIR Ver. 3.0 Endpoint Criteria Set to occur; with most types of images, these changes are easily noticeable in side-by-side comparisons with an unfaded original. **(b)** Because of the disproportionately rapid light fading of the red (orange) ink in the 8-ink Canon ChromaPLUS dye-based inkset used in the Canon i9900 printer, which is not properly assessed by the Status A densitometrically-based WIR 3.0 Endpoint Criteria Set, the Display Permanence Ratings should in reality be lower than the figures given here. The disproportionately rapid fading of the red (orange) ink is particularly noticeable in skintones.

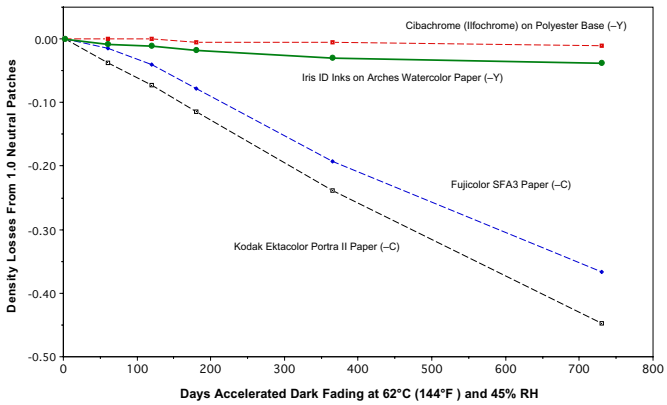


Figure 1. In accelerated dark aging tests conducted in 1994, it became clear that the dark fading (thermal) stability of the dyes used in Iris inks, even those inks with very poor light stability, was far superior to that of then available chromogenic (silver-halide) color prints. Cibachrome silver dye-bleach prints on polyester base had the best dark fading stability of all color materials tested, but the inkjet prints on 100% cotton fiber paper were almost as stable as the Cibachrome prints.

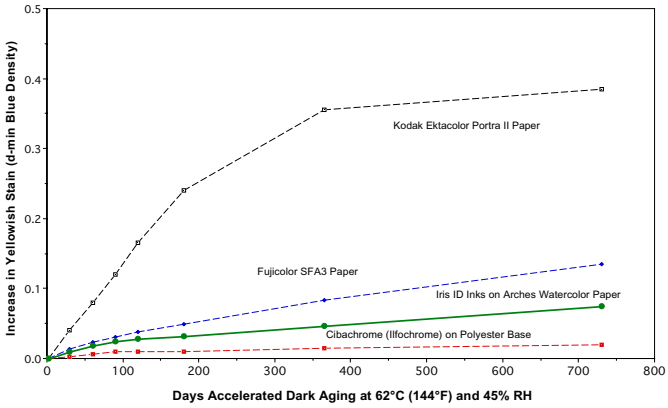


Figure 2. When made with long-lasting 100% cotton fiber artists papers (non-coated), the Iris inkjet prints also had very low levels of d-min yellowish stain formation – even after more than two years of aging at 62°C (144°F) and 45% RH. Tests conducted with prints made with more recent inks and papers (protected from ozone) show that the dark storage stability of most inkjet prints is limited by the thermal stability (yellowing) of the print paper itself – and not by the stability of the inks.

printing in B&W. He indicated it was difficult to impossible. Boulter also told us about a guy at the Walt Disney Studios who had been using the Iris for a while. Graham is going to set up a meeting to see if we can make some test prints." "On April 27, 1989, Steve Boulter and Disney colorist David Coons came for dinner at Graham's. Over dinner Graham described the situation with some of his lost negatives. Coons suggested that he take one of Graham's contact sheets and scan it using a hand-built high-resolution scanner that he had constructed for Disney. Coons left with a sheet of images of Joni Mitchell taken in 1969. He returned a few weeks later with a 24" x 30" print on heavyweight Arches watercolor paper. The results were encouraging. There were still problems, but Graham felt that with a little more work truly gorgeous black-and-white prints would be possible."[3] In December of 1989, Graham signed the papers to purchase an Iris 3047. First used to print their own photographs, Graham and Mac soon realized that other photographers and artists wanted to have their own work printed on the Iris and in July 1991, Nash Editions opened its doors as the world's first digital fine art photography printing company. Other pioneers who set up Iris 3047 printing businesses included John and Maryann Doe of Harvest Productions in Anaheim Hills, California; Jon Cone of Cone Editions Press, Ltd. in East Topsham, Vermont; Peter Hogg of the Digital Pond in San Francisco, California; and David Adamson of Adamson Editions in Washington, D.C.

Graham, Mac, Adamson, and other printmakers were quite concerned about "the permanence problem" and it was not long before Jeff Ball, head of Lyson in the United Kingdom, and Michael Andreottola of American Inkjet in the United States, began development of improved stability dye-based inksets. The unique continuous flow inkjet head and nozzle design employed with the Iris printers precluded the use of pigmented inks. In 1994, Adamson became the first Iris studio to print an exhibition using the then newly introduced Lyson Fine Arts inkset: "The Washington Portfolio." Galleries, photographers, and artists were concerned about the lack of permanence (in part because of a negative effect on sales to collectors and museums) and this led to the founding in 1997 of an influential but short-lived organization known as the International Association of Fine Art Digital Printmakers (IAFADP). The author was involved in testing new inkjet materials throughout this period and was asked to provide image permanence test data to the IAFADP for distribution to its members. (It was also in 1997 that WIR launched its free-access website <www.wilhelm-research.com> for the purpose of publishing frequently updated print permanence information.) Much of this data was also published by *Digital Fine Art*, an influential magazine edited by Patrick Sarver, that abruptly ceased publication following the September 11, 2001 terrorist attack on the World Trade Center in New York. The magazine's publisher, who was located in Long Island near New York City, came to fear that anxiety about future attacks would cause the art market to collapse and decided to close the magazine. IAFADP's demise was caused in part by tensions that developed between members who owned fine art printmaking companies that supplied reproductions of watercolors and paintings to the art decor market, and an emerging group of members who wanted to shift the focus of the organization to individual photographers and artists who wanted to learn how to make and market their own prints.

The author also gave presentations on the light fading stability of digital print materials at IS&T's annual conferences in 1994 and 1995, and numerous presentations on digital print permanence and preservation at industry conferences, museum and archive meetings. Wilhelm Imaging Research received its first contract to test digital print materials from Iris Graphics in 1996 and since that time WIR's business has come to focus almost entirely on permanence testing of inks and media for inkjet printer manufacturers including Canon, Epson, Hewlett-Packard, and Lexmark, as well as suppliers of inkjet photographic papers, canvas materials, and print coatings. During this period a number of companies specializing in digital art reproduction using Iris 3047 printers were started and most placed great importance on good image permanence. In 1999, one of these printing studios, Old Town Editions in Alexandria, Virginia, which was started by Chris Foley and Mark McCormick-Goodhart, was the first to use the improved-stability Lysonic i W2 hybrid inkset in an Iris 3047 in combination with the then new flat-matte coated Lysonic Standard Fine Art Paper. Old Town Editions was also one of the first fine art digital printmaker to implement a full ICC profile based color-managed workflow with soft proofing and with remote proofing for customers.

The Iris printers allowed on-demand printing of limited edition prints as they were sold – something that had not been possible before with screen printing (generally called Serigraphs in the art reproduction business), litho printing, and other reproduction technologies. Inkjet printers provided another advantage that quickly proved very attractive to photographers and art reproduction houses alike: they can print on a very wide variety of types, surfaces, and thickness of papers and canvas. This degree of media independence was new to both photography and the printing business! For use by the art reproduction market, which for various reasons often felt uncomfortable with telling customers they were buying inkjet prints, Jack Duganne coined the name "Giclée" for inkjet

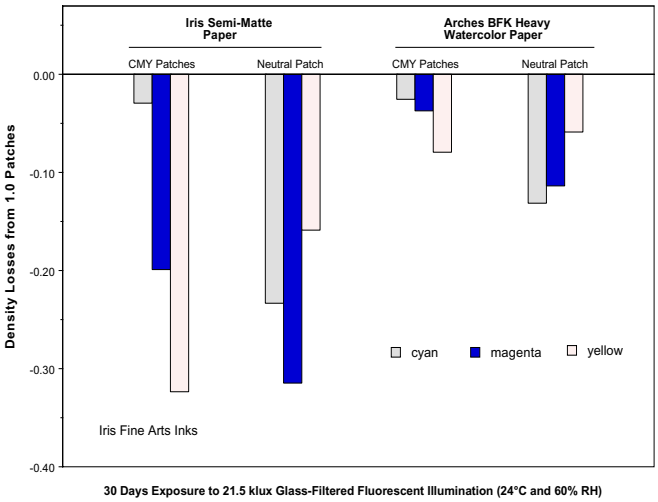


Figure 3. Light fading tests conducted by the author in 1994 showed that the Iris FA inks, as well as other dye-based ink/media combinations, could be subject to "catalytic fading" in which the presence of one dye in a neutral or near/neutral image area can destabilize the other ink. In this example with Iris FA inks, when the cyan ink is mixed with the magenta and yellow inks in a neutral scale, the cyan ink faded much more rapidly than pure-color cyan. At the time, the author called this increased sensitivity to light fading "ink intermixture effects." This is now commonly referred to as "catalytic fading," a light fading phenomena that appears to be unique to dye-based inkjet inks. Pigmented inks are not known to exhibit catalytic fading.

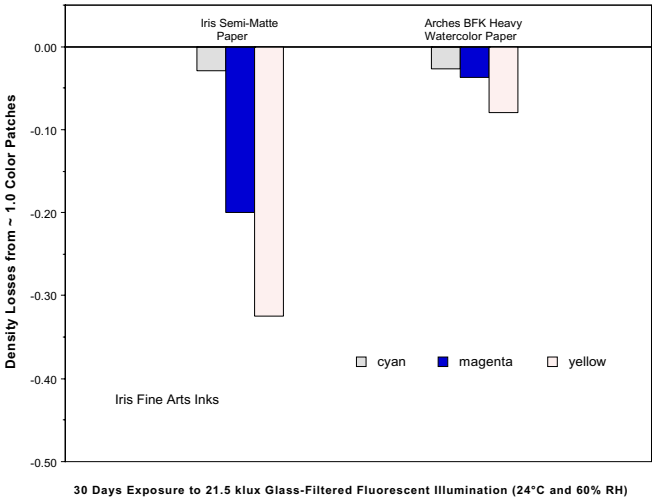


Figure 4. These 1994 tests with Iris Fine Arts inks (later sold as Lyson FA inks) showed that the light stability of these dye-based inks was greatly influenced by the type of media used to make the prints – as also shown in Table 1. Further research with a broad range of dye-based and pigmented inks printed on various types of media has shown that a fundamental difference between the two types of inks is that the light stability of dye-based inks is much more influenced by the type of media/ink receptive surface than are pigmented inks. This has come to be recognized as a major advantage of pigmented inks – they can be printed on a very wide range of photo papers, both glossy and matte-surface, with little difference in light stability behavior.

prints as an analogous term to "Serigraph." In reference to inkjet technology in which inkjet nozzles "spray" inks onto paper, Giclée was derived from the French word "gicler," which means to spray or squirt a liquid. The term is only applied to prints made with matte surface fine art papers or canvas, and not to RC base semigloss or glossy photo papers. It has been pointedly avoided by Nash Editions and other digital print providers catering to high-end artists and photographers – and is also shunned by most photographers themselves.

In 1999 Nash Editions became one of Epson's beta test sites for the ground-breaking Epson Stylus Pro 9500 large-format printers using Epson "Archival" pigmented inks and, as a result, Mac Holbert was asked by Epson America to work with New York photographer Stephen Wilkes to print a major exhibition of his work, "Epson's America in Detail." The show opened on January 11, 2001 in San Francisco and, with extensive press coverage, went on to New York, Santa Monica, and Chicago. Nash Editions was not only the first digital fine art printing studio, but it also printed the first major photography exhibition to be printed with high-stability pigmented inks.

Said Wilkes: "The year 2000 ushers in the explosion of the digital revolution, which will undoubtedly change all of our lives, much in the same way the industrial revolution did at the turn of the 20th century. It is now possible to create beautiful images without ever stepping into a darkroom. Epson has provided me with the opportunity and the archival printing technology to produce the images captured during [his photographic tour across the United States in 2000] through a unique new method – one that is the wave of the future."

The introduction of the Epson Stylus Pro 7500 (24-inch) and 9500 (44-inch) pigmented ink printers in 2000 started a period of rapid change in the fine art printing business. The new Epson printers were able to handle a wide variety of fine art and photo media, including very thick papers which could be sent through the printer's straight-through paper path without bending, and they were easy to operate and practically maintenance free. Nash Editions started to convert its printing operations to the new Epson printers, and by the end of 2004 it had retired its last Iris 3047. The original 3047 purchased by Nash was accepted by the Smithsonian Institution in a ceremony on August 12, 2005 in Washington, D.C., that was attended by Graham Nash, Mac Holbert, and Steve Boulter. The large-format Epson printers cost only a small fraction of the price of an Iris printer, making the printers accessible to photographers themselves and this brought about far-reaching changes in the printmaking field.

Photography has had a very long tradition of serious photographers making black-and-white prints in their own darkrooms. Ansel Adams, Edward Weston, Paul Strand and W. Eugene Smith are but well-known examples. With the advent of color photography, however, the high cost and complexity of color printing and processing equipment caused most photographers to abandon their darkrooms and send their color films to commercial laboratories. As a result, photographers lost touch with using or even understanding the limited controls that were available in color printing with an enlarger. When printing color negatives with an enlarger, it is not possible to adjust image contrast, the tone reproduction curve shape, or color saturation – only overall density and color balance can be controlled. Adobe Photoshop and other image editing software offers far greater control with just a few clicks of a mouse.

In the modern inkjet era, far more people are printing their own photographs than was ever true in the history of photography. With a little practice, even school children are printing beautiful color photographs taken with their family's digital cameras! Now, as the 70-year period of "traditional" silver-halide color (chromogenic) photography is coming to an end, printmaking has finally returned to the photographer. The result, of course, has been a complete transformation of the photography industry.

The Shift to Pigmented Inks

To understand the evolution of print permanence in the inkjet field, it is important to appreciate the fact that among the four major manufacturers of inkjet printers, inks, and papers – Canon, Epson, Hewlett-Packard,

Los Angeles photographer Greg Gorman making a print of the actress Sharon Stone with his Epson Stylus Pro 9800 printer and UltraChrome K3 pigmented inks. Gorman's printers and computers are located in the living room of his home in the Hollywood Hills. Gorman long printed his own black-and-white silver-gelatin prints in a darkroom, but when he started shooting in color he, like most other photographers, had to send his color transparencies out to a commercial lab to have prints made. But with the advent of digital cameras, Photoshop, and inkjet printers, he now makes all of his black-and-white and color prints himself. Gorman is internationally known for his photographs of movie stars and other celebrities. <www.gormanphotography.com>

James Nachtwey, a New York based documentary photographer, with a black-and-white photograph printed with an Epson Stylus Photo R2400 printer. For much of his photography, James Nachtwey has long preferred black-and-white and, when assignments and deadlines permit, he still shoots B&W film. The "Advanced Black and White Print Mode" provided with the Epson R2400 and other Epson UltraChrome K3 printers gives subtle control of the hue and tonescale of black and white images and also provides a simple way to make high-quality B&W Prints from RGB image files. Nachtwey, a founder of Agency VII, a group of nine of the world's most renowned photojournalists, has been a contract photographer with Time Magazine since 1984. <www.jamesnatchtwey.com>

Henry Wilhelm – 2005 (3)

Douglas Kirkland with a photograph of actress Marilyn Monroe made with his Hewlett-Packard Photosmart Pro B9180 using HP Vivera Pigment inks and HP Hahnemühle Smooth Fine Art Paper. The photograph was one of a series made in 1961 on assignment for Look magazine. In a far-ranging career as a photojournalist and portrait photographer that spans five decades, Kirkland has published 10 books and his work has appeared in countless publications. Kirkland has always driven to make his own prints. In 1946, when Kirkland was 12 years old and living in Port Erie, Canada, near Niagra Falls, he built his first darkroom in a closet on the second floor of the family home and taught himself to develop B&W films and prints. Kirkland and his wife and business partner, Francoise, live in Los Angeles, California. <www.douglaskirkland.com>

and Lexmark – none were in the traditional photography field. Canon of course has long made cameras and lenses, but neither Canon nor any of these other companies have ever made photographic films or papers. All four of these companies developed inkjet technology to print plain paper text and pie charts in color. Over time, initially in an effort to print sharper text, image quality got better and better. One can cite the 1994 introduction of the Epson Stylus Color 720 dpi printer – which came to market only five years after the Iris 3047 became available – as the start of low cost inkjet photo printing. Quite suddenly, Epson found itself in the photography business. Hewlett-Packard, Canon, and Lexmark soon followed. Like Iris Graphics, none of these four companies had even considered the permanence requirements of photographs coming out of their printers that would be hung on the wall in the very same way that photographs have always been displayed. The inks supplied with all of these early inkjet printers had very poor light fading stability. But as shown in Figures 1 and 2, it was clear to this author that inkjet inks and papers from the beginning had the potential to be far more stable in dark storage than the then available silver halide color photographic papers. At the time, the principal permanence shortcoming of inkjet prints was light stability.

Once this was understood, the industry set about to improve light fading stability, initially with the goal of reaching a level of light stability equal to that of traditional Kodak Ektacolor silver halide color prints. (Fujicolor prints had significantly better light stability than the Kodak prints, so the printer manufacturers initially only attempted to equal the stability of the Kodak prints.) Hewlett-Packard came close to reaching this in 1997 with the introduction of the original PhotoSmart printer, and Epson achieved it with dye-based photo inks introduced in early 2000. At the time, dye-based inks had the advantage of a wider color gamut, high d-max, little or no differential gloss, and minimal metamerism. But, compared with pigmented inks, dye-based inks suffered from inferior light stability, high sensitivity to ozone on instant dry porous papers, poor water fastness on swellable papers, potential catalytic fading problems (see Figure 3), humidity-fastness problems, often high sensitivity to different types of media, generally poor light stability with most matte-coated fine art papers (see Table 1 and Figure 4), and short-term color drift behavior that can be very problematic for color-managed workflows and proofing applications.[4]

From a permanence point of view, pigmented inks were better than dye-based inks in virtually every respect. The shortcomings of pigmented inks involved image quality and appearance issues, including reduced color gamut and lower d-min which results in a lack of color brilliance, differential gloss problems on glossy photo papers, metamerism problems, and a tendency toward "bronzing" on glossy or semigloss photo papers. But beginning with the Epson UltraChrome pigmented inkset introduced in 2002 with the Epson 9600 printer, these problems started to be resolved – or at least minimized – one by one. By the end of 2006, Epson, Hewlett-Packard, and Canon had all moved to pigmented inksets for their advanced amateur and professional level printers. In the end, with the image quality of new pigmented ink/media systems approaching or in some cases even exceeding that of dye-based inks, the considerable overall permanence advantages of pigmented inks triumphed. It was very clear that a new era of enduring color photography had arrived!

Conclusion

Digital fine art photography has in many ways defined the market for advanced amateur and professional inkjet printers, inks, and media. Photographers in this segment want to be able to make large prints on a wide range of inkjet papers and canvas, including very thick, almost rigid papers that require straight-through printer paper paths. They also want the best, most brilliant color reproduction that can be achieved while at the same time desiring a very high level of image permanence for displayed prints. And many photographers desire to make black-and-white prints that are equal to the best of black-and-white silver-gelatin prints in terms of brilliance and smooth, linear tonescale.

Escalating prices are being paid for photographs in the art market – in 2006 many color photographs by major artists sold for more than

$100,000 in galleries and in art auctions – and this has also helped push demands for a high level of print permanence. Photographers have come to understand that their place in history requires that their vision – including the subtleties of color and tone in the prints that they work so hard to create – must endure essentially without change.

The professional portrait and wedding photography market has many of these same requirements, including very high print permanence expectations. Photographs become all the more appealing to customers when they can be sold as family heirlooms that have the intrinsic stability to remain in excellent condition when displayed for many generations.

Inkjet technology has proven to be extremely well suited for these markets: inkjet printers are readily scalable and can provide large print sizes by merely extending the length of travel of the inkjet heads. Inkjet technology allows use of a greater range of dye and pigment colors than any other printing process. Inkjet technology also allows use of a wider range of glossy and matte-surface photo papers as well as canvas and other materials than any other imaging process – all in compact and relatively low cost printers that require no darkroom, no processing chemicals, and no wash water. The ease, accessibility, and excellence of inkjet printmaking has allowed – and encouraged – more people to become involved in printing their own photographs than has ever been possible in the more than 160-year history of photography.

Throughout the 15-year formative period of digital fine art printing, Wilhelm Imaging Research has provided a uniformly applied image permanence testing methodology that has both made print permanence a more visible issue in the marketplace, and encouraged manufacturers to develop better, longer-lasting inks and papers. With no applicable permanence test methods standards available from ANSI (American National Standards Institute) or from ISO (International Organization for Standardization, based in Geneva, Switzerland), WIR has provided fair comparisons of print permanence across brands and between available printing technologies.[5] WIR testing methodology has also given manufacturers permanence design goals for research and development of new inks, papers, and print systems. This in turn has fostered major R&D efforts in improved systems with manufacturers having confidence that the performance of their products would be fairly evaluated and that permanence data would be made broadly available to photographers and the marketplace through WIR's website www.wilhelm-research.com. This has helped provide an environment where honest competition has flourished to the benefit of photographers and manufacturers alike.

Permanence properties are aspects of a print that cannot be seen when a print emerges from the printer. If one ignores permanence, it is relatively simple to manufacture inkjet inks that have a wide color gamut and produce beautiful images. If one ignores image quality, it is not difficult to select colorants that provide a very high level of permanence. What has proven to be very difficult is to accomplish both. That is, to develop inks, media, and printer systems that provide wide gamut, brilliant color prints and black-and-white prints with high d-max and a luscious, smooth, linear tonality – and with excellent permanence characteristics.

Future projects at WIR include work with the ISO WG-5/TG-3 standards group in the development of improved test methods which better simulate the spectral power distribution of indoor daylight through window glass for accelerated light stability tests, and the implementation and marketing of the WIR i-Star full tonal scale colorimetric image deterioration analysis software developed over the past four years by Mark McCormick-Goodhart, Dmitriy Shklyarov, Yaw Nti-Addae, Kabenla Armah, and the author.[6] Current densitometric image analysis methods have proven inadequate for the complex, multi-colorant inksets used with modern inkjet printers.

WIR's central mission has always been to serve as a fair and visible advocate for the importance of permanence and the long-term preservation of photographs.[7] We have tried to be an advocate for photographers of every level, for museums, archives, and film libraries – for everyone who has come to understand and appreciate the unique power, beauty, and historical value of photography.

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Biography

Henry Wilhelm was one of the founding members of American National Standards Institute (ANSI) Committee IT-3, which was established in 1978 and developed the ANSI IT9.9-1990 image stability test methods standard published in 1990 (revised in 1996). For the past 18 years he has served as Secretary of the group, now known as ISO Working Group 5/Task Group 3 (a part of ISO Technical Committee 42). Wilhelm serves as Chair of the Indoor Light Stability Technical Subcommittee of WG-5/TG-3. With contributing author Carol Brower, he wrote "The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures," published in 1993. An 80MB PDF of the complete 758-page book may be downloaded at no cost from www.wilhelm-research.com.

Wilhelm is co-founder and president of Wilhelm Imaging Research, Inc. and has served as a consultant on the long-term preservation of the photography collections at the Museum of Modern Art in New York, the Corbis photography collections in the United States and France (Corbis is private corporation personally owned by Bill Gates of Microsoft). Wilhelm has also served as an advisor on the preservation of traditional and digital photographs to other museum, archive, commercial, educational, and personal collections worldwide.

Wilhelm has been an active photographer since childhood; at age 12 he built is first black-and-white darkroom in a closet of his mother's home in Arlington, Virginia. He holds two patents for the design of archival print washers which isolated individual black-and-white silver-gelatin prints in vertical compartments to thoroughly remove fixer and other processing chemicals without physically damaging the delicate surfaces of the prints during prolonged washing.

In recent years, as a personal project, Wilhelm has been spending time with photographers, commercial silver-halide processing laboratories, and print service providers to document their shift from analog to digital photography and printing.

Wilhelm took his last photograph using a traditional camera and silver-halide color negative film during the summer of 1999; since that time he has been shooting and printing digitally.

Paper by Henry Wilhelm (Wilhelm Imaging Research, Inc.) entitled:

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Paper presented by Henry Wilhelm on September 19, 2006

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