

NASH EDITIONS

PHOTOGRAPHY AND THE ART OF DIGITAL PRINTING

introduction by GRAHAM NASH
with essays by RICHARD BENSON, R. MAC HOLBERT, HENRY WILHELM
edited by GARRETT WHITE

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INTRODUCTION BY **GRAHAM NASH**

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Co-founded in 1990 by rock musician and photographer Graham Nash and R. Mac Holbert, Nash Editions was the world's first professional fine-art digital printmaking studio. In the more than fifteen years since opening its doors in Manhattan Beach, California, Nash Editions has attracted leading artists—including Manuel Alvarez Bravo, Horace Bristol, Eileen Cowin, Eric Fischl, Lynn Goldsmith, Robert Heineken, David Hockney, Pedro Meyer, Jenny Okun, Stephen Shore, and Maggie Taylor—and established an unparalleled international reputation for fine-art photographic digital printing.

Nash Editions: Photography and the Art of Digital Printing charts the history of digital photographic printing from early experiments in the mid-1980s to the present explosion in digital imaging and printing technology that has overtaken traditional darkroom printing and brought the medium to a wide public. The work of Nash Editions represents the entire spectrum of artistic involvement in digital imaging since its inception as a viable alternative form of expression, from images composed in the computer or on a scanner to traditional photographs printed digitally from scans of a print or negative.

The essays collected in this volume include an overview of the founding and development of Nash Editions by R. Mac Holbert; a history of photographic printing processes from the inception of the medium to the digital revolution by photographer and educator Richard Benson; and a detailed capsule history of advancements in digital printing technology, ink sets, and print permanence by Henry Wilhelm.

In 1998, a traveling exhibition, *Digital Frontiers: Photography's Future at Nash Editions*, was organized by the George Eastman House International Museum of Photography in Rochester, New York. On August 12, 2005, the first Nash Editions Iris 3047 inkjet printer was incorporated into the photographic history collection of the Smithsonian's National Museum of American History, along with selected prints from the Nash Editions archive.

With more than 180 full-color and black-and-white illustrations.



FROM THE ESSAY BY **HENRY WILHELM:**

There are people who dream of better ways of doing things. These are the people who focus their usually considerable energies on the potential of new ideas and inventions, and are not held back by the problems that almost always hinder early adoption. With the creation of Nash Editions, Graham Nash, R. Mac Holbert, and Jack Duganne joined that very special group of people in photography's history who got there first. They played a pivotal role in moving photographic printmaking into a completely new and clearly superior technology.

FROM THE ESSAY BY **RICHARD BENSON:**

If we date the practical implementation of the dry plate at 1900, then we can say that silver reigned unchallenged for a century, up to about the year 2000. Electronic image making began well before that date, but only by 2000 did most of us realize that silver photography was effectively dead — still being practiced, but fatally wounded by the wonders of electronic light-sensitive materials and computer-driven printing machines.



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Ken Merfeld, *Graham Nash and R. Mac Holbert*, ambrotype, scanned and printed at Nash Editions, 2005.

RICHARD BENSON has worked as a photographer, printer, and teacher since the 1960s. He has taught at Yale University since 1979, and became Dean of the Yale School of Art in 1986. His photographic work is in the collections of the Metropolitan Museum of Art and the Museum of Modern Art, New York, Yale University Art Gallery, and many other institutions and private collections. Benson has received two National Endowment for the Arts publication grants, two Guggenheim Fellowships, and a MacArthur Foundation Fellowship. He presently photographs with a digital camera and prints his images with inkjet printers.

R. MAC HOLBERT is a photographer and co-founder of Nash Editions. Prior to his work with Nash Editions, he was tour manager for Crosby, Stills & Nash; Peter, Paul & Mary; and Carole King. Holbert has lectured extensively and conducted workshops on digital output, digital imaging, and fine-art printing on Iris and Epson large-format printers. Under his supervision, Nash Editions is a beta tester for Epson America, Inc., and other software and hardware manufacturers.

GRAHAM NASH is a lifelong photographer and co-founder of the rock group Crosby, Stills & Nash. While best known as a musician — Nash first became famous as a member of The Hollies during the British Invasion of the mid-1960s — he has also pursued a parallel career as a photographer, collector, and digital imaging pioneer. His photographs have been exhibited in solo and group exhibitions in numerous museums and galleries. A retrospective book of his photographic work, *Eye to Eye: Photographs by Graham Nash*, was published in 2004.

HENRY WILHELM is co-founder and president of Wilhelm Imaging Research, Inc., which conducts research on the stability and preservation of traditional and digital color photographs and motion pictures. He has been a consultant to the Museum of Modern Art, New York, and many other collecting institutions, and is the co-author, with Carol Brower Wilhelm, of the landmark reference work *The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures*.

GARRETT WHITE, founder of Five Ties Publishing, Inc., New York, has edited and produced numerous books on photography and fine art, including *American Photography: A Century of Images*, *Eye to Eye: Photographs by Graham Nash*, and *Forbidden Art: The Postwar Russian Avant-Garde*. He is the former director of publications at the Los Angeles County Museum of Art and the Whitney Museum of American Art.

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A HISTORY OF PERMANENCE

IN TRADITIONAL AND DIGITAL COLOR PHOTOGRAPHY: THE ROLE OF NASH EDITIONS

HENRY WILHELM

From the very beginning of photography—

Joseph Nicéphore Niépce's photograph of the view from a window in his home near Chalon, France, made in 1826—followed by Louis Daguerre's announcement of the daguerreotype in Paris in 1839, Fox Talbot's negative-positive calotype process in England in 1841, and Sir John Herschel's critically important discovery of a hyposulfite of soda (later known as sodium thiosulfate) fixing bath following development of silver-halide-based black-and-white films and prints to render them "permanent" upon exposure to light during use, storage, and display—photography has seen a long struggle between the often conflicting requirements of making a beautiful image, and then keeping it beautiful as the years, decades, and centuries pass.¹

People of course see the world as a very colorful place, and the early inventors of photography worked hard to endow their monochrome creations with color. Long before Daguerre publicly revealed his daguerreotype process in France in 1839, he and Niépce had been experimenting with various materials that they hoped could be used to produce color images. In 1816, Niépce wrote to his brother Claude:

The experiments I have thus far made lead me to believe that my process will succeed as far as the principal effect is concerned, but I must suc-

ceed in fixing the colors; this is what occupies me at the moment, and it is the most difficult.

While neither Daguerre nor Niépce were successful in producing a workable color process, the desire to make photographs in color persisted, and it was not long before many photographers began to hand-color their daguerreotypes. Often this consisted of nothing more than adding a little rosy color to the cheeks of people in their portraits; sometimes rather elaborate work was done in an attempt to simulate the full range of colors in the original scene.

It is interesting to speculate about what place black-and-white pictures would have had in the history of photography if practical color processes had been invented before black-and-white systems had become widespread. Assuming equal costs and ease of use of both black-and-white and color, it is not unlikely that black-and-white photography would have been considered something of a curiosity, perhaps desirable only for certain scientific or artistic applications. The principal achievement of photography has always been to record events, people, and scenes; color is almost always a very important part of this reality.

It was in the early 1870s in Agen, a small town in the south of France, that the photographer and inventor Louis Ducos du Hauron first succeeded in making a color photographic print.

Stephen Wilkes, *Bow Fishermen*, Jackson Lake, Alabama, 2000.

¹ This essay has been based in part on: *The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures*, by Henry Wilhelm and Carol Brower (contributing author), Preservation Publishing Company, Grinnell, Iowa, 1993 (a PDF of the complete 758-page book is available at no cost from www.wilhelm-research.com), and "A Fifteen-Year History of Digital Printing Technology and Print Permanence in the Evolution of Digital Fine Art Photography, 1991 to 2006," by Henry Wilhelm, Final Program and Proceedings: IS&T's NIP22 International Conference on Digital Printing Technologies, sponsored by the Society for Imaging Science and Technology, Denver, Colorado, September 2006. A PDF of the article is available from www.wilhelm-research.com.



Building on the work of Isaac Newton, James Clerk Maxwell, and other pioneers in understanding color and how the human eye and brain perceive it, Ducos du Hauron developed a color photography process in which he exposed a succession of three black-and-white negatives through red, green, and blue filters to produce an RGB record of the scene, adapting the by then well-established “carbon process” used to make black-and-white photographs with highly stable carbon pigments.

Ducos du Hauron used his RGB separation negatives to make three positive gelatin images, one with a cyan pigment printed from the red record negative, one with a magenta pigment from the green record negative, and one with a yellow pigment from the blue record negative. These thin gelatin-pigment films were transferred in register to a final paper support, producing a full-color print! This was a difficult and tedious process and, unlike the immediate and widespread adoption of the much easier to manage black-and-white daguerreotype, met with little commercial success during Ducos du Hauron’s lifetime. He died in modest circumstances,

supported by a pension from the French government given in honor of his pioneering work in photography.

Ducos du Hauron fully understood the theory of subtractive color photography, and he also invented many other processes to make color images. He wrote two small books describing his color processes in detail—including selection and preparation of appropriate cyan, magenta, and yellow pigments—and they remain classics in the field today. As recently noted by Kim Timby, the director of collections at the Musée Nicéphore Niépce in Chalon, France, Ducos du Hauron also had an appreciation of the role of human judgment and preference in color photography:²

And for color, how many images suffice to satisfactorily deconstruct the phenomenon? And of what exact hues should the filters and final images be? These decisions emphasize that color photography, as well, is not a natural occurrence but man-made. This, also, was both praised and criticized at the beginning. Ducos du Hauron argued that ‘the arbitrary and the human judgment’ that necessarily influence the results in indirect color photography (and are already present in ‘ordinary photography’) take the image into the realm of artistic expression: he claims his method simply ‘offers the sun a selection of colors and makes it use them as a painter might.’

One could say that Ducos du Hauron’s work in color photography and the use of pigments to make color prints laid the groundwork that 127 years later, in 1997, brought us to the use of high-stability cyan, magenta, and yellow pigments in modern inkjet photo printers. And, as we do today with digital cameras and Adobe Photoshop and other image editing software, he made use of full RGB channel separation and control of the curve shape to adjust the tone scale of his color images. Like many innovators throughout history who have spent their lives

This 1877 photograph of Agen, France, by the prolific French inventor and photographer Louis Ducos du Hauron is one of the first photographic color prints ever made, and is currently in the collection of the George Eastman House, Rochester, New York. The image was formed with separate cyan, magenta, and yellow pigmented-gelatin layers.

working hard and following their dreams, Ducos du Hauron was simply ahead of his time. The most extensive collection of Ducos du Hauron's work, including a number of his earliest color prints, made from 1870 to 1875, is in the Musée Nicéphore Niépce. Perhaps his best-known color photograph, a beautiful picture of the city of Agen made in 1877, is now in the George Eastman House collection in Rochester, New York.

The Organic Dye Images of Silver-Halide-Era Color Films and Prints Versus the Metallic Silver Images of Black-and-White Photographs

Black-and-white silver-halide photographs have images made of metallic silver. The images appear black because the filamentary structure of the tiny grains of silver absorbs, rather than reflects, light. These silver images are unaffected by prolonged exposure to light, and are also essentially permanent when stored in the dark. (At least this is true with correctly processed fiber-base prints; the black-and-white RC papers introduced in the early 1970s, with their often self-destructing images when exposed to light during display, are another matter altogether and these papers should be avoided.) Many people have fiber-base black-and-white photographs of their ancestors that have remained in good condition for 50 to 100 years—or even longer. Museum collections have significant numbers of fiber-base black-and-white photographs from the late 1800s and early 1900s that are still in excellent condition.

Unlike the usually very long-lasting silver images of black-and-white photographs, most color photographs made in the silver-halide era now drawing to a close have images formed of cyan, magenta, and yellow organic dyes that fade when exposed to light on display. The brighter the light, the faster they fade. While current Fuji and Kodak silver-halide color papers have relatively good dark storage stability, earlier silver-halide color prints and most other

types of color photographs found in collections also gradually fade and form a yellowish stain when stored in the dark; the slow but inexorable image deterioration begins the moment processing is completed. High temperatures and/or high humidity in storage accelerate the deterioration process.

With the market for silver-halide black-and-white papers rapidly shrinking, Kodak discontinued manufacture of all black-and-white papers—both fiber-base and RC-base—at the end of 2005; Ilford, Fuji, and a few other companies still continue to manufacture wet-processed silver-halide black-and-white papers.

Now Drawing to a Close, the Era of Silver-Halide Color Photography Began in 1935–36 with the Introduction of Kodachrome and Agfacolor Neu Color Transparency Films

Although a number of color processes were available in the early 1900s, such as the additive screen Autochrome plates introduced by the Lumière brothers in France in 1907 and dye-transfer and tricolor carbonyl prints made from glass-plate separation negatives photographed sequentially through red, green, and blue filters—or in complex “one-shot” cameras that exposed all three separation negatives with a single exposure—all of these early color processes saw only limited use. They were either so cumbersome and time-consuming that only the most dedicated photographers would consider using them, or, in the case of Autochrome plates and the other additive screen processes of the time, they lacked the resolution necessary to produce satisfactory results in any but large-format cameras, and making good-quality prints from the additive screen images was difficult and time-consuming.

With the introduction of Kodak Kodachrome transparency film in 1935 and Agfa Agfacolor Neu transparency film in 1936, high-quality color photography suddenly became accessible

With the introduction of Kodak Kodachrome transparency film in 1935 and Agfa Agfacolor Neu transparency film in 1936, high-quality color photography suddenly became accessible to everyone.

2 Kim Timby, “Colour Photography and Stereoscopy: Parallel Histories,” *History of Photography*, Vol. 29, No. 2, Summer 2005, pp. 183–196, ISSN 0308-7298, the Taylor and Francis Group Ltd. Kim Timby, director of collections at the Musée Nicéphore Niépce in Chalon, France, has been researching the life and work of Ducos du Hauron.

Among the available color processes, chromogenic films and prints as a group have the distinct limitation of being relatively unstable in dark storage.

to everyone. These films, which formed images by a process known as chromogenic development, were the first successful integral tripack color films. Kodachrome film was first marketed in 1935 as a 16mm amateur movie film. Kodachrome for 35mm color slides was introduced in 1936; the film had an ASA speed of 10. Kodachrome sheet films in sizes up to 8" x 10" were supplied for the professional market from 1938 until 1951.

Beginning in 1941, Kodak supplied the amateur market with prints made with the Kodachrome process under the Minicolor name; the prints, which had rounded corners, were made with a white pigmented acetate base. From 1946 until 1955, the acetate-base prints were sold under the Kodachrome Print name. The Kodachrome Print name continued to be used for many years after 1955 to signify any print made from a Kodachrome or Ektachrome transparency by Kodak Processing Laboratories. Most of these prints were made on Kodak fiber-base or RC-base color negative papers with an internegative made from the transparency. In later years, many "Kodachrome Prints" were made with Ektachrome RC reversal papers.

Kodachrome process acetate-base prints supplied to the professional market were called Kotavachrome Prints from 1941 until 1946; from 1946 until 1956, the prints were sold under the Kodachrome Professional Print name. All Kodachrome process prints have relatively good dark storage stability. Kodachrome grew out of the research of Leopold D. Mannes and Leo Godowsky, Jr., who were professional musicians and avid amateur photographers. Interested in the work of the two inventors, Kodak coated a number of experimental plates for Mannes and Godowsky beginning in about 1922, and in 1930 Mannes and Godowsky accepted an invitation to join the staff of the Kodak Research Laboratories and work with other Kodak personnel in perfecting their new process. From 1935 to 1938 Kodachrome was designed to be processed using what was

known as the controlled-diffusion bleach method; this was a very complex twenty-eight-step, more than three-hour process requiring three separate processing machines. The dark-storage stability of this first version of Kodachrome was relatively poor, and most examples have by now suffered nearly total loss of yellow dye.

In 1938 the processing of Kodachrome—as well as some aspects of the film itself—was changed to the selective re-exposure method, and the use of controlled-diffusion bleach baths was abandoned. Beginning with the improved film and processing procedure introduced in 1938, Kodachrome has had very good dark fading stability. Kodachrome film is still the only transparency film that remains totally free of yellowish stain formation during long-term storage. Kodachrome processing has continued to be a very complex procedure and can be done only with large, continuous processors. The three separate color developers and the two precisely controlled colored light re-exposure steps make it impractical for the user to process the film. Kodak itself no longer processes Kodachrome film, and only a small market remains for the product.

Agfacolor Neu transparency film was the first incorporated-coupler color film. Introduced by Agfa in Germany in 1936, one year after Kodachrome became available, Agfacolor Neu film was probably more significant than Kodachrome in that the basic incorporated-coupler design of Agfacolor Neu is now used in all chromogenic materials except Kodachrome. Because the color couplers were incorporated into the emulsion layers during manufacture, only one color developer was required, and processing was greatly simplified compared with that required with Kodachrome film.

Although the technique Agfa devised to prevent color couplers in Agfacolor Neu film from migrating from one emulsion layer to another when the emulsion was wet and swollen during manufacturing and processing has been replaced by other methods (e.g., the "protected" or oil-encapsulated couplers invented by

Kodak in the early 1940s and the latex “L-couplers” employed by Fuji in recent years), the incorporated-coupler concept pioneered by Agfa soon became used with all color negative films, color negative papers, and with all Process E-6-compatible transparency films. With the photography market rapidly shifting to digital cameras and inkjet printers, AgfaPhoto filed for bankruptcy in 2005 and is no longer in business.

Among the available color processes, chromogenic films and prints as a group have the distinct limitation of being relatively unstable in dark storage. While most classes of dyes are subject to light fading, chromogenic dyes are almost unique among commercially available dyes in that many of them also have poor stability when stored in the dark unless kept at refrigerated temperatures.

While many of the dyes and pigments intended for use with fabrics, printing, watercolors, and other purposes have less than adequate light fading stability, nearly all of these colorants have very good stability when kept in the dark. For example, although the four-color process inks used in offset printing typically have poor light fading stability (the magenta and yellow inks are generally much less stable than the cyan and black inks when exposed to light), the dark storage stability of these inks appears generally to be excellent. When a book of color photographs is printed on good-quality, long-lasting paper and is protected from undue exposure to light, the printed reproductions will probably far outlast the original color prints. Both dye-based and pigmented inkjet inks generally have very good dark storage stability, even those dye-based inks that have poor light stability.

In the years following the introduction of Kodachrome film, there have been tremendous differences in the permanence of the many types of color films and prints that have been marketed. While Kodachrome films and prints were successful products for Kodak, the company, which from its very beginnings has always been oriented toward the mass market, believed that the

Kodachrome system had several serious shortcomings. First, in common with all color transparency films designed to be viewed by projection, Kodachrome films had a very narrow exposure latitude, which meant that the film was unusable in the simple, fixed-exposure box cameras of the day. This limitation alone effectively closed Kodak out of the bulk of the potentially huge market for amateur color snapshots. Kodak was well aware of the fact that although advanced amateur photographers were for the most part satisfied with putting on family slide shows to view their color photographs, most people preferred to have color prints which could be displayed, sent to friends and relatives, kept in wallets and purses, and arranged in carefully inscribed and dated albums.

With the Kodacolor process, introduced in 1942, Kodak believed that it had solved most of the marketing limitations of Kodachrome. Kodacolor was a wide-latitude chromogenic color negative film designed for use in fixed-exposure box cameras; both the film and prints were relatively simple to process.

The Totally Lost Kodacolor Era of 1942–53

The fact that both Kodacolor films and prints were far less stable than Kodachrome films and prints—and black-and-white films and prints—did not dissuade Kodak from marketing the products to an unsuspecting public. Consumers who made the unfortunate decision to use Kodacolor now have nothing left but unprintable negatives and faded, severely stained prints. In fact, this author does not know of a single Kodacolor print taken from 1942 until 1953 (the year that Kodak managed to significantly reduce the print staining problem) that survives today in reasonable condition; all have faded and developed an ugly, overall orange or yellow stain regardless of whether they were exposed to light on display or kept in the dark in albums. The discoloration was caused by unstable magenta dye-forming color couplers that re-



The worldwide shift from black-and-white photography to color photography began to proceed in earnest in the 1960s, and by 1975 was essentially complete. Unfortunately, the change to color resulted in the loss of the essentially permanent images provided by black-and-white photography that had long been taken for granted by photographers and the general public alike. These faded and cracked Kodak Ektacolor prints made between 1969 and 1976 were returned to a portrait studio by angry customers asking for free replacements.

mained in the print after processing. These hundreds of millions—perhaps billions—of Kodacolor prints and negatives represent the first great era of color photography to be totally lost.

In the early days of color photography Kodak adopted a policy of strict secrecy on matters of color stability; the company concluded that it would not be in its best interests to let the public become aware of the extreme stability advantages of Kodachrome over Kodacolor. (Looking back on the history of color photography, it is difficult to find another pair of products offered by a manufacturer at the same time that had such an extreme difference in image stability.) Kodak apparently feared that if the general public knew just how poor the stability of Kodacolor prints was—even if the prints were kept in an album in the dark—the market for Kodacolor would be seriously restricted. Most amateur photographers would simply continue to use black-and-white films. Color photography

was much more profitable to Kodak than was black-and-white photography.

The decision not to disclose color stability information to the public meant that there was little incentive to introduce more stable color print processes. With stability data kept secret, Kodak could not advertise improvements in image stability, and over the years this effectively doomed Kodak's interest in silver dye-bleach materials and other potentially long-lasting (and probably more expensive) color print processes for the general market.

As a result, during the early 1940s Kodak made a policy decision that was to have far-reaching consequences in terms of color permanence: The company decided that it should try to satisfy the requirements of nearly every branch of photography with one basic chromogenic color print material. This allowed considerable economies of production and a concentration of research and development activities. The design, processing speed, and cost requirements of this color print material were unfortunately dictated by its principal market: drugstore photofinishing. This is a hotly competitive market in which every fraction of a cent spent in producing a print is considered important.

Thus we have arrived at the present, with professional portrait and wedding photographers, fine-art photographers, and photographers producing prints for historical documentation, all using a color print material whose every design aspect was dictated by the drugstore photofinishing and minilab business. Very few people know that the most expensive color portrait or wedding photograph purchased from their local studio is printed on the same type of color paper used for the 35-cent prints they pick up at their local drugstore. In fact, because of the stability problems associated with the lacquering and retouching often done in the professional portrait field, there is a good possibility that the drugstore print, made on Kodak Edge Generations paper, is more stable than portrait and wedding photographs costing hundreds of dollars.

When Kodak replaced large-format Kodachrome sheet films with Ektachrome films at the beginning of the 1950s, no one outside of the company was aware that these new films faded in the dark at least twenty times faster than the discontinued Kodachrome films. The large difference in image stability between these films was a closely held secret within Kodak. The unfortunate results of this product downgrading can be seen in the now severely faded Ektachromes from the period in the collections of *Life* magazine (at Time Warner, Inc.), *Vogue* magazine, the National Geographic Society, the Library of Congress, the George Eastman House International Museum of Photography, and other institutions around the world.

For example, the original 8" x 10" Process E-1 Ektachromes of the famous Marilyn Monroe calendar photographs taken by Los Angeles photographer Tom Kelly in 1947 have suffered severe fading. The images survive only because Dye Transfer and tricolor carbonyl (pigment) prints were made from the Ektachromes, and because many photomechanical reproductions have been published in the years since the photographs were made.

During the period from 1959 to 1976, most professional commercial, advertising, and fashion photographers in the United States used Kodak Process E-3 Ektachrome films in sheet-film and roll-film formats. These films, and the E-3 duplicating films, had very poor dark fading stability and were far inferior to the then-available "amateur" 35mm Process E-4 Ektachrome films (1966–1977). Kodak has never explained why—for a ten-year period—professional photographers using Ektachrome were supplied with a far less stable product than were amateurs, a fact that was kept secret from professionals and amateurs alike. It was not until 1977, when all Ektachrome films were replaced by improved E-6 Ektachrome films, that the stability of the professional films finally equaled that of the amateur films.

The Eastman Color Motion Picture Process: A Major Problem for Film Studios and Archives

Color motion pictures, most of which are now made with a negative/positive color process that is in most respects similar to that used with still-camera color negatives and prints, have (with some exceptions) been significantly improved in terms of image stability since the mid-1980s. However, even the improved products require humidity-controlled cold storage for long-term preservation. Most motion picture color negatives and prints made after the introduction of the Eastman Color process in 1950 until about 1985 have by now suffered significant fading. Nearly all Eastman Color prints made between 1950 and around 1970 have now lost most of the cyan dye component of their images (and usually much of the yellow dye as well), and all that remains is a ghastly reddish-magenta reminder of what once were brilliant, full-color images.



After only seven years of home display, this 1971 Kodak Ektacolor RC print suffered severe magenta dye fading and developed a yellowish stain.

The Worst Color Paper in Modern Times: Agfacolor Paper Type 4 (1974–1982)

In 1974, as a replacement for its then popular Agfacolor fiber-base paper, Agfa-Gevaert introduced Agfacolor PE Paper Type 4, the firm's first RC color paper. As the lowest-cost color paper available, Type 4 paper enjoyed wide use, especially in the mass portrait business, from the mid-1970s until the paper was discontinued in 1982. The paper was also used by a significant number of photofinishing labs in Europe and the U.S. The cyan dye in Agfacolor Type 4 paper had unbelievably poor dark fading stability, with the prints in most cases suffering from near-total cyan dye fading in less than six years. Untold millions of portraits of children, adults, and families made with Type 4 paper by PCA International, Inc., of Matthews, North Carolina, and other mass-market portrait labs are now worthless. Business losses resulting from the exceedingly poor stability of the paper led to the filing of a nationwide class-action suit in 1985 against Agfa-Gevaert on behalf of labs and photographers across the United States who had used Type 4 paper. The case was settled out of court for an undisclosed sum in 1987. It is almost certain that, had the extremely poor stability of the paper been known, not a single lab would have used the product.

Agfa did manage to improve its color papers by the early 1990s; however, with rapidly declining sales as photographers switched to digital cameras and inkjet printers, Agfa filed for bankruptcy and went out of business in 2005.

In what can be viewed as a landmark event that helped alert the museum world to the magnitude of the color stability problem and the need to better care for their collections, the George Eastman House International Museum of Photography in Rochester, New York, presented a "Colloquium on the Collection and Preservation of Color Photographs" in 1975. This was the first event of its type in the United

States (earlier, in 1973, a conference on color preservation sponsored by the Royal Photographic Society was held at the Victoria and Albert Museum in London). In a letter of invitation to those attending the meeting, which was not open to the public, William Jenkins, a George Eastman House staff member and the organizer of the conference, wrote:

As you may know, the International Museum of Photography has been concerned for some time with the difficulty of collecting color photographs. We have collected dye transfer and carbro prints believing these to be relatively permanent, but our policy has been to refrain from acquiring the less stable materials such as "Type C" prints. [Note: In current usage, "Type C print" is a generic term used to refer to a Kodak Ektacolor print or other silver-halide (chromogenic) prints made from a color negative.]

George Larson, a key figure in stability research at Eastman Kodak, and Charleton Bard, who during the 1980s became Kodak's regular speaker on the subject of color stability, represented Kodak at the conference. Larson and Bard, for the first time, gave some basic room-temperature dark-keeping stability data for the then-current Kodachrome and Ektachrome films. The meeting was marked by some strong denunciations of Kodak for its secrecy policies and for the very poor image stability of many of its color products. The renowned portrait photographer Arnold Newman said at the conference, "Millions and millions of people have taken color wedding pictures, vacation pictures, and family snapshots. What's going to happen to these pictures in twenty-five years? They're going to disappear."

Newman, who passed away in 2006, showed the group a selection of severely faded Ektachrome transparencies he had taken some years earlier of President John F. Kennedy, and expressed alarm about the fate of color portraits: "These things are carefully hung on walls and

they are expected to last. The great American public doesn't know it, but it is buying junk. [Kodak and other manufacturers] are going to find that the public is going to start getting angry in about eight to ten years from now when all these personal pictures begin to fade." Eastman House later changed its policy of not collecting Kodak Ektacolor prints (a potentially embarrassing situation in light of the fact that this is by far the largest-selling print material produced by Kodak, the museum's most important benefactor); the collection now includes a sizable number of recently acquired Ektacolor prints.

Refrigerated storage was one of the major recommendations to emerge from the 1975 conference. With the acquisition of the 3M-Sipley Collection in 1976, Eastman House possessed the most valuable collection of historical color processes in the United States. Many of these early color photographs have already seriously deteriorated because of improper storage in the past, and the damage is becoming worse with each passing year.

In spite of the immense value of these photographs, many of which were made by color processes of which examples exist in no other collection in the United States, Eastman House did not include a refrigerated vault in its \$7.4-million archive building completed in 1988. At the time this was written in 2006, Eastman House continued to store its priceless collection of color photographs under improper conditions, without refrigeration.

Neither Ilford, the manufacturer of Ilfochrome (then called Cibachrome and, at the time of the Eastman House Conference, the world's most stable color print material), nor Polaroid or Fuji was invited to attend the 1975 Eastman House conference.

Art Museums Begin to Respond to the Problems Posed by Color Photographs

Almost immediately after the fine-art photography world had finally embraced color photog-

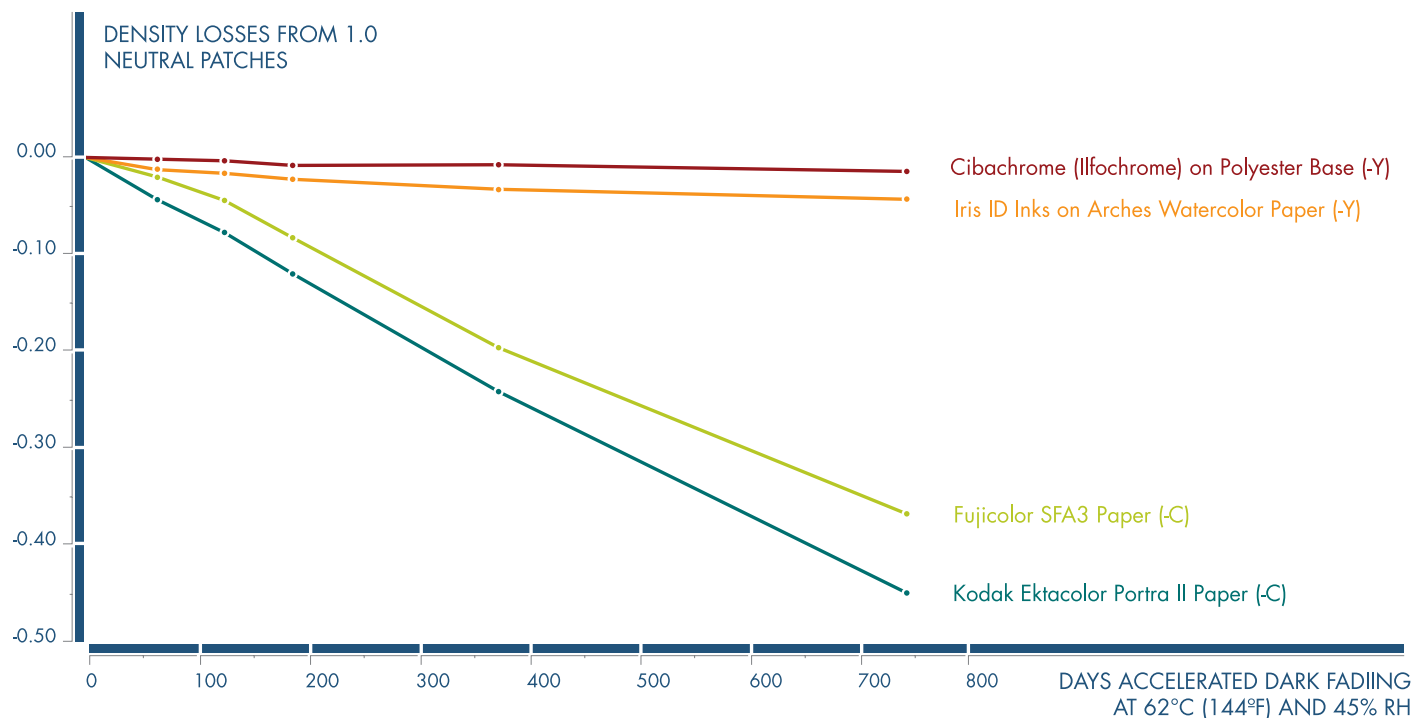
raphy as an art form in its own right in the late 1970s, museum curators, private collectors, and a new generation of photographers working in color began asking questions about how long color prints could safely be displayed. Some wondered if Kodak Ektacolor color prints actually faded in the dark. Others would collect nothing but Kodak Dye Transfer prints, hearing that they would last forever. Some museum curators and collectors, fearing that their investments would depreciate as the prints faded, would not collect color photographs at all.

Among fine-art museums, a three-part strategy to deal with the color print fading problem gradually emerged. The first step was to obtain from the photographer two identical copies of each color photograph chosen for acquisition. This approach provides an "expendable" copy for display purposes, for use as a study print, and for loan to other institutions for exhibition. The second "preservation copy" is kept in the dark under the best storage conditions available. A major benefit of the two-print approach is that the condition of the "expendable" print can easily be assessed at any point in time by a simple side-by-side visual comparison with the "preservation" print.

The Museum of Modern Art in New York and the Art Institute of Chicago are among the museums that have instituted a two-print acquisition program. Both of these museums have found that photographers working in color are almost always supportive of efforts to preserve their work for posterity and are happy to provide the second copy at a sharply reduced "lab price" (the actual cost of making the print). The Museum of Modern Art—which is generally credited with launching the modern era of fine-art color photography with its 1976 exhibition of William Eggleston's color photographs curated by John Szarkowski, then director of MoMA's Department of Photography—issued the following statement in 1984:

Millions and millions of people have taken color wedding pictures, vacation pictures, and family snapshots. What's going to happen to these pictures in twenty-five years? They're going to disappear.

Figure 1.



The Museum of Modern Art New York Statement to Photographers Who Work in Color

It is now well known that with a few exceptions color print materials show a noticeable fading or color shift within as little as ten to twenty years when stored under normal room temperature and humidity conditions, even in the dark. Most such works in the Museum's Collection, prints up to 20" x 24", are now stored at about 30°F [-1.1°C] and 35% relative humidity. These conditions will substantially increase the life of the prints.

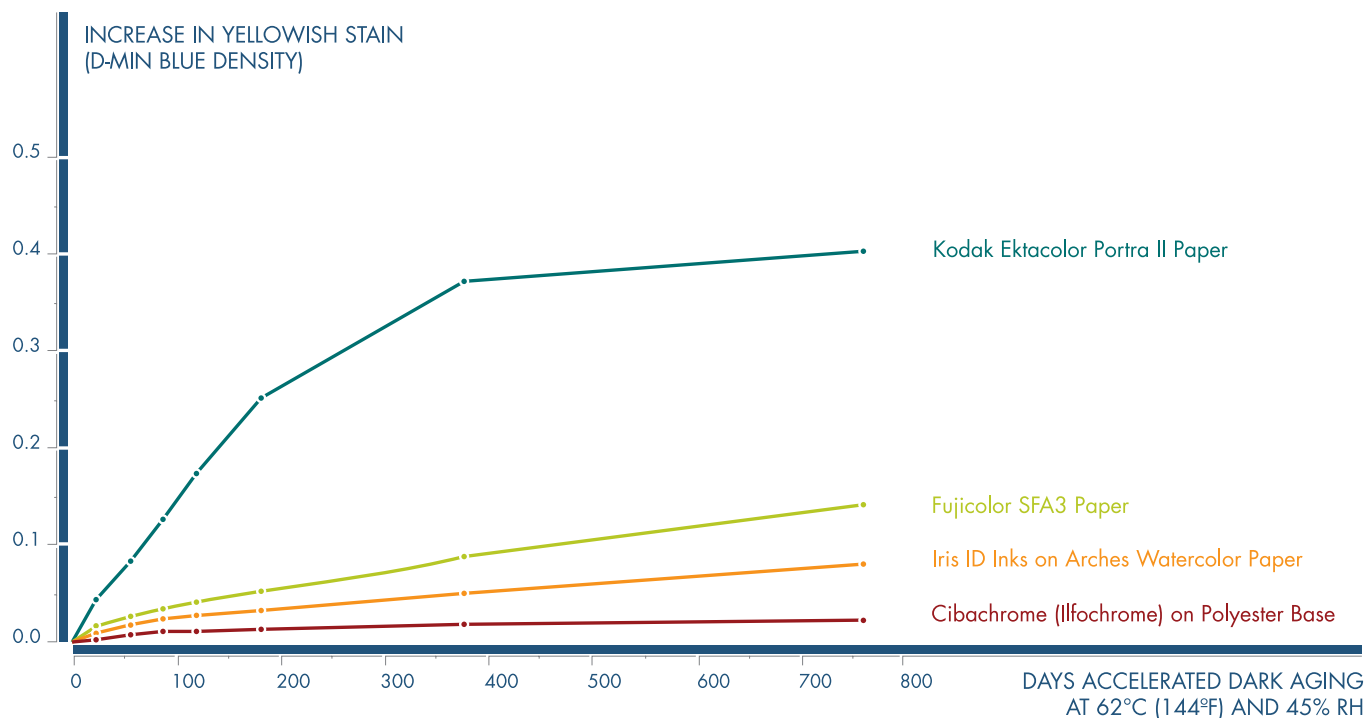
However, these same photographs also fade or change color when, on exhibition, they are exposed to light. Since it is our purpose not only to preserve but also to show the pictures we collect, we propose the following:

When we decide to purchase a color print in unstable materials, we will ask to buy two prints, one at the artist's price, the other at the presumably much lower "lab" price, or what it

costs to make the print. The Museum will agree to regard the two prints as equivalent versions of a single work of art, and will so record them. Neither print ever will be sold. Both prints will be placed in cold low-humidity storage. One will be available for exhibition and loan; the other will be kept in effect as a back-up, until such time as the first is judged to have faded significantly. This solution is not perfect, but it will help to resolve the conflict between our goals of preserving the Collection and making it known through exhibition here and elsewhere.

The second preservation step being taken by concerned fine-art museums is to provide humidity-controlled cold storage for their silver-halide (chromogenic) color prints and other materials with problematic dark storage stability. The Art Institute of Chicago constructed a two-part humidity-controlled cold storage vault in 1982 for housing its entire photography

Figure 2.



collection; color materials are kept in the colder of the two vault sections.

The National Gallery of Canada in Ottawa began operation of a cold storage vault for its extensive fine-art collection in 1988. Corbis, a commercial photography collection, which includes the historic Bettmann Archive, opened a cold storage preservation center in a high-security underground facility near Pittsburgh, Pennsylvania, in 2002; the humidity-controlled vault was designed to temperature at minus 20 degrees Celsius (minus 4 degrees Fahrenheit). In 2004, The Museum of Modern Art in New York opened a large new cold storage facility to preserve its fine-art photography collection.

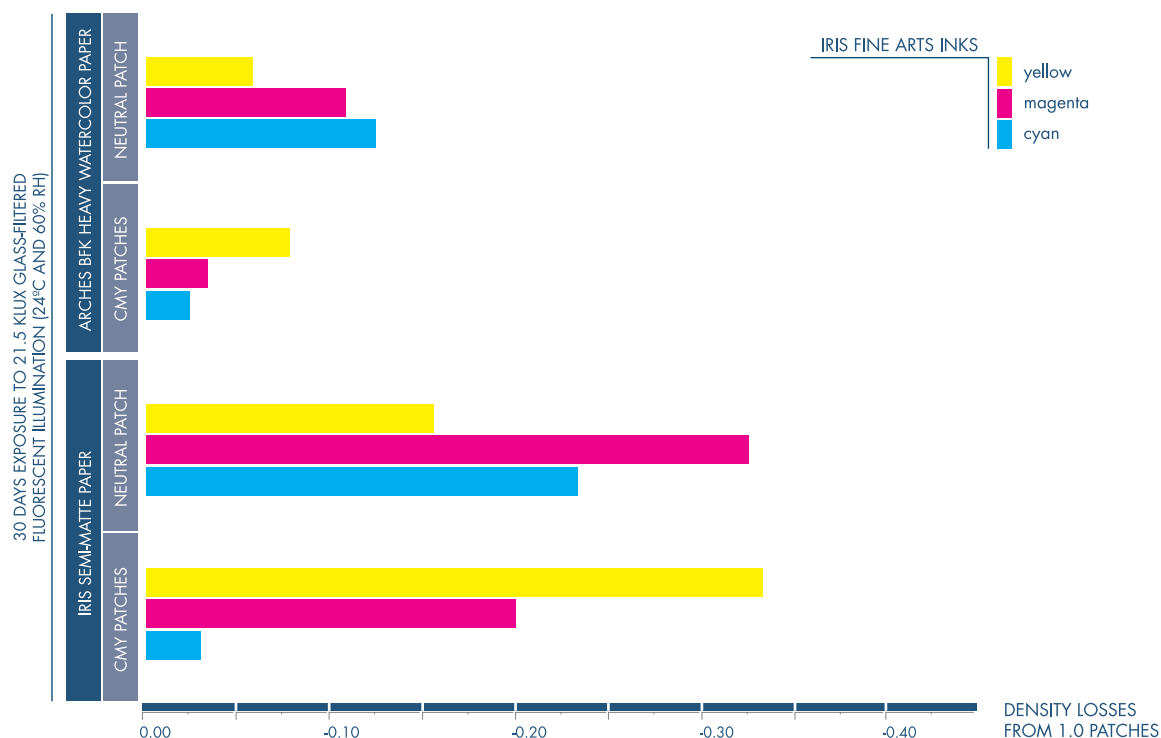
Among other museums providing cold storage for their photography collections are: the Whitney Museum of American Art in New York; the Amon Carter Museum in Ft. Worth, Texas; the Museum of Photographic Arts in San Diego, California; and the J. Paul Getty Museum

in Los Angeles (the new Getty Photography Center has a cold storage vault for large-scale color prints). In the coming years, many additional institutions with important fine-art and historical photography and motion picture collections are expected to provide low-temperature cold storage facilities for the long-term preservation of their collections.

A Fifteen-Year History of Digital Printing Technology and Print Permanence in Digital Fine-Art Photography, 1991 to 2006

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 34" x 46") on a wide range of papers and canvas was the Iris Graphics Model

Figure 3.



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.”³

The Iris 3047 was not originally 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 R. 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. This excited them greatly, and in December 1989 Graham signed the papers to purchase an Iris 3047. The colorful history of Nash Editions is chronicled elsewhere in this book by Mac Holbert.

They first used their new 3047 to print their own photographs, but Graham and Mac soon realized that other photographers and artists

³ Steve Boulter, e-mail correspondence with the author, August 1, 2006.

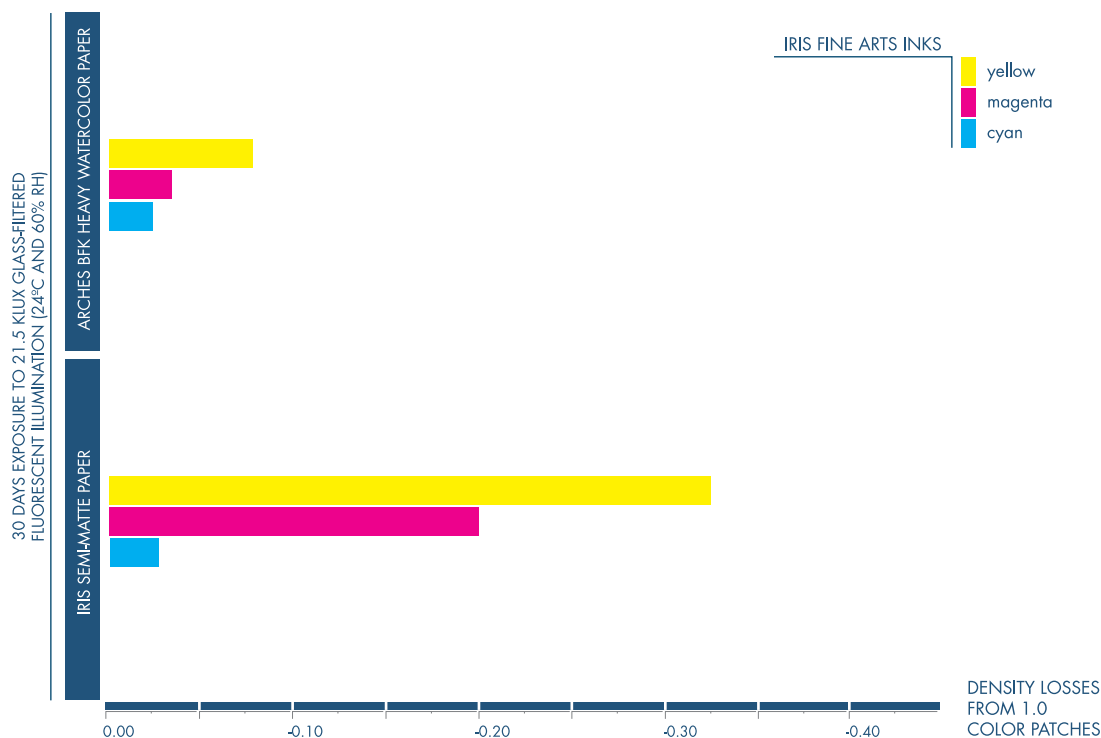


Figure 4.

wanted to have their 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 ink sets. 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, *The Washington Portfolio*, using the then newly introduced Lyson Fine Arts ink set.

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 Wilhelm Imaging Research (WIR) launched 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 on 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 the Society for Imaging Science and Technology's annual conferences in 1994 and 1995, and numerous presentations on digital print permanence and preservation at industry conferences, and 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, founded by Chris Foley and Mark McCormick-Goodhart, was the first to use the improved-stability Lysonic i W2 hybrid ink set in an Iris 3047 in combination with the then-new flat-matte coated Lysonic Standard Fine Art Paper. Old Town Editions was among the first fine-art digital printmakers to implement a full ICC profile-based color-managed workflow with soft proofing and 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 to 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 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

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 artwork. The scanner could accommodate originals of up to 4 x 4 feet.

and photographers—and is also shunned by most photographers.

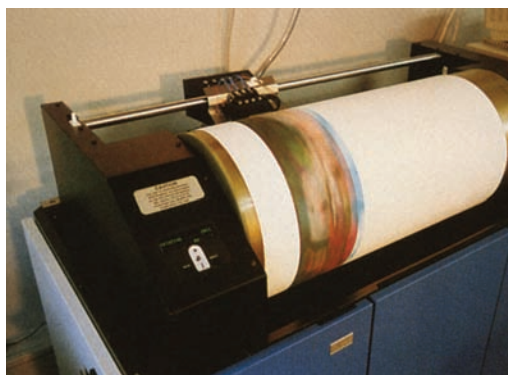
The introduction of the Epson Stylus Pro 7500 (24-inch) and 9500 (44-inch) pigmented ink printers in 2000 started a period of rapid change in the fine-art printing business. The new Epson printers were able to handle a wide variety of fine art and photo media, including very thick papers which could be sent through the printer's straight-through paper path without bending, and they were easy to operate and practically maintenance free. Nash Editions began to convert its printing operations to the new Epson printers, and by the end of 2004 it had retired its last Iris 3047. On August 12, 2005, the Smithsonian Institution in Washington, D.C., accessioned the original 3047 purchased by Nash in a ceremony attended by Graham Nash, Mac Holbert, and Steve Baulter. 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 film 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 offer far greater control with just a few clicks of a mouse. In the modern inkjet era, 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 seventy-year period of traditional silver-halide color (chromogenic) photography comes to a close, 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, and Lexmark—none were in the traditional photography field. Canon of course has long made cameras and lenses, but neither Canon nor any of the other companies has ever made photographic films



Far left: Iris inkjet 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 inkjet, which slowly moves across the image from left to right, is clearly visible.

Left: Bottles of the water-base inks employed in the Iris inkjet 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.

EPSON'S AMERICA IN DETAIL

STEPHEN WILKES



Opening night of the Epson's *America in Detail* exhibition at the Patricia Correia Gallery at Bergamot Station Arts Center in Santa Monica, California, March 2001.

Right: Graham Nash, R. Mac Holbert, photographer Stephen Wilkes, and curators Carole Kismaric and Marvin Heiferman leading a panel discussion that brought together photographers, collectors, and journalists at the Santa Monica, California, Epson's *America in Detail* exhibition. Similar events were organized in each city where the show was exhibited. With large-format inkjet prints and high-permanence pigmented inks, both major new developments in photography, the exhibition assumed an important role in bringing these concepts to the public.

Opposite: Stephen Wilkes, Charles Dayton, *Grand Central Worker*, New York, 2000.

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. As a result, Mac Holbert was asked by Epson America to collaborate with New York photographer Stephen Wilkes to print a major exhibition of his work, Epson's *America in Detail*. Over 52 days, Wilkes traveled across the United States with the goal of capturing a cross-section of American life, chronicling Americans at work on farms in Iowa and oil rigs in the Gulf of Mexico, street musicians in Venice Beach and Times Square, and spectacular landscapes in several states. The show of forty images, curated by Marvin Heiferman and Carole Kismaric, 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.

"The year 2000," Wilkes wrote, "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 twentieth century.... Epson's *America in Detail* offers me a unique opportunity to capture a moment in American history, and to be on the forefront of digital printing, taking advantage of the ability to control the entire photographic process.... 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 this shoot through a unique new method—one that is the wave of the future."

In her review of the exhibition for the New York Times, critic Vicki Goldberg wrote, "Color photographs up to now have been compromises, but we





were accustomed to them. No photographer can print quite what he or she saw or what was registered on the negative or transparency because no enlarger can handle it adequately. The computer program Photoshop, however, can—in combination with the right inks, printer, and paper, and in the hands of a master printmaker like R. Mac Holbert, who printed Mr. Wilkes's images. Mr. Wilkes made his photographs with standard cameras and film, then scanned them into a computer; Mr. Holbert added nothing that was not there but brought out what was.

"Digital color printers have up to now used dye-based inks, just as traditional color printing processes have. The new Epson printers use pigment-based ink sets, similar to those used by the automotive industry. Both Epson and Hewlett-Packard devised such ink sets for outdoor signs; they had been looking for something permanent and resistant to pollutants. Dyes fade: consider your upholstery. Pigments last: consider oil paintings."

— HENRY WILHELM



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 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 prints had very poor light fading stability. But as shown in Figures 1 and 2, it was clear from the beginning to this author that inkjet inks and papers 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 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 finally achieved it with dye-based photo inks introduced in early 2000. At the time, dye-based inks had the advantage of a wide 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-

Manufacture of cyan dye-based ink for the Iris 3047 printer at the American Ink Jet Corporation factory in Billerica, Massachusetts. The unique design of the inkjet nozzles employed in Iris printers precluded use of pigmented inks.

term color drift behavior that can be very problematic for color-managed workflows and proofing applications.⁴

From a permanence point of view, however, 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 ink set 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 ink sets 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-whites that are equal to the best black-and-white silver-gelatin prints in terms of brilliance and smooth, linear tone scale.

Escalating prices paid for photographs in

the art market—in 2006 many color photographs by major artists were selling for more than \$100,000 in galleries and in art auctions—have 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 fifteen-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 method standards available from ANSI

Escalating prices paid for photographs in the art market—in 2006 many color photographs by major artists were selling for more than \$100,000 in galleries and in art auctions—have helped push demands for a high level of print permanence.

4 Henry Wilhelm, “A Review of Accelerated Test Methods for Predicting the Image Life of Digitally Printed Photographs—Part II,” Final Program and Proceedings: IS&T’s NIP20 International Conference on Digital Printing Technologies, sponsored by the Society for Imaging Science and Technology, Salt Lake City, Utah, November 2004, pp. 664–669. A PDF of the article is available from www.wilhelm-research.com.

(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. Manufacturers now have confidence that the performance of their products will be fairly evaluated and that permanence data will be made broadly available to photographers and the marketplace through WIR's website. This has helped to 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, and black-and-white prints with high D-max and a luscious, smooth, linear tonality—and with

excellent permanence.

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, multicolorant ink sets 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.

The Special Place of Nash Editions in the Ongoing History of Photography

There are people who dream of better ways of doing things. These are the people who focus their usually considerable energies on the potential of new ideas and inventions, and are not held back by the problems that almost always hinder early adoption. With the creation of Nash Editions, Graham Nash, Mac Holbert, and Jack Duganne joined that very special group of people in photography's history who got there first. They played a pivotal role in moving photographic printmaking into a completely new and clearly superior technology.

With Nash Editions, there were really three firsts: Creation of the world's first digital fine-art inkjet photography studio in 1991. (By that time, Nash Editions had already made the first photographic portfolio printed by digital tech-

Left to right: R. Mac Holbert, John Bilotta, and Graham Nash at Nash Editions viewing a black-and-white print from an Iris 3047 in 2004. While the first Epson pigmented inkjet printers could produce beautiful color images, they had limitations with black-and-white images, and the Iris printers continued to be used at Nash Editions for black-and-white prints until Epson resolved this shortcoming with a new generation of printers and inks in 2004.

Opposite: Brent D. Glass, Graham Nash, Steve Boulter, Shannon Perich, and R. Mac Holbert at the Smithsonian's National Museum of American History, August 12, 2005, when Nash Editions' first Iris 3047 inkjet printer was incorporated into the museum's photographic history collection, along with prints from the Nash Editions archive.





nology. Printed in an edition of sixteen during the formation of Nash Editions from 1989 to 1991, Nash's *Portraits Portfolio* of sixteen images sold at Christie's on April 8, 1998, for \$21,500.) Then, in 1999, Nash Editions printed the first major photography exhibition to be printed with the new Epson large-format inkjet printers and highly stable Epson pigmented inks introduced into the market the following year, in 2000.

Considering that Nash Editions was born when museums and collectors strongly resisted showing and collecting "digital" photography, the third important contribution was their highly visible and vocal advocacy of the control, beauty, and permanence that only digital photography can provide. From the very beginning, Graham and Mac worked hard to engage a field that initially rejected inkjet prints as even being legitimate "photographs." At that time, many people believed that because images printed with an Iris 3047 had an image structure built up of millions tiny dots (which could be

clearly seen under low-power magnification), they were "photomechanical reproductions," belonging to the same group of processes that includes ordinary offset lithography printing. Others insisted that a true photograph must have an image that is created as a direct result of exposure to light and, therefore, an inkjet print could not be considered to be a photograph.

In July 1991, when Nash Editions opened its doors, digital imaging was in its infancy. Photographers were still using film, and moving the analog image into the digital space required the use of then very specialized and expensive high-resolution scanners. Making a good scan required a level of expertise and experience that photographers did not have. Adobe Photoshop Version 1.0 had been shipped only a little over a year earlier, in February 1990 (at first, Photoshop was an Apple Macintosh-only application; the first Windows PC version was not introduced until 1993). When Nash Editions started, most photographers had never even heard of

5 Wilhelm Imaging Research, Inc., WIR Display Permanence Ratings for Current Products in the 4" x 6" Photo Printer Category, March 2, 2006. Available in PDF format from www.wilhelm-research.com.

6 Mark McCormick-Goodhart, Henry Wilhelm, and Dmitry Shklyarov, "A 'Retained Image Appearance' Metric For Full Tonal Scale, Colorimetric Evaluation of Photographic Image Stability," Final Program and Proceedings: IS&T's NIP20 International Conference on Digital Printing Technologies, sponsored by the Society for Imaging Science and Technology, Salt Lake City, Utah, November 2004, pp. 680-688. A PDF of the article is available from www.wilhelm-research.com.

7 Henry Wilhelm and Carol Brower (contributing author), *The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures*, Preservation Publishing Company, Grinnell, Iowa, 1993. A PDF of the complete 758-page book is available at no cost from www.wilhelm-research.com.

WIR DISPLAY PERMANENCE RATINGS FOR SELECTED

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

Year	Printer/Ink/Paper Combination	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) Iris Semi-Matte coated inkjet proofing photo paper	4 years 1.4 years	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) Iris Semi-Matte coated inkjet proofing photo paper	14 years 4 years	17 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) Printed with Cibachrome print material (silver dye-bleach color prints) Printed with Kodak Ektacolor Portra II Color Negative Paper (silver-halide color prints)	36 years 29 years 12 years	40 years 33 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 Liege Inkjet Fine Art Paper matte-coated fine-art paper	22 years 2 years	25 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 Somerset Enhanced Velvet matte-coated fine-art paper	30 years 4 years	- na - - 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 Somerset Velvet uncoated 100% cotton fine-art paper Iris Canvas Lysonic Standard Fine Art Paper matte-coated fine-art paper Somerset Enhanced Velvet matte-coated fine-art paper	34 years 22 years 17 years 8 years 3 years	- na - - na - - na - - na - - 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) Somerset Velvet uncoated 100% cotton fine-art paper Arches for Iris 100% cotton fine-art paper Pinnacle Gold Enhanced Watercolor fine-art paper UltraStable Canvas	70 years 32 years 24 years 19 years	- na - - na - - na - - 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) Epson Premium Glossy Photo Paper Epson Photo Paper	25 years 10 years 7 years	- na - - na - - na -

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

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 Epson Watercolor Paper Smooth (matte-coated 100% cotton fine-art paper)	>225 years >225 years	>250 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) Epson Premium Luster Photo Paper (250) Somerset Velvet for Epson (matte-coated 100% cotton fine-art paper)	108 years 71 years 61 years	175 years 165 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) Printed with Ilfochrome Classic [Cibachrome] Material (silver dye-bleach color prints) Printed with Kodak Edge Generations color negative paper (silver-halide color prints)	40 years 29 years 19 years	49 years 33 years 17 years
2004 Hewlett-Packard DesignJet 130 printer (HP's first 18 x 24-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] Canon Photo Paper Pro PR-101 (glossy) [see Note B below]	10 years 6 years	12 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) Epson Premium Glossy Photo Paper Paper Epson Premium Luster Photo Paper	200 years 104 years 64 years	>250 years >175 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) Epson Premium Luster Photo Paper (250) Somerset Velvet for Epson (matte-coated 100% cotton fine-art paper)	108 years 71 years 61 years	175 years 165 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 Canon Luster Photo Paper, Canon Photo Paper Pro, and select other Canon photo papers	>100 years >100 years	>150 years >150 years
2006 Canon imagePROGRAF iP5000 and iP9000 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 Canon Luster Photo Paper, Canon Photo Paper Pro, and select other Canon photo paper	>100 years >100 years	>150 years >150 years
2006 HP DesignJet Z3100 printer (HP's first 12-ink pigmented inkjet printer) Printed with HP Vivera Pigment inks (11-ink pigmented inkjet prints) HP Advanced Photo Paper Glossy (improved version with 10.5 mil paper thickness) HP Photo Matte Paper (matte-coated fine-art paper) HP Hahnumühle Smooth Fine Art Paper (matte-coated fine-art paper)	>150 years >230 years >230 years	>230 years >230 years >230 years

Note 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 unframed original. **Note B:** Because of the disproportionately rapid light fading of the red (orange) ink in the 8-ink Canon ChromaPLUS dye-based ink set 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 skin tones.

Photoshop. And few owned a Macintosh computer with enough power and memory to run Photoshop. Once a transparency or negative had been scanned and digitized, there was little one could do except to gaze at its beauty on a Macintosh screen—or send it into prepress. Affordable photo-quality dye-sub printers and RGB laser silver-halide photo printers had not yet appeared in the marketplace.

And the Iris 3047, the only printer capable of outputting a digital file as a high-quality, large-format print, was far too expensive and complex to operate for an individual to actually own one. The “digital darkroom” was simply beyond the reach of even the most committed photographer. Thus the logic of Nash Editions—a small digital printmaking studio operated by skilled and passionate individuals whom photographers could enlist to have their work printed.

In the early days, Nash’s customers often visited the studio, both to learn what digital printing and Adobe Photoshop were all about, and to work with Mac Holbert, Jack Duganne, and other staff members to achieve exactly what they wanted in their prints. From the beginning, teaching photographers how to use Photoshop and the fine points of printmaking has always been very central to Nash Editions. While most of the other Iris printmaking studios that started after Nash Editions have focused their businesses on the short-run art reproduction market, Nash Editions has remained firmly committed to photography. There has always been a certain purity and energetic charm about Nash Editions. Just to walk in the door is to be immediately immersed in the latest digital technology—and a love of photography and of making beautiful, long-lasting prints.

Indeed, in recent years a whole new community has formed of people who are passionate about digital photography, Photoshop, and digital fine-art printmaking. These people love to share their knowledge and enthusiasm. They write articles and books, conduct workshops, run websites, lecture at conferences, and do

beta testing of new software, printers, inks, and papers for manufacturers. Many travel widely and get together with members of this informal and far-flung group at every possible opportunity. They are all bound together by a deep love of and involvement in photography. Mac Holbert and Graham Nash, both accomplished photographers and gifted teachers, are firmly a part of this new and expanding worldwide digital photography community.

A working knowledge of Photoshop has become the language of photography. And now that powerful computers, high-quality and low-cost inkjet printers with long-lasting pigmented inks, and calibrated monitors running under fully color-managed workflows have become readily available, the early dreams of having one’s own digital darkroom have become the reality for most photographers. Printmaking has finally returned to the photographer—after a twenty-year-plus absence that began when silver-halide color printing proved too complex and too costly for most photographers to be able to make their own color prints. Printmaking has returned to the tradition of Edward Weston, Ansel Adams, Alfred Stieglitz, Edward Steichen, Paul Strand, Walker Evans, Paul Caponigro, Lee Friedlander, Joel Meyerowitz, and the many other great photographers in history who have viewed making their own prints to be central to the expression of their work—and to be deeply intertwined with their evolution as artists.

With the continued evolution of photography and, in turn, of the role served by the small digital printmaking studio, Mac Holbert has been utilizing the broad experience gained over the years in working with photographers at Nash Editions and with his own photography to devote more of his energy to teaching—to help photographers gain a deeper understanding of what they can accomplish with Photoshop, and of the nuances of fine-art printmaking using inkjet printers, beautiful papers, and long-lasting pigmented inks.

Carll Goodpasture, *Passionflower fritillary*, 1999.