

Image Storage and Permanence Considerations in the Long-Term Preservation of Photographic Images – An Update and Additional Considerations

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Abstract

Archivists and consumers, alike, need to become aware of long-term storage and preservation issues that relate to the preservation of the data behind digital photographic images. The more obvious issues, such as accidental or catastrophic data loss and hardware format evolution, are only now being recognized in the archiving community. Consumers need to be alerted to these issues and be prepared to develop preservation strategies as well. However, longer-term issues beyond routine backup and migration of data need to be considered. The very basic solution of preservation via hardcopy images stored in shoeboxes or albums is one option, but this raises a fundamental question regarding image preservation that transcends even the more complex solutions—the long-term stability of the chosen media, whether digital or analog. This paper discusses archiving and preservation as it relates to images, and the data behind those images, along with historical perspectives and an overview of possible longer-term preservation strategies [1–3]. The importance of image permanence standards, as they relate to overall selection of preservation strategies, will also be discussed.

Introduction

As digital imaging becomes more and more popular as the primary mode of capturing memories for the consumer, there is an ever-growing concern over long-term storage and the preservation of these memories. Despite growing efforts by the industry, the average consumer continues to be generally unaware that there is an underlying risk associated with image storage on computer hard drives or optical media. In many cases, because it is digital, the consumer actually feels that the images are safely preserved. Museums, conservators, and archivists, on the other hand, are starting to recognize the problem of digital image storage. Relative to preservation strategies, research and other published works are available on the topic. These strategies, however, are based on shorter-term storage with an associated longer-term migration plan. While some risk is mitigated, much remains.

Definitions

For the purposes of this paper, differentiation between image preservation and image archiving is needed. Archives are places where records and documents are stored. For digital image archiving, consider this to be a repetitive process of image file storage on the most current media and file format. As the formats change, a routine data migration plan is required to move the information to the next generation of media or file

format. For digital image preservation, however, consider this to be a long-term, low-maintenance operation where the information is stored on a medium that is stable—physically stable and stable in terms of format and readability. The need for frequent management of the data is highly reduced.

Historical perspectives

Many studies are available on the long-term storage of digital information [4]. The work has been driven largely by libraries, museums, and governmental institutions, and addresses the threats associated with computer-dependent systems. There is recognition of the need for ongoing data migration as hardware, software, and operating systems evolve. Because the quantity of information for these large institutions is huge, high-capacity systems are needed. A benefit of these systems is accessibility—the data is searchable and can be quickly retrieved. However, the cost of this accessibility is the dependence upon the computer and its associated storage devices, which continue to evolve, thus requiring a migration plan. An example of such a system is the on-line photo servers where storage is essentially free. Alternatives to these types of rapid access, computer-dependent systems have been studied where the ability to have rapid access is reduced in exchange for a reduction in the need for data migration. Examples have been discussed in the literature that make use of photographic film as the preservation medium [5].

Actually, the use of film for preservation is not new, as it has been done extensively in the motion picture and document industries for many years. Polyester-based, black and white silver separation films enabled the creation of separate red, green, and blue records of color motion picture that could last over 200 years in controlled, room temperature storage. The viability of this process has been demonstrated repeatedly in recent years with successful restorations of many classic films. Black and white microfilm provides stability up to and beyond 500 years at room temperature with good storage efficiency. Compression of documents in the order of 25 to 45 times is possible. New hybrid document imaging systems enable the use of film with scannable metadata for enablement of automated search and retrieval functions [6].

Preservation in the home has historically centered on hardcopy prints in albums, scrapbooks, and shoeboxes. There has been significant growth in digitally generated scrapbooks and photo albums in the last couple of years and growth of these products is expected to continue. Negatives, which are a somewhat compressed and more efficient storage format, are often times unorganized or simply not available. While a

hardcopy print provides no compression of the information, and as such, tends to take up a large volume, it is human readable and therefore requires no system architecture to be put into use. Negatives and transparencies, on the other hand, do require some level of supporting system to use optimally, but they are human readable, nonetheless. They also provide for some compression of the data (4.2 times in 35 mm format, for example). Longevity of both print and film media will be discussed later in this paper.

As consumer imaging continues its rapid advance to the digital world, preservation remains erratic or non-existent. There has been little to no thought by the consumer for long-term preservation of their images. It seems they are taking for granted the automatic, "built-in" preservation that came with the traditional analog negative and print that was available for many decades. Today, digital files tend to be loosely organized on hard drives, CDs, and DVDs. But, often, there is no organization and little to no awareness of the vulnerability to loss of the image through hard drive crashes, media decay, and data corruption. Even if there is some level of organization, the consumer tends not to think about what will happen in the shorter term when they need to replace their computer, or the longer-term impact of file format and media format changes. All of these impacts result in the need for continual long-term migration of an ever-growing digital image collection.

Fundamentals of archiving

As mentioned above, archiving requires an ongoing commitment to manage records to keep them intact and ahead of any type of time-dependant changes. Key requirements of a good archiving system include low maintenance, cost-effective retrieval (based on the need for immediate or less-than-immediate access), as well as high storage density, longevity, and cost-effective life-cycle costs. What is an acceptable life cycle? The answer depends upon risk and balancing factors of hardware and media longevity. If one looks at 5.25- and 3.5-inch magnetic floppy disks, one could conclude a cycle of 20–25 years provides an acceptable risk, with note that the availability of computers with 3.5-inch drives has essentially disappeared over the last two years. However, looking at the more rapid evolution of optical media, one could conclude the time is well under 20 years. While consumers are now burning DVDs, there is a new, incompatible DVD format on the horizon from the entertainment industry, with the Blue-ray DVD format now pretty much established over the HD DVD format. An additional risk factor is the breadth of usage of a particular format, which can have both positive and negative consequences on the risk of obsolescence. CDs have been well established for many years by the music industry and could therefore be considered a long-surviving, low-risk format. However, unanticipated technology changes occur that can increase risk and shorten longevity. Music CDs are now under some challenge from microdrives in MP3 players. Will there be a full-scale format change? Consider VHS tape. It also became well established and actually rendered the Beta format obsolete. In 1990 it would have seemed likely that VHS was well established by virtue of the motion picture industry and would be low risk for a format change. Today, of course, VHS has become obsolete by DVD technology, driven by the same

industry. So risk is always present and usually cannot be predicted far in advance of a format change. Being conservative on the risk from all sources, a 15–20 year migration cycle is very likely too long, and even half that time could be a problem. Depending on the media selection and how mature the system, using a five- to ten-year cycle is a better balance. A total rewrite of your database every five to ten years is a huge amount of work, however, especially when considering how quickly the volume of information grows. Total rewrite is a short-term consideration. One also must consider that consumers want the information to last for many generations, if not a lifetime or more, and this requires a very long-term commitment. Migration cycles are short because of the rapid and ongoing advancement of the computer and associated systems and the short life cycle of the media (see Figure 1.)

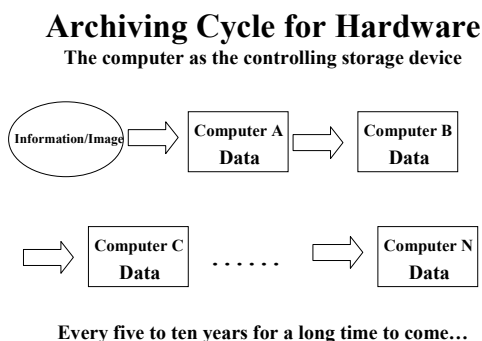


Figure 1. Information archiving with a computer-dependent system.

In this system, data is migrated based on a cycle time driven by hardware and/or file format changes. Prior to any one of those components changing, a migration is required.

Fundamentals of preservation

Preservation takes a long-term perspective and attempts to reduce the need for short-cycle migration of the information. There are no simple solutions, however. The preservation system needs to be built to meet the user requirements, which is based on three broad-based options:

- Long-term need with immediate access: use an all-digital system and migrate frequently.
- Long-term need without the need for immediate access: use a hybrid-based system with an analog reference-archive backup.
- Long-term need that is low cost and simple to use: – use human-readable media with manual retrieval.

Reduction or elimination of the dependency on the computer can have a very positive impact on migration cycle time and allows for a preservation system that needs attention very infrequently. The key is to move from a digital storage format to a human-readable optical format using media that is very stable. Key requirements mentioned above (storage

density, longevity, etc.) still apply with the addition of human readability. The computer is not eliminated, per se, but it becomes a gateway to create and retrieve objects containing the human-readable information, see Figure 2. A computer is actually not truly needed at either end of the cycle; although it can, along with the writer and scanner, enable greater operational and storage efficiency. In a case where a computer is unavailable, the document can still be retrieved using first principles: the document was in a human-readable format to begin with, and visual retrieval of the information can be accomplished using only a light and a lens.

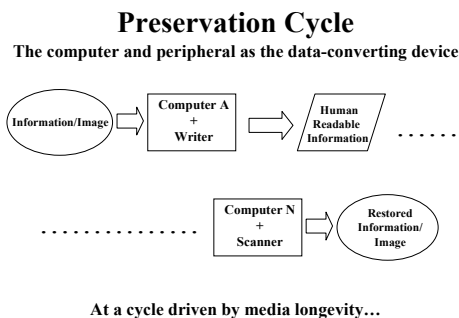


Figure 2. Information preservation with a computer-independent system.

Peripherals to enable enhancement of the system include a film recorder and a film scanner. Both of these devices are well established and of high quality today. Film scanners have reached a state-of-the-art position and their evolution has slowed, while film recorders continue to grow in capabilities such as speed and resolution. This is being driven primarily by the motion picture industry. Film has also reached a stable, high-quality position for both image structure and resolution, as well as for long-term image stability. This makes it an ideal candidate as a storage medium.

Preservation by consumers today

While a film-based system has not yet been designed to work as an integrated system for high-volume storage of consumer digital files, options exist today for the consumers to store their images for the longer term. The first and simplest way is to make hardcopy prints of the most valuable images. Media of various technologies exist today to provide over 100 years of storage life at room temperature conditions. Printing is easily accomplished at home using photographic-quality 4 × 6 or page-sized printers, at retail locations using self-service kiosks or a retailer-operated digital minilab, or online. A second option available for storage is use of an online service such as the Kodak Gallery or HP's Snapfish. These services make use of digital storage devices to provide ready access to images;

concerns about format migration are the responsibility of the service provider and should not be a concern of the end consumer. In most cases, this storage is available for free, if a minimum annual quantity of printing is done. A third, and less desirable, storage option is to routinely move images to optical media such as CDs or DVDs. Three critical concerns in this option, as discussed above, are the media longevity, the hardware format longevity, and the file format longevity. The end consumer should set up and commit to maintain a long-term routine to rewrite the images to the latest media and format. A cycle of no longer than five years is recommended. While CD and DVD optical media is becoming available with advertised longevity of 100 years and higher, there is a growing amount of anecdotal evidence being gathered on low-cost CD media that lasts for two years or less. Any short-term plan by the end consumer to use optical media should center on higher quality, higher cost media only.

Stability of materials used for preservation

Table 1 outlines reflection and transmission media for use in preservation and provides information on their advantages and disadvantages. Reflection media has the advantage of being excellent for human readability. However, it is poor for storage density (albums fill up fast) and has variable longevity, which is technology dependent. Nonetheless, should the file ever become lost, a hardcopy print is a human readable record of the digital file. The industry needs to encourage people to make prints as preservation records of their images. Transmission media has variable unaided human readability, depending on image compression, which is a direct tradeoff to storage density. Depending on film type, the media has good to excellent storage longevity.

Table 1. Characteristics of reflection and transmission media for preservation.

Media Type	Human Readability	Storage Density	Longevity
Reflection	Excellent	Poor	Excellent to Poor
Transmission	Poor to Excellent	Excellent to Poor	Good to Excellent

Tables 2 and 3 discuss the longevity of various reflection and transmission technologies, respectively, and provide specific examples and longevity information for Kodak media [7, 8]. With one noted exception, the lifetime estimates in these tables use a new endpoint criteria that is more conservative than that typically used for consumer images [9, 10]. Because the application is for long-term storage, these predictions are based on dark keeping applications, and they include the effects of heat, humidity, and atmospheric pollutants; but they do not include effects of light.

Table 2. Stability of reflection media for long-term storage applications.^a

Media Type	Media Name	Estimated Longevity	Comments
Thermal Dye Diffusion Transfer	<i>Kodak Professional Ektatherm XtraLife™</i> media	80–100 years for 5% dye loss ^b	Virtually no sensitivity to humidity or ozone
Inkjet/Swellable Media	<i>Kodak Ultima</i> picture paper	Over 75 years	Using high-quality pigmented inks; media and inks continue to evolve
Inkjet/Porous Media	<i>Kodak Ultra Premium</i> picture paper	50 to over 75 years	Using high-quality pigmented inks; long-term testing in progress
Silver Halide	<i>Kodak Professional Endura</i> papers	Over 150 years	Virtually no sensitivity to humidity or ozone; greatest longevity of any silver halide paper

^aUsing a much tighter dye loss criteria of 15%; room temperature storage conditions of 23C and 50% RH and pollutant-free air; lower storage temperatures can provide significantly longer longevity

^bTime for 15% dye loss has not been determined due to the extremely high thermal stability; actual time will be well beyond 100 years

Table 3. Stability of transmission media for long-term storage applications.^a

Media Type	Media Name	Estimated Longevity	Comments
Silver halide color reversal film	<i>Kodak Ektachrome</i> films (E-Series)	Over 100 years	<i>Kodak Ektachrome</i> duplicating film has the highest image structure, lowest ISO speed of the <i>Ektachrome</i> family
Silver halide color reversal film	<i>Kodachrome</i> films	Over 120 years	Similar benefits to <i>Kodak Ektachrome</i> films; limited processing availability
Silver halide color negative film	<i>Kodak Vision</i> color intermediate film (motion picture)	Over 100 years	Image structure comparable to <i>Kodachrome</i> film; limited processing
Silver halide color negative film	<i>Kodak Professional Portra</i> films	Over 50 years	Image structure slightly reduced vs. <i>Kodachrome</i> , but high ISO speeds; processing widely available
Silver halide B&W negative film	<i>Kodak</i> black and white films	Over 500 years ^b	Silver image as opposed to dye; includes motion picture, micro-, and camera films

^aUsing much tighter dye loss criteria of 15%, room temperature storage conditions of 23C, 50% RH, and pollutant-free air, lower storage temperatures can provide significantly longer longevity

^bWhen used with polyester-based films.

Evident in Table 3, there are significant longevity benefits for silver halide film. This makes sense because the design criteria for most films relative to image permanence has been to optimize for dark storage. In addition, film provides benefits in that it is a very mature technology, with few unknowns. Because film has been around for so long, there has been good confirmation of longevity predictions with real-time, natural aging data. In addition to its maturity, color films provide increased storage capacity because of their ability to record three separate channels of information, and they offer excellent

image structure for high resolution and low noise. Color reversal film provides an additional benefit of its black surround (unexposed area), which reduces flare in viewing and scanning operations. Because they are gelatin based, these silver halide films all offer high resistance to humidity and atmospheric pollutants.

A long-term preservation solution was proposed and patented by Eastman Kodak Company in 1996 [11]. Using polyester-based microfilm, three color-separation files are created, and those files are written as a luminance channel and red and blue chroma channels, onto the microfilm within the space of a traditional 35 mm frame. Additional information within the frame is a

calibration gray scale and human- and machine-readable metadata, see Figure 3. Additional details on this method

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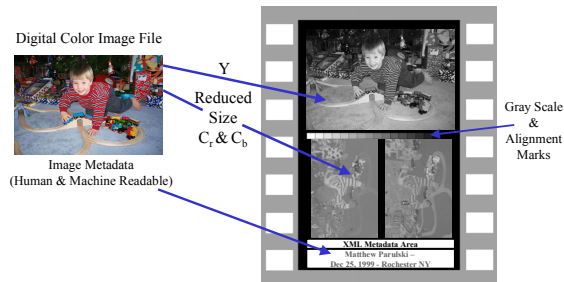


Figure 3. Patented method for long-term preservation using black and white microfilm.

were presented at the Imaging Science and Technology's Archiving Conference in San Antonio, Texas, in April 2004 [12]. Further information on digital file color encoding specifications and transformations was presented at the 2005 Archiving Conference in Washington, DC, on April 2005 [13].

The importance of metadata preservation

Metadata is, quite simply, data about data. Virtually all digital cameras today record a wide range of metadata when an image is captured, covering simple information like the date and time the image was taken, to information about the specific camera and actual camera settings used to capture the image. In cameras with GPS sensors, the location of the image can be included in the metadata information package as well. For professional and commercial photographers, efforts by the International Press Telecommunications Council (IPTC) established specific categories or "headers" for information to be recorded about the photograph beyond what was recorded by the camera. In 2001, Adobe Systems Incorporated created a new metadata framework called Extensible Metadata Platform (XMP) to allow cross-synchronization with the IPTC headers and newer IPTC core framework [14]. While professional and commercial applications of metadata are beyond the scope of this paper, it is important to understand that metadata can be edited, added to, or lost from the digital file of a photograph.

From the perspective of long-term storage and preservation of consumer digital images it is very important to understand the value of metadata and the

risks of losing the metadata associated with long-term preservation. From the value side, metadata replaces the human "recorder" of information—the information previously written on the back of photographs, such as date and time the picture was taken. In the digital and computer world, metadata allows for rapid sorting of information by a multitude of categories. Examples of the more commonly used categories include file size and type, date modified, date picture was taken, author, title, and camera model. Less common attributes include picture dimensions, owner, author, and copyright information. On higher end digital cameras, specific information such as exposure and ISO settings, lens focal length, exposure and flesh compensation, color space, and white balance are available as well. As mentioned above, if GPS enabled location information is available. All of this information is available for sorting and is often used in photo-album software for picture grouping and sorting. From the risk side, users need to be aware that this data can be corrupted or lost when making successive copies of the digital images during routine migration. The data can be lost as image files are moved in and out of certain photo editing and albuming programs (a short-term concern) or when file formats change (a concern primarily for the long term). For example, Exchangeable Image File Format (Exif), which is a specification for image file format including how and where metadata is stored, is supported by JPEG and TIFF but not by JPEG2000 file formats. Users of these types of software and file formats need to be certain that metadata remains intact.

Because of the value it brings to digital photography, metadata needs to be considered for long-term preservation outside the digital domain. In the film-based preservation scheme mentioned in the previous section, writing of metadata is taken into account in both human-readable and machine-readable formats. While it may not be needed for a consumer-oriented preservation scheme, recording all of the metadata contained in the original digital file may require a dedicated frame adjacent to the human-readable image. In the hardcopy media-based preservation scheme, recording the metadata is more problematic. Key information can be added into the image itself (shown as actual numbers such as some cameras do with a date function); doing this on all files in a collection would certainly be time consuming. Manually writing the information on the back of the print is the other alternative, which is also time consuming. So in addition to the low storage density offered by reflection media, preservation of metadata also needs to be recognized as a disadvantage, although not an insurmountable one. For those most cherished images that are printed with the purpose of long-term preservation, the benefits of recording the critical metadata information may well outweigh the disadvantage of the effort involved.

Image permanence standards

Clearly, the industry needs standards, both on image permanence and physical durability, as a commonly agreed method to assess the stability of various media. The standards need to be well documented, extensible, and data-driven; the data behind the standards needs to be based on scientifically sound principles. This is especially important as the need for image preservation grows, driving further the need to evaluate media stability and accurately assess tradeoffs. As mentioned previously, preservation requires good information on dark stability. This is more than just thermal stability, which has been the norm in the silver halide world, and includes gas pollutants and humidity as well. The ISO technical committee on photography is currently working on these standards to define methods for testing. Methods for predicting life estimates are also needed, however, and these must include the four environmental factors (those previously mentioned plus light), and they need to be relevant to the specific application and end user. As mentioned, tighter degradation criteria are needed for the application of preservation compared to consumer predictions. The longevity estimates included here are 50% tighter (allow for half the dye loss) than those generally in use for consumer longevity predictions, which are taken from the ANSI Illustrative criteria contained in the silver halide stability standard [7]. These tighter criteria would yield a net change that would be considered close to a just noticeable difference (JND). For this application, that level of change is about the maximum tolerable.

Conclusions – A call to action

Much work is being done in academia and in large institutions on the preservation of digital information and images. Concerns around long-term preservation have been recognized in these applications. As digital imaging grows into the mainstream consumer and professional photography space, more education is needed to make the consumer aware of the risks of image loss for not having an archiving and preservation plan. The initiative that was announced in 2007 by the International Imaging Industry Association on consumer photo preservation is a start to creating this awareness among retailers and the consumers [15]. The “SaveMyMemories.org” website, also launched in 2007, has received positive response, and similar websites are in place today. These efforts need support from the entire industry—this includes imaging manufacturers as well as museums and libraries—essentially any institution dealing with images. Creating the awareness will help create the demand for high-volume systems to address the need for image preservation.

This paper has reviewed both traditional (silver halide), and digital (inkjet, thermal) media for storage on both hardcopy prints and film. Electrophotographic media, such as that used for on-line generation of photo albums and scrapbooks also needs to be considered.

Recognition is also given to the fact that larger hybrids, as well as all-digital storage systems, are extremely important. All will play a large role in digital preservation depending on accessibility needs and cost constraints. Eastman Kodak Company has played, and will continue to play, a strong role in all of these applications, including entertainment, document, medical, and consumer imaging, but the industry, as a whole, needs to work together to make a viable long-term image preservation system a reality.

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Joseph LaBarca joined Eastman Kodak Company in 1976 with a Bachelor's of Science Degree in Chemical Engineering. He has spent the majority of his career in the research, development, and commercialization processes for Kodak Ektacolor papers and processing chemistry in both technical and leadership roles. This included extensive involvement in the stability of color papers beginning in the early 1980s and continuing through today. In 1997, Joe was appointed Senior Research Lab Manager in the Imaging Media and Materials organization of the Kodak Research Labs, directing a laboratory with systems responsibility for professional color negative films, papers, and display materials, and held this position through June of 2004. He is now Technical Director, Image Permanence in the Research Labs of the Consumer Digital Imaging Group with responsibilities that include silver halide, inkjet, thermal, and electrophotographic imaging systems. Joe is member of the American Institute for Conservation. Joe is also a member of the ISO Technical Committee on Photography and is directly involved in the ANSI/IT-9 and ISO Working Group 5 Committee on color print stability.