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ABSTRACT Film scanning and printing methods are investigated with respect to costs and quality, for a reassessment of the cost and performance trade-offs for the telecine conversion or high-resolution scanning of film, to investigate whether it is cost-effective, over a 20-year media life-cycle, to scan at sufficient resolution that the film originals may safely be discarded.

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1 SUMMARY

The high quality of film, which considerably exceeds current video broadcast and videotape quality, requires preservation at commensurate quality. Current technology for conversion of film directly to videotape (telecine) involves loss of quality, so archives keep the original film, and pay for repeated telecine conversions as videotape formats change. High-definition video offers a doubling in capture quality, the price for very high resolution scanning is dropping, scan speed is increasing, and related technology is emerging for the digital cinema and digital film production sectors. All this change requires a reassessment of the cost and performance trade-offs for the telecine conversion or high-resolution scanning of film, to investigate whether it is cost-effective, over a 20-year media life-cycle, to scan at sufficient resolution that the film originals may safely be discarded.

Film scanning and printing methods will be investigated with respect to costs and quality. This survey will include state of the art systems like Sony HD-Telecine, Philips Spirit, Cintel C-Reality, high resolution scanning/printing devices as well as new high-speed, high-resolution technologies.

2 CURRENT TECHNOLOGY FOR FILM PRESERVATION

2.1 Introduction

As cinema enters its Bi-centenary, thought naturally turns toward an examination of film's glorious first 100 years, the many achievements of this most popular of art forms, the growing importance of motion pictures in cultural history and, more sadly, the large portion of cinematic heritage that has already been lost due to age degradation.
For those of us who work in film, the unquestionable duty becomes ensuring that both archive and future film does not suffer this tragic fate and will forever remain a living part of our memory, secure for everyone’s education and enjoyment.
Barely thirty years ago, film preservation faced what appeared to be a hopeless crisis point. Motion picture studios, with a few exceptions, focused solely on current theatrical releases and saw little benefit in preserving their holdings, assessing their own film libraries as nothing more than "yesterday's films." Film archives, on the other hand, made valiant yet often futile efforts to fill the gap, but did not have either the sufficient funds to preserve their holdings, or the advanced technical techniques required to carry out a sufficient restoration program.
Today prospects seem much brighter. Beginning with the introduction of cable and satellite television, and the inevitable prospect of widespread digital transmission sometime in the near future, the demands and rewards have persuaded studios once more to preserve their films, or face the prospect of extinction and commercial irrelevance in these expanding markets.
Film preservation now stands on the verge of a new, more promising (digital ?) era. A once diffuse film community, plagued by duplication of effort, lack of communication, and occasional discord, has grown that much closer together. Sadly though it should be noted that some quite incredible facts remain. For example in the United States film market alone:

- Fewer than 20% of feature films from the 1920’s survive in complete form; for features of the 1910s, the survival rate falls to about 10%. Of films made before 1950, only about half survive.
- Films made after 1950 (on supposedly "safe" acetate film stock) face major preservation catastrophes from "colour fading," "vinegar syndrome" (an irreversible film base decay), dimensional stability and soundtrack deterioration.
- Many films can be found only in foreign archives.
- Funding for film preservation has fallen to half its 1980 level, when adjusted for inflation.

So the question is just what are we doing to save our film heritage for future generations? And how are we going about it?

The aims of this report will describe some of the methods that are currently being employed in the preservation of today’s film. But firstly, some background information is required as to why there is such an urgency in preserving our archive film material.
Films are ephemeral, fragile products. For the technical reasons outlined in the next section, even the most durable of films can become unusable in less than a single human lifespan, although some types have proven to deteriorate more rapidly and spectacularly than others. While preservation can be thought of as any effort to keep a film in a viewable form, most archivists consider a film preserved only when it is both viewable in its original format with its full visual and aural values retained, and secondly protected for the future by "preprint" material through which subsequent viewing copies can be created.
In practice and in casual language, preservation has usually been synonymous with duplication. The archival rallying slogan for the last two decades has been "Nitrate Won't Wait," and the primary preservation task has been to copy unstable, nitrate-base film without significant loss of quality onto more durable "safety" stock. For a variety of reasons, this definition of preservation is being rethought and broadened to include the costly issue of storage conditions. Preservation is increasingly being defined less as a one-time "fix” than as an ongoing process.
Related term’s need to be distinguished from preservation. "Restoration" goes beyond the physical copying of surviving material into re-construction of the most authentic version of a film. Ideally, this requires comparison of all surviving material on a given title, consultation of printed records of the production and exhibition history, and then decisions regarding the film's "original" state. Also distinguishable from preservation is "conservation," which requires no physical copying, only the decision to treat film material with greater care because of its perceived use as a future preservation source. Typically, a film which has been regarded as an access or "reference" copy becomes a conservation copy when it is suspected to be the best surviving material on that title.
In the widest sense, preservation is the assurance that a film will continue to exist in something close to its original form (and we should also encompass high resolution digital archives).

2.2 Technical reasons for preservation

As we have learnt film is a fragile medium, and motion pictures of all types are deteriorating faster than archives can preserve them using traditional methods. Preservation practices slow film's inevitable decay by environmentally controlled

storage and by copying endangered works onto more durable modern film stocks or onto a digital storage medium.
Fuelling the crisis is the deterioration of films from the last 50 or so years, films previously thought not-at-risk. Preservation efforts were once directed solely at copying nitrate- base film, an older, unstable film stock. "Safety film" replaced nitrate in the early 1950s, and now preservationists must deal with recently discovered problems of this less flammable substitute--the fading of colour film and "vinegar syndrome", an irreversible film base decay--in addition to the still-pressing task of nitrate conversion. Research is increasingly demonstrating the critical role of low humidity and low temperature storage in extending these precious films life and as technical expertise grows, better copies are being made from these older film materials.
Before turning to current preservation practices a few technical notes may be useful. Some of these facts relate to longstanding preservation problems, others have taken on new prominence. Physically, all motion picture film consists of two primary layers with a binder to hold them together: emulsions (which carry the image) and a transparent support base. Film preservation is necessary because of the very nature of these materials: emulsions fade, the binder breaks down, and the plastics of the support base decompose.

Film Bases

Historically, motion-picture bases have been of three main types: (1) cellulose nitrate (usually called simply nitrate), in commercial use through the early 1950s; (2) cellulose acetate (usually called acetate), available for some uses since the 1910s but widely employed only after 1950; and (3) polyester, available since the mid- 1950s and in wide use today. Both acetate and polyester are sometimes called "safety" film, in distinction from nitrate.

Nitrate base had certain excellent qualities, but its chemical composition destabilises over time. As it ages it has a tendency to shrink, to give off gasses that destroy the emulsion, and to become highly flammable at relatively low temperatures. Once a nitrate fire begins, it is nearly impossible to extinguish, since in burning it creates its own oxygen. It was a rash of fires in the late 1940s that led to the industry's conversion to triacetate safety film. More recently, large nitrate fires have occurred in the United States (notably at vaults of the National Archives in 1977 and 1978 and at the George Eastman House in 1978) and in foreign archives (most disastrously at Mexico's Cineteca Nacional in 1982, and at a warehouse for the Cinémathèque Française outside Paris in 1980).

The hazards of nitrate should not be minimised but it is also possible to exaggerate them. Under the right conditions, nitrate film can have a long useful life, as demonstrated by surviving 90-year-old examples, such as an original negative for *The Great Train Robbery* (1903). In some stages of decomposition, nitrate can ignite spontaneously, though not so easily as is sometimes feared. For many years nitrate was considered expendable after being copied onto safety stock, but increasingly archives are rethinking this policy. The chief reason for retaining usable nitrate is that it is closer to the original, often carrying a shimmering visual beauty lost in even the best new copies, whose emulsions are incapable of reproducing nitrate film's tonal qualities. The nitrate retained is then available for reuse as duplication or storage technology improves, as well as for colour-tinting records and for special public screenings. It is also increasingly expensive to dispose of nitrate in a way that meets safety, environmental and health standards.

Acetate-based film solved the fire hazard and was long considered an ideal preservation material. Kept properly stored, it may still be that. But the discovery in the 1980s of what is popularly called "vinegar syndrome," from the acetic acid smell given off when acetate base begins to decay, is currently giving film preservationists serious pause. There is increasing scientific evidence that, kept under identical conditions, acetate film decays at approximately the same rate as nitrate, though with nothing of nitrate's volatility. This is not illogical: Both are cellulose plastics and apparently deteriorate at similar speed. The later stages of acetate decay do not destroy emulsions in the same way as does nitrate but nevertheless renders the film unusable.

One basic archival principle is that preservation is not accomplished unless the new medium has a considerably longer life than the original from which it is copied. On the surface, continued copying onto acetate base would seem to violate that principle. But there are two reasons to qualify such a conclusion: First, the original nitrate prints are older and usually well into its decomposition cycle; and, second, the new acetate print can be given proper storage right from the start. Thus vinegar syndrome has not been detected in films duplicated under archival conditions and put into ideal storage immediately. The implications of vinegar syndrome in acetate have not yet been fully assimilated into preservation practice, but scientific research into its causes has also been accompanied by compelling evidence that it can be delayed by proper storage.

Polyester base’s seem to promise a significantly longer life span than acetate, although archivists have been reluctant to embrace it. Only after the evidence of vinegar syndrome in acetate was there much renewed consideration of polyester, especially because, at least in its early manufacture, it showed problems with the binder separating from the emulsion, leading to loss of the image. It should be noted however that polyester is now days much more stable and generally used for release print copies.

Emulsions and colour fading

One other current preservation concern rivals that of uncopied nitrate in significance: the fading of the colour dyes in "dye-coupler" films-- better known as "Eastmancolor"-- which won over the industry in the early 1950s. It is the least quantifiable, least easily solvable, and probably most expensive of current preservation problems. Among theatrical prints and home movies of the 1950s through the 1970s, the problem is often painfully obvious in colour images that have turned a low-contrast brownish pink. The technical irony is that earlier colour prints--in the "Technicolor" process--have essentially retained their original hues, though of course those before 1950 are on unstable nitrate base. This problem with colour emulsions parallels that facing libraries in the preservation of twentieth-century books on acetic paper, which deteriorates much more rapidly than older papers. In both cases new technology created a less expensive product--and a nightmare for the future.

The Technicolor system differed from Eastmancolor at both the negative and the print stages. To produce its negatives, the bulky "three-strip" Technicolor camera (in use from 1933 through the early 1950s) filtered the visible light spectrum to capture the blue, red, and green portions on three separate black-and-white negatives, not subject to fading because they involved no colour dyes. (A two-strip Technicolor system, in use from 1922 to 1933, functioned similarly but caught less of the full spectrum.) Eastmancolor's supreme commercial advantage came in producing a "monopack" multilayer emulsion that captured colour on a single negative, although the complex chemistry that allowed for this also made the vegetable dyes, when "coupled" in developing, unstable. Technicolor release prints for theatres--known also as "imbibition" or "dye-transfer" prints--were created by the transfer of previously manufactured coal tar dyes onto blank film through matrices, in a way roughly comparable to printing with inks on paper. In Eastmancolor's dye-coupler prints, the dyes are created, as they are in the negative, through a chemical processing that again leaves certain colours unstable.

There are several complications about the relationship of colour fading in negatives and in release prints that are worth mentioning. Technicolor prints continued to be made until 1974 or for twenty years after the Technicolor negative process was abandoned (the three matrices necessary for prints being created by filters from the single dye-coupler negative). Thus it is possible for the colour in Technicolor projection prints to look superb even while the original negative is in danger. Contrarily, it is common for dye- coupler prints to fade to that dull purple even while preprint material exists that allows for the striking of excellent new prints. There remains, however, dispute about the state of the original studio negatives from this era and of preprint backup material made from those negatives. (Although the fading rate is slower in some preprint material, restoration expert Robert Harris in his submission claims that "we have lost the original negatives to almost every [colour] film of the 50s into the 60s.") Undoubtedly there is great variation in the rate of fading depending upon when the original stock was manufactured and the quality of the original processing.

Over the last two decades, the Eastman Kodak Company has introduced a number of lower-fading preprint and print stocks. If Kodak's lower-fading stocks were long ignored by the industry, it was essentially for economic reasons (the low-fade stocks of the late 1970s cost about 10% more).

Despite a few imaginative experiments, there remains only one proven method to prevent colour fading: through what are known as "separations." In this widely used process, colour film is copied through red, blue, and green filters to create three separate black- and-white records (roughly equivalent to what the Technicolor process created in the camera), each of which holds one of the three colour records and which cannot fade because no dyes are involved. In theory, it is then a simple matter to recreate the colour by combining the separations. In practice, there have been frequent problems, especially since most separations are not tested at the time of their creation to see if they can be recombined. Such a full testing would essentially double the initial cost of making separations, currently running at least £20,000 for two-hour feature. Even if tested, separations can develop their own preservation problems; shrinkage differences among the three rolls can prevent their alignment, creating a hazy, unfocused image in the new colour print.
Only one other method is known to reduce, if not completely prevent, colour fading cold-and-dry storage.

2.3 Storage.

Several of the technical matters described above--especially vinegar syndrome, colour fading, and the retention of nitrate after copying--have conspired to give a new prominence in current preservation practice to storage conditions. The combined effect of lowered temperatures and lowered relative humidity in retarding both vinegar syndrome and colour fading is startling and increasingly well documented. The one encouraging finding about these deterioration processes is how significantly both can be slowed by the right storage conditions.

The variations are complicated, but to take one example, the lowering of storage temperatures by 20 degrees Fahrenheit, from 80 degrees to 60 degrees, while lowering relative humidity by 20 percent, from 65% to 45%, delays the onset of vinegar syndrome from approximately 15 years after film stock manufacture to 100 years.

The effect of storage conditions on colour fading is less easy to quantify because fading depends so much on the initial stock and processing quality, but the effect of cold-and-dry storage on relative rates of fading are equally dramatic. For instance, by lowering temperature from 75 degrees F to 45 degrees, the colour fading that would have occurred in 10 years will take 100 years.

For such reasons too, recommended storage temperatures and relative humidities from the national organisations ANSI (American National Standards Institute) and SMPTE (Society of Motion Picture and Television Engineers) have been lowered in the last few years. SMPTE's pending proposal for "extended term" storage of colour prints suggests a maximum of 35 degrees F and of 20-30% relative humidity and of black-and-white prints a maximum of 70 degrees F and 20-30% RH. For public archives particularly these are difficult and expensive proposals. In its 1986 survey of public collections, the National Center for Film and Video Preservation found only 11 of the 28 responding institutions able to maintain their safety film at temperatures of less than 61 degrees F, and only 8 institutions could maintain a relative humidity of 45% or less. Still, since any lowering of temperature and humidity has major impact on film longevity, the SMPTE storage proposals can be thought of as goals. In practical terms, it has proven easier and cheaper to lower temperature than to lower humidity.

As well as these technical issues we should also consider the cost of film storage held in modern archives today. In the main film is stored in film cans and naturally a 5 or 6 reel feature occupies a certain amount of space within the vault. Prices vary from archive to archive but generally a storage charge of between 20 to 50 pence per item per month would be a ballpark figure. It should be noted that a “nitrate” surcharge of anything up to 100% might be added where specialist arrangements are required. Add to this “hidden” movement charges of up to as much as £50 a feature and very soon film storage becomes an expensive proposition.

3 TRADITIONAL METHODS OF PRESERVATION

As we have seen there are many factors to consider which will affect the physical transport of film but just how do laboratories deal with some of these issues using traditional methods of restoration? What other problems are typically encountered by film technicians today? And what are some of the costs involved?

3.1 Film Inspection.

This is the first stage in any laboratory process and this can be both time consuming and expensive. Early damage diagnosis can also be advantageous in making decisions about repairing the film using traditional laboratory techniques or digital restoration techniques in the case of “unsalvageable” film. Typically a laboratory will charge anything between £20-£50 per reel of film although for nitrate material there may also be a surcharge.

3.2 Film Damage.

There are many different types of film damage some of which are repaired relatively easily and cheaply using traditional laboratory techniques others may require re-printing or re-washing material. In some cases however it is virtually impossible to restore badly damaged or “missing” footage and this is perhaps where digital techniques for restoration are most prevalent.
The following is a list of some of the more common problems that laboratories are likely to encounter:

Abrasion and Scratching. Where film base scratches exist wet gate printing technology is used to minimise or eliminate their effect however in the case of emulsion scratches it is virtually impossible to artificially “hide” them. Another method which can be employed in the treatment of scratches is by coating the film using high resistance coatings such as 3M’s PHOTOGARD which is a polymer coating that is cured by ultraviolet light. Although this treatment appears advantageous toward film protection serious doubts have been raised as to the long term effect as the film ages. The fact that this treatment is actually a coating that encases the film raises serious questions as to how much of the acid gases that triacetate base material naturally releases is trapped within the molecular structure of the base and how this reacts over a period of time. The cost of PHOTOGARD treatment can also be expensive at around 35p per foot.
Certainly where extreme emulsion scratching is evident the most efficient method of eliminating this type of damage would seem to be by using digital re-touching technology.

Perforation damage or edge repair. Fairly easily repaired by the laboratory using edge repair or splicing tape although an inspection and treatment charge of approximately £14 per 1000 foot roll would be charged.

Breaks. Are generally impossible to repair invisibly and in the main a reprint section would be required if master material is available. A duplicate negative would be required for this purpose and this would normally require an intermediate stage to be printed first hand. Intermediates and duplicate negatives are charged at around £1per foot for a wet-gate copy but a minimum footage (of approximately 200 feet) would normally have to be printed.

Surface contamination. Film naturally becomes physically contaminated by mishandling and lack of cleanliness in the work area substances such as glue, oil and water will permanently disfigure either the emulsion or the film base. Again, if master material is unavailable for reprinting the only sure method of reparation is within the realms of the digital lab.

Colour shift. This is perhaps one area where there has been some recent success using traditional laboratory techniques. Cinetech's RCI (restored colour image) process has seen a photochemical technique where by the film is said to restore the film back to its original hue, saturation and contrast. It is intimated that currently this process is some 75% cheaper than restoring similar damage using digital re-colouring techniques.

Creasing. Generally repaired using traditional laboratory methods.

Blistering. Where the film has seen some form of heat damage causing the emulsion to separate from the surface of the film base. Again, unless master material is available from which to strike a replacement the easiest form of repair is by using digital painting.

Sprocket damage. Similar to scratching sprocket damage shows more on the emulsion side of the film than on the base. Naturally, this can be replaced using a duplicate negative although again if one is not able to replace the damage because of unavailable material then digital restoration is the most logical form repair.

Shrinkage. Film shrinkage cannot be fully recovered. Because perforations are evenly spaced along the edge of the film, any change in pitch will cause transport problems. Polyester stocks are generally less susceptible to shrinkage however in nitrate stocks shrinkage is extremely common and the only efficient way to deal with this issue is by copying the material to a "safety stock". Generally, this is done using optical printing techniques.

Emulsion contamination. Like any other organic material film can suffer greatly from micro-organisms such as mould or fungus. Generally, this is common with film that has been stored for long periods at humidities above 60%. Although it might be possible to remove this type of damage by film cleaning this type of deterioration can damage the material to the point of uselessness. Unless a duplicate can replace material, then again digital techniques would be required to repair any damage.

3.3 Methods of counteracting deterioration

Common Repairs. Traditionally the most common approach to repair is good cleaning followed by careful splicing. Let us look at some aspects of the latter.

Replacement Footage. Removing damaged footage from a film without replacing it often involves an aesthetic decision, simply extracting damaged footage may have noticeable consequences to the story or other key phrases may never be known. Sections that are seriously damaged must be removed or replaced. Any removal of film can be a crucial loss and it is far better to avoid the need to remove any footage by careful maintenance and storage.

Nevertheless, we will find times when footage must be removed or replaced because it is truly distracting or because the damage is such that it may lead to further damage.

Before removing that section, consider the effects on the continuity and the future uses of the film.
Most laboratories are able to replace footage at a relatively modest cost, but there are minimum footage orders. In addition, delivery time may not be very timely. Before ordering replacement film, consider the physical quality of your film. Is it worth replacement footage in terms of its abrasion, colour quality, number of splices etc?

Perforation Repair Tape. Perforation repair tape, a thin, narrow and very flexible strips of polyester base adhesive tape with perforations identical to those of the film. When applied over damaged perforations with a specially designed machine, the tape makes a strong bond, which is quite resistant to cleaning solvents and temporary high temperatures.

Splicing. You can replace buckled and misaligned splices with new splices. In addition, you can ruin film by poor splicing. Splices that are wide, stiff, buckled, or out of alignment can cause the film to jump projector or printer sprockets and tear the perforations or break the film. Perforations next to these splices are generally subject to strain and eventual breakage. Any long sections of a print that are structurally damaged or show heavy abrasion should be repaired or replaced using splicing methods. Again splicing tapes are usually in the form of a strong adhesive polyester strip which will “cover” two frames (in the case of 35mm film) to aid the invisibility of the join.
Other forms of slicing are by using an ultrasonic joiner, which literally fuses the film together or a cement joiner that uses specially designed glue for joining “cut” film.

Solvent film Cleaning. Film cleaning is concerned with the removal of dust and other loose particles, gritty dirt or oil’s. All of these anomalies lead to minor film base scratches or visual artefacts. There are some relatively simple cleaning devices that can do this job adequately, but, for occasional cleaning, many choose the simplicity of chemically moistened, soft, lint free pad. These wet cleaners lessen the chance of abrasion from gritty dirt particles that build up on a dry cloth during the cleaning process.

Another form of cleaning is by using continuous ultrasonic liquid devices that use hazardous and flammable chemicals and environmental controls are now limiting their use. The material cost for cleaning an average release print is quite reasonable. However, considerable time may be spent if the rewind cleaning method is used.

Non-solvent cleaning. A dry method of cleaning incorporates a specially developed material that picks up dirt, dust, hair, and other unwanted particles from the film by contact with one or more Particle Transfer Rollers (PTR). The PTR is made from inert polyurethane with no adhesives, silicones, or leachable plasticisers and is environmentally sound, unlike the liquids. It has a 95 percent average cleaning efficiency and has become increasingly widespread with film laboratories.

Cloth/Solvent Sandwich. A method where by the film is drawn through a sandwich of lint free cloth that has been soaked in a solvent at a speed that is slow enough to allow the cleaner to evaporate before the film reaches the take up reel.
Winding up wet film can cause spots and blotches. Plastic or rubber gloves are worn to protect hands against the solvent's ability to draw the natural oil from the skin.
Lubrication. Motion-picture films destined for projection does require some level of lubrication. Most laboratories do apply a lubricant where necessary. Theatrical 35-mm

release prints require considerably higher levels of lubrication to provide longer lasting trouble-free performance during projection nuns.

4 THE TECHNOLOGY AVAILABLE FOR RESTORATION

4.1 Printing

In general, the bulk of film preservation and restoration will at some stage require the use of some form of printing or reprinting equipment. Coupled with this is a need to ensure that when material is re-printed that it “matches” in with any original film footage. In this section, we will take a closer look at what is currently available to laboratory technicians in the area of printing, and how they are able to ensure that they produce accurate results.

It is difficult to estimate the costs of such operations in general terms but typically, a 35mm intermediate from a separation master might be in the region of £5 per foot. For more general optical intermediates, the cost would be less, somewhere around £3 per foot although there are surcharges for “nitrate” handling and a minimum charge of £100 for each separate item. Printing a feature from YCM separation masters tends to be more expensive depending on the total footage although somewhere in the region of £13,000-£18,000 would be “usual”.

Wet-gate printing tends to cost less and typical charges for a wet-gate intermediate would be £1 per foot for an internegative/positive again with a minimum order of 200 feet.

Step-contact printing. Step-contact printers advance both negative and print films through the printer gate with an intermittent motion, and shutter similar to that of a camera. Close-fitting register pins position the two films with extreme accuracy during exposure and a pressure plate at the printing gate assures film flatness. Because of the complexity of the machine and the precision of film registration achieved, the speed of a step-contact printer is relatively low. Step contact printers are precision instruments used for making colour separations and effects printing that may require several passes of the raw stock through the.

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Step-Optical Printer. The step-optical printer combines the precision of a step-contact printer with optical flexibility Like the step-contact, the step-optical printer finds its main use in the production of intermediates and effects work.

Whenever the image size of the print is different from that of the original or certain special effects are desired, an optical printer is used. The optical printer can be thought of as a projector on one side and a camera on the other. The image produced by the projector is focused at the plane of the film in the camera gate. Optical printers can be quite complex, providing such effects as blowups, reductions, skip frames, anamorphic compression, zooms, mattes, etc.

Continuous-Optical Printer. These printers are used for high-volume reduction printing. Like a continuous-contact printer, the exposure is made through an aperture, thus necessitating exactly matched relative film speeds. This is obtained by mounting both the sprocket driving the original Film and the one for the print film on the same shaft. The different diameters of the two sprockets provide the proper film speed ratio. The light path from original to print is U-shaped as a result of using the same shaft to drive both films. The addition of image-dividing lenses or prisms permits multirank printing.

Wet-Gate Printing. One of the most troublesome problems encountered by motion picture laboratory personnel are scratches (digs, abrasions, cinch marks, etc These scratches print through to the release print and degrade the quality of the projected picture by introducing image elements that have no relationship to the originally photographed scene.

Error! Not a valid filename.Error! Not a valid filename.A scratch on the support of a negative film acts as a diffuser that scatters light. Light from the printer passes in straight lines through the undamaged portion of the support and emulsion of the original. When light strikes the scratch, it is scattered and displaced from the straight-line path, reducing the light on the receiving emulsion. Scratches on the support of a negative film printed onto positive film usually produce more objectionable effects on the screen than scratches on reversal originals printed onto reversal print films. This is because scratches on the support of negative films appear white on the positive film and are generally of lower density than any other white in the picture. In reversal printing, scratches on the support of the original appear black on the screen print and generally tend to blend in better with the picture. Scratches on the emulsion side of negative films present another situation. Shallow emulsion scratches on a black-and-white negative will appear white on the positive film. Emulsion scratches that penetrate to the support on a black-and-white negative will print black. Scratches on the emulsion side of colour negative films may appear coloured on the print, depending upon how deep the scratch is and whether image-bearing layers have been disturbed. When base scratches exist, a "wet" or "liquid" gate is used to minimise or eliminate their effect, depending on severity In a wet gate, liquid having a refractive index close to that of the film base is applied to the original. The liquid fills in the scratches and reduces the light

5 DIGITAL FILM PRESERVATION

5.1 Introduction.

Traditionally, when we speak of "restoration" in a preservation context, we refer to the activity of bringing together all of the images present in what is considered to be the original state of the film, at the highest fidelity to the original, replacing damaged, technically inferior or inconsistent sections with material from a superior source in another element.
These changes in the original version occur not only through physical deterioration or mishandling, but also through loss of elements, replacement of missing or damaged footage from a superior, comparison of different versions, etc.
Reconstruction of a film in the “electronic “sense operates at a micro-level, by using highly technical devices to adjust characteristics within the individual frame at the level of the grain structure of the image, the restoration of lost colour, or reconfiguration of a frame that has been subjected to gross damage. Although some of these technical operations have photographic correlatives, they are optimally performed in a digital (electronic) mode rather than an analogue (photographic) mode.

Photographic solutions to problems such as negative dirt, colour fading, deep abrasions and other forms of overt physical damage to the emulsion usually consist of processes which mask or render transparent these aspects of the image in the transfer process. Digital solutions approach the problem by essentially electronically painting the problem out of the image and if necessary, replacing lost picture information from data resources in other parts of the image or from surrounding frames.

Electronic processes such as scratch removal and negative dirt extraction ("dust-busting"), grain and noise reduction are approximations, processes designed to replace "noise" or non-signal information to an image which has been altered physically over the course of time.

Many of these processes are additive in so far as they attempt to replace information that has been lost because of damage or degradation. This is the case where a program isolates a spot that it identifies as negative dirt and replaces that spot with an average of the colour of the surrounding pixels. Although this processing yields an image that is subjectively superior, the process exceeds the bounds of strict duplication. Moreover, because of the nature of the photographic image, the computer assessment of true information requires human verification and intervention. It is entirely possible for such programs to remove valid pictorial information if they are not properly deployed.

Some processes, such as the "restoration" of colour depends upon a mathematical assessment of the differential between the current state of an image and its original colour content. This type of reconstruction consists primarily of extrapolation, of taking a faded image back to its original state in a digital environment, based on an understanding of the rates of colour loss in each layer of the film, and then rendering the image again on film. It is intended to be transparent, and capable of rendering without subjective distortions the original state of the colour information of the film. In essence, this type of restoration works with data resources that still exist within the image to re-establish the prior state of the image. The set-up and oversight of the digital restoration process always requires human intervention, but digital tools can be generally divided between those that are subjectively and those that are primarily applied by the computer programming.

The more individual decisions about the look of the images, the more human intervention will be required.

The current capabilities of electronic imaging have attained a stage where digital technology can now solve some of the problems that are impossible to solve in the domain of film. Particularly in the area of severe damage, digital reconstruction can accomplish work not possible in the photographic realm. Certain printing defects such as incorrect framing are relatively trivial to correct digitally. Intermittent problems involving flicker, fading or discoloration can also be corrected using various digital techniques, especially when there is ample picture information available in surrounding frames to extrapolate the original condition of the imperfect frames. Embedded negative dirt and abrasion’s can be effectively removed, although, this work begins to approach the limits of acceptability, because these techniques are based on excising damage artefacts from the image and then synthesising the image area to be reconstructed from surrounding picture information. When the damage occurs in areas of complete dark or light, or areas with a consistent and replicable pattern, such synthetic re-constructions can be made virtually invisible. However, physical damage in areas of complex and redundant image data is difficult to restore. In addition, problems such as the accretion of contrast, characteristic of multi-generation photographic duplication, cannot be reconstructed easily by digital (or photographic) methods. Continuing research into factors which produce image and support degradation is refining our concepts of long-term conservation and storage technologies. Digital restoration should not be considered as an alternative to the traditional methods of film preservation. But digital techniques, in conjunction with high quality laboratory work, allow us to enhance the quality of the preservation work we are doing in the practical sense as we inherit materials which have already sustained damage, contamination, fading and deterioration.

5.2 The problem of digital change and user expectations:

Digital technology and high speed networks are leading to sweeping changes throughout society, and moving image production and distribution are in no way immune to either the technological changes nor to the social expectations that these changes have induced. Thus far, the most far-reaching changes in production have been felt in the arena of special effects. For years, most special effects have been done digitally. In the past the completed digital effects were transferred back onto film and intercut with the rest of a production, but as general moving image production itself becomes increasingly digital, this intermediary transfer to film will become far less common. The digital impact is likely to promote widespread changes within the moving image archival community also. The increasing amount of material originating in digital form (some of which may never be transferred to film or video), the release of moving image products that contain a variety of ancillary material, the increased focus on fragments that need to be easily found and that sometimes may be repurposed and reused in multiple digital products -- all these elements imply significant changes in practices for moving image archives.

Technological developments have led to a large number of users no longer being satisfied with merely viewing end products. The high demand for additional content implies that some organisation needs to supply the ancillary material that helps context the finished product. Interviews, scripts, correspondence, sketches of sets, special effects, out-takes, and even moving images of initial casting calls are all valuable assets that surround a completed work. In the past, only a limited number of this type of material was saved, and often it was saved outside the moving image archive (in records management units, print archives, or special collection libraries). In the future, as new digital products and services emerge, there will be increasing pressure to minimise the dispersal of these assets. In addition, moving image archivists who do not move quickly to widen their areas of responsibility may soon find themselves marginalised and subordinated to digital asset managers.
Archivists need to shift from a paradigm centred on saving a completed work to a new paradigm of saving a wide body of material that contextualises a work. They also need to proactively seek out material (particularly moving image material) that may today be routinely be thrown away, but in the future may prove historically and/or commercially valuable. And they need to fulfil their traditional role of making sure that this material will persist over time.

Archivist involvement in the stages before the final cut implies new skillsets. Ingesting out-takes means developing new skills for organising and managing this type of material. In addition, doing a good job of managing special effects data implies understanding how to keep software files accessible over time. Preserving special effects files may prove to be critically important. Several decades from now, a person looking back on a film like *The Matrix* will be far less interested in the film as a whole, and much more interested in the special effects and how they were done. Access to the special effects data files is likely to be valuable in understanding the historical development of moving image material, and the final cut on film reveals little of the ground-breaking processes involved.

As we have seen with both the World-wide Web and DVD’s, there is increasing demand to view material in fragments. This type of fragmented use is a perfect complement to a post-modern era, where cultural elements are repeatedly re-contextualised. Promotional units within a studio, advertisers, production companies, and end users all periodically request to see and/or use a particular clip. This implies an increasing need for access at lower levels of granularity than a completed work. Moving image archivists need to prepare themselves for requests at this lower level of granularity, and would do well to follow some of the literature on methods for finding clips that do not rely upon human labour to catalogue and index all the sub-parts of a work.

Archivists shifting to articulate an asset management approach can have strategic advantages. Some of the greatest influx of money for preservation in the past 20 years emerged when studios realised that there was an after-market for older films. Today we are living in an age where content repurposing is a driving economic force, and there is high expectation that any given media asset will be used in a variety of secondary multimedia products (from a clip on the Web, to incorporation within a video game, to a variety of DVDs and CD-ROMs, to even including clips of one film within a subsequent film. Perceptive administrators recognise that today's capital investment in adequately preserving and indexing media assets can pay off in long-term repeated use and re-use.

Still, the shift from managing completed works as a whole to managing a range of assets will be a profound one. Moreover, much of this shift requires background and knowledge about how to make digital files persist over time.

5.3 Problems with Preserving Digital film

Information encoded and stored in digital form is fragile, but in different ways than film stock. Though digital storage shares some characteristics with video storage, there are differences here as well. Below we will outline several special problems with preserving works in a digital form. Digital storage, like video storage, requires periodic refreshing because the physical storage stratum decays. Digital storage offers the illusion that preservation is not a problem, because, unlike analogue storage formats (such as film and video), a digital copy is ostensibly an exact replica of what was copied (whereas each copy of a film or video loses quality from that of the previous copy).

Though digital refreshing is itself near-loss transparent, work stored in digital forms raise enormous other preservation problems. Chief among these is the problem of rapidly changing file formats -- files encoded in AVI or MPEG-1 or the various flavours of MPEG-2 can be periodically refreshed onto new physical strata, but it is highly unlikely that those formats will be viewable a decade from now. To understand this problem, we need only to turn to recent experience with much simpler word processing documents. Word processing files (which are primarily ASCII text, and thus much simpler formats than moving or even still images) are generally readable for half a dozen years after they are created. However, even these word processing formats become inaccessible after a dozen years. Fifteen years ago WordStar had (by far) the largest market penetration of any word processing program. However, few people today can read any of the many millions of WordStar files, even when those have been transferred onto contemporary computer hard disks. Even today's popular word processing applications (such as Microsoft Word) typically cannot view files created any further back than two previous versions of the same application (and sometimes these still lose important formatting). Image and multimedia formats, lacking an underlying basis of ASCII text, pose much greater obsolescence problems, as each format chooses to code image, sound, or control (synching) representation in a different way.

Elsewhere other digital longevity problems such as "the translation problem," "the custodial problem," "the scrambling problem," and "the inter-relational problem." In addition, these problems apply to electronic art .All of these are relevant to digital preservation of moving image material. Particularly notable are "the custodial problem " and "the translation problem."

"The custodial problem" focuses upon who should be in charge of making something persist over time. Though we have developed traditions of which organisations (and who within a given organisation) should take responsibility for preserving and maintaining various types of analogue material (film, video, stills, correspondence, manuscripts, printed matter), no such traditions exist yet for digital material. As a result of this, much current material originating in digital form falls through the cracks, and is unlikely to be accessible to future generations.
For example, print archivists and special collections librarians who aggressively pursue print-based collection development in their particular speciality areas rely on

the responsibility of their computing staff to pursue collection development of material originating in digital form. Yet, those computing staff claim that it should be the subject matter for film specialists to pursue collection development of digital materials. Meanwhile, much of this fragile material is not collected at all.
Many moving image archivists feel they have neither the resources nor the technical knowledge to take charge of digital files of moving image materials. They have no money for file-servers and no idea of how to develop a long-term digital migration strategy. So digital moving image files end up either not being collected at all, or they become the responsibility of a department that has not been trained in archival and preservation practices (such as an information technology department or a digital asset management department).

Though at present resource allocation and technological skills may force the handling of digital material into another department, this is a dangerous long-term strategy. Archivists have well-developed training and skills for handling moving image materials, and these skills are seldom found in staff from other departments. As costs for handling digital materials diminish and as strategies for long-term maintenance of digital files become better known, reasons for handling digital material separately will start to fade, and administrators will begin to realise that digital files of moving images have much more in common with film and video than with word-processing files and databases. At some point, the idea of handling digital moving image files in a separate department will sound as old-fashioned as establishing separate departments for 16mm, 35mm, and cinemascope film formats.

A number of experiments are underway to explore strategies for maintaining digital content over time. We still need to develop guidelines and best practices so that organisations and individuals who want to make the effort to try to make digital information persist will know how to do so.
An important function of archives is in ensuring the authenticity of a work. Print archives do this by amassing "evidence" and by maintaining a "chain of custody". Film archives follow a variation of this through strategies like identifying the release negative. However, when works are subject to repeated acts of "refreshing" as most approaches to digital longevity propose, these traditional ways of ensuring authenticity break down. Files repeatedly copied to new strata face the likelihood that changes will be introduced into these files, and we know little about how to control mutability across repeated "refreshments". This set of problems constitutes "the custodial problem."

Another important issue is how a work translated into new delivery devices changes meaning ("the translation problem"). While a lay person may occasionally confuse the two, people in the cultural community are clear that a photograph or poster of an oil painting is definitely different than the painting itself, and that a video of a motion picture film is not the same as the film. We clearly understand that a reproduction of a work (particularly changing into another format) may convey certain characteristics of that work, but is dramatically different from that work. The faithfulness of the photographic reproduction processes has raised questions about differences between originals and reproductions particularly of photographs. But those of us in the cultural community still recognise that a digitised photograph displayed on a screen is quite different from the paper-based photograph it was digitised from, or that a motion picture film converted and shown on a video screen is quite different from the original film.
Today, electronic moving image works (both video and digital) are displayed on cathode-ray tube screens (CRTs). With the advent of liquid crystal and other flat-panel

display units, a decade from now CRT screens may be as rare as black and white monitors are today. In addition, fifty years from now it is unlikely that one would be able to even find a working CRT screen. For some electronic works (certainly for artistic ones that concern themselves with the "look" of a CRT), attempting to display that work on a flat-panel screen would result in something that the creator would regard as poor reproduction of his or her work (perhaps akin to a photograph of an oil painting).

Computer-based moving image works are often designed for particular screen dimensions. As screen resolutions get higher, these older works end up looking smaller and smaller on contemporary screens. (For example, a work created to fill a 640X480 screen would take up about 1/3 of a contemporary 1024X768 screen.) This raises issues of how best to display older digital works on newer digital screens. Though there are certainly parallels between this problem and those experienced by film archives wanting to display older films with proper lenses, in appropriate aspect ratios and original frame rates, digital works convey the illusion that one merely needs to play them and they will be displayed appropriately. With traditional media, the separation between the work (stored on film or video) and the display device is clear; with digital media the public often does not understand the separation between the stored work and the display device (particularly since the stored work may be repeatedly copied from device to device or even streamed).

5.4 Approaches to Digital Preservation

During the mid 90's the archive community began to worry about the fragility of works stored in digital form. The Commission on Preservation and Access and the Research Libraries Group formed a task force to explore how significant this problem really was. The Task Force report sounded an alarm "Rapid changes in the means of recording information, in the formats for storage, and in the technologies for use threaten to render the life of information in the digital age rather short. As the problem of digital longevity had repercussions within the arts community as well, the Getty Conservation Institute and Getty Information Institute collaborated with leading technologists to put together a conference and book trying to broadly outline and bring attention to the problem. Both of these works identified the depth of the digital longevity problem but only pointed out very general approaches that might possibly lead to solutions.

The concept of *Refreshing* involves periodically moving a file from one physical storage medium to another to avoid the physical decay or the obsolescence of that medium. Because physical storage devices decay, and because technological changes make older storage devices inaccessible to new computers, some ongoing form of refreshing is likely to be necessary for many years to come. Besides raising the issue of assuring authenticity, this suggested approach ignores the even more substantial problem of constantly changing file formats.

Two approaches have been proposed to deal with the problem of changing file formats): ***migration*** and ***emulation*****.** These are seen as alternatives to one another, but both approaches are supposed to be used in conjunction with ***refreshing*****.**

Migration is an approach that involves periodically moving files from one file encoding format to another that is useable in a more modern computing environment. (An example would be moving a WordStar file to WordPerfect, then to Word 3.0, then to

Word 5.0, then to Word 97.) Migration seeks to limit the problem of files encoded in a variety of file formats that have existed over time by gradually bringing all former formats into a limited number of contemporary formats.
Emulation seeks to solve a similar problem that migration addresses, but its approach is to focus on the applications software rather than on the files containing information. Emulation backers want to build software that mimics every type of application that has ever been written for every type of file format, and make them run on whatever the current computing environment is.

5.5 Escaping artefact-based approaches

The conventional paradigm that has shaped all types of conservation efforts for centuries is focused on "preserving the artefact." Though moving image archivists are much more aware of the limitations of this paradigm (having dealt with reformatting of nitrate and Eastmancolor) than conservationists in charge of other formats, the field still focuses on saving "original" artefacts like negatives and release prints. However, in a digital world, the concept of saving an original artefact carries little meaning. First of all it is unlikely that there is a single original; there will be at least several copies that are absolutely identical (back-up copies, copies stored offsite, etc.). And, unlike film or video where copies lack some of the pristine qualities of originals, a digital copy is indistinguishable from the digital work that was copied. And as we have seen earlier, any digital work will have to be copied and "refreshed" on a periodic basis.

A digital archivist needs to move away from an artefact-based approach and instead adopt an approach that focuses on stewardship of disembodied digital information. This requires some knowledge about strategies for making digital content persist (such as refreshing, migration and emulation). It also requires honing skills to determine the definitive version of the work to be saved. In a digital environment, the concept of a "master" is likely to be more useful than the concept of an "original". Unlike the word "original", "master" does not necessarily convey physical embodiment. Nevertheless, it does convey the idea that this is the definitive version of a work, though not in such strong terms that it prevents the possibility of multiple variant forms.

The moving image material of the future will resist any attempts to try to put it back onto a linear medium like film or video. We are already seeing multimedia creations complete with moving images, still images, and audio files. We have DVD's with various levels of navigation and degrees of interactivity. In addition, we even have works that are designed to periodically change their attributes (somewhat analogous to various cuts of a single film). This type of material just cannot be effectively put back onto a linear medium. And the plethora of media types and file formats pose serious problems for maintaining such a work over time. Once digital archivists have shifted their conceptual framework to focus on preserving disembodied masters, the question remains of how best to do that. Moving image archivists can learn from other fields, such as conservators of electronic art, who have begun meeting regularly to share approaches and best practices, as well as to develop some generally agreed-upon standards.

Embracing the essential approaches of refreshing and either migration or emulation will go a long way towards ensuring digital longevity. But the file format problem can best be approached by minimising the number of file formats and standardising on a limited number of file formats, amongst the large number of formats currently used for moving images, sound, still images, synching, and special effects. Because formats for storing works are rapidly changing and outdated, custodians of these works may need to involve themselves in standardisation processes. Encoding files and records in widely-adopted standard formats acts as a hedge against rapidly changing software -- the more people who are using a standard for encoding, the more likely that new formats will recognise that encoding standard. A variety of standards may be useful for moving image materials.

High-order multimedia encoding standards (like MPEG-4) may make moving image material less fragile and subject to changes in application software such as Director, Acrobat, and Flash. Moreover, capturing and encoding post-production information such as Edit Decision Lists (EDL) can be critical for future viewing of today's moving image materials. The moving image archivist community needs to involve itself in the standardisation process for these high-level encoding standards and make sure that they incorporate the features future users will need. And these same archivists need to press the production community to use more standardised formats and to hand over more material than final polished productions. Groups like the Los Angeles area moving image archivists and AMIA are may be effective places for this effort to begin.

5.6 Conclusion:

Digital encoding is not "just another new format" for moving image archivists to handle. Though many traditional archivist skills can be applied to the new digital material (which is why this material should be handled by archivists rather than technologists). Digital works force a new paradigm of preserving disembodied content, and making sure that that content will be viewable far into the future. This is more than a hardware problem of saving a projector for a particular film gauge; it is a software problem involving file formats and applications software. In addition to moving away from an artefact-based paradigm, digital archivists will need to learn about refreshing, migration, and emulation, and will need to get involved with multimedia standards developments.

At the same time moving image archivists need to be aware of changes in the production process and changes in viewer expectations. The World-wide Web and enhanced DVDs have created a world where all kinds of ancillary materials have become important parts of an enhanced production, and a world where viewers want to see small fragments of a work almost as much as they want to see a work in its entirety. Moving image archivists need to respond by moving from a focus on completed works to a focus on managing a large set of assets related to a particular work (which itself may have numerous versions). Again, this community has a breadth of knowledge in this area, but for many, it will be a large conceptual leap to see themselves as asset managers. By combining their vast set of skills in handling of analogue objects as well as moving to new paradigms provoked by the digital age, moving image archivists can continue to play a critical role in preserving our cultural heritage and ensuring that today's works will last well beyond the life of the team that produces them.

6 DEVELOPMENTS IN TELECINE

6.1 Technology and Cost

In the past there have been a few basic hardware choices for telecine scanning of film. Each hardware design was intended to create the most accurate translation from film within the constraints of the technology of the day. With the current need for high definition scanning of film and even higher rate scans for digital manipulation of film images, new techniques have been brought to the marketplace.

The current competing telecine technologies involve three very different basic categories of hardware to get the job done; CRT based flying spot scanners, CCD based linear array scanners, and area array CCD scanners. The oldest technology still in widespread use is the flying spot telecine using a CRT as the scanning light source. This concept has been in use since the 1930's and has undergone several generations of improvements since that time to bring it out of its early primitive days. CRT scanning machines have gone from intermittent movement analogue black and white scanners to high resolution digital scanners with continuous film movement.

The next technology that has wide market penetration is the telecine built with linear array CCD's for scanning the film images. This technique was first introduced in the 1970's and has also gone through several generations of improvements over the years to increase bandwidth and improve performance.

More recently, large area array CCD's have been incorporated into a telecine machine using intermittent movement of the film.

There are pros and cons to each technology. Each technique presents a unique set of problems the design engineers must solve in order to make an economical and practical machine that is able to scan film in real time and at high resolutions.

The most flexible scanning technique is flying spot since it allows scanning at arbitrary resolutions, although this flexibility requires added complexity and cost. The most appropriate technology for low cost, fixed resolution scanning is linear CCD due to its potential for low cost implementation. However, the telecine market is driven by the post-production market and all current CCD based scanners are designed for maximum flexibility and are consequently expensive.

Currently Available Equipment.

Telecines:

	Data Res	Speed
Millennium.	2048 x 1556 4096 x 3112	7.5fps & 15fps 1.875fps & 3.75fps
C-Reality	2K	Less than above
Spirit	1920 (Half b/w Chrominance)	“

Dedicated scanners:

Oxberry - Cinescan: Two models. One for 16/35 and one for 35 to From 8mm to 65mm, 16perf.

Imagica – Imager 3000V: Scans up to 4K (4096 x 3484) at 27seconds /frame for 35mm (4perf). Or 4K (4096 x 6144) at 52 seconds /frame. (8perf Vista)

Imagica – Imager XE: 2K at 4 seconds / frame and 4K at 8seconds / frame.

ITK Northlight: 4K at 4.5 seconds / frame.

Kodak Cineon Lightning and Genesis scanners: Discontinued.

6.2 Virtual Telecine

Traditionally a telecine has been more than just a dumb film scanner, but has actually been a centrepiece of the creative process. Colour grading and some special effects are performed directly on the telecine rather than downstream since the telecine is working with the full film resolution and colour range rather than a diluted downstream product. With the advent of telecines that can scan at very high resolutions and with almost perfect colour reproduction it has become possible to push the creative process downstream to a "virtual telecine".

The virtual telecine performs the same colour grading and other creative processes that the telecine performs, but with a digital input rather than a film input. This potentially allows a more streamlined workflow, with a single film scanner working continuously and feeding data to multiple downstream virtual telecines for scene-by-scene grading.

6.3 High-Resolution Scanning

Telecine technology has evolved to the point where high resolution film scanners and video resolution telecine's have to a large degree merged. Current high-end telecines on the market are capable of resolution as high as 4k (4096 by 3112 pixels), which has traditionally been the domain of film scanners. Since the actual resolution of film is generally accepted to be in the region of 4k, telecines are now capable of capturing all of the information contained on the film.

Film scanning technology has been advancing as well, and there are now film scanners on the market capable of 6k resolution.

6.4 Special Techniques for Archive Film

Archive film needs to be treated with the utmost care whilst being scanned. The transport in any potential archive scanner must be able to handle such abnormalities as shrunken film and perforation damaged film. Both of these run the likelihood of

incurring further damage if Pinned, which is the system used with most dedicated scanners.
With regards to the Telecine's offerings for careful transportation, they are in the better position of finely honing the servo performance without pinning and they can scan faster.

6.5 Storage

Current high-resolution telecines can scan at 4k resolution as fast as 3.75 frames per second and future generations of telecine promise 4k speeds as fast as 20 frames per second. This corresponds with a data rate of 171 Megabytes/s at 3.75 fps and 911 Megabytes/s at 20 fps. Clearly the storage used must have a very high bandwidth to keep up with the scanning speed. However, the total amount of storage required also poses a problem. A 3000ft roll of 35mm 4perf per frame film shot at 24 fps and scanned at 4k resolution requires about 1.6Terabytes of storage.

There are presently no viable long term storage solutions that can offer this kind of capacity at a reasonable cost. Optical storage promises both very long life media (over 100 years) and capacities as high as 20 Gigabyte per disk, but this would still mean that 3000ft of film would require 80 disks. Magnetic tape capacities are higher, ranging up to 200 Gigabytes per tape. However, even properly stored tapes have a relatively short life of about ten years.

Hard disk capacity of this size is now available and, at the time of writing, the cost of the drives has come down to approximately 1600 EUR's per Terabyte. Film resolution transfer to hard disk space is now becoming common place, but only for temporary storage. It is a certainty that capacity will continue to increase of both magnetic and optical storage devices. Dr. Gordon E. Moore's famous prediction back in 1965, that the number of transistors per integrated circuit would double ever couple of years still seems to apply 37 seven years later, and more importantly here, seems to apply to storage devices too. DVD-R disks can now be bought for as little as 1.87 EUR, so it really is the quantity of disks and the speed they can be written to that is the problem, not the cost of the media.

6.6 Economy of storage usage

There is an important aspect about the storage of data, which is that not all material needs to be stored at 4K RGB. There are many instances whereby the content is well below the need for 4K RGB resolution. For instance;

- The ability for one given camera lens to resolve detail to the same degree as another is variable. The accuracy of some older lenses that could have been used to shoot archive footage may well be lesser performers. The net result is film that does not hold detail to the degree that 4K would be needed.
- Black and white film contains only a single element of content, unlike colour with R, G & B. There for, the post scan information required is effectively one third, which in turn requires effectively, one third the storage.
- 16mm film can be scanned with potentially a maximum of 2K, to retain the detail.

Being able to assess each case on its own merits and differentiate between how much detail one piece of film has over another is a function that could directly address the very important storage economy aspect.
An operator could perform this function, but the results could potentially be inaccurate and variable, being a subjective process.

There is a way that a scanner could be made to intelligently analyse the frequency components of a given piece of film. Using an FFT function to assess these components and thereby having the information with which make a judgement as to what degree of down sampling should be applied, if any. There is a point here that all scans must still be at 4K so that the resolution assessment can be made. If after analysis of the material it is found that there are no spatial frequencies above, say, 2k resolution then this is the point at which to down sample to, in this instance, 2k.

6.7 Compression

Near loss less compression has been in use for many years now in broadcast equipment such as digital Betacam video recorders. Very mild compression ratios with 10 bit depth has been found preferable to no compression with only 8 bit depth. A mild compression ratio would be of the order of 4 to 1.

6.8 Practical storage example

By way of example, if we examined a 1000ft roll of black and white 35mm film and found there to be no spatial frequencies above 2k and used mild compression at 4:1 then the storage requirement at 10 bit depth is 2048*1536*10/8 = 3,932,160bytes per frame. There are 1000*12*0.748 = 8976frames in 1000ft so uncompressed we need 3,932,160*8,976 = 35,295,068,160 bytes, or about 35Gigabytes. If we compress this 4:1 then we end up with 8.8Gigabytes. This will fit on one DVD-RAM disk, or two DVD-R disks!

6.9 In conclusion

There is not currently a film scanner on the market that meets the requirements of the archive industry. All of the specialist scanners are pin registered devices and so will not handle variably shrunken and fragile film. They are all far too slow to address the massive quantities of film in the world’s archives. They are also too expensive. All of the telecine machines are just too expensive for anything other than major film with big earning potential. Present telecines are still not fast enough at high resolutions.

There is a requirement for a ‘Scanner’ that can cater for all of the points above. This scanner must have the following properties:

- Able to handle film of very varied quality from pristine film to damaged, very shrunk archive film. Therefore continuous motion is required with some very special edge guidance to cope with a wide range of film widths with no user adjustments.
- Able to scan 4K at a speed beyond that of the fastest telecines available at the moment.

- Be matched to down sampling and compression hardware/software such that the real life storage issues are addressed.
- Comparatively cheap and cost effective.
- Easy to use.
- It must have built in optical scratch and dirt reduction.
- An infra red channel for detection of scratches too bad to optically conceal. This will help with electronic restoration later.

7 EMERGING TECHNOLOGY

7.1 Digital Cinema.

Christie Digital Systems

Product name: Digi Pro.

This company has been trading since the 1930's. It now has 25,000 large screen digital projection displays in over 50 countries. It was the licensed manufacturer of DLP projection technology from Texas Instruments. This current product has a 1000:1 contrast ratio and is capable of dealing with 720 line and 1080 line HDTV standards. It has a standard light output of 12fl when projected onto a screen size 15.4m X 6.8m, which is the same a standard cinema projector. In March 2002 it sited two of it's projectors in a multiplex cinema in China called Shanghai Paradise Cinema Chain.

Barco

Product name: D-Cinestar.

This projector was shown in October 2001 in conjunction with Quantum Digital at the Odeon Leicester Square, London. It has a light output of 12fl projected at up to 15m wide which is equivalent to 16fl output open gate from a film projector. It has two SMPTE 292M selectable input ports which support a range of outputs that include:
SMPTE 274M 1920 X 1080 scanned interlaced, progressive and segmented frame outputs, all at 1280 X 1024 progressive
SMPTE 260M 1920 X 1035 interlaced. With 1280 X 1024 progressive output.
SMPTE 296M 1280 X 720 progressive. With 1280 X 720 progressive output.

Kodak.

Product name: Yet to be launched.

This is a prototype projector that was demonstrated at the 'Showest' Conference in Las Vegas in March 2002, as part of Kodak's Digital Cinema System. This projector uses a QXGA 2048 X 1536 pixel, D-ILA micro-chip from JVC. This provides about 3million pixels as opposed to DLP, the current technology which provides 1280 X 1024 resolution which is about 1.2million pixels.

7.2 Digital Film.

Digital film has, over the last couple of years, been a subject that has spawned such phrases as ‘Film Is Dead’. This has yet to be proven to be the case. The annual January film festival known as ‘Sundance’ held at Park City – Utah, has, in the last year or two, issued pre show press articles about various subjects that relate to digital film making. At Sundance 2001, there was a renaming and relocating of the ‘New media and Technology Centre’ to become the ‘Sundance Digital Centre’. It was moved from a 20-minute ride away to the centre of the Park City action. This centre was being utilised to show new technologies in film making, such as cameras, projectors and editing systems. It was brought into the main throng, as it was deemed that “digital film making is central to independent moviemaking and hiding it away was no longer appropriate”. The Digital Centres’ mission was to reflect “ a digital transformation that will forever affect the way films are created, distributed and experienced”.

At the 2001 festival the Digital Centre was going to be showing demonstrations and presentations from such companies as Sony, Digital Projection, Panavision, Avid and Zenith. For the distribution side there were internet companies such as Streamsearch, Enron Broadband, AT&T Broadband and Internetstudios. Approximately 30 works were digitally projected which was a substantial increase from the 2000 festival.

Come Sundance 2002 there has been a downshift in the importance of this subject. Maybe it’s purely that from the technological standpoint, it has not got the wow factor it had a year ago and has been more accepted under the film making umbrella. This is not to say there has been a decrease in the format, just the opposite, but the general centre stage aspect of this ‘technology’ has dissipated somewhat. In reality, there was due to be somewhere in the region of more than a third of the 200 or so films on show, that will have been shot on digital video, or would be digitally projected.

Technology to give DV the film look:

Among the many well received, digitally shot films, there was news of work carried out on digitally shot film, by a San Francisco based effects house called ‘The Orphanage’. They have used a proprietary system of steps they call the ‘Magic Bullet’ process. This consists of de-interlacing, frame correction, colourisation, and applying filters to simulate bleach by-pass and other chemical reactions that are associated with traditional film.

One piece entered into the festival called ‘Manic’ was shot with the intention of not trying to steer clear of the harsh light and difficult colours often associated with video flare. Also the steady shot facility was turned off for several action sequences and instead the makers rocked the hand held camera at speed. This would normally end up exhibiting telltale edges of sharp detail around subjects, but the cinematographer Nick Hay, used diffused light in these scenes to capture a fluid effect. Under conventional celluloid conditions this would show up as photographic blur and be less evident. The footage was then processed in post by LA effects artist Andrew Chiaramonte, where he dropped frames for converting from PAL 25fps to a theatrical standard 24fps, and then subsequently a 3:2 pull down step to achieve a movie that ‘feels’ like it was shot on film.

There is another aspect to the projection end to the digital film saga. This is how long it will take for the increase in digital projectors to arrive in theatres, to replace or stand side by side with, current film projectors. When George Lucas first began shooting *Star Wars Episode II, The Attack Of The Clones*, in all-digital format, he imagined that by the opening of the film, it would be digitally projected in up to 2000 digital projection theatres, across the United States. It is estimated that as of the May 16^{th} 2002 opening, there will be 19 screens equipped in the appropriate way.

The Thomson Viper FilmStream Camera.

This new offering from Thomson was shown at NAB in Las Vegas in April 2002. The concept behind this camera is to address the various disadvantages that both film and digital video cameras are inherent with. Unlike other forms of digital or electronic image capture, the Viper captures all the information in a given scene in a 'transparent & reproducible way'. Down stream post production tools can know how many photons reached every CCD picture element. The Vipers signal path begins by capturing onto 3 x 9.2million pixel HD-DPM+ CCD sensors, from pure black to CCD saturation levels, via 12-bit A/D converters then RGB log converted. A 10-bit data stream is then transferred to the recorder via a dual HD-SDI link. Full 1920 x 1080 resolution is maintained for each colour. Nothing else happens to this signal like compression or colour sub-sampling etc. The cameras mechanical shutter enables the CCD exposure ramp to be similar to that in a film camera. This helps to provide the resultant images to exhibit similar motion characteristics. Hire company, Arri Media, are stepping up their High Def product line and ordered two Thomson Viper FilmStream Cameras at NAB this year.

The Digital Cinema System is described as 'an end to end solution, covering the preparation, distribution, protection and projection of images'. Kodak believe that a minimum of 2K resolution is required to create natural looking images that do not end up looking blocky or have jagged edges. The above system is at present undergoing 'stress testing' at a six screen multiplex in Hollywood.

8 CURRENT RECOMMENDATIONS FOR FILM PRESERVATION

8.1 FIAF

The International Federation of Film Archives (FIAF) brings together institutions dedicated to rescuing films both as cultural heritage and as historical documents.

In addition to these primary goals, FIAF also seeks:

- to promote film culture and facilitate historical research,
- to help create new archives around the world,
- to foster training and expertise in film preservation,
- to encourage the collection and preservation of documents and other cinema-related materials,
- to develop co-operation between archives and to ensure the international availability of films and cinema documents.

They also publish comprehensive guidelines and recommendations for film storage, preservation and restoration techniques.

8.2 EBU

The European Broadcasting Union is the largest professional association of national broadcasters in the world with 70 active members in 51 countries of Europe, North Africa and the Middle East and 46 associate members in 29 countries further afield. Activities include operation of the Eurovision and Euroradio networks, co-ordination of news and sports programming, promotion of technical standardisation, legal advice, and the defence of public service broadcasting.

They have also published a report on the preservation and restoration of film material for television, which gives guidelines on the nature of film degradation and recommendations for storage, preservation and restoration.

8.3 Other organisations

Other organisations that publish guidelines on storage, restoration and preservation of film are

- ISO (International Organisation for Standardisation) which publishes International standards for business, government and society, which works in partnership with international organisations, governments, industry, business and consumer representatives. [ISO 18917-1999, ISO 10636-1994, ISO 10602-1995 and ISO 5466-1996 are published guidelines on storage for photographic materials].

- SMPTE (Society of Motion Pictures and Television Engineers): SMPTE publishes standards and technical papers on the storage and preservation of film. [SMPTE RP 131-2001 - paper on Storage of Motion Picture Films].

- Raw stock manufacturers such as Kodak publish guidance on storage and preservation methods.

- The National Film Preservation Foundation (NFPF), a non profit making organisation created by the U.S. Congress to save America's film heritage. The NFPF awards grants for archive preservation and research projects into advancing restoration and preservation techniques. [Report of the Librarian of Congress report - Film Preservation 1993: A Study of the Current State of American Film Preservation].