Too Much Film, Too Little Time, & Not Enough Money

Material in film archives keeps deteriorating – too many films are already lost, and many others are in danger of being lost forever. If you are reading this, you're probably an archivist – so there's no need to convince you of the cultural and historical ramifications of this impending tragedy: we can instead consider how we might mitigate this catastrophe, working within the twin constraints of time and money.

Photochemical methods are typically used to copy old films, generating new dupes on stable polyester-based stock. For materials in good condition – especially original negatives – this is a good approach. But it's expensive, and many films require a significant amount of repair to get them into printable form. This takes time and costs money.

It can cost an archive with in-house lab facilities $40,000 (or more) to create a set of dupes of a 35mm black & white feature. If a (very) well-funded archive has an annual budget of $5 million for such work, and a large staff, they might be able to duplicate 125 feature films per year – if the films don't require digital restoration or other significant repair work. Damaged perforations, shrinkage, scratches, and other defects can drive the cost significantly higher. Color films are more expensive to preserve – especially if RGB separation masters are struck, which is good archival practice. And some defects particular to color film – dye fading, for example – often require digital restoration.

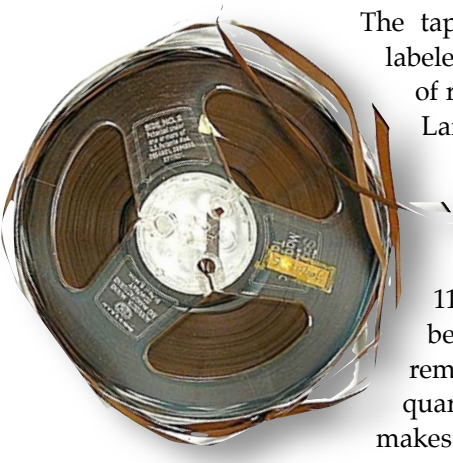
Archives are continually forced to decide which films to devote their limited resources to saving – and as a result many films suffer from unintentional neglect. With unlimited resources, this might not happen, but staff and funding are finite – it's *Sophie's Choice* on a daily basis.

Unknown treasures can't compete against "A" titles; myriad cans of mystery negative may never even get looked at – making a video access copy is too costly, let alone striking a print. Film preservation shouldn't be reduced to a popularity contest.

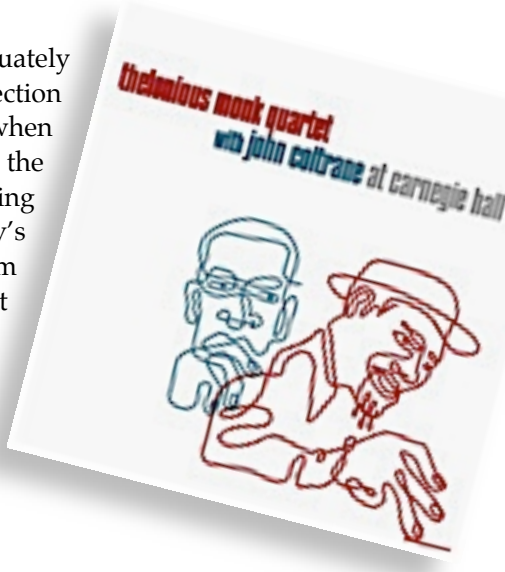
Unknown treasures are out there – not only the famous troves, like that abandoned swimming pool in Dawson City filled with over

500 reels of early nitrate prints: well preserved because they sat below the Yukon permafrost. There are probably jewels sitting right on your shelves (or someone else's shelves) – in poorly-marked cans, just waiting to be rediscovered.

Here's how Blue Note Records describes finding one such gem - a 1957 recording of the Thelonious Monk Quartet with John Coltrane at Carnegie Hall:

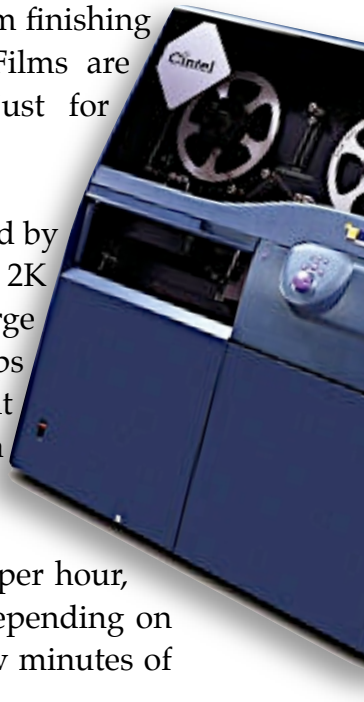


The tapes from that evening at Carnegie Hall were inadequately labeled, filed away amongst the Voice of America's vast collection of recordings, and apparently forgotten until January 2005 when Larry Applebaum, a supervisor and jazz specialist at the Library of Congress, came upon them by accident during the routine process of digitally transferring the Library's collection for preservation purposes. Applebaum noticed a set of tapes simply labeled "sp. Event 11/29/57 carnegie jazz concert (#1)," with one of the tapes bearing the sole marking "T. Monk." Until now, remarkably little recorded documentation of Monk's quartet with Coltrane has been known to exist, a fact that makes this finding all the more significant.

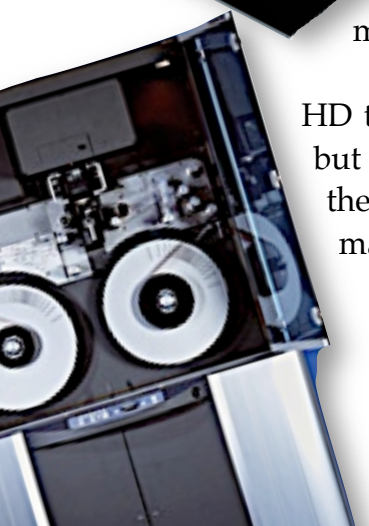


The Scoop on Scanning

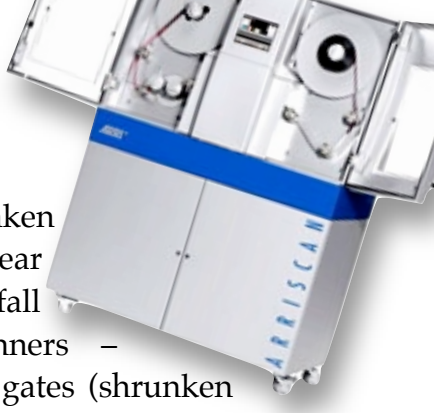
Digital scanning was originally reserved for special effects work – a shot here, a shot there (unless you're George Lucas) – but it's gaining popularity in film finishing (via digital intermediates) and that includes archival work. Films are usually scanned as part of a full restoration – rarely just for preservation – because it's so expensive.



How expensive? Motion picture scans are usually priced by the frame – list price is around $2 per frame for 2K scanning, though this is often discounted heavily on large jobs. (Still, there are 14,400 frames in 10 minutes of 24 fps film. Do the math – and get that decimal point in the right place!) With a significant discount, the cost may drop to a mere thousands of dollars per reel.

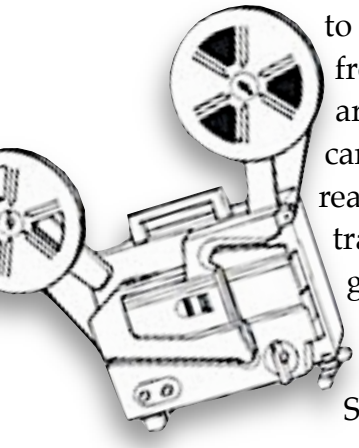


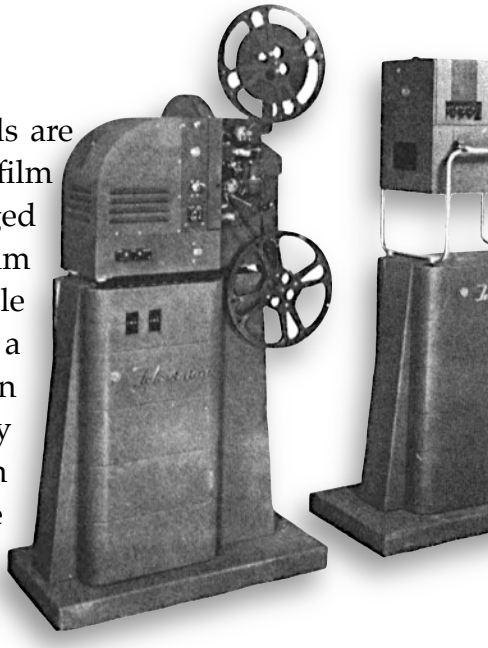
HD telecine, often used to cut costs, runs several hundred dollars per hour, but typically telecine involves color correction, which is slow – depending on the material, you might be able to color-correct and transfer a few minutes of material per hour.



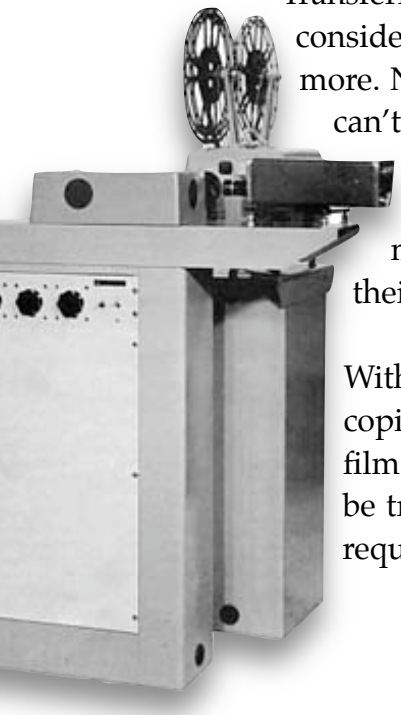
Current scanners are either pin-registered (and intolerant of shrunken film) or telecine-based – using the film's perforations to control linear scanning (subject to significant image distortion – the waterfall effect – with shrunken or damaged film). Some scanners – based on optical printers – can be fitted with special gates (shrunken heads, wet or dry) designed for damaged material, but these are custom built, expensive, and very slow.

Sweet Sixteen?





In the 16mm world, things are even worse. Irreplaceable materials are often run on Elmos – cheap projectors modified to transfer film to low-resolution video, or on old film chains scavenged from TV stations. Elmos are common in TV newsfilm archives (where almost all material is unique, irreplaceable camera original) because they can't afford to transfer on a real telecine ($150 per hour and up for standard definition transfers, not including tape). Unless the film is in very good condition (and often it is not) these devices can seriously damage film, leaving behind only a mediocre videotape – typically in an older format like Betacam SP that is nearing obsolescence itself.



Transferring film to standard-definition video can in no way be considered preservation – it's making an access copy, nothing more. Not that access isn't important: if an archive's holdings can't be explored they are essentially lost to the world – even if they are being preserved for the future. Ideally, an archive should be able to preserve materials in their care and provide easy access to all of their holdings.

With photochemical preservation, access copies become an added expense. Either more film prints must be struck, or the material needs to be transferred to video, which, depending on the quality required, can add thousands of dollars to the budget.

Not Fade Away

New technologies offer different ways of doing things, but new techniques aren't always better – or even as good – as what they replace.

A few years ago, DAT recorders were all the rage: many archives embraced the format, migrating their analog audio tape libraries to DAT. It was attractive: the tapes were small, clone-able, and cheap.

Now DAT is a dying format; it is almost impossible to purchase new DAT recorders. The same can be said about many video formats – 1-inch Type C seemed ideal compared to 2-inch Quad; DV looked better than Hi8 – and on and on.

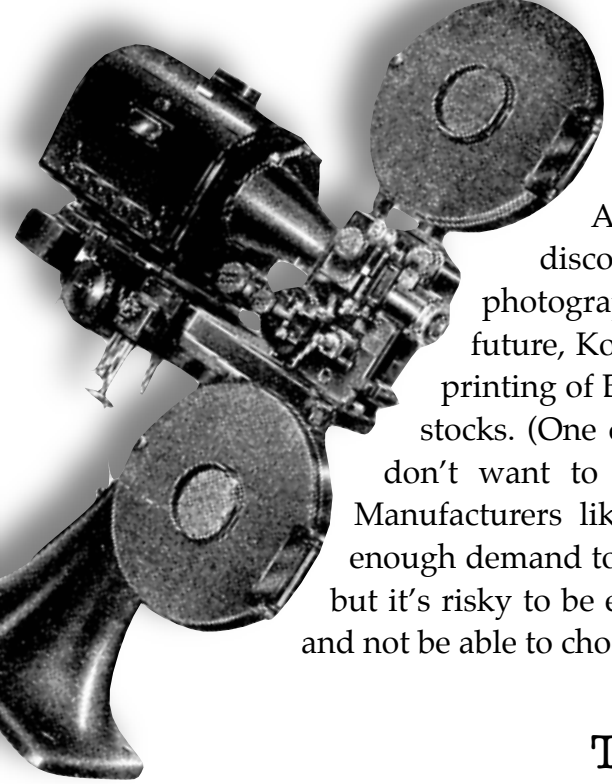
This has also hit digital data storage – Sony's SAIT format and Quantum's SDLT format have been discontinued, because LTO (supported by multiple manufacturers) has won over the market.

Planned Non-Obsolescence?

Film has been relatively immune to the constant churning of formats: 35mm has been a standard for more than a century, and 16mm has been with us for over 80 years. It is understandable that archives would choose to preserve film in their native formats. When good original materials are available, and cost isn't an issue, this makes sense.

But cost is almost always an issue. And original elements are often unavailable, or are incomplete – meaning that a film might be preserved by combining, a la Frankenstein, material of different provenance, which needs to be matched seamlessly. This requires skilled lab work – photochemical, digital or both.

The shrinking demand for film means that manufacturers are gradually phasing out some stocks used in archival work.



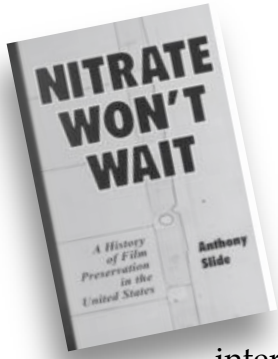
Agfa and Ilford have gone bankrupt. Kodak recently discontinued all reversal print stocks, along with their B&W photographic paper line. One can imagine, in the not-too-distant future, Kodak mandating that color print stock is acceptable for the printing of B&W originals – as a prelude to phasing out B&W positive stocks. (One can imagine scarier things from Kodak – but I don't want to give our friends in Rochester any ideas.) Manufacturers like ORWO may take up the slack, if there's enough demand to keep them producing B&W specialty stocks – but it's risky to be entirely dependent on one small manufacturer, and not be able to choose the most appropriate stock for the job.

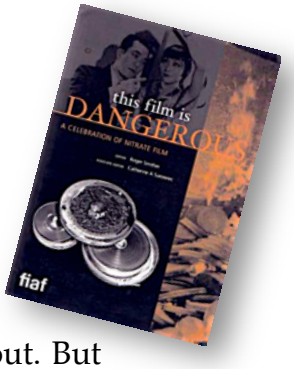
The Big Pixel

Digital projection is headed our way. In 2005, it looked like it might take ten years to become commonplace – but manufacturers have offered theater chains cheap financing on projectors and the requisite support equipment. The result: ten percent of the screens in the US are digital, with more being added every month. Film projection is still here, and will be for several years, but 35mm release print volume will eventually drop. This will eliminate one of Kodak's few cash cows – color positive stock – a painful notion to contemplate. I like film projection – it may not always be perfect, but there's an organic texture and feel lacking in digital projection. One man's artifacts are another's brushstrokes.

That said, there are some virtues to the widespread proliferation of digital projection. Films can be restored and released in digital form, at far less expense than making film prints. This means archive films that might not financially justify a film release can still be seen in theaters, and expensive 35mm showprints won't be subjected to destruction by poor projection. That doesn't mean film prints (and film negatives) won't be needed for preservation purposes, but it does mean more films might be seen theatrically.

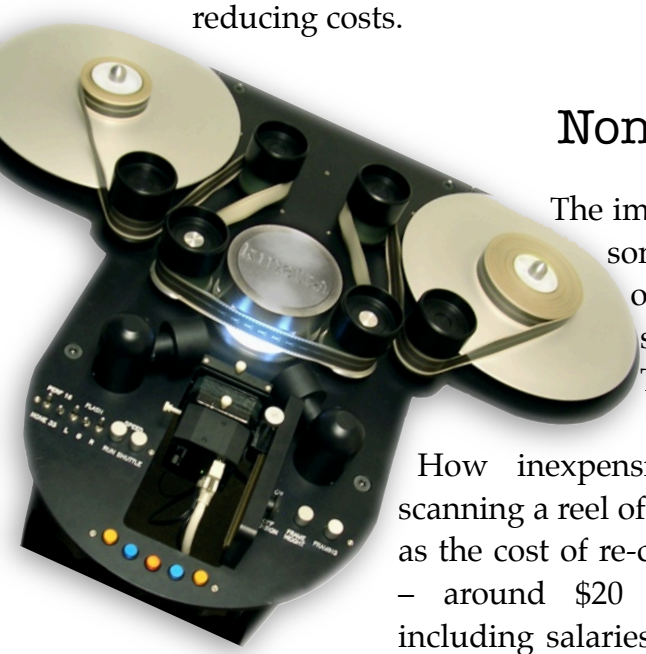
In addition, the adoption of HDTV (you know it's here when WalMart has lots of HDTVs for sale and very few standard definition sets) means that home viewers can now see films at a quality level (if not screen size or viewing environment) not imagined five years ago.





Nitrate Won't Wait (and Vinegar is in a Hurry)

Typically, one digitally scans a film as part of the process of digital restoration; the cost of scanning is intertwined with the cost of digital restoration and filmout. But one could take a different approach, and consider scanning as a form of preliminary preservation. The materials are captured to data tape at high resolution before they deteriorate further. Access copies are made from these scans, typically on DVD, to permit evaluation of the material at minimal expense. Digital restoration (if required), grading, and output to film or videotape, can be delayed until the material is needed, reducing costs.



The prototype Kinetta Archival Scanner scanning pre-1914 paper prints at the Library of Congress Film Conservation Center

Non-Judgmental Preservation

The important thing is to scan everything – rather than decide some films merit preservation, and others do not. This is only possible if the cost of scanning is truly affordable. If scanning is inexpensive, more films will be preserved. That's the point.

How inexpensive? The cost of scanning a reel of film can be as low as the cost of re-canning that film – around $20 per reel (not including salaries or overhead). That's not merely inexpensive, it's downright cheap!

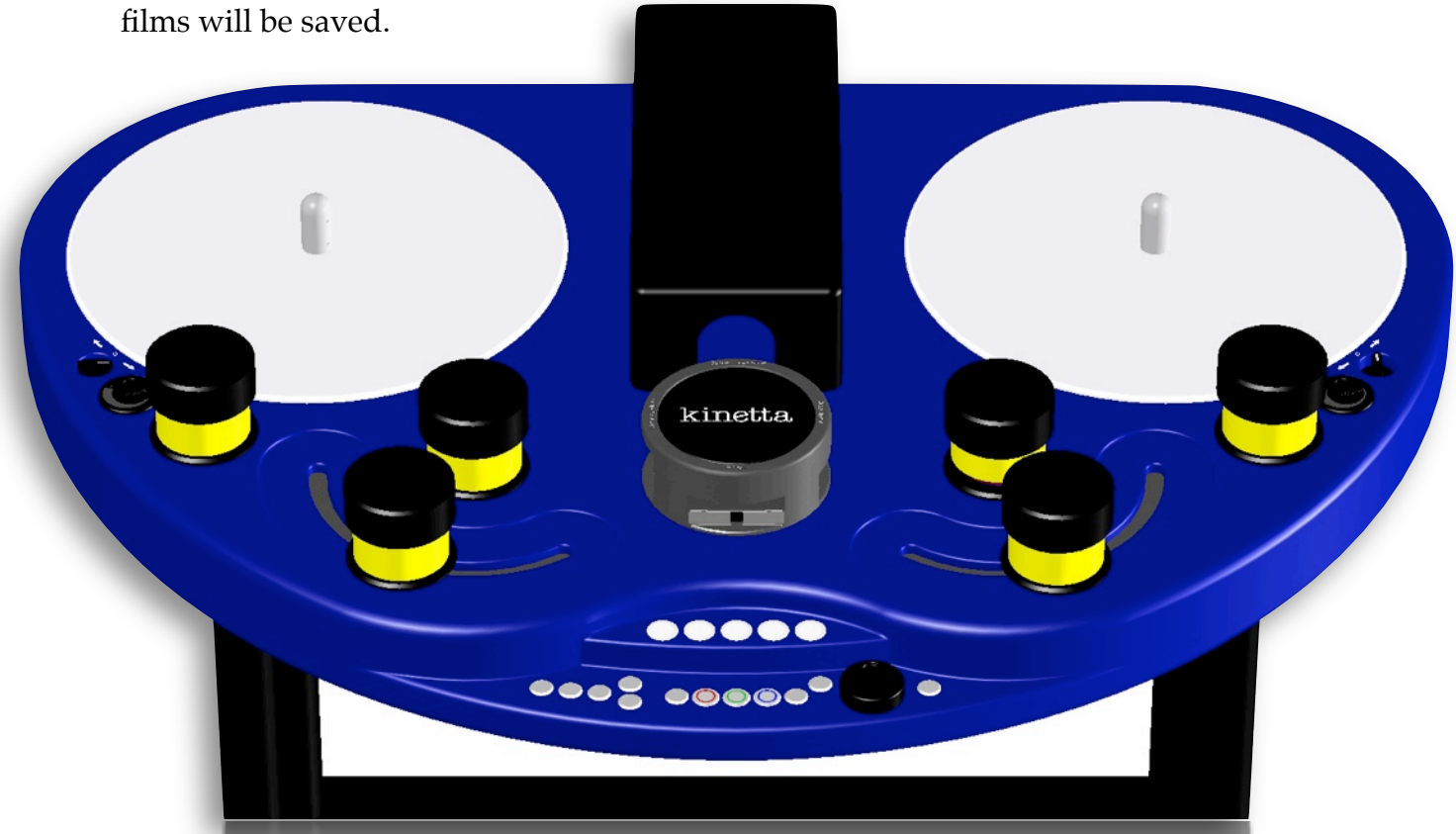
Kinetta has developed an archival scanner designed specifically for damaged material. It's sprocketless – meaning it can easily scan shrunken material, even material with un-repaired torn perforations – reducing the amount of repair and prep work required for damaged footage. The optical system greatly reduces the visibility of most scratches without reducing resolution.

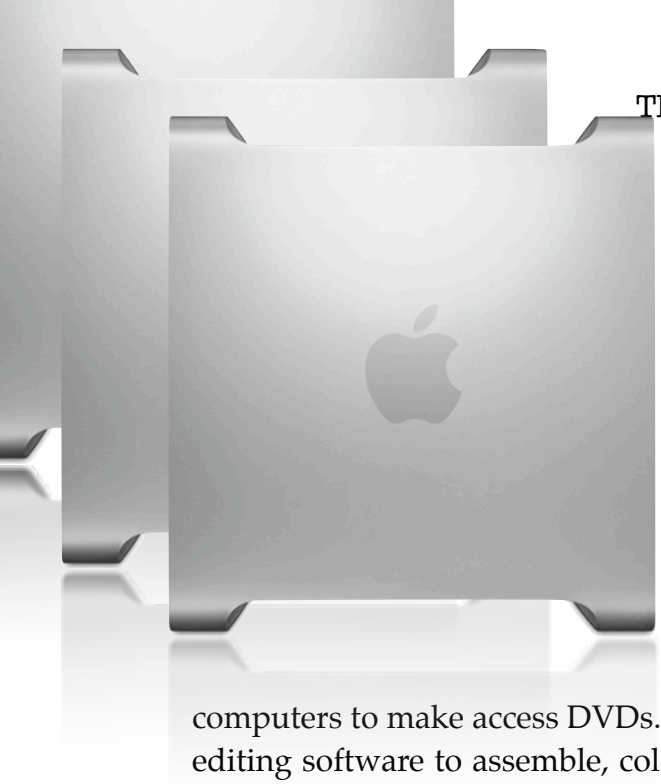
It's fast – currently, maximum scanning speed is determined by resolution – it can scan at 4K resolution at about 5 fps, 2K at 16 fps, and 1.6K (ideal for 16mm) at up to 32 fps (see charts below). Faster sensors are coming, and the scanner can be inexpensively upgraded in the field in ten minutes or less.

It can scan any format of film ever made. The standard version can scan (with the appropriate gates) 8mm, Super-8, 9.5mm, 16mm, Super-16, 17.5mm, 22mm Edison Home Kinetoscope, 28mm Pathe KOK, 35mm (2, 3, and 4 perf). (Vistavision, 55mm, 65mm (5/8/10/15 perf) and 70mm (type 1 or type 2 perfs) are available on special order.)

The scanner can be used as part of an entire digital restoration system, including restoration software from several manufacturers, audio scanning and restoration, archiving to digital data tape, grading (color-correction), and output to film, video, or data files. But it can also be used as a simple preservation tool – scanning film and archiving it to data tape – final output and/or restoration work can be done in the future, as needed. What's important is scanning film before it deteriorates further – everything else can be postponed.

It's designed to make scanning affordable for all archives – with the hope that more films will be saved.

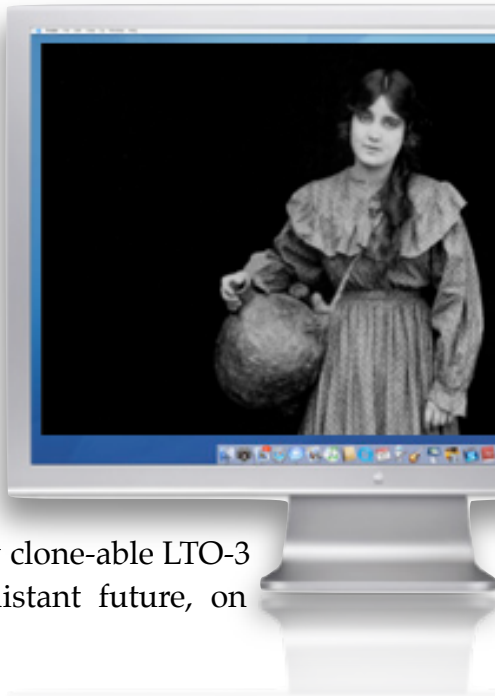




Systems Large and Small

A small system consists of a just a scanner, computer, a small storage array, capture software, and an LTO-3 tape drive. It's simple and compact enough to take to any location where there's film that isn't easily moved – it will all fit in a mid-sized car. We hope to make small systems like this available for rental to small archives, with limited holdings, who might be able to scan all their footage in a few months.

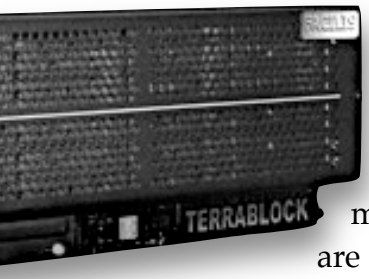
It's easy to add a couple of cheap networked computers to make access DVDs. And it's not too difficult to add a computer with video editing software to assemble, color-correct, and output clips as video or data files. Add image restoration software, for deflickering, stabilization, dustbusting, and scratch removal. Add a serious color corrector for 2K and 4K grading. Add a film recorder, for output to 35mm or 16mm film.



In a large system, multiple scanners, audio reproducers, restoration workstations, tape ...ting systems, color-correction workstations, and fi... networked by fast 4-Gig Fiber Channel to a c...m, like a Facilis Terrablock. The Terrablock c...-progress, so it needn't be huge – ten or tw... suffice for users working at 2K resolution. (M... added as needed – the price per terabyte keeps dropping.) Th...re stored – as both raw scans and as restored, color-corrected films – as data, on easily clone-able LTO-3 (or other format) data tapes – and in the not-to-distant future, on holographic discs.

Many changes here!

Things are more affordable now.



The Kinetta Archival Scanner can be fitted with 5K, 4K, 2.4K, 2K, HD, and 1600 x 1200 scanning heads. 5K or 4K is the best choice for modern 35mm material, and most 35mm color material. 2K and 2.4K are appropriate for older 35mm material, and for modern 16mm material. HD is a good fit for Super-16. 1600 x 1200 is especially suitable for older 16mm material – it's higher resolution for 1:1.37 material than HD, and scans are (currently) much faster than 2K. These scanners capture data in RAW form with a computer attached to the scanner. These files are captured in RAW form on centralized network-attached storage [NAS] – like a Terrablock module. The

Terrablock holds up to 24 terabytes per module, and attaches to the system by 4 gig fiber. Multiple modules can be attached through a fiber switch, for virtually unlimited online data storage.

Once the data is captured, it is copied to a pair of LTO-3 tapes in RAW form, for archiving. (These two tapes should be stored in separate locations.) The data is also converted, on an inexpensive workstation, to whatever data format is required – typically DPX, TIFF, or Quicktime files. Quicktime files can be compressed if required for offline editing, or downsampled to standard-definition video. These files can be burned to reference DVDs using another attached workstation.

Workstations or rendering farms attached to the system can run Kinetta's VIVA restoration software, which is included with each scanner. Restored files are then graded using software including Assimilate's SCRATCH, Iridas's Speedgrade or Apple's Color.

We are working with a team of talented algorithmists to make automated digital restoration (repairing jitter, flicker, dirt/dust, scratches, and stains) affordable— VIVA is now part of the Kinetta system, so digital restoration only requires additional computer time, not additional expense — meaning any film that needs to be digitally restored (many do not) can be. News on this at AMIA 2008.

The finished files are also archived to LTO-3 tape, and can be output to film (using a Kinetta Film Recorder), video (HD or standard definition, as files – no expensive video recorders required) or as data, in multiple formats.

No Way We Can Afford This... Right?

If you look at the cost of this equipment, it seems expensive – until you calculate the actual cost of scanning a reel of film (1000 feet of 35mm, or 400 feet of 16mm). Here's how we calculate the cost per reel. We take the cost of the equipment used for a particular part of the work (in this case: scanning, archiving two copies to LTO-3 tape, making DVD access copies) and calculate the cost of ownership over five years. (To be honest, the computers – a small part of the cost – will be obsolete in three years, but the scanner – upgradable at minimal expense – will have a much longer life.) We divide

each year into 50 weeks, and each week into 40 hours (we are basing this on running the scanner only one shift per week, but obviously it could be run twenty-four hours a day, seven days a week, if personnel are available – further reducing per-hour machine costs.) Financing, insurance, and salaries are not included. To scan picture (negative or positive), you need a Kinetta Archival Scanner, a storage, and an LTO-3 tape library. You'll also need a couple of inexpensive PCs attached to the network, for file format conversions, making DVD access copies, etc.

Let's assume such a system costs about $300,000, depending on options. (You can set up a simple scanning system for less than that.)

What does it cost per hour? And what can you do in an hour?

As long as the pipeline to the scanner keeps flowing (that is, film is inspected and cleaned and ready to scan) the scanner can run continuously. A reel change takes a couple of minutes.

COST	PER YEAR	PER WEEK	PER HOUR
$300,000	$60,000	$1200	$30.00

Scanning resolution is, for now, the biggest variable: higher resolutions currently take more time per frame to scan. (New sensors now in development will change that, and the scanner can be upgraded quickly at minimal expense by simply swapping out the image capture module, which takes five minutes.)

Let's examine scanning time.

RESOLUTION	Frames-per-second (max)	Reels per Hour
1600 x 1200 (16mm and smaller)	32	6.7
1920 x 1080 (HD - for S16)	32	6.7
2048 x 1536 and 2456 x 1830	15	2.5
4004 x 2672 (4K)	4.8	1
5K (2007)	3	1

Now it's a simple matter to figure out the equipment cost of scanning a reel by dividing the cost per hour of owning the equipment by the number of reels per hour.

RESOLUTION	Reels per Hour	Cost per Reel
1600 x 1200 (16mm/9.5mm/S8/8mm)	6.7	$4.50
2048 x 1536 and 2456 x 1830	2.5	$12.00
4004 x 2672 (4K)	1	$30
5K	1	$30.00

Next we add in the cost of storing the data on two separate LTO-3 tapes. We are storing the data in 12-bit RAW uncompressed form. In small quantities, LTO-3 tapes cost $35 each, and hold 400 GB of uncompressed data. The reels-per-tape figures are rounded down a bit to account for wastage. These tapes can be cloned or migrated in the future using automated tape library systems. (LTO-4 doubles the storage rate – and be backwards-compatible with LTO-2 and LTO-3.)

RESOLUTION	GB/Reel	Reels per Tape	Cost per Reel	Tape Cost (2 Copies)
1600 x 1200	42	9	$3.88	$7.77
2048 x 1536	65	6	$5.85	$11
2456 x 1830	100	4	$8.75	$17
4004 x 2672	225	1.75	$20.00	$4
24-bit/48 kHz mono	< 0.1 (85 MB)	2000	$0.02	$

Prices have dropped significantly!

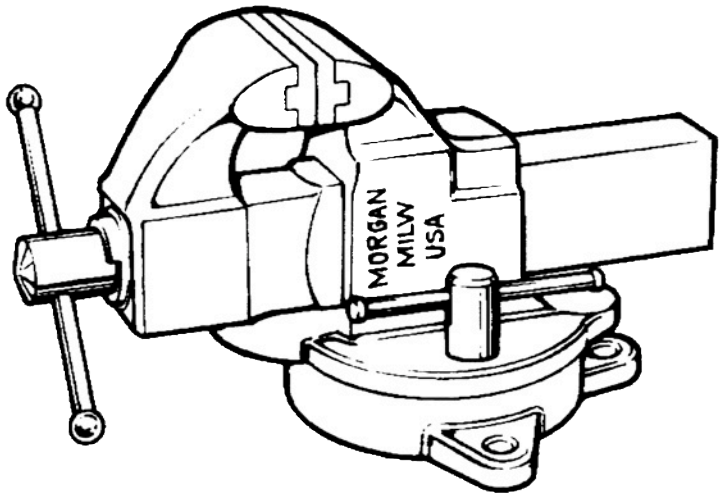
Finally, we combine the cost of tape with the cost of scanning, to come up with a cost per reel including tape, rounded up, and we'll add $2 per reel to cover supplies, including replacement PTR rollers.

RESOLUTION	Scan Cost per Reel (including 2 tape copies)
1600 x 1200 (16mm and smaller)	$17.60
2048 x 1536	$30.66
2456 x 1830	$39.00
4004 x 2672 (4K)	$89.14
Audio Scanning	$4.05

Note that the $40,000 required to preserve one 35mm B&W feature photochemically will cover the cost of scanning and archiving nearly 1400 reels at 2K resolution – that's about 150 feature films. And all that material can be scanned in less than fourteen forty-hour weeks.

Squeeze Play

Recent developments in wavelet compression are free from artifacts like mosquito noise that plague most MPEG algorithms. JPEG-2000 and Cineform Archival are algorithms worth considering if your budget is tight. Both are visually lossless – they're quite good – and greatly reduce the storage space required for a given file.



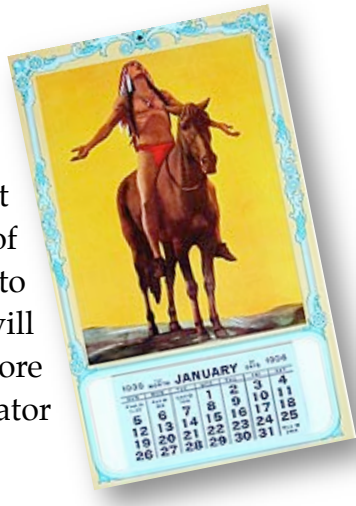
RESOLUTION	Scan Cost per Reel (including 2 tape copies)	
	Uncompressed	Cineform Archival
1600 x 1200	$17.60	$8.50
1920 x 1080	$19.00	$9.00
2048 x 1536	$30.66	$17.00
2456 x 1830	$39.00	$18.50
4004 x 2672 (4K)	$89.14	$38.50

For example, a reel of footage at 2K will require about 65 GB to store (12-bit, RAW or monochrome) uncompressed, but that drops to about 12 GB using Cineform Archival. The savings in media (and eventual media migration) and the savings in shelf space make this an option to consider for many archives.

There are many archives with huge holdings – millions and millions of feet of film. Preserving all of this material photochemically will never be economically feasible.
But scanning millions of feet is comparatively quite affordable. A large archive might want to look at not only the cost, but the timeline.

A Five-Year Plan?

Let's look at an imaginary archive, and see what it might cost to scan all of their holdings. This archive has 80 million feet of 35mm nitrate, mostly black & white. Let's assume they'd like to get funding to preserve all of this material over five years. This will require more hardware in order to meet the deadline, and/or more shifts. It can be cost-effective to add more hardware, as one operator can usually operate at least two scanners simultaneously.



We'll calculate this at 2K resolution, meaning 2.5 reels per hour per scanner, or 100 reels (100,000 feet of 35mm film) per machine per shift per week. 5000 reels (5,000,000 feet of 35mm) per machine/shift/year.

So how long will it take to preserve this footage?

Resolution	Reels per Scanner Shift Per Year	Reels per Scanner Shift over 5 Years
HD and 1.6K	13,400 (5,360,000 16mm feet)	67,000 (26,800,000 16mm feet)
2K and 2.4K	5000 (5,000,000 35mm feet)	25,000 (25,000,000 35mm feet)
4K	2000 (2,000,000 35mm feet)	67,000 (67,000,000 35mm feet)

A large project like this will require three or four scanners, or running multiple shifts, to complete the project on-schedule. These figures obviously are just a starting point -- your mileage will vary, depending on operator attitude and other factors beyond anyone's control (funding, rush jobs that interfere with an orderly workflow, and phases of the moon).

Obviously, I can only touch upon non-judgmental preservation and affordable scanning in such a short document. If you have questions, please contact me at: jeff@kinetta.com

"I was full of silly prejudices [and] missed out on incredible things. People who think they have taste, me included, are idiots. One must save everything. Never assume you know what's of value."
—Henri Langlois