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Digital Film Capture and Processing Production

by Derek Jenkins

Forward by Michael Kennedy
The accurate and efficient digital capture of microfilm is a production process dependent upon two main activities: the collecting and understanding of how the original film was captured and how it can be processed. Anyone, no matter how knowledgeable, would be well advised to use this article as baseline guidance on conducting their digital film capture projects.

Derek Jenkins brings more than fifteen years of digital film capture and processing experience to bear in explaining exactly how processing captured film will influence image attributes and overall specifications. Most digital film capture and processing projects encounter efficiency and accuracy problems that result from an inadequate data collection and analysis effort, prior to the production run. In the second part of the article Jenkins carefully gives a comprehensive list of project assessments which all project managers and sales professionals should use to obtain precise specifications and conformance requirements.

Image processing and approaches that are commonly used on digitally captured microfilm

Image processing consists of two phases: real time (scan time) enhancements, and post scanning enhancements. Both are important and must be considered for each job. In many cases, the real time enhancement delivers an acceptable image, but under some circumstances, a better result would have been obtained if the images were post-processed.

Real-Time / Scan-Time
During scanning most scanners on the market can apply image processing to a digital image in near-real time. These processes are capable of taking a marginal image and enhancing to the point where it would be considered 'good' or acceptable for some interpretation requirements. Real time processing can usually also take a 'good' image and enhance it to a 'great' image, but rarely can it take a marginal image and deliver a great image. Despeckle, edge enhancement, deskew, and crop are some of the basic processing techniques, but each method has its advantages and drawbacks.

Despeckle
As an image is processed it picks up the normal flaws in the microfilm along with the noise and dust on the image. Despeckle, using a traditional top hat filter[*1], will look for these isolated 'dots', both black or white, and change them to the predominant surrounding color. This works well at improving the appearance and G4 compression size of an image. However, despeckle filters can also remove dots above an "i", commas, and weak characters. On one hand it enhances the image, on the other it degrades the image, based upon the aggressiveness of the despeckle filter.

Edge Enhance
In the same way that a despeckling filter processes the image by removing dots, the edge enhancement filter is used to solidify data. It will, as the name suggests, improve a weak line or build a stronger character. However, the downside is that it will make noise (specs) stronger. So like despeckle, making these filtering decisions is a balancing act between enough enhancements and too much enhancement.

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Cropping & Deskewing

Cropping can be an enhancement, but in optional cases it needs to occur following a deskewing process. However, the deskew operation is a CPU or time-hungry process, and in most cases can be skipped, due to the fact that approximately 90% of all images are within a few degrees of true.

Assuming that a image is reasonably true, a cropping process would leave only the document plus the padding that has been requested. The padding can be either *positive*, adding pixels to the document, or *negative* taking pixels away. If the image needs to be deskewed, background will be exposed during the rotation. Depending on the type of scan, this will need to be made black or white to insure that the desired cropping is successful.

Unknown to many production operations personnel, film cropping (and its optional deskew) can be a very difficult task to accomplish accurately. With one common filming method, white pages of documents are filmed on a white copy board. The pages are placed, by hand, onto the scan area and the camera trigger is pressed. The pages are not always placed in the same position, and as a consequence, appear to move around the general center of the frame.

As time goes on, the copy board gets dirty from ink rubbing off the pages. This dirt shows up as noise on the filmed image. Looking at a scan of these images, it is very difficult to locate and crop the page out of the noisy image. The reason for this is that the position of the page moves from frame to frame, and the relative document area must be over-scanned, which produces a larger than expected image. The only way to crop this type of document consistently is to do it by hand.

Scanning on a black copy board is effective for eliminating noise caused by dirt, because most ink and dust does not show up, and a contrasting image stands out for more accurate cropping.

Enhancement operations at scan time is generally a compromise between production speed and output quality. Production scanning operations should be open to splitting the enhancements into two phases; scanning, followed by post-processing. Engineering drawing workflows are a good example in which to see how these operations can work.

Over the years the drawings have been updated, and each time they are updated, the draftsman may have used a different pen, pencil, or ink which made some of the drawing strong while other areas are weak.

The customer wants to see all the lines and text on the drawing, not just the strong ones. During scanning, the illumination light can be increased, which will enhance the lines and change the threshold of data that is captured. As a consequence, a lot of noise in the form of speckles and dots will be produced. However, if the light and thereby enhancements are reduced, some of the lines or text could be lost, so in this case, the best image is a noisy one.

If the resulting noisy image is run through a post-process despeckle, it will remove some of the specks and dots on the image, creating a far better image for the customer. This approach will take two steps, but the result is a better image.

Having said all of this about enhancements, I must remind project planners that it is aimed at bi-tonal images, because 90% of clients only want bi-tonal scans, due to the image sizes and scanner performance specifications, which in turn translate into less resources invested.

This same two-step processing does not always apply when scanning in greyscale. In greyscale scanning, the images acquired from film are captured in an 8-bit greyscale and stored as a JPG or TIFF. Even when compressed, the images take up much more room than the equivalent G4 TIFF. However the content (both weak and strong) is not lost in the thresholding process, because thresholding is not used to process greyscale imagery of film. The resultant image is an accurate representation of what was captured on the film. Any enhancements applied will only improve the image (a loss-less process, not a lossy process).

The compressed image size can be decreased by reducing the image (spatial) resolution. Monochrome images normally require 200dpi to 300dpi to enable the enhancement routines to have enough pixels to produce desirable results. Properly greyscaled, the data in an average document can be processed at half the resolution of most monochrome images, without loss of readability (interpretability). *Note: at half the resolution the raw image size is also reduced by a factor of 4, which in turn results in a smaller compressed image size.*

Some microfilm scanners can scan in greyscale as fast as they can in monochrome. With the current trend of disk space doubling in size (and halving in price) every eighteen months,

increased file size and its associated disk space usage will become less of an issue. A greater usage of DVDs over CD's will result in a reduction in the cost of transportation and delivery of images. The only bottleneck that exists today (and it's steadily being resolved) is the ability to transfer these images quickly over a network. The increased usage of high-speed network access and RAID-like tape backup methods of storage minimizes associated speed and load issues.

Greyscale Scanning

In scanning high quality film with good images, greyscale will probably not be needed. However, for the other 50% of the work encountered, greyscale processing will be more efficient, due to the reduced quantity of re-work from rescans.

In monochrome imagery all threshold processing must be done in either black or white. Thresholding processes any pixel higher than a certain level and converts high density values into black, and lower density values into white. This usually works fine if the density of the documents is consistent on the roll, but in real life, they will change. *The only consistent thing about microfilm is that it is inconsistent.*

In the average office folder there are white pages, pink pages, yellow pages, colored invoices, shaded invoices, and off-white note paper with handwriting and so on. Other factors that will influence threshold processing are the age and quality of the filming equipment, dust on the exposure meter, variations in lamp intensity complicated by outside (ambient) light coming through a window, or refracted light from the operator's white shirt.

If scanning in greyscale, the issues mentioned above are not as important. In greyscale acquisition, the image taken from the film is a picture of *exactly* what is on the film. For example, if it's a faded hand-written note, then it will still show up alongside the next image that may be a laser-printed page. The potential for rescan work will be with images that are not detected correctly, which may result in chopping the image.

One way to reduce and/or eliminate bad detection of poor images is to use the technologies and capabilities like, better CPU speeds and memory currently available in scanners. These methods are based on heavy mathematical analysis of full resolution, real-time data flows. Image detection based on scan-line density, can be done on one or more independent regions of the film being scanned. The resultant data can then be analyzed to trigger data capture, based upon these regions and logical operators to combine them. This analysis of full-speed and resolution allows reliable detection not previously possible.

This same logic is also used for cropping and deskewing. With available higher power CPU's and more efficient streamlined code, the image can be processed in full resolution allowing closer detection of the image and its skew.

Another processing model that is becoming more commonly used in production image workflows (which potentially reduces rework) produces both a greyscale image along with a monochrome image. During Q/A if the operator does not like the processed mono image they have the option of selecting the greyscale image and reprocessing it manually, or in extreme cases, storing the greyscale image in place of the TIFF. This process does not require the very time consuming (and operator expensive) tasks of remounting the film on the scanner, finding and rescanning the selected frame within a roll of film.

Adopting advanced processing methods in digital film production workflows reduces the required resources associated with rework and overall processing costs. Perhaps more importantly, the use of advanced film capture and processing techniques will, in most cases, create a more accurate and usable image for the original reasons that client captured the documents – interpretation.

Gathering Specifications and Interpretation Requirements

Collecting information about the film may be the most overlooked phase of a scanning process. Comprehensively educating the sales professional who has direct contact with the customer can insure that a project goes smoothly, and allows the client to have proper expectations for the project. The entire collection effort can be verified by running sample sets and calculating deliverables based the set of given rolls.

What follows are the main items that sales personnel should obtain from the customer, along with conducting a thorough examination of the collection, and selecting a representative sample set of roll contents and qualities. Even after this initial review is completed, running an actual sample provides the best information for the job to be estimated and it also provides validation of the customers statements.

1. Reduction Ratio
Many people have heard the term, but do not appreciate its exact meaning in a scanning process. Reduction ratio is the amount of reduction that is made to a document to store it on the film. The reverse measurement is how much to magnify the film to produce the actual original document size.

In a perfect world we would have a fixed set of reduction ratios used in this industry. However, we are not in a perfect world, and each piece of equipment is not perfect, so the reduction ratios can be nearly anything.

The best way of calculating the reduction ratio is to measure it. Using a $30 micrometer, measure the height of a known document on the film, i.e., the start target. Then divide this size into the known size of the actual document. This will give you the reduction ratio. With this knowledge repeat the process further into the film collection to validate the data. This information is key to setting up a good scan. If the reduction ratio is off, then the image aspect ratio (the ratio of height to width) will be off, and the document dimensions will be incorrect.

A method used to check if the reduction ratio is correct is to scan an image and see if the width and height are as expected, and then look for anything circular on the document. If it is not round on the image, you have a problem. Knowing a correct reduction ratio allows project planners to know how many images will be on a roll, as well as how fast it can be scanned, and what quality can be expected from the process.

2. Film Type: Positive or Negative - Silver, Diazo or Vesicular
Film type is one of the keys to obtaining the best image quality. Each type of film was developed for different uses and, in turn, different budgets. First let's look at positive vs. negative copies. From a service bureau perspective, you get what you get, and do the best you can, but if you have a choice, ask for the negative copy of the film.

Why? It all gets down to noise - flaws like dust, or even worse, scratches on a negative roll of film, are only a problem when they cover or cross over parts of the text. So 95% of the document is masked in the black area, with only 5% of the document visible where the flaws may show. The reverse is true with positive film. Ninety-five percent of the film (the white areas of a document) will produce noise from dust and flaws, making positive film generally noisier than negative.

The second issue is light levels. Light is a tool that can be used to improve an image. Slightly increased light levels can be used to 'burn' through weak characters or poor contrast on the film, producing a better image. The drawback of using light to enhance an image is the 'blooming' effect that occurs as the light floods through the white area and around the black areas of the film. This 'blooming' makes a negative image appear bolder, but on positive film it starts to degrade the characters.

Silver negative film is the best to work with especially if you are doing greyscale work. The master or second generation negative should be your first choice, if available. Even second or third generation negative silver copies can be better than some diazo duplicates. *Note: each time a film is duplicated it loses a percentage of its clarity. Duplication also can introduce changes in reduction ratios, and possible image movement on the duplicate, when the tracking is not perfect. These silver negative masters generally have great tonal quality, and produce the best results in greyscale scanning.*

Diazo negative film is a general duplicate film. The diazo copy produces a higher contrast than the original, so it loses some of the gray tones that contained in the silver. The copy process will degrade the images with each generation, so the newest version will always be the best to scan.

Vesicular is a high-contrast light blue film. It is not as common as diazo or silver types. I have seen a lot of 35mm copies and fiche copies, but have not seen 16mm versions of this film. Vesicular film is made with a heat transfer mechanism. It produces a very high-contrast image, which makes it not as tonal as diazo or silver. In general, vesicular film scans okay, producing reasonable monochrome images. The concept to keep in mind is that the earliest generation silver negative is the best film for scanning.

3. Orientation - Cine or Comic
On the surface, the orientation of an image on the film and the cost of scanning, do not appear to be related, but they are. For example, on 10 inches of film, there can be 20 comic mode images, or 12 cine mode images. Scanning a 100ft. roll of film will take the same time to capture, but the number of images produced would drop from an estimated 2,400 frames in comic to 1,440 frames in cine. This directly trans-

lates into the cost of scanning, making cine mode more expensive than comic mode. It also affects production and scheduling, as in this case, the cine mode production speed is only 60% of comic mode.

4. Duplex or Simplex
This can be translated into single page or double page per frame. On 16mm film, duplex mode tends to be cine mode with the left and right pages on each half of the film and is separated by a large gap. The reduction ratio is high (42X to 52X) and the film may or may not have blips. This format of film normally has the back of documents in one half while its front is in the other.

Does this constitute two pages? Does the customer want the back of the page for all images, even though many of them are blank? If they don't, then you have to look at each image and throw away the blank ones. This is labor intensive and pushes up the cost. We can use image size as a guideline, but what happens if we delete a page with a hand-written note that does not affect image size?

35mm film can have the same format, but I have seen more film in comic mode that was shot from an open book. The left and right page are logical pages, but they are within one film frame. Scanning of this type of film must take into account the customer's requirements, and in turn reflect the cost correctly. Are these two pages one frame (or image) to the customer? If yes, how are they indexed? If not, then how can I separate them, and how are they indexed? If this is two pages, do I charge the customer for two pages, or is it just one? 35mm is twice as wide as 16mm, but the information also tells us how many images may be on a roll.

5. Rotary or Planetary Filming
The camera method used in the filming may be more difficult to analyze than other film attributes. However, if you can find out early on, then the knowledge will help with the job cost estimating process, because it allows planners to anticipate for the unexpected. In general, planetary film is better than rotary film. I say in general, because film is a very unpredictable medium.

Filming with a planetary camera requires a more complex camera and lighting system. Planetary systems have a copy board, that may be black (if we are lucky), and may have a raised ridge to keep the document in a consistent position. There may be alignment marks that the document must be placed within. Since the operator is making these alignment decisions, the page will be skewed to some degree most of the time.

The copy board may be white, in which case a white page will appear not to have an edge on the film. However, a white copy board gets dirty very quickly, which shows up as noise around the image. While scanning, we cannot automatically cut the document out of its noisy background. Therefore, the whole area that encompasses the wanted document must be saved, thus increasing the file size.

A rotary system seems to produce poorer images than a planetary system, as the documents are fed through a system that exposes the film to the page as it passes through. The documents are frequently skewed. The only advantage of rotary scanning is that the background for the image is black, allowing easier cropping of the frame prior to saving the image file.

6. Blipped Film
Microfilm can have blips on one edge. The blips need room on the film, so the reduction ratio may be a little higher than non-blipped film. Blips come in four variations: large blip, medium blip, small blip and no blip. Blips can be used to indicate pages within a document and within folders. If a roll has blips, it is important to ask the customer what needs to be done with the information the blips indicate. The customer may not care, or they may want you to deliver a multi-image TIFF image containing all the pages of the document.

Blips may also be present on a roll of film and may not indicate anything about the data. The roll can be filmed using just the blips as an edge detection and nothing more. Find out from the customer what the blips indicate and determine whether it will be useful to the conversion effort.

7. Spools - Regular Reels or Cartridges
The type of spool that a film is on is not an issue until you try to scan 16mm cartridge film on a scanner that does not have a cartridge adapter. Also, because of the nature of cartridge film, the beginning of the roll tends to have more scratching than the end of the roll. This scratching tends to degrade the image quality, so when possible, find a master roll and work from it, as its quality will be better.

8. Thick Film or Thin Film
The thickness of a film is not a major issue. However, thick-

ness does let us know how many images are on a roll. From a production perspective, this translates into how frequently the rolls need to be changed, which affects productivity. For example, in a 100ft roll of film, a thick film can hold 2,400 frames, while a 200ft thin film roll can hold 4,800 frames.

9. Film Condition
Film condition is a subjective issue that is important for the overall success of the project. If the film is old, it may be brittle. In old film, splices may have failed and may have to be re-done. If the film is dirty, it may need to be cleaned. If the film has been kept in a hot place, it may have weak images. If the film has been stored in the wrong environment, it may have a film fungus. If the film has not been developed and washed correctly, it may appear to have been overexposed and be in poorer quality than is acceptable.

10. Resolution for Capture Purposes
Resolution numbers can cause so much debate. How many times has someone identified a roll of film to be scanned and said, "Scan it at the best resolution you think will work." This is too vague, and sometimes causes the sample to be done at 200dpi, 300dpi, and 400dpi, greyscale, and monochrome with and without gamma correction. *Gamma correction is a tool that can be used to enhance the image and should be used by operators as needed.*

In general, the average document can be scanned at 200dpi. If you want a little better image, 300dpi will be better. 400dpi does allow more image enhancement but does not seem to improve a microfilm image enough to warrant the cost. Greyscale scanning can occur at half the monochrome resolution and still give a high quality image. Also, scanning at a higher resolution will increase the image size significantly.

11. Monochrome or Greyscale
This should be a simple question, and up until recently, the only practical response would have been monochrome. However, it is now practical to scan in greyscale or monochrome, so the customer will need to decide which bit depth is desired based on an assortment of factors that can be determined by asking the following assessment questions:

Does the customer's image database and related systems support greyscale? If it does not, then monochrome becomes the only choice.

What is the quality of the original documents?
If the documents are old, faded, weak, hand-written, of mixed density, etc., then greyscale may be the best choice. If the documents are average, then monochrome scanning should be fine.

Can the customer's system handle the increased image size that greyscale creates?
If it does not have the disk storage, backup systems and network capability, then monochrome will be the only choice.

Even if the customer wants to have greyscale, because of document quality or expansion plans for the future, some compromises can be made like:
- Scanning in both greyscale and monochrome, and reserving the greyscale for future integration.
- Scanning and outputting both a full resolution and reduced resolution image at the same time, using the reduced image size until the network can handle the larger file size.
- Only scanning in greyscale those images that can't be successfully scanned in monochrome.

12. Black or White Copy Board
As stated earlier, the color of the copy board is very important to the cost estimation of a scan job. If the board is black, then there shouldn't be many issues as the document can be located and then cropped from the scanned frame. If however, the copy board is white and the pages 'float around' the center target registration, then cropping is difficult, frame size increases, image size increases and speed can decrease.

13. Do the documents need to be deskewed?
This should be a yes or no answer, but the client shouldn't expect every document to be perfect (a 0 degree skew). In general, every image scanned from film will have some degree of skew, because nothing is ever filmed perfectly. If every image needed to be deskewed to X degrees, then the real time scan speed will go down. It is possible to post-process the images off-line, and it is very valid to do it. Most images should only need to be deskewed (in the scanning phase) above a given threshold of 2 or 3 degrees. Therefore, I suggest that all service bureaus should offer to deskew badly skewed documents as a standard practice.

When deskewing in greyscale, set a limit that is acceptable and only process those above it, just like regular monochrome

images. Anything more, or if the images are very large, then post-process them to keep production speed efficient.

14. Film Content
Understanding the general content of film will help in assessing the potential issues and document types that will be encountered. For example, in film containing medical records, there will be the normal 8.5 x 11 document, colored carbonless forms, hand-written notes, maybe the three-fold oversized nurse's notes, and even continuous monitor strips or EKG's. Each document type will have different issues to be resolved, and the customer needs to be made aware of them.

15. Length of Film for 10 Images
One very straightforward way of estimating scanning performance is to measure a segment of the film. This measurements provides a confirmation of reduction ratio, inter-frame gap, and image size, but remember, this is only an estimate. If however, you can't remove the film to scan a sample, then this is method better than nothing.

To make these estimations, first measure the distance from the start of frame X to the start of frame 11. This will give you the total distance, including the inter-frame gap, for 10 frames. Then, take the 10 frame length and multiply it by the reduction ratio, and then by the resolution, to calculate the number of scan lines in the sample. Next, calculate the scan rate by dividing the known CCD scan speed into the sample size to get the time it will take to do the 10 images. Then adjust the result to a 60 seconds duration to calculate the estimated scan rate for the sample. The CCD scan speed can be obtained from the manufacturer, or calculated by dividing a known length of film into scan lines (length X reduction ratio X resolution) and by accurately timing the duration it takes to scan the segment. *Note: this rate will change for different resolutions and reduction ratios.*

***Example*:** A scanner runs at 3,000 scan lines per second. The sample of 10 images is 6 inches long, and the reduction ratio is 24x with a resolution of 300dpi.

Samples size = 6 x 24 x 300 = 43,200 scan lines.
At 3,000 scan lines per second it will take 14.4 seconds to scan the sample of 10 frames.
60 / 14.4 x 10 = 41.66 Frames per minute (FPM)

In general, the level of information gathered about a project will be proportionate to the accuracy of the cost estimate. Gathering this information will also make the customer think through what they expect from the service provider. Once this information is carefully documented, it can serve as a basis for performance. There are many issues that can occur as a result of poor information gathering, such as agreements based upon inaccuracies that lead to delivering the wrong image specifications.

Asking the right assessment questions about a project, combined with building the necessary familiarity with the production film capture and processing system, will be the formula that results in the least rework and the most client satisfaction. Working with a skilled systems vendor that places a great importance on production specifications, customer education, and technical support is a way of ensuring the best possible efficiencies and accuracy in any project.

Derek Jenkins, President, IImage Retrieval Inc., 3630 N. Josey Lane, Carrollton, TX 75007; 972-492-0930, Email: derekj@iiri.com

Professional Development Assessment Questions

This section provides a method to evaluate comprehension of the article in this issue, *Digital Film Capture and Processing Production*. Reasonings as explanations are given on the facing page.

Objective 1.
To be familiar with the possible phases of image processing in film scanning work. (ref. page 1).

Question 1.
How many phases of image processing are there in most film scanning projects, and what are they?

a) three: real-time (or near-real time), post processing and pre-processing
b) two: real-time (or near-real time) and post processing
c) one: near-real time
d) two: real-time and near-real time
e) none of the above

Objective 2.
To understand three common film capture practices that usually require real and post image processing work (ref. page 2).

Question 2.
Identify three filming practices that are commonly encountered in film scanning work, which can produce image attributes that can usually be either corrected or enhanced via image processing techniques.

a) filming on a white copy board (background)
b) improper illumination and, or unwanted refracted light
c) inaccurate feed alignment of the original on the filming target
d) capturing images with rotary cameras
e) improper film processing
f) a, d, and c
g) a, b, and c
h) a, d, and e

Objective 3.
To be aware of two approaches to scanning film that can yield potentially more accurate and efficient digital capture and processing in a production workflow (ref. page 4).

Question 3.
Identify two approaches which may be options in a film scanning project that are likely to produce more precise and productive output.

a) scan from a silver negative if possible
b) scan form the earliest generation of silver film possible
c) scan from vesicular film when possible
d) scan from diazo negative film when possible because it retains better tonal values
e) none of the above

Professional Development Assessment Questions:

Reasonings as explanations

Reasoning 1.

There are two primary phases in image processing work for image capture from film medias: a real-time/scan-time and post processing phase. The real time (or near-real time) phase is used mostly for image correction like deskew alignments. The post processing phase is used more for image enhancements like running advanced filters. Any image processing technique can be theoretically used during either of the two phases. However, any processing run during the real-time/scan-time phase will be done at a sacrifice to performance in terms of system resources availability and overall production speed. For this reason, most mathematically intensive image processing operations are accomplished in the post processing phase, so that the scanning can proceed at an acceptable rate. The most accurate response is (b).

Reasoning 2.

Identify three filming practices that are commonly encountered in film scanning work, which can produce image attributes that can usually be either corrected or enhanced via image processing techniques.

The three most common filming practices that are encountered in digital film capture work that produce unwanted image attributes are filming on a white copy board, improper illumination and, or introducing additional refracted light and inaccurate feed alignment of the original on the filming target. White copy boards can produce larger than required image files due to poor page boarder edge detection and additional noise from ink and other marks on the copy board. Improper illumination and, or additional refracted light can produce an overall de-emphasis of contrast resolution. Misalignment of the original on the filming target will produce a dependency on image correction processing. The most accurate response is (g).

Reasoning 3.

Identify two approaches which may be options in a film scanning project that are likely to produce more precise and productive output.

The two approaches which can be used to improve accuracy and overall production efficiencies are scanning from a silver negative and scanning from the earliest generation of silver film available. The master or second generation silver negative will be the best sources for the most accurately reproduced source data.

Using the negative will potentially improve the preservation of contrast resolution and reduce noise. Noise reduction and better retention of contrast resolution will decrease overall dependencies on image processing, which will improve production performance. Scanning from the earliest generation of the negative silver copies should produce the best digital capture accuracy, since duplication causes a loss in clarity and potentially significant changes in reduction ratios. The most accurate responses are (a) and (b).