ter. In a recent week I spent every afternoon in the darkroom getting prints just right for a paper. Should the print be a little darker, a little lighter, a little less contrast, a little more contrast? Then there is the trimming, the mounting, the scale bars, the arrows, extra sets for the reviewers, the other authors, etc. We've all been there. The whole job could have been done in one day with PhotoShop. However, the negatives would still have to be scanned in and I would need a high quality printer. Alternatively, these tasks could have been contracted out.

In the final analysis the question of film versus digital will boil down to a time versus money decision; slower, cheaper film versus faster, more expensive digital. Different labs will have different needs. Several of my colleagues are choosing to merge the technologies. They acquire their images, both light microscopy and TEM, on film and then digitize selected images for transmission to collaborators, inclusion in grants and manuscripts, etc. while retaining the quality, storage advantages, and low cost of film.

The Case For Digital Imaging

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Geoff eloquently makes a case for film as opposed to digital image acquisition and processing. And while I agree with many of his points, I also have a slightly different point of view on several aspects.

Let's start with the darkroom. While Geoff is correct in saying that many institutions already have a darkroom or have access to one at no cost, this only tends to hide the cost. Somebody has to build the darkroom and somebody has to pay for building maintaining and equipping the darkroom. If this is paid out of some overhead and not paid for directly, then the cost is hidden in that overhead, which would be less without the darkroom. But in the final analysis, this cost factor does not even play a significant role, as we will see below. And by the same logic many institutions and companies do have high quality digital printers, which we should take out of the equation as well. So, to be fair I will include both darkroom and printer for a cost comparison.

Let's take Geoff's numbers for prices: $6000 to equip a darkroom and $1,600 for negatives and paper and chemicals for 1000 negatives, *i.e.,* $1.60 for each negative. As I mentioned above, I will include the construction of a darkroom in the equation. As a rough estimate I will assume $10,000 for the entire darkroom: building material, space, water, power, sewer, labor cost, etc. Further, let's assume, that the darkroom has a lifetime of about 20 years, which leaves us at $800/year in fixed costs plus $1.60 per negative without calculating the cost of labor we will add later. On the other hand, a complete digital imaging system with a high quality printer is roughly $ 60,000. Let's assume only a lifetime of 10 years for this equipment.

Item	Film	Digital
darkroom	$800/year	$0
digital system	$0/year	$6,000/year

So far, film looks pretty good. Now let's add the cost for acquisition and assume that we use 100 negatives a week, and that only 10% of the images are actually printed. The acquisition costs for film consist of negative ($0.70), chemicals ($0.05), storage

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Costs Of Photographic Film Versus Digital Imaging

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($0.05), time for indexing (2 minutes at $25/hour). This adds up to about $ 1.60 per negative. For digital the costs are for storage ($0.003 for 2 MB) and indexing (0.5 minutes), which adds up to about $0.21 per acquisition. For 5000 acquisitions per year we have:

Item	Film	Digital
acquisition	$8000/year	$1000/year

The next cost item is printing. If we assume that about one tenth of the negatives are printed, the cost for paper is about $0.50 for digital and film and we need about 3 minutes for film and 1 minutes for digital, the total costs are as follows

Item	Film	Digital
printing	$900/year	$450/year

Maintenance: Assuming that the upkeep and maintenance of a darkroom including mixing all the chemicals replacement for broken parts takes about 1 month/year. For digital systems we can assume, that once in a while a computer part needs to be replaced. On the expensive side we need to replace the computer each year. Estimates are as follows:

Item	Film	Digital
maintenance	$4300/year	$2000/year

Another minor expense is the distribution of images. If we assume 1/10th of the printed images for distribution, we have to print them again and ship them through mail, while sending files through the internet is much faster and cheaper. However, due to the small numbers the costs are minor in both cases.

Item	Film	Digital
distribution	$200/year	$20/year

Adding all the numbers we arrive at an annual cost as follows

	Film	Digital
annual cost	$14,200	$9,470

This is a significant cost advantage for digital acquisition, contrary to what Geoff indicates. There is, however, a cross-over from film being more economical to digital at about 2000 negatives a year, or about 40 negatives a week. This cost difference becomes more pronounced when taking into account other than standard processing functions. If burning and dodging of the image is required, it will takes at least minutes for film, only seconds for digital. Similar for other processing like particle measurements, counting, etc.

Geoff is right about information density on film. Digital is at this point no match for film. However, my experience tells me that most users of TEMs fall into one of two categories: Those who use the high information density (high resolution TEM) and those who don't (mostly bio-medical). The former normally will enlarge the negatives many fold to get at the smallest details, but rarely do they use large areas of the negative. They get a few good prints from a negative, something that can be easily achieved with a few digital acquisitions. In addition, a digital camera allows to see the image immediately, so one does not need to acquire several negatives to make sure one of them is good. The other group of users normally prints the entire negative, which is equivalent to

taking a single digital image. If images at a higher resolution are required, one can simply take them at the microscope, rather than trying to find the information on the negative at a later point, a tedious and time consuming proposition.

So, in addition to being superior for processing the images and ease of storage, digital actually appears to be less expensive for more than about 40 negatives per week. The lower information density of digital images is usually not an issue, as it is possible to see the images immediately, making the acquisition of redundant images unnecessary.

Of course, digital is not the cure for everything. Applications that need the large area of negatives AND the high information density will be dependent on film for some time to come. Other parameters may make it necessary to stay with film. And while optical storage should be safe, digital storage simply cannot touch the proven track record of film storage if done correctly. This is not to say that optical storage is unsafe, It just has not been around as long as film.

Geoff McAuliffe's Reply:

In response to Michael's cost analysis, there are a few points of disagreement (which is how this discussion got started in the first place!) First, Michael calls the costs of building a darkroom from scratch hidden or insignificant but includes them anyway. If one needs to build a separate darkroom and pay for it from Departmental or grant funds, by all means include those costs. I think that there are few EM facilities in that position. Second, Michael includes darkroom maintenance at one month per year and costs that at $4300. What could possibly consume that much time and money? I do all of the darkroom "maintenance" for a Department of 25 active faculty, and it amounts to, at most, 4 hours per month. The only chemical I mix from powder is D-19 and that takes zero time to mix. I put a big beaker on the stirrer and add a bit of the chemical in between other chores, reading journals, e-mail, etc. Once a year I put a new bulb in the enlarger. Cleaning the print processor takes 90 minutes twice a month in a busy month. Also, Michael does not mention the cost of "down time" due to computer crashes, software incompatibilities, the occasional unavailability of technical support and the steep learning curve of programs like Photoshop. Finally, a ten year lifespan for a digital system seems very optimistic, if the system were replaced after seven years the cost analysis would change dramatically.

I think that Michael and I do agree that there is a point at which digital can become more cost effective than film. I think that point is much higher than the 40 negatives per week that he comes up with but in the final analysis each lab will have to make that determination for themselves. I hope the points raised in this article will help them do that.

Editor's Note: With the full knowledge that the debate will continue, we hope readers find the above positions of interest. We would be most interesting in publishing additional comments from our readers.