Digital Film Scene-to-Screen

A Users Guide to Digital Cinematography, Production & Post-Production

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Contents

Audio

Deliverables

Film Recording and Processing
Digital/Data Deliverables
Video Deliverables

Archive

Film
Digital
Digital Film?

Introduction

General Overview

The aim of this document is to provide a step-by-step guide for companies and individuals working on film projects looking to utilise digital film technology at some stage of the production and/or post-production chain.

This may involve the use of digital cameras for capture, Digital Intermediate post-production for on-line editorial, grading, vfx, etc., or the generation of digital deliverables for theatrical release and home viewing.

What is intended is that the use of digital technology described within this document is for on-line work at full 'film' resolution, working with the original images in the generation of the final master. It is not intended to describe the use of off-line digital systems, where low-resolution proxy images are used to build an edit decision list and off-line cutting copy, to which the on-line is matched.

It is intended that this document will be of use to anyone utilising digital technology anywhere within the on-line process, regardless of original capture medium or required deliverables. Therefore, if you are shooting traditional film, digital high-resolution or HD, this document will be of assistance. The same is true if the deliverables are to be theatrical film, digital projection, or purely digital video.

However, this document is generic in it's approach, and is no substitute for equipment manufacturer supplied user documentation or knowledge.

For example, do not expect to find specific camera setup details, rather generic information on the approach to adopt for best results. And this includes an understanding of HD video vs. HD capture for theatrical film applications - the two having markedly different requirements and producing very different results from their capture of the same original scene.

This document should also be read in conjunction with Digital Praxis's additional DI documents: **Digital Intermediate - A Real World Guide to the DI Process**, and **Quantel's iQ Pablo Digital Intermediate System - A Real world Guide to iQ Pablo and the DI Process**.

Document Breakdown

The layout of this document is split into four main parts - Capture, Dailies, Post-Production, and Deliverables, with an additional fifth part dedicated to Archive requirements, for reasons that will become apparent within that section.

As expected, Capture deals with best camera practices, including generic camera setup for contrast, colour, and dynamic range;

Dailies looks at the best workflow for accurate dailies review - from both film & digital sourced images;

Post-Production looks at the best methodologies for Digital Intermediate work;

Deliverables describes the best way to generate the final images for distribution and viewing;

Archive looks at the possibilities for long-term storage of digital material.

Capture

Image

When capturing images to be processed via a Digital Intermediate system there are some general rules that can be applied to ensure the best possible results, regardless of the capture medium being used.

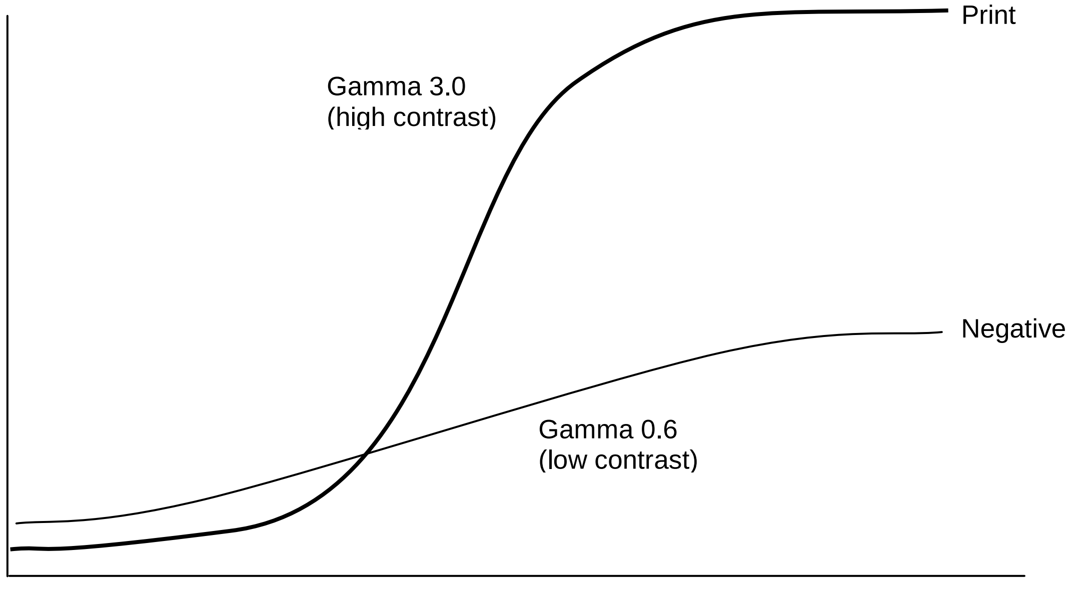
Low Contrast - High Dynamic Range
As a rule, it is usually (always!) best to capture the image without, or with minimal, in-camera grading. That means capturing an image that is as perfectly mid-level exposed as possible, combined with the highest dynamic range capture possible, which means capturing a low contrast image. From such an image a DI system can generate the best possible result, matching the creative requirements of the DoP, Director, Producer and/or Studio.

What limiting 'in camera grading' does NOT mean is limiting correct lighting, or filtering, or other optical camera setups. Such 'looks' are important in maintaining the real look and feel of any movie, and cannot easily be replicated in post. This includes capturing the correct 'mood' in-camera, be it dark and moody, or light & airy - just don't clip or crush highlight or lowlight detail.

Digital Intermediate is not a replacement for camera & lighting skills!

Film already captures this way, with OCN (Original Camera Negative) having a very low contrast, which is printed onto high contrast Print film for viewing. The problem is that when production is confronted with digital capture cameras there is a obvious desire to make the images 'pretty' when viewed on-set via a monitor. As we will see this is actually the last thing you want to do in generating the best possible deliverable, and good & understandable use of on-set ViewLUTs is key - see later.

OCN film contrast vs. Print film



The above diagram shows the difference between OCN's (Original Camera Negative's) low contrast capture and Print film's high contrast final deliverable. Note that the combination of the two contrast values (0.6 for the negative x 3.0 for the print) results in a final image contrast of above 1 (1.8) which means that the final image has a higher contrast ratio than the original scene! This is required to overcome the less than optimum viewing conditions encountered within a film theatre.

OCN

Print

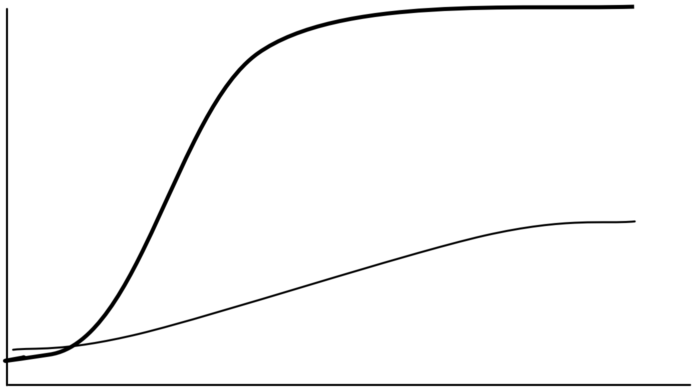
The reason for capturing a low contrast image is that if in-camera grading is performed it is possible to clip or crush lowlight or highlight detail (under expose or over expose) which it is then impossible to regain in post-production. And it's only in post-production where the real interaction of shots can be seen as it’s only here they are viewed in their real final edit context. More later on this.

There is nothing new in this approach, as chemical lab grading has relied on this technique for years with film captured images, as can be seen from the images above. It is just worth restating before we get into specifics for different capture mediums as understanding this approach will guarantee the best possible final images.

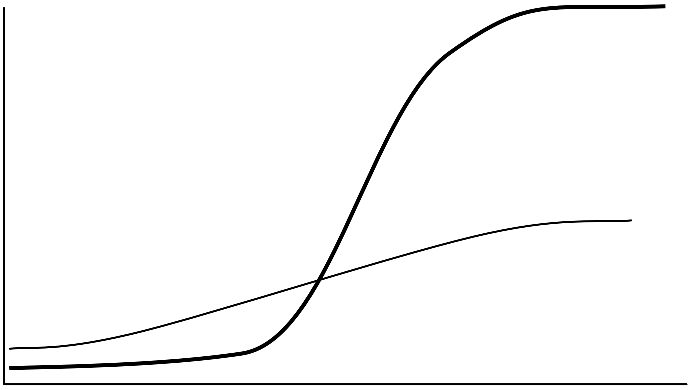
While we are looking at the ‘print’ process, it’s worth expanding a bit more on the print process, and how grading is performed by ‘moving’ the print curve up and down the captured low contrast image data.

This is done by increasing, or decreasing, the amount of light used to 'expose' the low contrast negative image on to the print stock - low light-levels only 'revealing' the less dense areas of the negative image,

Moving the print curve into the shadow detail will brighten, or print up, the image.



Moving the print curve into the highlight detail will darken, or print down, the image.



Film Cameras

Using traditional cine film cameras is often the easiest approach to capturing images for DI post-production of a motion picture film. This tends to be because of the plethora of knowledge within the industry with regard to film capture, enabling the capture of near perfect images without recourse to unusual techniques or the need to learn new technology.

And as DI requires no special capture techniques from film sourced material all that experience and knowledge can be applied to best effect.

So the answer for film capture is to proceed as normal, with no new or different requirements, keeping in mind it is always best to aim to capture perfect mid-exposure images, enabling the widest range of image manipulation in post-production without restriction.

Colour Management

One of the problems facing any DoP is the worry that his, or her, images will be altered in post-production, away from his intended look. This has caused some DoPs to capture images deliberately under exposed or over exposed, preventing large re-grading in post-production, be that via DI or the chemical lab. While the intent is easy to understand, this approach can severely compromise the quality of any final image, especially with under exposure as the film grain will be 'enhanced' through minimal excitement of fine grain detail, while over exposure will greatly limit highlight detail should it become necessary to reveal it later in post.

With the growth in Digital Intermediate post-production there can be more concern that the possibilities for alteration are greater. Whilst true to an extent, the reality is that with some limited planning any problems can be avoided, ensuring the best possible quality and correctly graded image.

To assist with this process Kodak have produced their 'Look Management' system, which enables off-line grading decisions or 'looks' made by the DoP to be carried through to the on-line grading session. Check www.kodak.com for additional information. While not the only approach to guarantee final grading, it shows what is possible with some simple management of the whole colour process.

What can't be done, without a high level of colour calibration understanding, is for the DoP to simply grade stills on his/her home PC, using a commercial paint program, and deliver a CD to the DI post-production house as a grading guide.

Although I have seen this approach attempt to be used, it is flawed for one very simple reason. The monitors used will not be 'film' calibrated in any way; with the result that what the DoP saw on his/her PC at home will look completely different on a PC in the post house. It will also be displaying 'electronic' video colours that are often impossible to display via chemical film.

There is also no way to guarantee any digital stills camera will match in any way the colourimetry of the real film image.

The calibration procedure used to ensure accurate calibration of DI systems is an integral component of the digital film chain and cannot easily be replicated with consumer products. Hence Kodak's introduction of their Look Management system to overcome these calibration issues.

Ideally, the DoP should become an active part of the post-production process and build a good working relationship with the project's DI operator and colourist. In this way not only will the correct look make it to the big screen, but with the best, uncompromised quality.

Lens Centre

One of the biggest issues when it comes to using film cameras to capture images to be post-produced via a DI system is the optical centre setup of the lens. Traditionally, film camera lenses have been centred on the academy area of the film frame, making direct optical duplication easy with respect to the soundtrack.

For DI post-production it is better to centre the lens on the full Super 35mm frame (perf. to perf.) to maximise resolution and allow the DI system's film recorder to resize and reposition the image for a final academy output. It is also better to not mask the image to the final projection aspect ratio (1.85 for example). This maintains the digital film image at 2048x1556 for a 2K DI throughout, rather than the reduced 1828x988 academy 1.85 size.

The point to re-stress is the need to use film cameras with lenses centred for the full 35mm frame - perf. to perf., rather then the historically normal academy centring.

Lab Processing Effects

Another point it is worth stressing is that in the same way as it is best to avoid in-camera image manipulation, it's also best to avoid film processing effects, such as bleach bypass, as such effects can easily be replicated during the digital intermediate post production operation, with far better control and therefore more accurate results. If done within the chemical lab it is impossible to 'undo' the effect within DI post.

For projects looking for a specific feel to the final image, as with bleach bypass, it is always worth spending time prior to shooting testing the DI process's ability to deliver the required look. Time spent testing the whole process will pay major dividends during the production and post-production processes.

Capture Aspect Ratio

Something else that is worth considering is the aspect ratio to capture in. The obvious possibilities here, assuming 35mm, is spherical vs. anamorphic lenses. Without going too far into maths and optical vs. digital losses it is always better to shoot spherical 4:3 and digitally generate an anamorphic image, if anamorphic is what is required for final projection.

The main reason is the difficulty in getting perfect optical anamorphic lenses. They all tend to suffer chromatic aberrations and parallax distortions towards the edge of image that are not so apparent in spherical lenses. Therefore the digital process of generating an anamorphic image from a spherical lens image generally (always?) produces a higher quality final image.

Additional options include the use of 3 perf. and 2 perf. cameras instead of the normal 4 perf. as they can provide cost savings in stock usage when the final image will be a 1.85 ratio (close to 16:9), which 3 perf. is great for, while 2 perf. is great for final 2.35 anamorphic images.

However, the restriction they generate is a lack of vertical pan & scan freedom during post, the same as when masking a 4 perf image to 1.85 as discussed above. However, as most DoPs frame accurately during shooting there is often little difference in the final image, and the cost savings can often be of more importance to a production.

HD vs. Data DI?

An additional benefit for the production team is the ability, or option, to use a HD 'video' workflow for the DI process, rather than a 2K data centric process. This is explained further in the later Post Production section, but can have a significant impact on production and post-production costs for minimal loss of quality. It is well worth understanding this optional post-production workflow approach for film captured images.

Digital Cameras

The use of digital cameras for theatrical 'film' projects is something that is gaining in popularity as the benefits offered become better known and understood. The century and more of experience and knowledge gained with traditional celluloid film cameras is not going to be replicated quickly with digital cameras, but it will come.

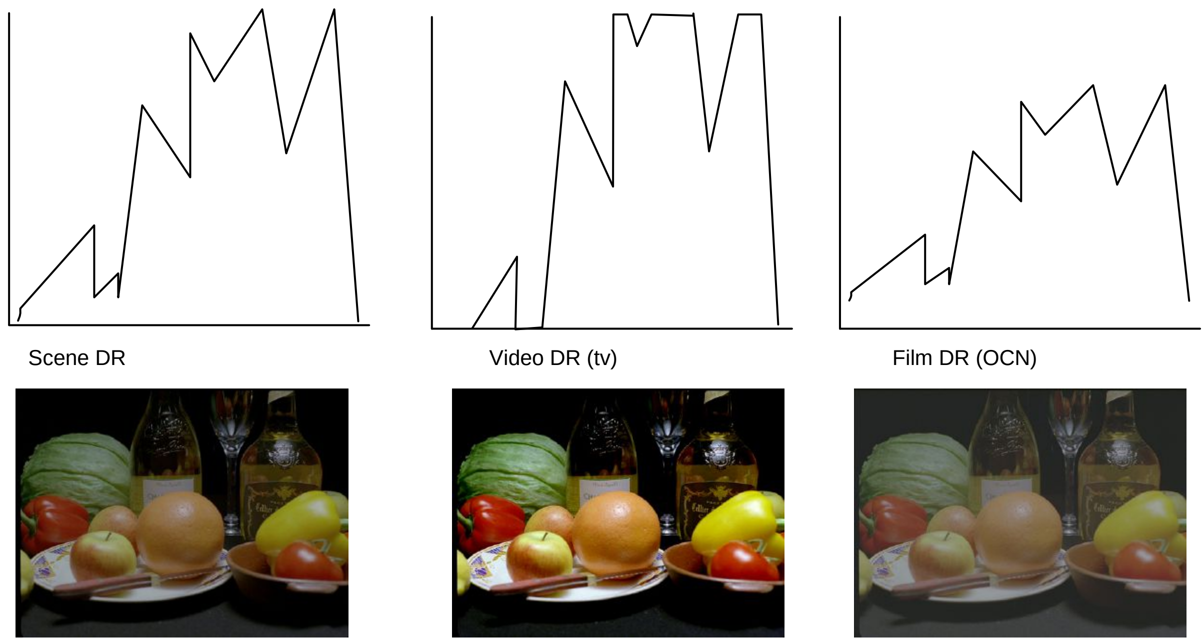
One thing I am compelled to say up front is that digital camera manufacturers have not helped themselves in explaining the use of 'HD' cameras for 'theatrical' projects. Their attempts at explanation and guidance have either been overly complex, lacking in useful information or unnecessarily competitive vs. film. I guess this is because most 'digital camera' manufacturers are from a 'video' background and lack the experience of film acquisition and the following film post-production process. This has to change.

Therefore, I hope the information contained herein proves to be of more use. It is written with practical experience and knowledge.

Digital Film - Not Digital Video!
Before proceeding with specifics for Digital Cinematography it is worth reviewing the use of digital capture for video, exploring why there is a marked difference between digital capture for standard tv video use and for Digital Intermediate film use.

Traditional video capture expects the home tv to be the final viewing medium. This sets in place a number of constraints that affect the capture technique.

Foremost amongst these is contrast. The home tv viewing environment requires a high contrast image to overcome ambient lighting conditions in the average living room, which restricts the available dynamic range. Therefore, tv images tend to have crushed blacks and clipped whites as as much contrast as possible is pushed into the available dynamic range.



The above diagram is a simplified representation of a comparison between scene dynamic range, tv video and OCN film. What this shows is how video clips whites and crushes blacks as it has a high contrast, low dynamic range, while film has headroom and foot-room via its low contrast, high dynamic range capture technique.

For this reason - the needs of tv - most video cameras are set to capture an image immediately viewable on a standard monitor, as shown above. Compare this with film's approach to capturing a low contrast, high-dynamic range image, which if viewed directly would appear flat and lifeless. This can be seen in the two images at the beginning of this document showing an OCN image (in positive form) and a print image. The OCN image being very flat and lifeless.

Therefore, when capturing digital imagery for DI film applications it is preferable to adopt a more 'filmic' approach and reduce the captured contrast, increasing the available dynamic range.

High Dynamic Range
Irrespective of common film industry thought, today's High Definition (HD) digital cameras can actually capture a very wide dynamic range, if setup correctly. This is something most professional digital camera manufactures are assisting with, with the introduction of 'film style' gamma modes (see later).

If the camera is setup and used as for traditional tv video capture the available range will be video's nominal 4 to 5 stops. However, if the camera is set correctly for low contrast, high dynamic range capture, an amazing 8 to 9 stops becomes available. While this is not as large as film's nominal 10 to 11 stops it is more than enough due to digital's benefit of being able to present to the DoP and the production team the actual image being captured on-set, enabling exposure and lighting adjustments to be made as required to ensure perfect image capture.

Note: both film manufacturers and HD camera manufacturers quote larger dynamic ranges for their products. The figures used here have been gained from practical experience and show a nominal reality.

In this respect HD digital capture can offer serious benefit over film's blind capture process. And that's before the issue of lack of grain has been discussed.

Describing film as 'capturing blind' refers to the fact that what is actually captured on the negative cannot be seen until the film is processed and printed. It is only then that the true exposure level can be proven, and is a big part as to why OCN has such a large exposure latitude - the bit of interest is almost definitely going to be in there somewhere!

The use of a video tap, or video assist, tells nothing of the image the negative is actually capturing, and it is the knowledge and experience of the DoP/cameraman that ensures the final image will be as required. That, and over 100 years of film history.

Digital cinematography provides an immediate view of the image being captured, allowing for far more accuracy in 'exposure'.

View LUTs
However, it must be pointed out that the raw captured image viewed on-set will be a low contrast image, not suitable for direct use - exactly as for the approach with film negative, or more specifically reversal film as the 'HD' image will be a low contrast positive image, while OCN film is low contrast negative.

For the more technically inclined it is possible to use an on-set viewing, or View, LUT to present the image in a 'print' form, but this tends to restrict the on-set understanding of the image being captured from a technical level of understanding.

Having said that, for the DoP an image presented via a View LUT is preferable as it helps with making lighting assessments that are otherwise very difficult when looking at a low contrast high dynamic range image.

To assist with this the Digital Praxis LUT Builder can be obtained via www.digitalpraxis.net for use with LUT enabled monitors, such as from Cine-tal, or via an image converter box & TFT monitor, such as Black Magic's HDlink.

The following image shows an ideal low-contrast digital capture and an example of the possibilities for grading. Note: this image was captured with no additional key or fill lighting, and aimed to produce a dark and moody result.

Original low contrast capture, with lifted blacks and lowered whites resulting in a very low contrast image.

Nominal graded image, preserving a fair amount of shadow and highlight detail, while giving the dark and moody feel required.

Image graded darker to show the extra available latitude visible out of the window.

Digital Cinematography Cameras

There are presently four main 'digital cinematography' cameras available, with more being revealed to the market almost daily, and each offers subtle and not so subtle differences. The four are Sony's HDcam range, Panasonic's Varicam, Thomson's Viper, and Panavision's Genesis. Others are coming to the market, such as Dalsa's Origin and Arri's D20, but these are not yet available to the larger market.

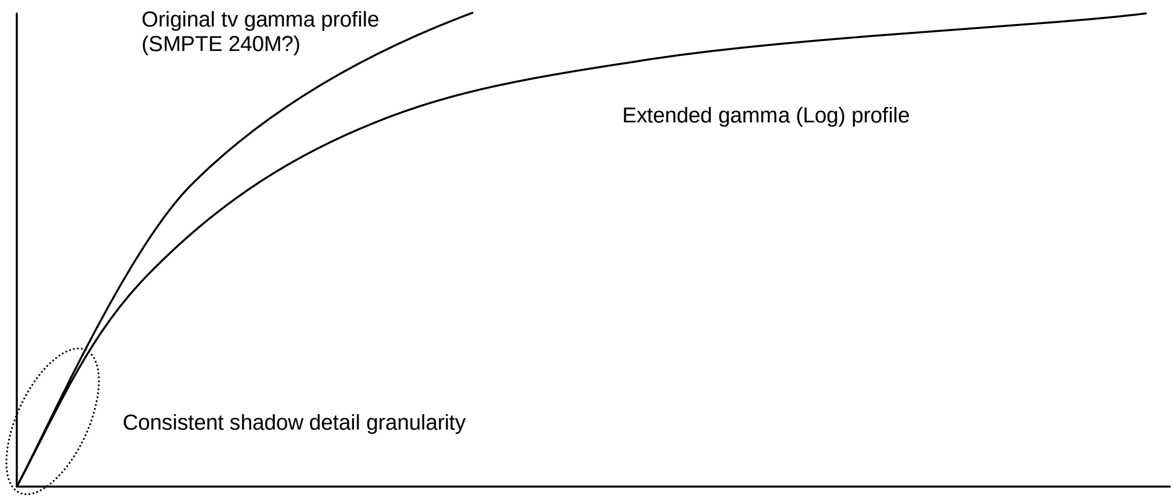
Extended Dynamic Range
The first thing to assess with each camera is how to maximise its available dynamic range and ensure it is capturing the best possible image for later Digital Intermediate post-production.

With Sony's HDcam and Panasonic's Varicam this means taking advantage of their user setups that allow a more 'filmic' gamma curve.

Sony in particular provide a PC (Excel) based gamma setup program (CvpFileEditor) that enables a great deal of user control – sometimes too much – and excellent results can be obtained with care. There is a selection of gamma curves available as downloads from the Digital Praxis website (www.digitalpraxis.net) which have proven to be very popular, and have been used on the new BBC blockbuster 'Planet Earth'.

Panasonic offer in-camera controls to provide a similar gamma profile capability called Cine Gamma, but the results obtained via this mode have often proved less than optimal compared with alternatives.

One of the problems with 'playing' with the camera's gamma profile is that it is imperative not to lose shadow detail granularity. If you think back to the way OCN film captures an image it has a Log profile with good shadow granularity, lessening as it moves towards the highlights – just like the human eye. It is this profile you need to map the gamma profile to. This is shown in the following diagram.



The above simplified diagram shows a standard video camera (Rec. 709) gamma profile compared with a 'modified' digital cinematography gamma profile aimed at maximising the dynamic range captured. Looking at the 709 profile it is easy to see how the curve 'clips' before its natural end, resulting in cropped highlight detail. The modified curve shows what can be captured if the resultant image is not made to look immediately viewable. i.e. the image captured with the modified curve will be a 'flat' low contrast image. Perfect for DI manipulation. This diagram is based on the Digital Praxis Sony gamma curve 'Cin Log 709' which is downloadable from the Digital Praxis website.

Both the Sony HDcam and Panasonic Varicam can match or come close to the above extended gamma profile and enable a very 'filmic' response to image capture, ideal for DI post-production. Their problem, though, is that it is still possible to clip blacks by under exposing as there is no 'toe' characteristic to the profile. This means it is still possible to crush shadow detail too easily.

There is also the issue of image granularity when capturing to internal tape cartridge recording, which uses pixel reduction, frequency filtering, bit depth reduction and image compression to get the image on to tape. It is possible that the extended gamma curves will reveal image artefacts, such as image banding, due to such post capture image processing and reduction. The only way to avoid this is to capture to uncompressed disc storage, or minimal compression vtr systems such as Panasonic D5 or Sony SRW. If in-camera storage is unavoidable pre-production test are strongly advisable.

The Thomson Viper camera takes this a step further when used in its FilmStream mode as it takes the 12 bit Linear signal from the CCD (the CCD's A-to-D actually as all CCDs output an analogue signal) and immediately converts this to a 10 bit Log signal, mimicking OCN film stock (or rather Reversal film stock). As this is done up front within the camera, unlike the Sony and Panasonic 'Cine Gamma' profiles, which are done later in the signal processing chain, the resultant signal is potentially superior.

Bit Depth & Bit Range

However, and there is always a however, extending the camera gamma profile to increase dynamic range obviously increased the amount of information each digital 'bit' within the signal has to represent. This is why it is so important to keep the shadow detail granularity consistent to maintain detail resolution and prevent 'banding', and avoid heavy frequency filtering, pixel reduction, bit depth reduction and image compression.

This can become a problem in extreme conditions when using the Sony and Panasonic cameras in 'HD camcorder' mode (i.e. recording to their internal tape recorders) as they record only an 8 bit signal (256 levels), derived from the original 10 bit source (1024 levels), combined with frequency filtering, pixel reduction (Sony HDcam drops from 1920 captured pixels to 1440 stored pixels per line), as well as direct image compression. This can result in visible banding in extreme cases, as well as a loss of resolution and even colour. The way to avoid this is to record directly to a low compression vtr format or disc recorder.

The Viper, in FilmStream mode, can only record to an uncompressed disc pack, such as from S-Two, or a Dual Link capable DI system, such as Quantel's iQ, or to Sony's mildly compressed SRW vtr, which avoids this issue – it has no internal vtr capability.

Another consideration is the actual 'bit range' of information captured by the camera and recorded onto the capture medium, vs. the range ingested into the DI system through compliance with legal video levels.

This is different for 4:2:2 YUV HD and 4:4:4 Dual Link RGB HD.

For example, most digital 4:2:2 HD cameras can be set to capture image detail beyond HD legal video levels; above white's legal 940, if not below black's legal 64 too.

This enables the cameras to see and capture extra image detail, especially in highlight areas, without clipping. Cameras set to capture this way are said to be capturing over 100% (106% for example).

Therefore, the post-production DI system need to know if it is to ingest legal HD levels, or extended range values. It must then know how to map them back to legal values for outputting the final work.

If ingest or output is done incorrectly it is therefore entirely possible to introduce unwanted clipping, severely degrading the actual images captured.

However, the various pixel reduction, bit reduction, pre-filtering and compression techniques in HDcam mode (recording to the camera's internal tape) mean it is possible to over extend the captured dynamic range, introducing banding errors.

Care must be taken when using a HD 4:2:2 camera beyond its nominal settings...

Dual Link 4:4:4 HD has different legal levels, set very closely to 0 for black, and 1023 for white (actually 4 to 1019) so there can really be no confusion. This also means Dual Link cameras capture an extended dynamic range compared to 'normal' HD cameras.

Resolution & Quality

The other possible issue with HD capture is resolution, and what is acceptable for a 'film' image. It has been repeatedly proven that the 'average' film release print contains no more than the equivalent of

1.2K pixels of image detail, equal to about 700 lines. This is due to the losses involved in processing and duplicating of film to generate the final release print.

The Sony HDcam and Viper capture 1902x1080 resolution and the Panasonic Varicam 1280x720, which can be considered at least equal to an average release print. More importantly, the digital post-production process can be lossless, if managed correctly, enabling the full captured resolution to make it to the final deliverable image.

This is obviously slightly simplistic, as HDcam, as discussed above, uses pre-filtering, compression, 3:1:1 sub sampling and 8 bit image data when recording in HDcam mode – i.e. recording to its own internal tape recorder, and similarly with the Panasonic Varicam. However, the newer Sony F950 and SRW vtr record at much higher data rates and any HD camera can be connected to an uncompressed disc recorder to record as a minimum the full 1920x1080 10 bit 4:2:2 yuv image, or even 4:4:4 rgb.

The Viper was the first HD camera to offer 4:4:4 rgb capture and as with the new Sony F950 HDcam produces amazing images with limited restriction on final quality. Such uncompressed (low compression when recording to SRW vtr) rgb 4:4:4 cameras really show what is possible with digital cinematography. But, the standard HDcam F900 and Panasonic Varicam can capture equally amazing results if used correctly, and we have yet to see the real results capable from the newer range of enhanced digital cameras, such as Panavision's Genesis and Dalsa Origin.

Examples of the more common Sony and Thomson camera images can be seen on the Digital Praxis website – www.digitalpraxis.net

To summarise the main HD camera options in descending quality order:

- Viper FilmStream/Sony CineAlta F950 4:4:4 rgb recorded to uncompressed disc recorder.
- Viper FilmStream/Sony CineAlta F950/Panavision Genesis 4:4:4 rgb recorded to SRW low compression vtr.
- Viper YUV/Sony HDcam F900 4:2:2 yuv recorded to uncompressed disc recorder.
- Viper YUV/Sony HDcam F900 4:2:2 yuv recorded to D5 low compression vtr.
- Panasonic Varicam 4:2:2 yuv recorded to D5 low compression vtr.
- Sony HDcam F900/Panasonic Varicam recorded to high compression internal tape recorder.

Because of the different pre-filtering, compression and other 'things' done to the image when in HDcam mode, the final entries in the list are not as easy to rate… As always, it's best to check for your self and see what empiric testing shows. There is also the question of the modified Sony F900 cameras, as supplied by Panavision, which offer yet another alternative, as well as the yet to be released Arri D20 and Dalsa Origin.

Camera Lenses
It's also worth remembering that camera lenses can do more to affect the quality of the final image than anything, and I have ignored those here. The rule as with film cameras is to go for the best, and this usually means fixed focus 'primes'.

It's also worth noting that cameras with '35mm' sized sensors, with the ability to use '35mm film camera' lenses are often not a good quality combination, even if the 'film' lens works well on a film camera. This is because of the different ways film and digital sensors capture images.

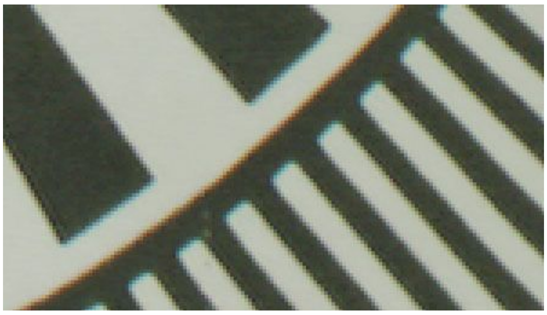
In basic terms, film grain will respond to light hitting it at any angle, while digital CCDs require light to be much more collimated, or parallel, to excite each CCD cell. For this reason 'digital' prime lenses tend to be of a much higher quality than their 'film' equivalents, and produce better captured images.

This goes a long way towards explaining why HD 3/4" 3 chip cameras with DigiPrime lenses can produce images of superior quality than single chip '35mm' aperture HD cameras with 'film' lenses.

This also helps explain why 3/4" 3 chip HD cameras don't suffer with depth-of-field issues normally associated with smaller sensors.

The following images show examples of the sort of artefacts bad lens/camera combinations can introduce:

Chromatic aberration



Contrast ringing

In the first image note the red fringing to the left, and cyan to the right. In the second image note the dark ringing within the black areas directly after a white part of the image.

In assessing digital cameras I have also ignored cameras only capable of 25p/50i and 30p/60i as today cinematic release requires 24fps, and conversion from 25fps and 30fps to 24fps can cause major issues, especially with audio - see below, as well as heavily compressed pro-sumer cameras

Cinematic Approach to Digital Capture

When shooting HD for a theatrical project the approach, as outlined above, is to use the camera to capture a low contrast, high-dynamic range image. This should be considered equivalent to film's original camera negative (OCN), but in positive form.

For those used to film capture think of high dynamic range HD as being equivalent to Reversal film stocks, which is a very good simile when using HD for theatrical DI projects.

When using camera negative film DoPs expose for shadow detail, allowing highlights to fall almost where they will. When using Reversal film exposure is set for highlight detail, and this is the approach to take with HD capture - although this does rely on good high dynamic range camera setup. See elsewhere within this document for more info.

And like film, working with a HD camera setup for low contrast, high dynamic range capture requires post-production to 'reveal' the correct image, with additional creativity provided via post. Exactly as for the chemical grading or timing process required for film printing.

HD Rough Shooting Guide

The following guide points are just that - rough guides not god given rules. They will result in an image suitable for DI manipulation and will generate an image that will be low contrast and 'flat' when viewed on/under normal HD monitor/conditions. The biggest worry in following these guide points will be the introduction of digital noise [video grain?] if exposure levels drop too low. As with film capture, lighting plays a vitally important role both in quality of the final image and setting the correct creative mood and needs as much care as with film capture.

Rough Guide to shooting HD

- Check back focus – and re-check it regularly!

- Shoot 24psf - maintain a 24 fps filmic image without interlace artefacts - also vital for audio phasing for 24fps film/25fps video masters.
- Use 1/48 shutter speed - mimic nominal 'filmic' motion blur
- Use ND filters rather than stopping down - maintain a filmic depth-of-field
- Expose for highlight detail - treat HD capture as a Reversal film stock
- Take care with scene lighting - avoid highlight blow-outs
- Set camera for low contrast, extended dynamic range capture - mimic film DR *(see camera manufacturer's instructions for set-up – if available use the camera's Cine Gamma mode or Viper's FilmStream.)*
- Avoid black crushing - mimic film toe characteristics
- Avoid white clipping - mimic film shoulder characteristics
- Aim to grade or time in post-production not in-camera - retain flexibility
- Use on-set View LUTs to see 'graded' images while capturing high dynamic range, low contrast images.
- Watch scene framing - there is no safe area or over scan area in an HD image

If followed, the result will be the most flexible use of HD capture for DI post-production, without the restrictions usually associated with HD vs. film.

For additional information on shooting HD for DI post-production review the additional documentation provided on the Digital Praxis website.

Audio

Audio capture techniques obviously depend to some extent on the image capture technique used.

If using traditional film cameras the only requirement is to follow standard working practices, recording audio onto a separate recorder for later audio post-production. Need any more be said?

If using digital cinematography cameras there are a few more options, as most digital capture formats allow for simultaneous image and audio recording combined with variable frame rates.

While it is unlikely that this in-camera audio will become the definitive audio source, because, as with film, separate audio capture has benefit, it is nevertheless worth capturing audio 'in-camera' for immediate review and rough editing in association with the image.

One of the biggest concerns for audio capture is the frame rate used. Obviously, this has to match that of the image, but it is actually the requirement for audio that dictates the best image frame rate more often than not. This is because altering audio speed is fraught with more dangers and problems than with images.

This is also primarily a PAL issue, for reasons that follow.

For example, if a project is shot at 25fps any film theatrical release will require a change to 24fps. For the image, playing 1 frame per second slower is not an issue. The human eye cannot really see such a small speed change.

However, if audio is played 1 frame per second slower the associated pitch change can become very obvious. To overcome this audio tends to undergo a pitch change process, during or after the speed change, to maintain the correct audio sound. The issue with this is that the process of changing the pitch and adding new audio samples to slow the original 25fps audio to 24fps can introduce phasing errors between stereo channels, making left and right audio go out of sync.

Speeding up audio - from cinema's 24fps to tv's 25fps is a far easier process as samples can be removed equally from both stereo channels.

The result of this is to always shoot 24fps if there is to be a cinematic release of the project.

For the NTSC market 3:2 is used to convert between film's 24fps and tv's 30fps (ignoring drop frame for the moment as it matters not to the practicalities). This 3:2 process means the same number of original frames is played within one second, so audio doesn't require any adjustment.

Therefore, once again the best practice for digital cinematography is to shoot 24fps (23.98) if there is to be a cinematic release of the project.

Digital Dailies

Dailies are one of the most important aspects of film production as it's the first chance the production team have of seeing the raw source material that is the bedrock of the whole project, and which determines the final quality attainable.

It is also the only way to check for technical errors and plan for the coming day's shoot.

As a result there is a lot hanging on dailies reviews, and yet there is often little attempt to ensure the image being reviewed is accurate to the underlying captured image information, regardless of film or digital acquisition. And it's all to do with understanding colour management.

Colour Calibration

One of the most talked about, yet least understood aspects of digital film workflow, is colour calibration - especially with regard to the dailies review process.

It's easy to understand the problems that are being experienced by some DoPs and Studios, with digital dailies not representing the actual colour, contrast or mood of the image shot on-set. But such errors should never be being allowed to happen in the first place. Digital image quality control is easy to manage, and there is no excuse for inaccurate image presentation - ever.

It is eminently possible to provide digital (SD, HD or otherwise via tape, DVD or data) dailies that are at least as accurate as film prints, if not more-so, to the underlying captured image present on the OCN, with the following Digital Intermediate process being just as accurate through it's use of the same basic image data. All that is needed is a bit of workflow understanding.

Film Capture

When capturing images via film cameras there are two dailies paths available:

Printing and projecting the dailies as film prints.

or

Generating digital dailies and reviewing via a digital projector or monitor.

And far too often the view is that digital dailies don't accurately represent the original image as captured by the DoP, while there is almost total faith in film print dailies.

This is understandable, for all the wrong reasons.

What seems to be happening is that the companies providing the dailies are not aware of the very simple workflow required to make digital dailies a totally accurate methodology for image review via total colour control and calibration. And worse, the production team and Studio assume that as they are watching a 'digital' image it must be right.

How wrong can anyone be?

The problem is that predominantly dailies are being creatively graded by telecine colourists, when that is actually the last thing that should be being done. Even telling a telecine colourist to 'grade in the middle' or 'perform a technical grade' or to 'do a one light' offers no guarantee that the resultant digital image will be anything like what the DoP actually shot.

This is because the creative process of telecine grading relies on the colourist to control a system that has no guaranteed datum point referencing the image contained on the OCN film.

In basic terms telecines are not 'calibrated'. It's what a telecine suite exists for after all - producing an image that is pleasing to the eye, regardless of the underlying image information contained on the film being transferred.

And to compound this further, the dailies review environment, when being performed digitally, is often someone's office, hotel room, or other non-theatrical environment, with a dodgy tv and vhs player.

Why, when dailies review is so important, would anyone risk compromising the image they are reviewing to such an extent just because it's now 'digital'?

Having said that, I have seen many theatrical screening rooms that have been out of tolerance that they have been just as useless. The difference tends to be that when viewing film dailies a simple statement like 'we knows it about 3 points magenta' or 'this projectors a bit cool at the moment' seems to make those reviewing the images accept that everything will be ok. I guess that's 100+ years of experience for you? Show a digital image that is anything but perfect and no one will accept it's nothing to worry about. Any why should they when it's possible to be so more accurate with digital imaging, if it's done right?

That's because there is a very simple process that can be applied to digital dailies, and the ensuing DI process, that ensures the digital image seen is always faithful to that captured by the DoP on-set.

Rather than using a telecine as a creative tool, it should be used to transfer an image via a fixed relationship between the film density and the digital data.

This we have all been doing for years with film scanners, which transfer images based on Kodak's Cineon film density transfer characteristics, generating a known digital image file that represents the underlying film image very accurately, effectively creating a digital clone of the OCN film image. This image, usually a 10bit LOG DPX image, can then be shown via a calibrated LUT, on to a calibrated monitor, to present a very accurate 'preview' of the film image when printed.

In fact, so accurate that the problem then becomes ensuring the film processing lab can print and process as accurately as the calibrated LOG digital film transfer and LUT presented image, so accurate is the basic process.

The one caveat here is that the viewing medium - monitor, digital projector, etc. - needs to be correctly calibrated as part of the LUT building process. Happily, companies such as Kodak provide calibration systems to ensure that this is an easy process to complete, leaving the viewing conditions as the only real variable. Dailies should always be reviewed in identical viewing conditions to those the final film will be viewed in, not someone's office with dodgy window blinds leaking light. That doesn't mean a theatre, a room with but similar lighting conditions and a calibrated viewing medium. And it's very easy to set this up.

Therefore, the workflow that should be adopted for dailies is to transfer the film via a non-creative transfer engine (a telecine/real-time film scanner calibrated to Cineon/DPX density transfer characteristics) to generate an accurate LOG image which is a clone of the OCN.

This can be in any 'video' or digital format you chose, from SD to HD or greater, via and digital medium from tape to DVD or raw data, depending on the dailies viewing requirement and the transfer device used.

This 'cloned' LOG image can then be 'timed' via calibrated LUTs to present a very accurate viewing image, true to the DoPs work.

The calibrated LUTs used can easily represent a perfect 25 across print (or 28 or 32 across depending on the density of the OCN the DoP likes to generate...), and can easily introduce CMY, RGB timing alterations (printer light adjustments) to show the scope of the negative for grading, all without deviating from the underlying OCN image - something it's all too easy to do with traditional telecine/colourist digital dailies grading.

It really is that simple, and I can't for the life of me understand why such a process isn't being demanded by DoPs and studios as the saving offered in understanding exactly what the captured image looks like is too great to be ignored. It's also a far simpler process than that presently used, where the transfer process relies on the un-calibrated creative process of a telecine and colourist.

Digital Dailies Workflow

the following describes the workflow that should be adopted for accurate, and simple to perform, digital dailies.

The OCN film should be transferred in to the digital data of choice (SD, HD or 2K being the most common formats) via a film transfer device (telecine or film scanner) calibrated to Kodak's Cineon/DPX film density to date transfer profile which generates a 10bit LOG digital image, ensuring that the digital image has a direct relationship to the source image. In basic terms D-Min (image black) reads 95 counts in a 10bit DPX LOG image, with 18% grey reading 470 counts and 90% white reading 685. D-Max (pure white) will be heading towards 1023, but may not make it, depending on the original scene contrast range.

Technical note: A 10bit digital image has 1024 digital samples within it. 0 to 1023. Each sample represents a 0.002 change in OCN density, providing a total D-Min to D-Max range of 2.048 density (0.002x1024=2048). Therefore, if all digital images adhere to this relationship they will all be calibrated identically to the underlying OCN image - making them truly accurate when viewed via calibrated LUTs and monitoring devices.

This image data can be passed in real-time through calibrated LUTs (Look Up Tables) to generate viewing dailies totally accurate to the OCN image (or other film stocks) being transferred. Simple control of the LUTs to mimic a timer's printer lights (CMY, RGB) provides basic timing, without distorting the contrast of the original captured image, providing total guarantee that the images being viewed as digital dailies are totally truthful to the DoPs work.

The generation of accurate LUTs has become a relatively easy process due to the likes of Kodak's DCM system (Digital Colour management), which provides full monitor system calibration and setup as well as building very accurate 3D colour cube LUTs.

There is no excuse for inaccurate digital dailies in this day and age!

Another benefit of this calibrated dailies approach is that the images generated are far better suited to the ensuing off-line editorial work than colourist graded images, making the editorial process more likely to produce a desirable edit first time as any serious image mismatches will be more obvious.

The original Cineon/DPX LOG data can also be saved without LUT application for later DI grading using the calibrated 'dailies' LUTs as an accurate guide to the look of the image signed off during dailies screening, ensuring a fully controlled and calibrated digital film workflow. Even if the OCN has to be re-scanned at higher resolution for the DI process, due to the dailies process being performed at too low resolution, the use of the same Cineon/DPX 10bit LOG transfer characteristics ensures the same LUTs will generate exactly the same look with the new high-resolution digital image data as everything is calibrated to the same known datum.

Digital Capture

When shooting with digital cameras there is less issue with screening digitally. This is in part due to the psychological fact that as it was shot digital the dailies must be accurate - but if you've followed the above argument about viewing conditions and monitor calibration you will know this to be inaccurate - but also because of the WYSIWYG nature of much digital capture (What You See Is What You Get - see elsewhere in this document and it's sister documents). There is often not the latitude for post-production (lab timing) changes that exist with film originated material, unless you are using a Viper camera (or similar) or are shooting in an extreme low-contrast mode, as described elsewhere in this document.

If using Viper or a extreme low contrast mode of capture the same approach outlined above for OCN needs to be adopted.

While these is no fixed relationship between the captured image and the viewed final, as with OCN and Kodak's Cineon digital image specification, it is just as possible for the production operation to set-up and operate their own dailies transfer characteristics.

The fact that digital cameras are being used in Viper FilmStream mode, or low contrast (Sony/Panasonic CVP/cine gamma) capture setup, suggests there is someone on the production team that knows what needs to be done. Ensure they are aware of calibration requirements and LUT generation for dailies review operations.

View LUT Calibrated Dailies
For digital cinematography there is the previously defined requirement to capture high dynamic range, low contrast images, but with a equal need for 'graded' or 'best light' images for offline editorial and dailies use.

The difference with digital cinematograph when compared with 'film' capture is the expected immediacy of review - no processing, telecine transfer, or time delay.

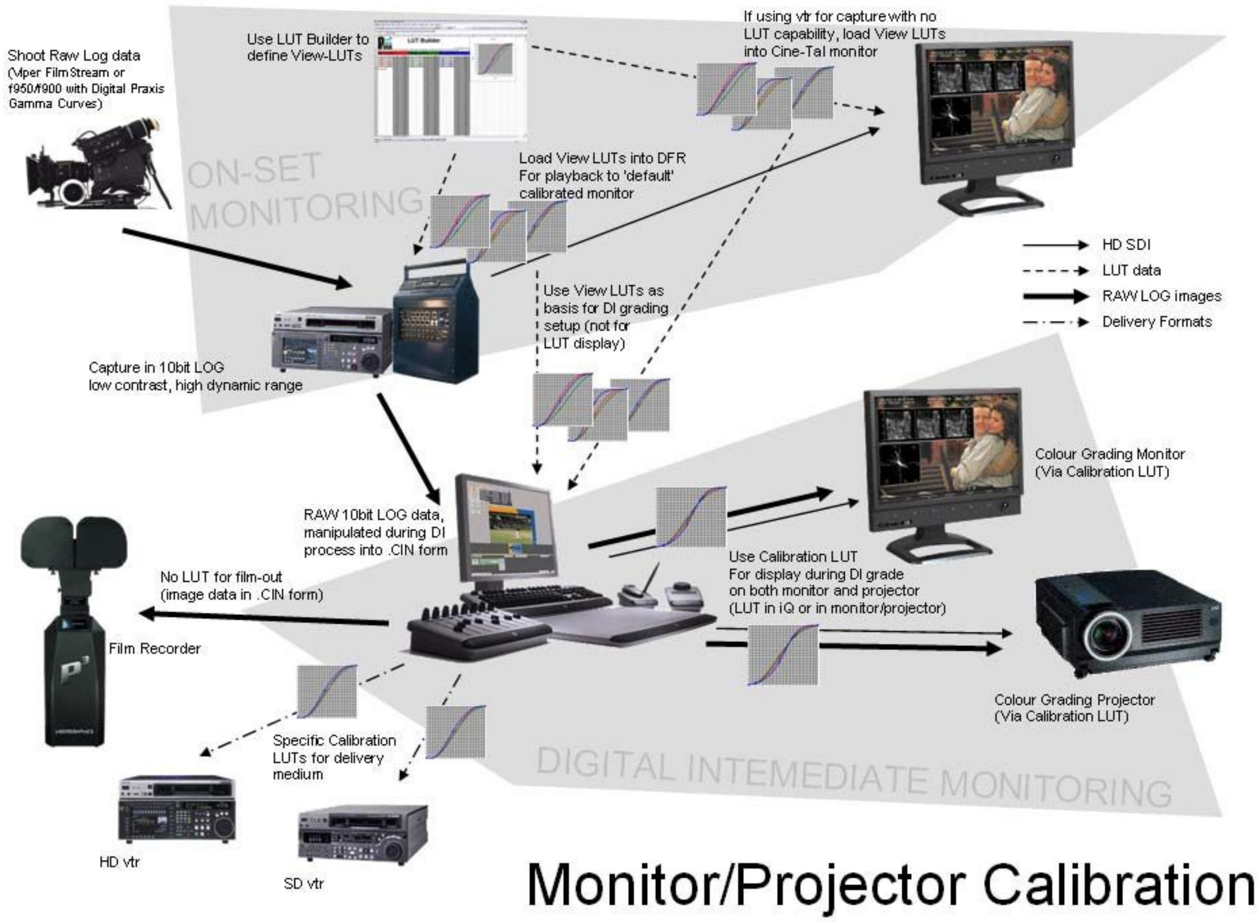
To manage this immediacy requires a different approach to dailies calibration.

Some may suggest an on-set grading system, much like a cut-down DI system, but in reality there is vary rarely the time, or environment, available for such a complex and time consuming approach. And in reality such grading is unnecessary for digital captured dailies.

A better, and more flexible approach, is to use pre-calibrated View LUTs - the exact same ones used for on-set Director & DoP viewing.

This approach is instantaneously real-time, and through the use of a creative LUT builder, such as Digital Praxis's own View LUT Builder, many real-time LUTs can be used for varying shooting conditions and specific looks.

View LUT Workflow for Digital Cinematography



The above diagram shows a View LUT based workflow, including on-set viewing, off-line ingest & dailies deliverables.

Post-Production

Workflow Calibration

Having just discussed colour calibration for dailies we are now going to discuss calibration for post-production - specifically the DI operation.

It's hard to quantify how important calibration is - for each process and step in the digital film chain. Chemical labs go to extraordinary lengths to attempt to keep their baths calibrated within specified tolerances. With a little bit of thought and planning it's possible for a digital operation to become better calibrated and maintain a level of consistency chemical labs can only dream of.

Technical note: Chemical labs work to a Kodak specified tolerance of +/- one printer light per chemical process. One printer light is equal to 0.07 density on the final print, which is a visible difference. If making release prints from an internegative, that may itself be more than 3 generations down, the resultant colourimetry of the print can have significant variation from the original answer print - which would have been struck from the OCN or DI master.

The first step in calibration is to ensure all aspects of the digital film operation are working to the same digital standard. This is important as it enables images to be shared between operations with the same understanding as to what the image looks like.

The image/file format that has become the standard across the digital film industry is Kodak's Cineon format, now ratified as the SMPTE DPX format. This specifies a specific relationship between OCN density values and the respective digital file data values throughout the whole film D-Min to D-Max range.

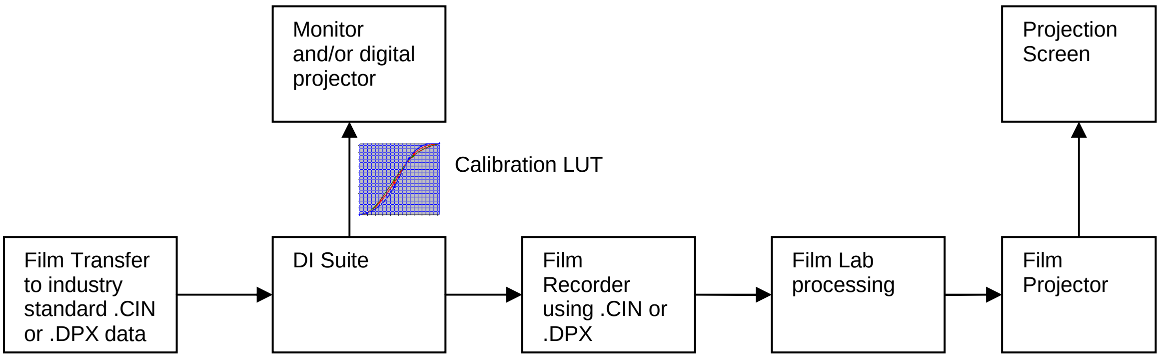
This digital image format is based on a LOG transfer characteristic for reasons explained in one of this document's sister papers, but in simple terms it's because the human eye sees light in LOG space, not linear.

For example D-Min (image black) equals 95 digital samples, 18% grey equals 470 and 90% white equals 685, within a 10bit signal.

With these fixed settings it is possible for any point in the digital film process to understand the underlying image and remain calibrated to it.

To do this requires the use of calibrated monitor systems (monitors or digital projectors) and the use of calibrated LUTs (Look Up Tables) to present an image true to a 'perfect' film print projection. However, as we have discussed, a perfect print is a very rare beast indeed, so be realistic about your expectations.

Calibration Steps



Using a DPX/Cineon workflow the calibration requirements are very straight forward:

- Scanner: calibrated to Cineon/DPX 10bit LOG format.
- Display Device: calibrated to manufacturer specifications to allow LUT to work correctly.
- LUT: calibrated to accurately display a 'print' image from the Cineon image on a 'calibrated' display device.
- Film Recorder: calibrated to accept Cineon specification images for accurate output.

Film Scanning

Film scanning for DI can be split into two distinct alternatives: data telecines and film scanners, with the choice dependent on the projects budget, quality requirements and possibly even the distribution process to be used.

This choice is then further sub divided into resolution - 4K, 2K or HD. Colour space should only ever be Log if a quality result is to be required. If the suggestion is ever made to scan/transfer Linear image for DI reject the proposal immediately.

To scan Linear is directly equivalent to shooting 'video', with no available latitude for later grading within the DI process.

It is also worth stating up front that it is advisable to only transfer OCN (Original camera Negative) and not IP or IN (Interpositive or Internegative) as the losses encountered during the dupe process are unacceptable if a quality image is to retained throughout.

Data Telecines

The more modern of today's telecines are capable of scanning film - 35mm at 2, 3 & 4 perf., 16mm, and even 65mm - at HD, 2K and 4K resolutions, depending on the system used.

The results can be every bit as high quality as with film scanners, usually at higher transfer speeds.

The negative is higher cost.

However, data telecines can also work as traditional 'telecines' when married to a traditional colour correction system, such as from Pandora or da Vinci. This provides for real-time video grading as an additional revenue stream, if needed. But cost is even greater...

CCD vs. CRT
Technically, there are 2 technologies used for telecine operation - CCD and CRT.

CCD telecines (Thomson's Spirit and Spirit 4K) use a single, bright white light source to illuminate the film frame and allow the CCD sensor cells to register each equivalent pixel (one sensor for each colour, R, G & B). The CCDs are line arrays, meaning the film must be moving across the sensor to build up a complete frame. There was an area array CCD telecine available (Sony's Vialta) that captured an entire frame's worth of pixels simultaneously, but this has ceased production.

CRT telecines (Cintel's DSX,C-Reality, Millennium & dataMill) use a moving spot CRT (Cathode Ray Tube) to effectively illuminate each 'pixel' in turn with a single light sensitive sensor reading each equivalent pixel (a single sensor for each colour, R, G & B). As the CRT is a moving spot scan it is possible for a single frame to be scanned while static, although in normal operation the film is kept in continuous motion with the CRT spot tracking the films motion as it scans.

This variation in technology produces two immediate differences between the telecines. The line array CCD based telecines have to keep the film moving to build up a full frame's worth of pixels, making it impossible for mechanical pin registration gates to be used, relying on the accuracy of the telecine's edge guidance and capstan roller for motion consistency. This is not usually a problem when working with new film stocks that are not suffering from shrinkage or warping but can be a real problem if overlap or tape splices are encountered.

CRT telecines can be fitted with mechanical pin registration gates, giving them an immediate advantage in stability, especially when confronted with aged film and/or bad film splices.

However, using a pin registered gate with film that is shrunk, warped or with bad splices can bring its own problems as the possibility for inflicting additional damage on the film is increased. You pays your money, makes your choice, and takes your chances.

Frame Instability
When using non-pin registration the possible issues within the scanned image are fairly consistent between the technologies. Namely image instability, both frame to frame as well as within a frame.

Frame to frame (inter-frame) instability is fairly obvious to spot, although the accuracy of the taking camera must also be understood. As film cameras use a mechanical 'pull-down' mechanism they impart an amount of instability into the image they are capturing. This cannot be undone, other than by non-real-time electronic tracking means as a post-production process.

Within the telecine frame-to-frame instability is usually a low frequency weave, imparted by inaccurate edge guidance or capstan error.

Instability within a frame (intra-frame) is due to the film being kept in continuous motion during transfer (all line array CCD telecines and CRT telecines in normal operational mode) or due to the movement of the CRT spot in pin registered CRT telecines. If either of these motions is not perfectly linear and consistent a 'wateriness' can be seen within the frame, most noticeable when a transferred clip is played back as data/video in real-time. Any such 'wateriness' instability should be rejected immediately.

This intra-frame instability becomes a real issue for non-pin registered telecines when bad splices are encountered. A bad splice, as far as the telecine is concerned, is any splice that is not a perfectly executed butt-weld splice, although these are still far from perfect themselves.

The sort of problems encountered include miss-alignment side-to-side, miss-aligned cuts perf. to perf., overlap splices that double the thickness of the film and tape splices that both increase the film's thickness as well as reducing its flexibility for the duration of the tape splice.

The problem is that the splice sets up instability within the frames being transferred some three (3) feet either side of the actual splice, due to the splice traversing the various rollers within the film path as well as the actual film gate and capstan.

Therefore, when working with new film material it is advisable to either work with uncut original camera rolls (usually spliced into 2000ft rolls) or with over length cut negative (flash to flash or slate to slate is good) to ensure any film splices remain well away from the area of the scene to be transferred.

Dynamic Range
Having ensured the transferred image is as stable as possible the data transfer technique needs to be defined.

Telecines were originally developed to output a linear tv image from a film master. This required a plethora of additional equipment within the telecine suite to enable the best possible final image. However, with data transfers for Digital Intermediate work the requirement is somewhat different.

To maximise the benefit of post-producing a film via a Digital Intermediate route requires that the film images be transferred as a clone of the OCN data. This requires the film transfer process to be performed as a technical transfer, not a creative one, matching the process performed by a traditional film scanner.

This can be done as an ultra-low contrast linear scan, but this has the possibility of errors being made as well as the image containing poor levels of granularity if not enough bits are employed.

For example, to maintain an acceptable level of granularity when transferring a film density range of 2.0 D-min to D-max requires a linear bit depth of 13 to 14bits per colour per pixel, which equates to a staggering 8,192 samples per colour at 13bit. Compare this with a 10bit Log image that requires only 1,024 samples for the same level of granularity.

For this reason the industry has predominantly standardised on a Log based 10bit per colour file that adheres to the Kodak specified .CIN file format or the SMPTE ratified version .DPX file.

All data telecines can output Log based .CIN or .DPX files with correctly mapped density to data mapping ensuring a digital clone of the original film negative is produced as well as allowing for easy data exchange between the various DI and digital VFX platforms used to finalise the required images.

For those interested the mapping specification can be obtained as a download from the Digital Praxis website (www.digitalpraxis.net).

Although some people suggest the use of linear data for Digital Intermediate work it is difficult to stress enough the dangers and likely restrictions such an approach brings. There is no beneficial reason to scan for DI in any way other than Log.

Recently Cintel have introduced their new dataMill scanner, based on their Millennium telecine, but calibrated to output Cineon/DPX 10bit LOG images in SD, HD, 2K and 4K resolution, without the use or need for a colourist or da Vinci/Pandora controller. This is a real step towards fully operational DI workflow for the entire digital film chain. See www.cintel.co.uk for more info.

Resolution
The only other variable to consider is resolution. What is the best for DI work?

This is a fairly long argument and has been explained in some detail within Digital Praxis's additional DI documents.

However, there are 2 points it is worth making here. Firstly, the average resolution of today's film prints generated through the traditional opto/chemical lab process average about 1.2K pixel resolution on the final projection print. This has been proven time and again and is a good benchmark against which to compare Digital Intermediate work (see **Digital Intermediate - A Real World Guide to the DI Process**). And secondly, the DI process is lossless, so the initial starting resolution will be maintained throughout the entire DI process.

For these reasons, as well as others it's not worth going into here, 2K has become the standard for DI with a file pixel/line size of 2048x1556 for a 4:3 35mm full aperture film frame.

While it is fair to say there is more information contained within the OCN (about 4Ks worth) this is beyond the ability of the human eye to see in the average film theatre and much like 13bit linear data vs. 10bit log requires far greater data management for no beneficial realisation.

If the guidelines outlined above are followed the resultant digital images will be perfect for the following DI post-production process.

Having said that, it's inevitable that 4K will become a desirable format for film captured images, if for no other reason than to compete with the growing quality of digital cinematography! Be prepared for 4K workflows.

HD - An Alternative Workflow for DI
One of the issues with a 2K (or 4K!) data workflow is quite simply price. Data scanning is slow and requires a data infrastructure that if not already in place can be expensive to install.

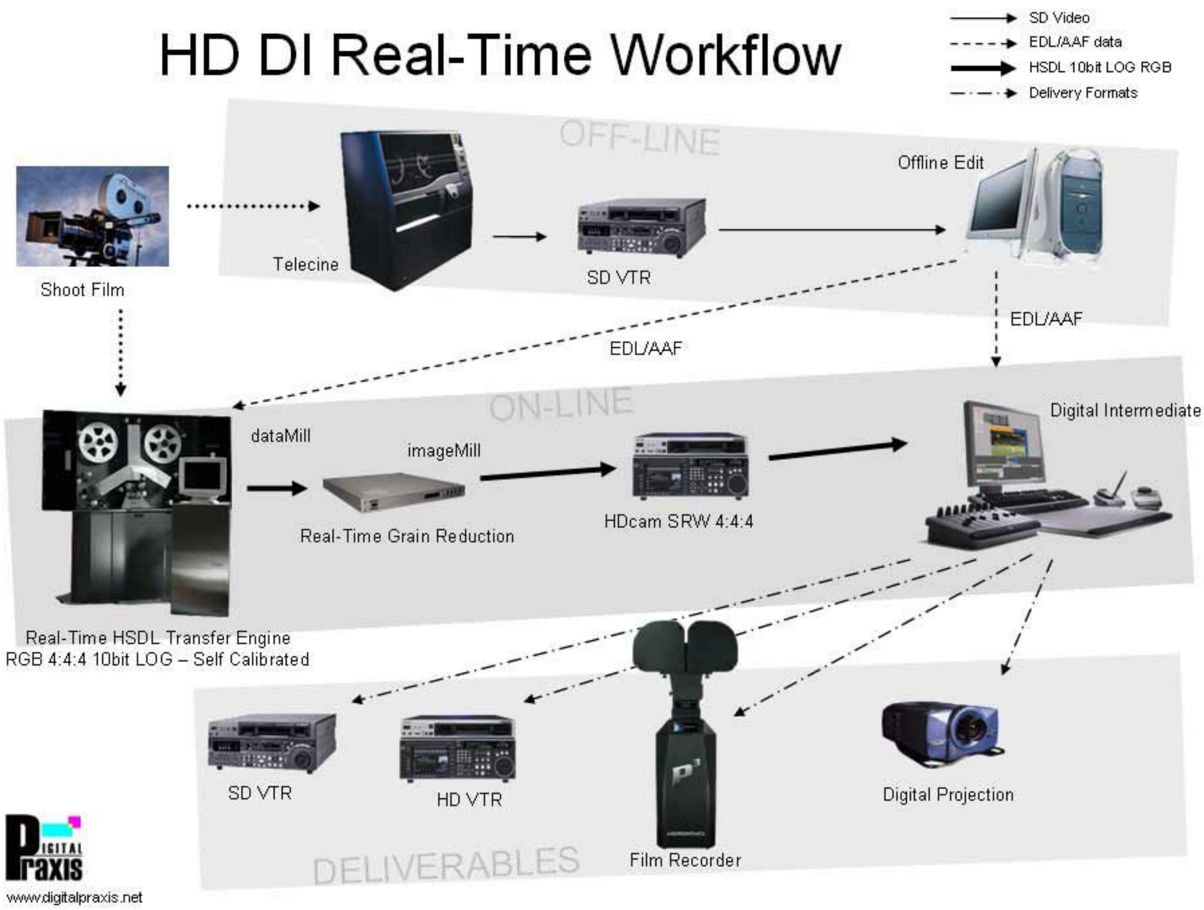
The alternative is to adopt a real-time HD workflow, but using Log mapped image information. This is possible as there is no requirement for HD video to contain Linear images, even if recorded to a vtr.

This is an approach Digital Praxis has used a number of times with great success, and the advent of low compression vtr formats (such as Sony's SRW, which can record low compression rgb images) make this even more compelling.

Technically, a 16:9 HD image is very close to a 2K 1.85 image. 1920x1080 vs. 2048x1107 or even 1828x988 if an academy offset camera has been used to capture the film image.

Using dual link HD enables 4:4:4 rgb operation, but realistically single link 4:2:2 yuv images can produce stunning results.

If budget or time is an issue, a real-time HD workflow can be real alternative. More indepth information can be found within the Digital Praxis website (www.digitalpraxis.net).

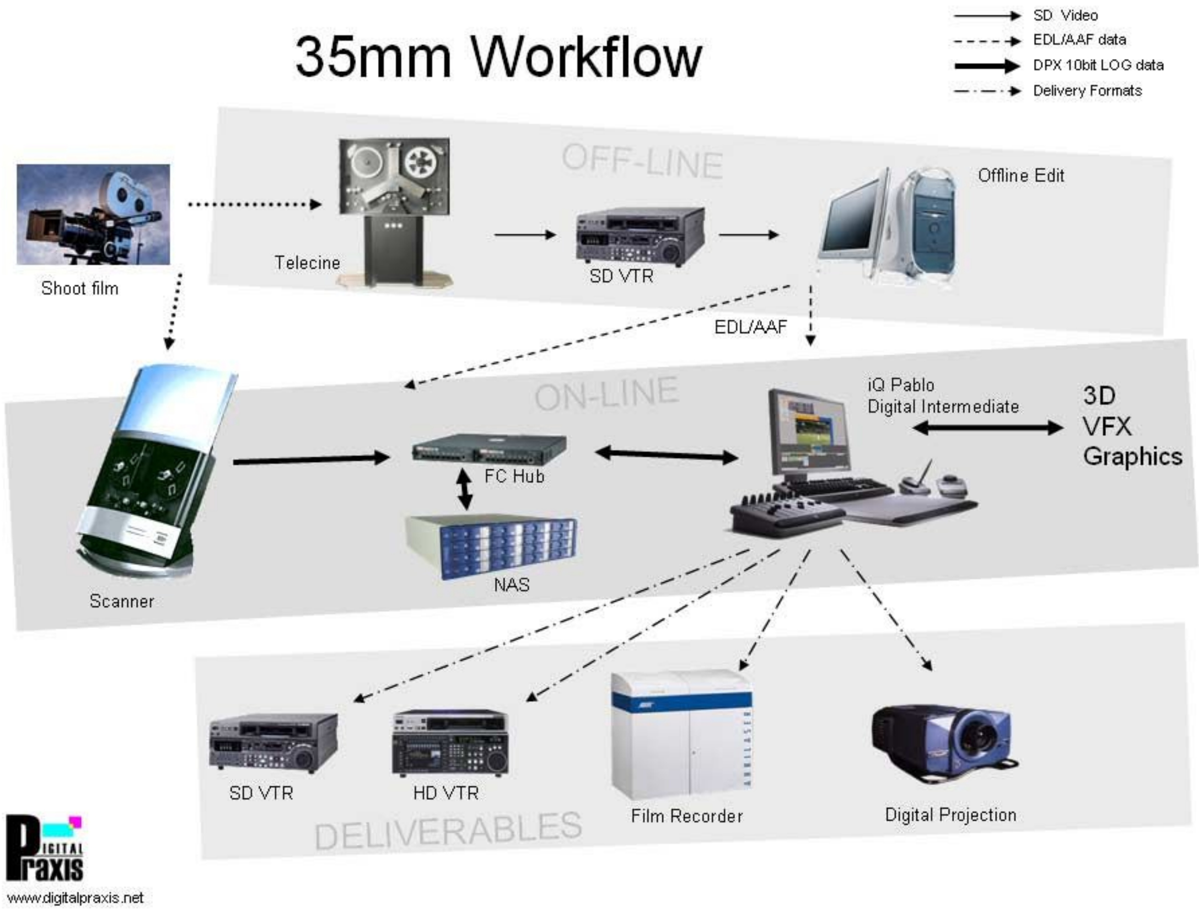


Film Scanners

Film scanners have been around for some time, having been introduced to enable digital clones of film negative to be made for VFX work. Obviously, such VFX work was always intended to be cut back into the OCN and duped and printed as for opto/chemical lab work. Therefore, the scanners had to match the quality of the OCN, not just provide an image at least as good as the best final projection print (answer print, not lower quality release print).

For this reason scanners offer a level of quality that traditional telecines can find hard to match, especially as all scanners use some form of pin registration and high resolution CCD or CMOS sensors. They are also pre-calibrated devices, ensuring a correctly mapped .CIN or .DPX log file is produced from the scanned OCN.

Film scanners presently available include the new Cintel diTTo, ArriScan from Arri, FilmLight's NorthLight scanner and Imagica's scanner.



Speed
The problem with film scanners can be summarised as speed, or lack of it. Telecines can transfer 2K data files at between 4 and 15 frames per second, with the new (and expensive) Spirit 4K offering 2K scanning at 24 fps and 4K scanning at 4fps.

Film scanners run at multiple seconds per frame, with the ArriScan & NorthLight managing 1 frame per second at 2K.

But new generation scanners are changing this, with Cintel's diTTo scanning 3K resolution - for 2K & 4K deliverable images - at 4 frames per second.

Super 2K

What film scanners do provide though is the ability to output a 2K data image via Nyquist sampling of a larger 4K or 6K scan. This produces a 2K image that is superior to a raw 2K scan due to a higher MTF figure - Super 2K. This has been explained in depth in the additional DI documents available from www.digitalpraxis.net.

The Choices

So, how do you choose the transfer system to use?

The answer depends on your requirements for the project.

Time can often be the biggest decider. If the schedule is shrinking by the day, the offline not locked and the release date looming, the speed of a data telecine can be very appealing.

The ability of telecines to insert timecode data in the data file header can also help, enabling easy autoconform from an offline edl - although film scanners are starting to offer timecode insertion as well as DI systems using keycode for autoconforming.

Data telecines require a level of user setup for data transfer, unlike film scanners which are pre-calibrated very accurately. This can be a very important point as the chance for errors is greatly reduced.

Film scanners tend not to insert timecode into the data frame header, working with keycode mainly. This can make online autoconforming of the film project sometimes difficult.

Film scanners obviously guarantee a quality and image stability telecines find hard to match, especially important if there is a lot of additional vfx work within the project.

Budget can also play its part as the lower unit costs of film scanners (half to a third the price of data telecines) mean the overall cost of transferring OCN to data is reduced.

At the end of the day, if you accept the argument that 2K is the optimum resolution for the data transfer of an image from 35mm OCN (see the full DI documents) there is little to chose between the two systems if both are used well. The majority of DI project performed to date have been data transferred on data telecines, but the newer generation, cheaper and faster film scanners are starting to make an impact on the market.

If you're interested, I like the ability of film scanners to Nyquist image data from higher resolutions to 2K and chose this option by preference if at all possible. However, business economics and timescales often preclude this option, and the client has never complained about the final result.

Digital Image Ingest

The use of digital film cameras - HD cameras almost exclusively - presents little problem for image data ingest. Any potential compromise will have been taken when deciding how to capture the image: Uncompressed disc recording, low compression vtr, high compression 'HDcam' as well as the resolution of the camera and colour space used (1920x1080 vs. 1280x720, yuv 4:2:2 vs. rgb 4:4:4).

Obviously the better the origination quality the better the final result can potentially be. However, for general cinematic projects without the demand for complex visual effects (multi-layer keying, excessive grading and mixed 3D animations) standard HDcam and Varicam capture can generate stunning results.

For projects that are to utilise more special visual effects it is best to avoid cameras using their own internal vtr recording systems (camcorders) and rely on external low compression vtr decks or, better still, disc recorders using uncompressed Dual Link 4:4:4 HD (yuv or rgb, although 4:4:4 rgb is more common that 4:4:4 yuv) or even uncompressed yuv 4:2:2 HD.

The Digital Intermediate Process

The Digital Intermediate process is where the majority of creative decisions will be made - after those made previously in-camera. For this reason the DI environment is critical in maximising the possibility for a given project and requires a high level of understanding from those involved.

When looking at DI systems the biggest requirement is to assess their ability to perform the necessary functions required for a full DI process, not just the obvious colour correction.

This has been covered in some depth within this document and the additional documents **Digital Intermediate - A Real World Guide to the DI Process**, and **Quantel's iQ Pablo Digital Intermediate System - A Real world Guide to iQ Pablo and the DI Process**, and you should review them before making any decisions on what approach to take.

Graphics & vfx

The use of graphics and vfx within a film project is not new, and is the history from which the Digital Intermediate process has developed and grown. For this reason there is already a lot of understanding within the market, although much comes from the traditional approach of generating vfx shots for re-insertion back into a traditional film process chain. Using a DI process does change subtly some of the requirements.

Audio

Audio post-production for a DI project will almost definitely be performed in a separate sound suite dedicated to the requirements of high-quality audio post production.

However, the ability for true DI suites to work simultaneously with audio brings new possibilities that can enhance the final product.

In the most basic form audio from the offline edit can be used and played along with the imaged within the DI environment. If using a digital projection system for the DI process - and why wouldn't you? - the result is a far better understanding of the likely final film through being immersed in both image and sound.

If audio post-production is being performed in parallel with the DI image process .WAV files can be imported into the DI system on a regular basis to continually check image and sound and gain a better feel for the ongoing post-production.

Deliverables

Deliverables defines the primary goal for any DI film process - the generation of a revenue earning product that requires presentation to a paying audience, either through direct theatrical projection - film or D-Cinema, or via home tv viewing - broadcast or DVD.

Film Recording & Processing

Film recording and processing, for traditional celluloid deliverables, is one of the more difficult areas of DI to manage due to the opto/chemical nature of the processes. It's very hard to maintain full control and gain expected results - although the theory is very simple.

Most Digital Intermediate operations either have their own digital film recorder or have a relationship with a film recording service operation. Either way, the important thing is to ensure the company responsible for the digital film recorder operation understands its calibration requirements and maintains an active calibration loop process with their chosen film lab.

It is important to remember that the digital side of the DI process is calibrated to a known quality - the Cineon .CIN/.DPX digital film file - which if maintained accurately ensures direct translation of the image data: for example from scanner to DI workstation and DI workstation to film recorder. The biggest variable is the film lab where the chemical mix changes almost hourly and no two labs are the same.

Therefore, the film recorder's relationship with the film lab is a unique one-to-one setup, with each recorder calibrated to a particular lab. And because of the lab's variation in chemical makeup the recorder must be re-calibrated regularly, with the best film recorder companies performing this multiple times per day!

The other side of calibration for film recording is monitor calibration for the DI workstation. Ideally, given a perfect lab and film recorder this calibration would be almost universal, with only the variation in the display medium (monitor or projector mainly) requiring different calibration settings.

With an accurately calibrated film recorder/processing lab and DI workstation monitoring environment the print process is simply a 'print to aim' requirement. Using a Kodak 445 grey patch, or LAD, the lab can print to an accurate Status A value for R, G & B (C,M,Y) to generate a perfect matched print - within standard lab tolerances.

For additional and more in-depth information on the vagaries of the film recording process please review the Film Recording appendix within the twin document to this one - Quantel's iQ Digital Intermediate System. A Real World Guide to iQ and the DI Process.

Digital/Data Deliverables

The requirement for digital/data deliverables depends on the reason for their generation. The two likely options being for long-term archive or direct digital projection. Archive is dealt with later.

For digital projection there is no single format in use (such as with NTSC & PAL video for SD tv broadcast). Therefore the actual data format, use of compression, image colourimetry, etc. must be chosen based on the project's distribution requirements.

However, there are a number of approaches to generating the data for a digital delivery that are consistent.

During the DI process a LUT (lookup table) will most definitely have been used to generate a 'film colourimetry' presentation of the project. This LUT works by distorting the underlying image data as it is presented to the display device. Therefore, this LUT data must be available in the final projection to ensure correct image calibration, and there ate two ways to perform this.

The first is to burn the LUT into the data being recorded for D-Cinema delivery, ensuring that standard projector settings can be used for theatre projection. The requirement for the projector is that it is set to known values so that no additional image colour or contrast distortion is introduced at the point of projection. This is the most widely used approach at present.

The second approach is to record the underlying non-LUT data and install the required LUT directly into the D-Cinema projector. This is not presently widely used but has the advantage that local viewing conditions can be taken into account when projecting the data, such as when there is higher light contamination within the theatre requiring a lifting of shadow detail and a brighter image to maintain the perception of contrast range. The dangers here are obvious - who will ensure the correct LUT is loaded into the various projectors at the theatre? It is likely that as D-Cinema develops imbedded metadata will manage this process, but that's not yet the case.

The realistic answer at present is to burn in the calibration LUT during manufacture of the D-Cinema deliverable and rely on standard calibration of the D-Cinema projectors.

After all, that's how the traditional chemical film deliverable process has worked for years. The print burns in the film equivalent of a LUT from the film negative image, relying on the film projector to be set to a known standard for the image to be displayed consistently. And worse, the printing process relies on the various processing labs around the world to be calibrated identically. If you have ever seen the same film in a number of different theatres in different locations around the world you will know how well this approach works - badly! Even in its worse case D-Cinema should be able to match the celluloid projection experience for colour and contrast consistency.

Video Deliverables

Video deliverables are slightly different to D-Cinema deliverables in that the likely viewing conditions are going to be significantly different to the cinema and grading environments. The biggest difference being the amount of light contamination within the average home tv-room and the medium upon which the image is viewed - the home tv.

Because of these differences it is not possible to simply burn the grading LUT into the video deliverable images the resulting image will tend to be too dark overall, with crushed shadow detail.

Therefore, as a minimum, a global colour correction will be needed to correct for the different viewing conditions. This can be performed through the use of an alternative LUT built for video deliverables if a global change is all that is required. However, it is often the case that selected shots or scenes will require more creative adjustments and it is usual to use a combination of tv specific LUT and user adjustment colour correction to ensure the perfect result that gives the impression of being identical to the cinematic deliverable when viewed within the home tv viewing environment.

It is usual for a single video deliverable format to be used in the later generation of multiple deliverables, for example for direct tv broadcast transmission and DVDs. However, there does need to be multiple video deliverables from the DI master to account for the various video formats, viewing aspect ratios and standards available, such as 4:3 and 16:9, SD and HD, PAL and NTSC.

The outputting of different standards (SD, HD, PAL and NTSC) is relatively straight forward as all that is required is the correct aspect ratio to be predefined and recorded in the correct standard - assuming the DI system in use is capable of real-time variable deliverable generation, or at least can pre-process the correct format for play out.

Generating a different aspect ratio video deliverable can be more of a chore as it will inevitably require some form of 'pan and scan' from the film's 1.85 or 2.35 master. This is a creative process and requires planning and client interaction as for the creative grading process.

This generation of various deliverables is the main differentiator between the different DI systems available and cam make or break the profitability and money saving aspects of the DI process. It is well worth checking out a given DI system's multiple deliverable capabilities before committing to DI, either as a user in the form of a post-production facility or a client in the form of a production company. More time and money is wasted in the generation of deliverables than at any other stage of the DI workflow!

Archive

The process of generating a long-term archive master for a film DI project is probably today's most difficult area to define in terms of suggested working practice. Obviously, if a traditional film deliverable is required the digital negative generated via the film recorder is a capable archive master, as with the traditional optical film lab process.

However, the use of a Digital Intermediate process suggests the ability to hold a digital master for archive, allowing for future changes and re-output should additional sales be made in new areas or regions where subtly different requirements may require alteration to the original master - for example where censorship rules differ or for foreign language requirements.

The archive question gets even more difficult if the capture medium has been digital film cameras as with traditional camera negative capture at least the OCN can be archive as a failsafe for future requirement.

Film

Using film as an archive format for the final deliverable is a safe approach as film is a stable long term archive format, assuming there will no requirement for later alterations to the DI final deliverable.

The problem is that future change is very often required, therefore requiring a more flexible approach to archive, especially as digital becomes the medium of choice for 'film' capture, post-production and delivery.

Digital

Digital archive has a lot of promise as it can be a lossless environment, promising a 100% accurate regeneration of any deliverable and any time in the future.

The problem is that today the shelf-life of any standard magnetic based digital format is measured in only 10's of years at best, vs. films 100's of years.

Note: film's claim to 100's of years shelf life is entirely dependent on the film stock in question - B&W silver halide based, which has long term storage properties, or colour dye based, which fades over time if not correctly stored. And correctly stored means in low temperature, ideal humidity conditions. Film is also very easy to damage if handled incorrectly.

Due to digital magnetic media having a comparatively short shelf-life there is an inherent requirement to duplicate the digital data within a certain timescale (every 10 years?) to ensure survivability. This is not something that appeals to archives for obvious time and cost reasons.

Digital Film?

A final thought is to record digital information onto a more stable medium, such as silver halide based B&W film. This is something Kodak have been looking into for some years, with a project called 'DOTs'. If you get a chance you should ask Kodak about it!

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