DIGITAL WORKFLOW

A new paradigm is taking shape in filmmaking—a significant shift from the use of just film, or analog tools, to the use of digital tools—allowing filmmakers everywhere to explore creative options with great success and relative ease. The post-production phase of filmmaking has changed significantly with the advent of the digital intermediate (DI) process. The traditional workflow has been completely transformed through advancements in film scanning and computer technology. Digital processes in post-production are replacing traditional photochemical steps such as negative cutting, color timing, printing, and optical effects.

Here is an example of a simplified digital workflow: convert your film footage to video using the telecine process to professional formats like 3/4, Beta SP, Digital Beta, HD, and DVCAM and store the video files on your computer.

Convert telecine dailies from 29.97 to 24 fps using the reverse telecine feature. This allows the editor to edit at true 24 fps, establishing a one-to-one correspondence between the video frames and the film frames. You can edit your project quickly and easily using the real-time architecture and non-destructive editing features of a software program like APPLE Final Cut Pro.

When editing is finished a film cut list is created to conform the original camera negative. This allows the negative cutter to use the film list and the edited video as a guide to conform the original negative to match the edited digital project. Release prints are created from the conformed negative.

DIGITAL INTERMEDIATE

With the wide array of digital post-production techniques and tools available, it is best to assemble your post-production team before you shoot. Their ideas, presented early in the filmmaking process, provide valuable insight, influence various aspects of your production, and help you price out options. A post house can review your project and provide a breakdown of post-production costs, and can also help establish the best workflow.

What is a Digital Intermediate?

The three main stages in the DI process are:

- **Input:** During the input stage, or acquisition, the processed camera negative is scanned using a high-resolution film scanner. The scanner digitizes each frame of film and converts the film images to a series of digital files.
- **Image Processing:** Once the film has been scanned, conforming, color correction, creation of special looks, and addition of special effects are all performed digitally in the image processing stage.
- **Output:** The edited digital files are used to render a digital master, which is recorded out to film using a film recorder or used to render a variety of electronic formats.

The term digital intermediate (DI) is often misunderstood. A digital intermediate is simply a project in its digital state during the image processing stage. Digital Intermediate, therefore, refers to the digital data's transitional nature—a state between the input stage and final delivery.

Traditional Lab and DI Comparison

The digital intermediate process can encompass the whole post-production stage of filmmaking. It can replace a lab and optical finishing workflow by using digital processes to conform, integrate effects, color grade, and prepare the project for final delivery.

Conforming

In a lab and optical finishing workflow, the negative cutter uses a film cut list or an edit decision list (EDL) to cut the original camera negative, place shots in the edited order, and splice them together to produce a conformed negative.

In a digital post-production workflow, negative cutting is eliminated. Rolls of original camera negative are delivered to the post-production house, and only the select shots in the final edit are scanned. Once scanning is complete, the EDL is used to auto-conform the digital intermediate. In this process, the original camera negative is scanned only once and remains intact.

Visual Effects

In a lab and optical finishing workflow, computer-generated effects shots are printed to film, then cut, and matched with the rest of the film frames. Other effects or transitions, such as fades and cross dissolves, are produced optically during the printing process.

In digital post-production, complex effects are created at a computer workstation and are seamlessly integrated with the rest of the files in the digital intermediate. All transitions, such as fades and cross dissolves, are also produced digitally. The duration of transitions can easily be changed and reviewed almost instantly.

Color Timing/Color Correction

In a lab and optical finishing workflow, the color timer uses a color analyzer to look at and adjust the colors of every scene in the movie. The color timer can perform only primary color correction by adjusting the overall color balance of the three primary colors: red, green, and blue. Usually, a number of answer prints are made to view results and gain full approval of color timing adjustments.

In a digital post-production workflow, a colorist performs primary and secondary color correction digitally. In secondary color correction, specific colors and objects in the scene can be selected and manipulated without

affecting the overall color balance of the scene. Adjustments can be tested and viewed in real time. Digital color correction, applied to an entire film, has given filmmakers great creative control and flexibility.

Output

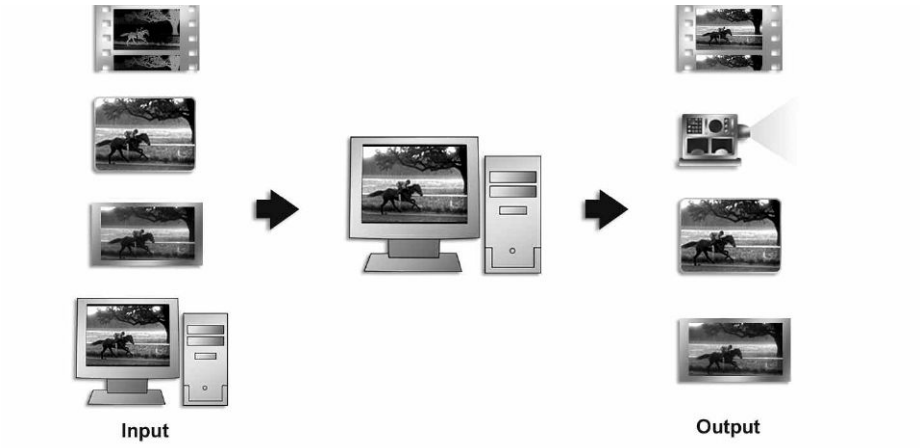
In a traditional lab and optical finishing workflow, the finished film goes through the printing process to create release prints. After timing for color and density is approved, a master positive is printed from the original negative by exposing it onto color intermediate film. All color-timing corrections approved by the filmmaker are applied during the printing of the master positive. Next, the master positive is printed onto intermediate film a second time to create one or more duplicate negatives. Then release prints are made from the duplicate negative. For finished films exhibited in theaters, the master positive is usually used for transfer to electronic formats.

In digital post-production, the final digital intermediate is used to render a digital master. The digital master is recorded directly out to film to create prints or an internegative for release printing or to output a variety of electronic formats including digital cinema, SD, HD, and DVD.

Benefits of DI

The Digital Intermediate process offers flexibility and creative control. The DI process allows digital color grading, visual effects, and digital mastering in a collaborative and interactive environment.

The DI process is also format independent—you can input various formats including film, video, digital media, and computer-generated material. Then, after image processing, any number of formats can be created from the digital intermediate. Therefore, a project captured on film can be output to any number of electronic formats. A project captured electronically can be output to film, although quality can be compromised. Or a project can contain any number of sources. Filmmakers use the DI process to mix media and experiment with different sources.



DI Process is Non-linear

The digital intermediate is a series of digital files that can be sorted, indexed, tagged, viewed, and manipulated in any order. This lets you jump to any point in the project and work in any order. You can also change the order of scenes or instantly view any two shots in the production to check visual continuity.

Full Editorial Control

The digital intermediate process allows the filmmaker to have full editorial control, including the ability to:

- Auto-conform from an updated EDL
- Make manual edits to the DI by duplicating, moving, replacing, or removing frames
- Adjust the timing of cuts and transitions

This level of flexibility makes last-minute changes possible and reduces the costs incurred in a traditional, post-production workflow.

Digital Color Grading

The ability to apply digital color grading provides you with unprecedented control over your work, such as:

- Creating a look or mood
- Manipulating individual colors and objects in a scene
- Painting, retouching, and fixing images
- Emulating lighting
- Emulating camera filters and lab processing techniques

Computer-generated Effects

The digital intermediate process provides better interchangeability with computer-generated material. Effects shots can be fed into the digital intermediate pipeline at various stages for feedback and approval. When finished, the files containing special effects are color-graded and integrated into the digital intermediate.

Visual Effects and Transitions

In a digital post-production workflow, many traditional optical effects can be completed digitally. Some include:

- Transitions such as wipes, fades, and dissolves
- Cropping, resizing, and repositioning of images
- Freeze-frames
- Titles and text

Image Restoration and Repair

There are also many techniques to repair imperfections that include:

- Scratch and dust removal
- Digital painting and retouching

- Image sharpening and blurring
- Reduction or increase in grain

Instant Feedback

The DI environment is interactive and provides the ability to view changes as they are made. One example is digital color grading. The colorist and filmmaker can adjust the colors and view the changes instantly on an electronic display. Instant feedback gives filmmakers more freedom to collaborate, experiment, and respond immediately to changes.

Preserve the Original Camera Negative

The digital intermediate process also helps protect the original camera negative. The negative has to be scanned only once, and then the project files are conformed digitally. The intact, uncut original camera negative can be archived.

Post House Contacts

It is important to know the contacts in a post-production facility and establish clear communication.

Account Executive/Bidding Producer

The account executive (AE) is responsible for your project's contract and financial arrangements for the duration of your project. Initially, the AE provides bid information in collaboration with a post-production supervisor and/or digital effects supervisor.

Producer /Scheduler

The producer or scheduler is your main contact within the post-production facility. The producer's responsibilities include scheduling sessions, scheduling equipment, obtaining receivables, tracking elements in the facility, and delivering the final product.

Post-production Supervisor/Digital Effects Supervisor

The post-production supervisor or digital effects supervisor works on the production team and is your liaison to the post-production facility. The post-production supervisor attends and supervises editing and color timing sessions, and also approves all of the work done at the facility.

Editor

Working closely with the director and producer, the editor executes the EDL. The editor joins shots and scenes into a continuous narrative by using cuts, dissolves, and effects. The success or failure of a production may rely on the quality of the editor's work. If the editing work is good, it's invisible to the audience. If it's bad, it detracts from the story.

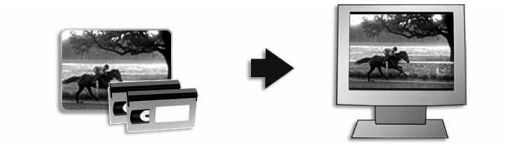
Colorist

Colorists are artists who work closely with you to color-correct the film. They are responsible for helping you achieve the overall Look. Colorists help establish continuity between shots and make color decisions that support the story.

INPUT

All digital intermediate workflows begin with acquisition of media in the input stage. As we learned earlier, media can come from different sources such as film, electronic capture, or computer-generated imagery. All source media must be either transferred or digitized.

- **Data Transfer:** If the source media is in a digital format, such as digital video or computer-generated material, it is transferred to storage in the digital intermediate pipeline. Data transfer may involve copying digital image files from one drive to another, or could require a transcoding process that converts a data stream from one digital format to another. Data is reinterpreted during transcoding, so some degradation may occur.



- **Digitization:** Analog source material must be digitized. A film scanner digitizes information from the original camera negative by sampling it at regular intervals and then encoding it. When film is scanned, therefore, the resulting digital image is only a sampling of the image information found in the film negative.

Film Scanning

Selected scenes are converted from film to digital data with a film scanner. Film scanners sample and digitize image information from the original camera negative to create digital image files.

Scan resolution refers to the amount of information sampled and digitized from each film frame. Higher resolution images offer better image quality and flexibility throughout the entire digital post-production process.

Film Scanners

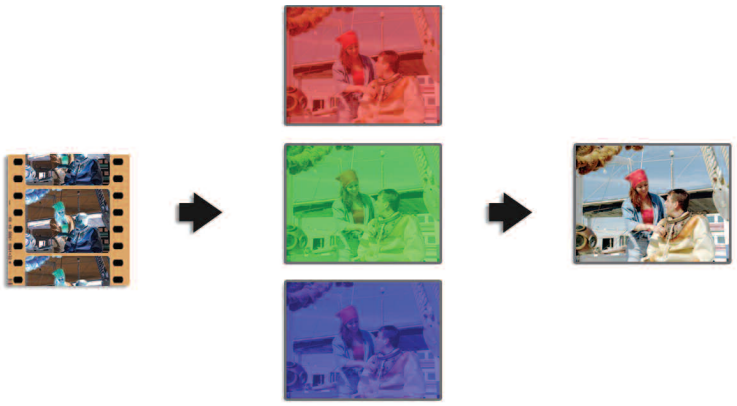
Today's motion picture film scanners deliver excellent image quality. High-end film scanners digitize each frame at a high resolution. When the digital image files are written back to film, the result is not readily distinguishable from the original. Scanning is accomplished by illuminating the original camera negative with a bright light source. For each sample point along a scan line, a charged coupler device (CCD) measures the level of transmittance for red, green, and blue light. This process is repeated a line at a time until the complete film frame is scanned. A digital image file is created that stores color information in three separate channels for red, green, and blue. Each film frame yields a separate digital image file.

Both devices convert analog film to a digital image, but there are major differences. A telecine is used to convert film images to video. They have continuous motion and operate at a high speed. Some telecines have the ability to emulate a film scanner and produce data files. A telecine may require images to be upsampled, depending on the workflow and demands of the project.

While telecine machines output a video signal, a film scanner outputs digital data files. High-resolution film scanning is for a data-centric workflow. Film scanners are often pin-registered, intermittent, and slower than telecines. At the time of acquisition, few adjustments are made to the images. The image files are typically stored on a hard disk for manipulation and digital color grading later in post-production. Film scanners capture more resolution than telecine machines and deliver higher quality images.

RGB Color Space

A color space is the range of colors a system is able to reproduce. A large percentage of the visible spectrum can be represented in the RGB color space by mixing red, green, and blue light in various intensities.



Digital image files use the RGB color space by mixing red, green, and blue to form a color image. Digital intermediate work is typically done in the RGB color space. It is the most common way of viewing and working with digital images on a computer screen.

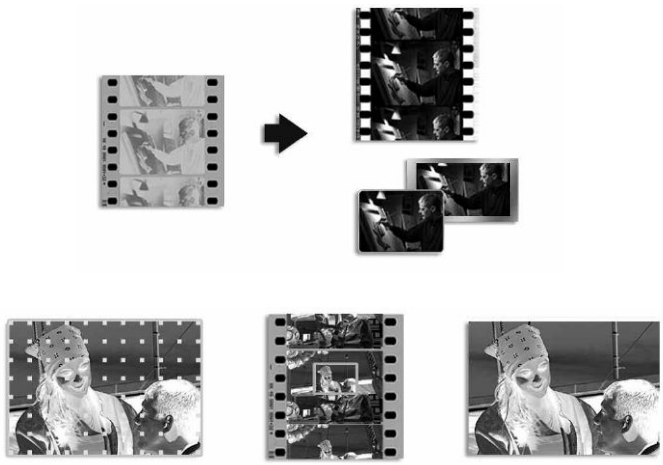
Color Channels

An RGB image is comprised of three different color channels: red, green, and blue. All three channels are combined to form a color image. Each channel acts as a layer that stores tonal information. When we view channels separately, they appear as gray scale images because each pixel in a channel is actually an intensity value.

The bit depth of the file determines the amount of values possible for each channel. In a 10-bit depth there are 1024 possible intensity values for each color channel. Each pixel in the red channel, for instance, is a discrete intensity value of red from 0 to 1023.

Scan Resolution

Before scanning, scan resolution must be determined. Scan resolution is the sampling rate, or how much information from the original camera negative will be digitized. Once a scan resolution is determined, the original camera negative is sampled at regular intervals. With a lower resolution setting, the sample points are farther apart, which eliminates more original image information. With a higher resolution setting, the sample points are closer together. Thus more original image information is captured. The higher the sampling rate or resolution, the more accurate the digital representation of the original film image.



Scan Resolution Considerations

Higher resolution images withstand image processing better because more detail and image information is present. Some considerations when deciding on scan resolution are:

- **The principal output medium:** If your principal output is film for theatrical release, you must scan at a high enough resolution. Scanning at a high resolution provides enough detail when the digital images are recorded back to film. If your principal output is SD or DVD, you can scan the source images at a lower resolution. Choose a resolution that provides the quality for the principal output medium.

- **The look of the production:** Another important consideration is the look you want to achieve during the image processing stage. There is no loss in quality when digital files are simply accessed and copied. The same is not true when files are manipulated—color grading and compositing are destructive to the original image information and can cause digital artifacts.

- **Budget:** Acquiring and working with high-resolution images can be expensive. Typically, images high in resolution provide better quality, but are also large in file size. Larger files take longer to access, manipulate, save, copy, move, and store. A digital intermediate workflow must balance file size, level of image quality, processing speed, and all associated costs.

The most popular scan resolutions for digital intermediate work are 2K and 4K (K represents thousands of pixels across the frame width). A 2K image is 2048 pixels wide, and has become the industry standard for digital intermediate work. A 4K image is 4096 pixels wide and is used when a large amount of detail is needed, such as special effects shots.

The 4K scan contains more detail than a 2K scan—it's also a larger file size at 48 MB per digital image file. A 2K-image file is about 12 MB. You would assume that a 4K file would be double the file size of a 2K file, but it's not.

The 4K file quadruples the necessary storage and bandwidth requirements because it contains four times as many pixels. Images are 2 dimensional, so doubling the two dimensions produces a file quadruple in size.

Dynamic Range

The range of values between the darkest and brightest perceptible points in an image is dynamic range, a term principally used to describe video and digital images. It can be compared to film's exposure latitude. The bit depth chosen in digital image files at acquisition determines how much dynamic range is acquired. The higher the bit depth, the better the dynamic range.

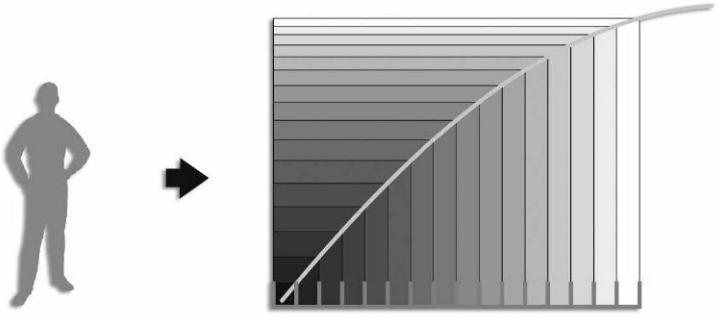
Bit Depth

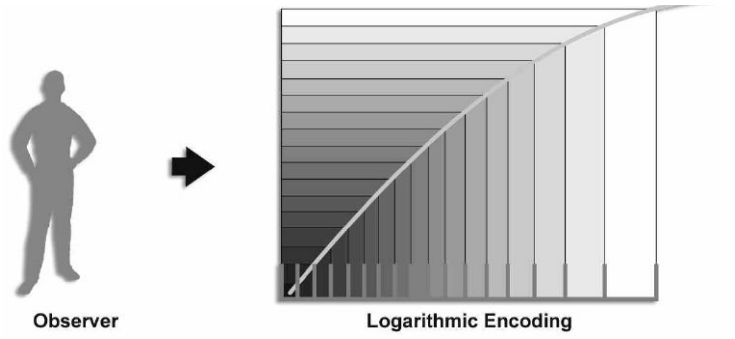
Bit depth determines how much dynamic range will be acquired. The higher the bit depth, the larger the range of values that are captured and encoded for each color channel.

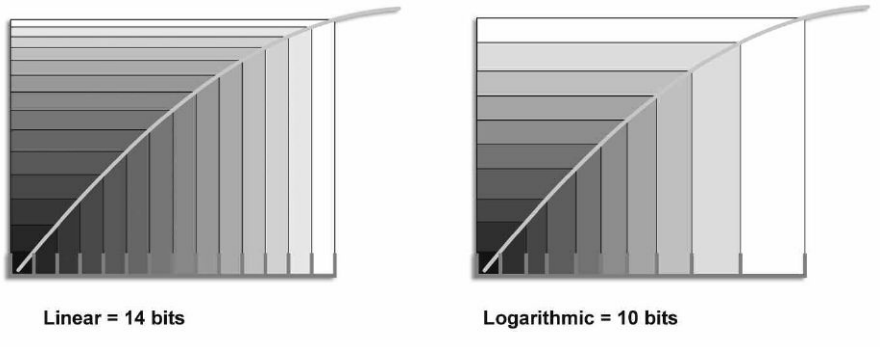
The dynamic range of a digital file can be represented either linearly or logarithmically:

- **Linear:** At acquisition, your film's dynamic range can be represented linearly—the complete tonal range from black to white is divided equally, from brightest to darkest values, and then encoded. This is not proportional to the sensitivity of the human eye, which more easily discerns blacks and shadows. To achieve enough precision in the darker areas to match the sensitivity of the human eye, more bits of information may be needed. Because information bits added linearly are spread equally across the entire tonal range, additional bits are also added to the midtones and highlights.

- **Logarithmic:** At acquisition, your film's dynamic range can also be represented logarithmically—the complete tonal range from black to white is encoded logarithmically. Thus, more bits of information are assigned to the image's darker areas. A logarithmic representation closely matches the sensitivity of the human eye, which more easily discerns blacks and shadows and helps capture the full dynamic range across a smaller number of bits.







DPX Files

The film is scanned after resolution and bit depth are set, resulting in a series digital image files. The most common file format is the Digital Picture Exchange file (DPX file). The DPX format is an ANSI and SMPTE standard. The flexible format is easy to share between workstations, equipment, and facilities. The format is resolution independent and various bit depths can be assigned, and it can represent the dynamic film range linearly or logarithmically.

IMAGE PROCESSING

After digitization, entire scenes, individual frames, and even individual pixels on a frame can be manipulated with precise control in the image processing stage. The DI environment is interactive, allowing the creation of custom looks and experimentation in real time.

Editing

Editing combines shots and sequences into a continuous narrative that captures and holds the audience's attention. The editor, in consultation with the director and producer, decides which scenes and takes to use, when, and in what sequence. Once editing is complete, takes used in the final edit are scanned, and the EDL is used to auto-conform the digital intermediate.

Digital Effects

Complex, computer-generated special effects are often completed while the movie is being edited. Then they are integrated into the digital files that make up the digital intermediate. Sometimes the computer hardware and software used to generate special effects is proprietary to your post-production facility.

Color Correction

A colorist modifies the color and contrast of scenes according to your input. It is important to use a post house that routinely calibrates hardware to ensure a color-calibrated workflow.

Dust Busting

Dust busting removes visible dust and scratches after film has been digitized.

Sound Editing

Audio recorded during image capture may have extraneous noise or poor quality. Sound elements such as dialogue, sound effects, music, and narration are improved and carefully mixed into a final soundtrack. The soundtrack is added to a production once editing is complete.

Film Recording

Film recording takes place after image processing. The scanned, edited, and color-corrected digital image is recorded back to film using a film recorder.

Video Mastering

Video mastering, or rendering, also takes place after image processing. The edited digital image data is used as a digital master to render all electronic formats such as digital cinema, HD, DVD, and SD.

Conforming

Conforming, the first step in image processing, matches the entire digital intermediate with the final edit. Special conforming software is used to auto-conform the digital intermediate by using the editor's EDL.

Conforming software and systems have some common features:

- **Playback:** The conforming system is often used for playback. Since the digital intermediate is a series of digital files, they can be played back and accessed in any order. This flexibility allows quick navigation to any point in the production. Often additional hardware is used to display and play back uncompressed high-resolution data. Or the conforming system can display proxies, which are smaller files used for playback and manipulation. Since the images are smaller, they are not as taxing on computer systems. Any adjustments made to proxy images can be saved as metadata and applied to

the full resolution images later. Using proxies can help save money. The smaller files are much easier and faster to process than full resolution scans.

- **Editing capabilities:** Most conforming software uses a timeline interface similar to non-linear editing software where frames can be duplicated, moved, replaced, or removed. The timing of cuts and transitions can also be modified. It is important to scan handles—extra footage before and after shots—so adjustments can be made. Handles allow some flexibility if a shot or transition needs extra frames.

- **Resolution independent:** Conforming systems are resolution independent—they can playback and access digital images of any size. Therefore, different capture media can be mixed together in its native resolution. Once the digital intermediate is complete, all the digital images are resized to the output resolution.

- **Conformed digital intermediate:** Once the DI is conformed, it should be compared to the original edit for accuracy. The major benefit of a conformed DI is that all changes made throughout the digital post-production process are performed in the final production context. You and the colorist, therefore, can experiment and directly assess changes to the film.

Digital Retouching

Digital retouching fixes imperfections in and damage to the digital images:

- **Dust busting:** Dust busting removes dust by cloning the same area on adjacent frames. The cloned information is used to fix the dust defect on the affected frame. Since images in a sequence are similar frame to frame, and the position of dust is random, this technique works well.

- **Digital paint:** Some imperfections found in scanned files can include scratches, chemical stains, and tears. An operator copies pixels from a good frame, and pastes them in the same area on a damaged frame.

- **Image sharpening:** Soft images resulting from degradation or poor lighting can be sharpened with algorithms. They detect edges in a digital image and then increase their contrast to make the image appear sharper.

- **Grain reduction:** While some grain is pleasing to the eye, too much can be distracting and obscure important detail. Grain reduction algorithms can reduce the amount of grain. Too much grain reduction, however, can soften an image.

Color Grading

We respond to colors because they symbolize and trigger emotions and memories. In the digital intermediate environment, color grading is not only used to establish continuity between shots and scenes, but to provide emotion to help tell the story.

The DI process can allow you to work closely with the colorist in an interactive and collaborative environment. Images are graded with playback in real-time using a color grading system. An experienced colorist can make an enormous difference in the look of a project. The grading process has two main stages: primary color correction and secondary color correction.

- **Primary color correction:** Primary color correction is completed first and sets the overall color balance. This first pass ensures that all scenes have a consistent color tone, with no sudden shifts in hue or brightness. The overall goal is to establish the base look and continuity between shots.
- **Secondary color correction:** Color adjustments to a specific item in a scene are possible with secondary color correction. Secondary color correction allows selection and manipulation of specific colors or objects without affecting the overall balance. This control allows you to warm up skin tones or to make the sky in a scene bluer.

Masks

A section of an image is often selected in secondary color correction with a mask. Masks can be compared to stencils placed over an image. Parts of the image are protected, while the openings are edited.

Shots often contain objects that move or have camera movement, changing a frame's content over time. Many grading systems provide the ability to animate masks in order to isolate and grade moving objects. Sequences containing complex shapes may require rotoscoping, which is accomplished by adjusting a mask frame by frame.

Many color-grading and digital post-production techniques can alter the principal photography significantly. They can:

- Emulate light
- Recompose shots
- Use motion stabilization
- Add vignettes, gradients, and highlights to lead the eye
- Emulate traditional camera filters and processing techniques

Metadata

Many changes, such as color grading changes, are stored as metadata. Metadata is information about a digital file or how it should be processed. This process is non-destructive, which means all color-grading changes are saved without actually altering the original content. Systems can read the metadata and play back a preview as if the changes were applied. When all image processing steps are complete, all metadata is applied at output.

Special Effects

A digital intermediate facility can perform many traditional optical effects digitally. The facility also works with effects departments to integrate computer-generated material and composites.

A variety of traditional optical effects can be completed digitally:

- Transitions such as wipes, fades, and dissolves
- Image alterations such as cropping, flipping, resizing, and repositioning
- Freeze frames
- Speed effects
- Titles and text

Computer Generated Material

Productions often integrate computer-generated material into the digital intermediate. This material is often created by specialized departments and can include:

- Still and motion graphics
- 3-D animation
- Digital composites

OUTPUT

Rendering applies all changes made throughout image processing on a digital source master. Rendering all the frames in the digital intermediate taxes computer systems and requires a significant amount of computer processing. Rendering is often completed on a rendering farm, which divides the task among several systems networked together to expedite the process.

Digital Master

The digital master is a final digital version with all changes applied. It is used to create all distribution formats, including:

- Film for release printing
- Digital cinema
- HD
- SD
- DVD
- Content for the Web

Video Output

The digital master is used to render all video formats for video output. Each video format has its own specifications and must be rendered out separately. Typically video output is a process of down conversion. The digital master is usually higher in resolution and has a larger color gamut. Here are some important considerations when outputting various video masters for video distribution.

Frame Rate: Film is captured and displayed at 24 frames per second. Video runs at 30 or 25 frames per second. Since film and video run at different rates, there is not a simple one-to-one relationship. For NTSC, which runs at 30 frames per second (60 fields per second), the difference in frame rates is solved by what is known as 3:2 pull-down. At output, the first film frame is transferred into the first 3 fields of video. The second film frame is transferred into the next two fields of video. This sequence of three fields, then two, continues until all 30 frames (60 fields) of video have been filled from 24 frames of film. This process allows film to play at the correct speed on video. For PAL transfers, the ratio is much closer: 24 frames of film for 25 frames of video. To avoid pull-down and establish a one-to-one relationship, it is common for film seen on PAL television to be transferred at 25 frames per second. Action onscreen is about four percent faster, a barely discernable increase. If sound pitch is critical, the track can be processed and pitch-corrected.

Color Space: Each video format has a color space. The RGB color space used during image processing is larger than that of video. This means that some colors are out of gamut and will not appear when broadcast. Most systems convert the color space to video safe colors at output, or a look-up table can be used to convert the colors to the appropriate color space.

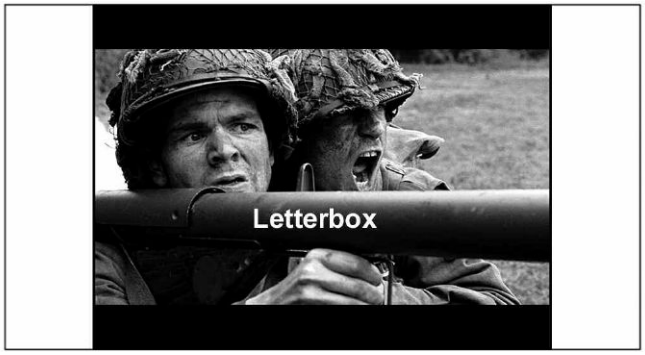
Aspect Ratio: Video formats have different aspect ratios, and there are a variety of techniques available to adjust the image for video output. HDTV has an aspect ratio of 1.78:1. This wide aspect ratio works well for wide screen film images.

Very little of the image requires cropping. Transferring wide-screen films to the standard 1.33:1 television aspect ratio poses a challenge because the entire film frame will not fit. Options include:

- **Squeeze:** The wide image is squeezed onto a standard video frame. Image distortion results.

- **Pan and Scan:** After the height of the film frame is maximized, the operator pans back and forth selecting the best part of the film frame for each scene. This technique shows important action occurring inside the television frame, but alters the original composition.

- **Letterbox:** Letterbox is a standard television display technique used more frequently in recent years. A black band on the top and bottom of the screen is used to maintain a wide-screen look, preserving the original composition on a standard television screen.



Film Output

The digital master is output to an internegative with a film recorder for film distribution. The internegative is then sent to the lab for traditional release printing and then distributed to theaters. Traditional film duplication is simplified because all color-grading decisions were applied digitally during image processing. This removes the need to make major color timing adjustments during printing.

Digital Cinema

A digital cinema distribution master can be created for theatrical release. Digital cinema projects images from a digital file. It is important to ensure that the digital cinema distribution master has the overall look, color, and contrast, of film prints.

COLOR MANAGEMENT

Controlling the way films are viewed is as important as quality control during the digital post-production process. The ability to view color fidelity, and make decisions based on those views, are integral to filmmaking.

Color management is the use of appropriate hardware, software, and procedures to achieve consistent color throughout digital post-production. There are two main goals in color management:

- All displays must provide consistent color.
- What is seen on displays is faithfully reproduced at final output.

Calibration

Each device in post-production must be calibrated to ensure that all devices display the same image:

- **Film scanners:** Scanning a series of gray and color patches of known density provides the aim for the scanner calibration. This ensures consistent input for subsequent workflow processes.
- **Monitors:** Calibration checks the monitor brightness, contrast, and color temperature for accurate color reproduction. Calibration is achieved by using a colorimetric sensor to measure the color output of the monitor. The output of the display is measured against defined input values.

  The measurement establishes a profile for the device. This profile is used to help display images accurately. Another important consideration for monitors is the viewing environment and the ambient light level. Ambient light can compete with the screen and cause color to look muted.
- **Digital projectors:** Many times the principal output medium will determine how the production is displayed in the DI environment. If the principal output medium is film release or digital cinema, it is best to project it for operations such as color grading. It is important that the projector is calibrated and accurately represents the color and density of the final film print.
- **Film recorder calibration:** Recording a series of gray and color patches of known density provides the aim for the recorder calibration. This will ensure consistent output for film prints.

Once all devices in digital post-production are calibrated to the same standard, the target output must be accurately displayed. Each display device and output medium has its own color gamut. The goal is to achieve the most accurate representation of the target output medium on the display. If a project is to be printed out to film, the most accurate representation of film should be displayed on monitors in digital post-production.

Look-up Tables

Look-up tables (LUTs) are used to adjust and accurately display the target output.

1-Dimensional Lookup Table

A 1-Dimensional Lookup Table is a static color translation table that converts one input value to one output value. It is an effective way to link two values together. A phone book is an example of a 1D LUT—for every name in the book there is a phone number. The 1-to-1 correspondence is simple to construct and to use.

3-Dimensional Lookup Table

A 3-Dimensional LUT is a static color translation table that converts a set of three-input color values to another set of three-output color values. A 3D LUT is often used to check for accurate color rendition between different color spaces. A colorist may use a 3D LUT to convert a red, green, and blue density color space to RGB monitor drive values for video.

Since LUTs link values together, they help speed up post-production processes.

LUTs provide feedback in real time and are often used to implement:

- Calibration corrections
- Color corrections
- Specific looks
- Color space conversions

"We were shooting with a handheld camera and no time to light. I exposed the negative so the exterior wouldn't blow out and the faces wouldn't be too dark. In DI, I could tweak those shots by making faces a little brighter and the outside a little darker, if necessary. DI is a creative tool that allowed us to shoot in Super 16 format and record directly onto 35 mm film without an optical blow-up."

—Christian Sebaldt, ASC, Cinematographer