Concurrent Workflows for HD Television Grading

Software-based color-grading applications integrated with concurrent HD finishing workflows offer the potential of highly differentiated creative looks and greater facility productivity. The net result is increased efficiency and profitability.

Color grading is an established high-value service in commercial post-production. In fact, film transfer and color grading are often the highest-value services a facility offers. They have traditionally been dominated by a relatively small number of facilities that have made large capital investments in dedicated hardware technology, such as telecines and color correctors; but things are changing.

A number of market forces are converging in such a way that there is a strong advantage to moving away from the traditionally dedicated, linear, hardware-based color correctors in favor of new software-based color-grading systems. Demand for high-definition (HD) content, the ability to work with all the media at your fingertips without the limitations of linear media, leveraging data-centric pipelines for collaborative purposes, and the need for greater creative differentiation as a way of standing out in a highly competitive market are making facilities seriously consider the new technologies.

Digital color grading can fundamentally change the color experience in television post-production, as it is highly creative and collaborative. Numerous facilities worldwide have chosen to enter this new market. The capital investment required is considerably lower than what was previously needed. In time, it is likely that everyone will change, similar to the way the market changed when nonlinear editing systems took the world by storm in the 1990s. As is often the case, the early adopters will gain a significant advantage.

A number of factors are leading to this shift in post-production practices for HDTV grading. These factors include creative-enabling technologies, system performance, and efficiencies through workflow. This white paper will discuss these factors with a heavy emphasis on the most important aspect to understand: the workflow advantages of a concurrent pipeline built around grading, finishing, and visual effects.
The purpose of this white paper is to introduce the concept of the concurrent workflow solution for creative color grading in an HD television post-production environment, and demonstrate how implementing a concurrent color workflow can improve the overall creative outcome while boosting facility productivity.

- **Concurrent Workflow** – A concurrent workflow describes a methodology for performing a number of post-production functions at the same time using the same media. For the purpose of this document, the functions discussed include color grading, visual effects design, and finishing.

- **Creative Color Grading** – The term Creative Color Grading is used to describe a digital color-grading process for television post-production based on software applications that use digital file formats such as 10-bit logarithmic DPX files.

The intended reader of this document works in, or owns, a television post-production facility that specializes in producing compelling visual content to address the storytelling needs of its clients. The type of content produced at this variety of facility can include national advertising spots, long-form prime-time and syndicated network television programming, broadcast promos, and so on.

Generally, this type of facility has built a successful business around high-quality conform and finishing, interactive visual effects design, title creation, and so on, all within the very tight constraints of rapid turn-around times, which are common in television.

![Figure: Concurrent workflow for simultaneous post-production processes](image-url)
Traditional Color-Grading Process in Television

Before examining concurrent workflows, let us begin by taking a brief look at how content has traditionally been graded for commercials and other television content – telecine-style grading by a colorist. In fact, the colorists are often the first link in the “finishing” chain to enable the successful transfer of film material (an extremely valuable asset) to a more manageable (and less risky) format for post work (either videotape or data). In the process of transferring from film, colorists perform color grading so that shots are balanced, corrected, and/or enhanced as needed.

Figure: Film is color graded during the process of transferring to video

The film transfer is usually performed by a telecine and a hardware-based linear color corrector device. The color correctors perform three key functions. First, they control the playback of the telecine. Second, they process the signal using a limited assortment of image processing functions. Third, they control the video tape recorder (VTR) or digital disk recorder (DDR) that is used to record the processed video signal.

The telecine grading process involves physically loading a film reel into the telecine, and then controlling the telecine to grade either a selection of shots or the entire reel. The process is linear in nature, much like an online editing bay: cue up a shot on the film reel, establish the grade, and then record the new images to videotape. Based on purpose-built hardware, these linear systems process the signal and record it to tape in real time. However, they are inherently limited in terms of their creative capabilities.

With regard to grading, there are two ways in which this is generally performed: one-light transfer and best-light transfer.

- A one-light transfer is used to quickly transfer an entire reel of film to videotape. In a one-light transfer, a single-grade setting is applied to the entire reel. This average setting is meant to offer a fast transfer; some shots will work better than others and they are ultimately dependent on the telecine operator who establishes the color
settings that are used for the entire reel. This is not ideal, as the one-light telecine operator is generally not a colorist. A one-light grade necessitates a final grade later in the finishing process.

- A best-light transfer is a creative transfer from film to video in which each shot is treated separately. Time is taken to balance shots, establish looks, fix specific problems, and so forth. A best-light transfer is performed by a colorist.

Once a reel is graded, it is removed from the telecine, a new one is racked, and then the process continues. If changes are required, shots are re-cued, re-graded, and re-recorded to videotape, overwriting the old grade. This can be a time-consuming process, especially if multiple shots require the same changes or if changes are needed across multiple reels. More problematic shots, those in which there is unpredictable motion, a scratch, or an occasional occlusion are usually sent to a dedicated compositing system for cleanup.

![Telecine-Style Grading Linear Workflow](image)

**Figure: Telecine-Style Grading Linear Workflow**

The final graded videotapes are then sent to the finishing suite where they are digitized one at a time into nonlinear editors where they are conformed and assembled into a finished project.

A concurrent workflow can significantly streamline this process and increase the overall creative results.
Advantages of Concurrent Workflow for Color Grading

The immediate and most obvious advantage of implementing a concurrent color workflow is that it allows a facility to offer a highly creative color-grading service in-house – one of the most highly valued services in the post-production industry. This is especially true for facilities that have an increase in projects that are shot in high-quality digital formats such as HDCAM SR®. In this case, no film transfer infrastructure is needed so start-up costs for color grading services are minimized.

For facilities that already own the film transfer infrastructure, the concurrent workflow can serve as a bridge to connect the analog workflow to the digital world. This enables more creative color-grading services and allows the established facilities to differentiate themselves from an increasingly crowded market, especially due to the advent of very inexpensive color-grading software.

Advanced Creative Tools in Software Systems

The television industry is poised to benefit from a new generation of tools for color grading that offer a wide range of creative advantages. Most high-profile movies today take advantage of software-based grading (the Digital Intermediates or DI process) to define the final "look" of the film. This process is considered as carefully as editing or special effects. These tools are also available for television workflows.

By offering the ability to apply and animate multiple layers of primary and secondary correction to an image (based on keys, mattes, complex shapes, and variable softness, without any loss in quality), creative color grading enables the colorists, directors of photography, and art directors to work with an image like a painter – subtly and profoundly adjusting the elements of light and color until the creative vision is achieved.

This artistic empowerment is further enhanced by the availability of tools that have previously been reserved for compositors who work in the realm of visual effects. In addition to the advanced layering capabilities offered by secondary shape systems, there are tools (such as automated multi-point tracking) that can be used to apply extremely precise color changes to moving objects, remove dust and scratches, and scale and reposition images. Plug-in filters are also available. These can simulate anything from Tiffen lens filters and skip bleach photo-chemical techniques to visual treatments that cannot be created in the physical world.
Workflow Efficiency: Requirements of a Concurrent Workflow

When it comes to workflow, there is no one way of working. Every client has unique requirements, and the ideal solution should be open and flexible enough to allow for facility customization. Most workflow solutions should be based on open concepts, open application programming interfaces (APIs), and standard connectivity in order to add the most value, in terms of creativity and efficiency, to a particular project. The following requirements must be considered.

Maximizing Creative Session Productivity

One of the first considerations is how to maximize artistic output while maintaining the greatest amount of flexibility to handle back-end processes such as video I/O, project setup, archiving, and rendering. Tasks related to rendering and archiving, for instance, are very difficult to charge back to clients and therefore should be offloaded to more cost-effective dedicated “assistant” systems. It is understood that creative tasks such as grading, visual effects, and finishing, which take place in the more expensive suites, are billable. By offloading noncreative tasks to back-room systems, the artists in the creative suites can focus on the kind of work that generates revenue (as well as the kind of work they enjoy).

Transferring Film to Digital

Another important consideration deals with getting analog film images into a digital environment so that they can be treated. For this to happen, the film must go through a scanning process of some sort, either using traditional telecine to video (and then to digital files), a datacine to scan to HD or even 2K, or a pin-registered digital film scanner. Rather than making recommendations regarding which system is best, since there is no one solution that is best for all workflows, we will state the general guideline: transfer the film to a digital format as quickly as possible while maximizing exposure latitude. It is only once the images are in the digital realm that the creativity of the artists can be exploited to its full extent. Determination of the best transfer system will be a function of the specific requirements of a facility.

Source Grading and In-Context Final Grade

Of course, while focusing on color grading, the colorist must have a concurrent color workflow to modify the sources. This allows the material to be graded as soon as it is transferred into a digital format, as well as the creation of an in-context final grade to focus on continuity and look development. C-mode sorting is certainly needed, as are A-mode grading capabilities.
Software systems that work from digital files also have the advantage of enabling a nonlinear workflow. In other words, there is no limitation to one particular sort order. Multiple files can be graded simultaneously, regardless of the reel or the position in a timeline.

**Nonlinear Workflow and Scheduling Flexibility**

One of the major downsides of a traditional grading workflow is that finishing cannot begin until the film, or at least the reel, is graded, transferred to video, and digitized into the finishing environment. Concurrent workflows do not have this constraint. As a result, the facility has the added flexibility to start a given process based on suite/system availability. If the frames are digitized onto centrally available storage, and the colorist is in a session with another client, the finishing artist can start working from the ungraded sources. Provided that finishing is nondestructive, no time will be wasted. Once the colorist is available and generates final renders, the finishing system should simply be able to point to new media and instantly re-conform to the graded images. This is easy, provided that basic image metadata, such as the source reel name and time code, is unchanged by renders.

![Diagram](image)

*Figure: Advantages of concurrent versus linear workflow*

In the best case scenario, both the finishing artist and colorist are available to begin working at the same time. In a truly concurrent environment, no duplication of media is needed. Both systems can work using the same media with
no sacrifice in terms of system performance and interactivity. Media duplication should be kept to a minimum, as it requires additional storage, time-consuming network transfers (which can also affect facility network performance), and can even lead to confusion regarding which version is the correct version.

**Working in a Shared Environment**

Shared storage and high-speed networks, capable of serving up images to all requesting systems as needed, must form the backbone of a concurrent workflow. Of course, a storage area network (SAN) connected to client workstation via a fiber channel is a viable option but may prove to be prohibitively expensive, especially for smaller facilities. Other options need to be available. Commonly, each system in a facility has its own direct-attached storage array that enables a high degree of interactivity and real-time playback of high-resolution images. Yet high-performance disk arrays (based on 4G-bit technology) offer far more bandwidth than is needed for a single system. In fact, a single disk array can stream multiple HD streams simultaneously. Coupled with a high-speed network, such as that provided by 4x Infiniband, multiple networked systems could pull data from one single disk array. While a SAN offers an elegant solution, it is not the only option for concurrent environments based on two to three systems.

**Bringing Analog into the Digital Realm**

Facilities with investments in traditional linear grading hardware will naturally want to continue leveraging these assets, but may want to bring their analog workflow into the tape-less digital realm. A concurrent workflow can serve as that bridge.

There are effective solutions that allow the use of the telecine as the film transfer device in the context of a data-centric workflow. Many high-end finishing systems offer a function called video tape recorder (VTR) emulation. This allows the system to be controlled by another device via the RS-422 machine control protocol, just like a tape deck. The use of VTR emulation has an important advantage; it makes it possible to bypass the very time-consuming process of outputting to videotape from grading before digitizing the film transfer directly into the finishing environment.

Working in this manner allows the facility to quickly digitize an entire film reel and then start grading or finishing the first reel while the second reel is being digitized. There is another advantage to this approach. Usage of the valuable telecine is not necessarily monopolized by a single color-grading device, which means an increase in the value of the telecine by using it to service multiple suites as an input device during the course of normal business.

VTR wear and tear is minimized if a facility is configured in the concurrent workflow manner. In fact, the facility may even need fewer VTRs (which in itself cuts cost as VTRs can be very costly hardware).
Integrating Visual Effects

In any facility, visual effects and compositing are often handled independently from (and concurrently with) finishing, so it is important that shot-based effects work can be easily integrated with the workflow. Additional complexity is added, but it is very common for visual effects iteration to result in last-minute changes. The ease with which new shot versions are integrated back to the final timeline, either at the finishing stage or during the final grade, can be the difference between successful completion of a project or missing a deadline.

Providing Final In-Context Grade

Software-based color-grading systems provide the ability to offer a DI-style final in-context color grade to clients. This session usually takes place in a dark grading theatre and allows the clients to experience the work in all its glory, projected digitally onto a large screen. This ability is changing both the client experience as well as expectations about what it means to attend a grading session, and provides a competitive advantage.

Color Management

The last consideration for the concurrent workflow relates to color management. Generally, color management is used in facilities specializing in film post-production as it offers a reliable way to accurately reproduce, on a given display device, how digital images will appear when printed to film. However, a robust color-management system has important advantages in a concurrent workflow. On any given concurrent project, work may happen on the same shot at the same time in three or more different suites (for instance, grading, effects, and finishing). A client could literally walk from one suite to another and follow a project’s progress. If the images do not match from one suite to the next, this could engender uncertainty and lead to a lack of confidence in the facility process.

An out-of-the box color-management system can do away with this concern, provided that each necessary system in the facility can use a common set of display look-up tables (3D LUTs) that account for the display device (DLP, LCD, or CRT) and the destination format (for instance, HD REC-709, SD ITU-601, or RGB). Thus, each system’s images would look the same within the constraints of its respective calibrated display device. Clients moving between suites would see matching images in each room.
The Need for Speed: How Much Performance is Enough?

Color grading has always been a process based on the real-time capabilities, albeit creatively limited, of the linear hardware color correctors. As such, an expectation has been established – any system that will be used for color correction when clients are present needs to be highly responsive. With the move to software, and therefore far more creative options, the line between grading and compositing blurs. Software enables creative flexibility, which comes at the expense of more complex processing algorithms. To handle these algorithms, applications benefit from as much processing power as possible, especially as the industry embraces HD workflows.

The increasing demand for high-quality HD content, with highly compelling and differentiated imagery, means that talented artists are still in demand. But, not to be overlooked, the challenge to produce these visuals in less time and with a limited budget means the facility engineers are just as important. Today, the engineers are overworked and infrastructures are stretched nearly to the breaking point.

Workflow is a major component in expediting the creation of high-value content. Consequently, open workflows that strengthen the high-end digital content creation chain are vital. Ideally these workflows should be built from industry-standard technologies; technologies that are being developed in a market-driven competitive world. Technologies of this nature are growing in performance and dropping in price at a staggering rate.

These technologies, with the aid of lower-cost software and information technology networks, are making it possible to do in HD what was previously only possible using expensive, dedicated hardware systems and SD video infrastructure. In terms of computer technology, the barriers to HD adoption are quickly crumbling.

- **High-speed networking**: Infiniband is an architecture for data transfer between processors and input/output devices that offers high bandwidth and promises enormous scalability to accommodate next-generation computer systems. Using a switched-fabric topology, Infiniband enables many devices to share a network at the same time. Although Infiniband is a serial connection, it is very fast, with 2.5 gigabits/second links in each direction per connection. Links can be aggregated in units of 4 or 12, called 4x or 12x. A dual-rate 4x link therefore carries 20 G-bit/s raw (or 16 G-bit/s of user data), and is capable of streaming data at rates that can easily sustain multiple streams of HD playback.
• **GPU processing**: The graphical processing unit (GPU) is the microprocessor of a graphics card. The highly parallel processing structure of a GPU makes it very efficient at performing certain types of operations, most notably image processing for the post-production industry.

GPUs are very efficient in terms of pure image processing applications. The cost-to-performance ratio is rapidly driving proprietary hardware devices toward extinction, and the GPU growth trajectory is constantly enabling new applications for real-time image manipulation. Although GPUs are commonly seen as a way to accelerate video games, and that is certainly where the most GPUs are sold, their advancement has always been driven by high-end applications like real-time 2K color grading. As processing and texture memory increase, the GPU will surely offer enhanced performance and rendering speeds for other high-end creative applications.
• **Multi-core processors:** Moore's Law accurately predicted that CPU performance would double every 18 months (since Gordon Moore made this assertion in 1965), previously due to advances in processor speed and now because of multi-core processors. The term multi-core processor refers to a single processor that combines multiple independent computing cores, and the respective caches and cache controllers, onto a single integrated circuit. Use of multi-core systems is growing rapidly, but only a small number of the high-end software products are optimized to take full advantage of more than one CPU at a time.

• **CPU clustering:** The process of clustering involves the distribution of processing to a series of dedicated CPUs to accelerate the time to completion of image processing tasks. Similar in concept to a render farm, CPU clustering is used to significantly boost application performance and interactivity while working creatively; this is known as inline processing, which also speeds-up render times. Generally, clustering requires a high-performance networking component (such as Infiniband) and dedicated CPU nodes.

Clustering technology has already found a significant place in post-production, enabling real-time 2K grading workflows. With rapid development curves for each of the component hardware technologies, clustering may soon enable scalable and interactive 4K workflows. This is a key trend to follow as it will represent the first time in the industry that such high levels of performance are enabled without the use of a single custom-built hardware device.

**Conclusion: Benefits of Concurrent Color Workflow**

Post-production facilities are adopting software systems for creative color grading even though there are incumbent solutions that have been used successfully in the market for many years. There are a number of reasons for this change:

• In a world of increasingly competitive project bidding, facilities are looking for ways of standing out from the crowd. The creativity of talented artists remains one of the best ways to attract clients, and fostering that creativity is paramount to success.

• A by-product of competitive bidding is declining billing rates. Creative color grading requires a lower capital investment, which therefore allows a facility to compete more easily for a project without the chance of losing money.

• Dynamics in the market are forcing change. If they have not already done so, facilities will have to adopt new technology to handle HD projects and to build more flexible digital pipelines that allow them to take on a broader range of projects.
• Increase in digital acquisition is making it possible to take on color-grading projects without expensive film transfer infrastructure.

• Adding software-based grading systems allows a facility to grow the list of services offered. Given that many software-based grading systems are also used in feature film digital intermediates, a facility can begin developing new areas of expertise, and attract new clients in the process.

Most post-production professionals understand that grading is recognized as one of the most highly valued services in post-production. Implementing a concurrent workflow can open the door to compelling new revenue opportunities based on a service that clients already understand and are willing to pay for – highly creative color grading inside a nonlinear visual effects and finishing environment.