



Avid High Resolution Workflows

2K, 4K, and UHD TV

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Introduction

This paper will start with a look at the emerging standards for UHDTV followed by a discussion of the challenges, solutions, and benefits of integrating high-resolution (> HD) file-based media into existing post and broadcast workflows.

Overview

As “4K” TV prices dip below \$5000 and head rapidly towards today’s HD TV prices, it’s increasingly clear that while HD has yet to arrive in many areas, it is already yesterday’s news for manufacturers and trendsetters in the consumer electronics market. Everyone has an opinion on the relative merits of these higher resolution displays, from “you can’t see the difference” to “it’s a game changer”. Although “4K” is frequently used as a catchall term for high-resolution formats, there’s no reason to assume that spatial resolutions will stop at 4K. While the lion share of most “greater than HD” digital production is being captured at 2K today, it’s important to note that there’s much more being proposed by the standards organizations than just 3840x2160 pixels. In terms of 2K/4K, there are many flavors, such as digital film scanning resolutions like 4096x3112 and native Digital Cinema Initiatives (DCI) 4K 4096x2160 and DCI 2K 2048x1080 formats, along with Digital Cinema Package (DCP) delivery, which have been with us as standards for many years. Instead of focusing on established practices for theatrical release, let’s look forward to the new broadcast workflows still being defined as Ultra HD or (UHDTV) since this is the specification of “4K” that display manufacturers and broadcasters are currently developing around. UHDTV is actually a collection of high-resolution standards proposed by NHK Labs and later approved by the International Telecommunication Union (ITU) in August 2012 as their ITU-R Recommendation BT.2020 UHDTV specification.

The fact that the 4K version of UHDTV is actually 3840x2160 pixels is no accident since that amount of pixels is exactly four times HD’s 1920x1080 and fits perfectly in a 16X9 aspect. Even though some would argue it’s not “true” 4K, maintaining compatibility with existing 16x9 content is a major factor that could have otherwise gated adoption of the new standard. In addition to spatial resolution, there are changes proposed to both frame rates and color encoding for UHDTV. All of these proposals are now part of a recommended “phased approach” by the ITU and SMPTE to make UHDTV a practical reality for manufacturers, distributors, and consumers alike.

UHDTV-Phase 1(2014/15)

The following features characterize the first proposed phase of UHDTV:

- Frame rates capped at 60fps (progressive only)
- Up to “4K” resolution (3840x2160)
- 10/12 bit color – (no more 8 bit)
- Bt. 2020 or 709 color space
- HEVC compression
- Audio 5.1 and 7.1

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In terms of raster, UHDTV Phase 1 is essentially “Quad HD” (4 1920x1080 images stitched together). Perhaps more interesting in the short term is the allowance for 60fps and progressive only formats. Everyone agrees that interlaced formats have exceeded their shelf life and 60P presents fast motion programs, such as sports, much better than anything we’ve had to date. The other significant move is in regards to color space and bit depth. While the current Rec. 709 HD standard is limited to an 8 to 10bit depth, Ultra HD’s Rec. 2020 removes 8-bit, supporting only 10 and 12-bit depths. The resulting increased color gamut could be a very noticeable improvement in quality albeit somewhat difficult to bring to market since it could carry additional technology expenses all the way to the consumer. Supporting either an expanded color gamut or higher progressive frame rate could improve current HD viewing substantially on an UHDTV display while waiting for 4K resolutions to become the norm.

UHDTV-Phase 2 (2015 onwards)

UHDTV phase 2 adds the following capabilities:

- Frame rates increased to 120Hz
- High dynamic range video
- Advanced audio

UHDTV-Phase 3 (2020 Tokyo Olympics)

Phase 3 adds:

- 4320x7280 “8K” resolution (Japan’s Super High Vision)

In UHDTV phase 2, frame rates are increased again, bringing even more benefit to sports and fast action. For 3D holdouts, a true 120fps picture creates a significantly improved 3D experience. High dynamic range would make a huge difference on a consumer display, effectively producing much more contrast and more closely preserving the luminosity of a real scene. Camera companies like RED and Arri have already developed digital sensors capable of acquiring HDR (high Dynamic Range) images. Also worthy of note is Dolby’s Dolby Vision technology, which clearly shows that an image with increased dynamic range is preferred by a majority of viewers over pure pixel density.

Although the audio formats proposed by UHDTV are beyond the scope of this document, it’s easy to imagine the challenges involved in going beyond 5.1 and 7.1 surround. Proposals like “scene based Ambisonics” and proprietary technologies like Dolby’s Atmos are all being discussed.

Finally, in UHDTV phase 3, support for 8K (4320x7280) is added which NHK plans to broadcast at the 2020 Olympic games. Obviously 8K is even farther off for the rest of the world, but it is part of the spec and will be here as soon as the supporting display technology becomes affordable.

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Working with high-resolution media today

It's clear that UHD TV is coming, albeit in phases, to content consumers everywhere. Resolution alone (HD to 4K/8K) may not rival the revolutionary improvement that HD was to SD for the viewing public, but with the addition of higher frame rates, wider color gamuts, and increased dynamic range, UHD TV represents a substantial next step in the evolution of digital media. For media organizations, this next step presents major challenges in regards to the distribution and monetization of content and will certainly break the mold of traditional broadcasting and distribution infrastructures. However, while the media distribution and consumption side of high-resolution content may be in the formative stages, the production and post production industry has well established workflows and has actively sought to reap the benefits of high res workflows for a number of years. As such, the remainder of this document will focus on the benefits of acquiring and working with high-resolution images in today's postproduction environment while keeping the evolution of UHD TV in mind.

Benefits of working with high resolution images in post production

Even if a majority of viewers can't tell the difference between 4K and HD sitting ten feet from their 50" screen, the tremendous benefits of working in higher resolutions is no secret to those professionals who create today's compelling content.

Why capture in greater than HD resolutions when the end deliverable is HD?

As high-resolution file-based cameras have become affordable, one of the primary reasons productions have chosen to acquire in increasingly higher resolutions is to capture the performance in the highest possible quality, effectively "future proofing" the investment. While archiving these large files presents its own challenges, it's a wise decision that helps content creators extend the media's shelf life.

Being file-based, high-resolution media is a natural fit for digital editing and storage equipment even though the infrastructure necessary to play back such large files smoothly can still mean a significant investment. By far the most significant benefit of acquiring high-resolution imagery is the increased flexibility and control achieved in postproduction. Assuming the broadcast delivery requirements are for an HD Master for some time to come, then a 2K, 4K or 5K source image will most likely need to be re-framed, effectively extracting an HD image from the original source. Having four times the pixels provides enormous flexibility in deciding which part of the image to display in an HD raster. An editor can pan across the image dynamically adding additional motion to the shot or zoom in significantly without any loss in quality. With an HD source such a significant zoom might be impractical due to the poor quality image produced by its insufficient resolution.

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Alongside spatial resolutions are the expanded color gamuts and dynamic ranges available from these cameras. Current HD cameras are limited to a 10-bit color depth, while higher resolution cameras typically provide 12 or even 16 bit color. Cinematographers can utilize techniques like HDR to capture light in new dramatic ways and assign looks to images to be faithfully maintained throughout all the stages of postproduction. This expanded range provides the colorist more latitude for changes in the final look of the production in terms of contrast and color without loss of detail and the introduction of noise.

Many networks still require a tape-based delivery of finished shows and while tape has its own limitations, it is relatively easy to manage throughout editorial and has a built-in archival system. When an editor or assistant is done with a tape, it is put on a shelf with a note added to the database as to what is on it. File-based media is beloved for the ease with which it can be duplicated and electronically distributed, as well as for its faster than real-time functionality. But, since there are many different formats and codecs making up the family of file-based media, editors are often required to transcode much of it into a common codec/format. Additionally, file-based media can be difficult to manage and archive when compared to tape's "set it and forget it" functionality. These "media wrangling" chores take valuable time away from the creative postproduction process. A central goal therefore, is to automate and remove as much of the non-creative labor from editors and assistants as possible and where feasible, push these processes into the background, freeing the editors and assistants to continue using their talents for telling a great story.

Minimizing the impact of high-resolution on efficient post workflows

Professional production environments most often consist of teams of creative talent working together on one to many projects. Picture editors, sound mixers and visual effects/graphics professionals collaborate to turn around the highest-quality production as fast as possible, maximizing the company's investment in its tools and talent. Working with the highest possible resolution is a necessity in VFX, color grading, and finishing processes. However, for core storytelling functions such as editing, logging, and review/approval, high res files are too large and bog down productivity when moving media among team members and place an extra burden on workstation and storage requirements. When it comes to collaboration, asset management, remote editing, archiving, minimizing storage footprints, and optimizing editorial performance, it's important to leverage the benefits of high-resolution media without putting undue constraints on the established, efficient workflows that businesses depends on. Maintaining such efficiencies are a fundamental goal of any business, and it's core to the design of Avid's media platform.

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AMA and DMF

The first step when working efficiently with high res media is to decide between working at the media's native resolution, or transcoding to an intermediate or "mezzanine" codec built for efficient postproduction processes. This decision can be based on the eventual output format the project will take, the agreed upon workflow of the facility, or the speed and performance required in editorial. In either event, the next step is to link to the source media for instant access. In Avid systems, this is done using AMA (Avid Media Access). AMA is an open plugin standard developed by Avid and used by major camera manufacturers to enable instant access to camera original media and metadata. This differs from the older style "import" functionality where editors and assistants would wait as the media was imported and transcoded or re-wrapped into the MXF format. While a mezzanine format such as Avid's DNxHD has many advantages, viewing and editing directly from native camera media without waiting for a lengthy import process is an important first step in efficiently organizing content. AMA enables this instant access and brings in all the metadata associated with the media as well. The only way to improve on such a streamlined workflow would be to automate it and do it as a background task when transcoding, copy, or consolidating the media is desired. Thankfully, this capability exists in a new feature called Dynamic Media Folders (DMF), a significant new feature of Media Composer® 7.

Dynamic Media Folders

The primary goal of Dynamic Media Folders (DMF) is to allow users to automatically process and stage file-based media in the background, removing what is typically a tedious and time wasting import process. Automated processes are invaluable for creating HD proxy media from hi-res sources that, by their nature, can be an impediment to acceptable real-time performance, parallel editing teams, storage space, and remote collaboration. Editors and assistants can organize their media in folders that are managed/watched, knowing that the media will automatically be processed as defined by a preset profile.

Items in a DMF can automatically be:

- Copied to another location and automatically be re-linked to the new location
- Transcoded
- Consolidated

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The DMF interface allows an editor or assistant to setup a “profile” to describe the desired task:

- Users can create multiple “profiles” to describe the actions that happen to media when it lands in a given folder. These profiles can easily be copied and shared. See figure 1 below.
- All processes occur in the background with available system resources. They function regardless of whether Media Composer is launched or not
- The editor is not interrupted or distracted by progress bars or other notifications
- Items in DMFs are “managed”, meaning they are indexed by the system and tracked to minimize the possibility of media becoming unlinked and therefore “offline”
- Users can monitor background task progress in a “background queue” window if desired

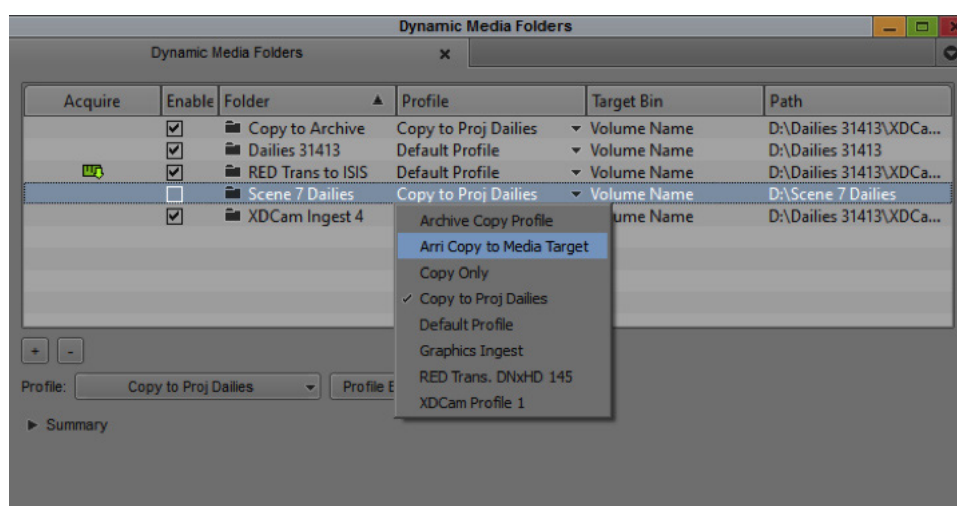


Figure 1 – Configuring multiple Dynamic Media Folders with user created profiles

The user assigns a Profile to the DMF allowing it to have unique characteristics such as Copy, Consolidate, Transcode and how those clips will populate in bins. These settings and actions are created using the Profile Editor (Figure 2), which establish AMA link settings and assign the Copy, Consolidate or Transcode operations so that any files or volumes placed in the DMF will be processed accordingly.

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In the case of high-resolution media, a common workflow would be to use the DMFs to automatically transcode media to a proxy format such as DNxHD 36 for editorial workflows so that performance and stream counts are not impacted for the user or others on the network.

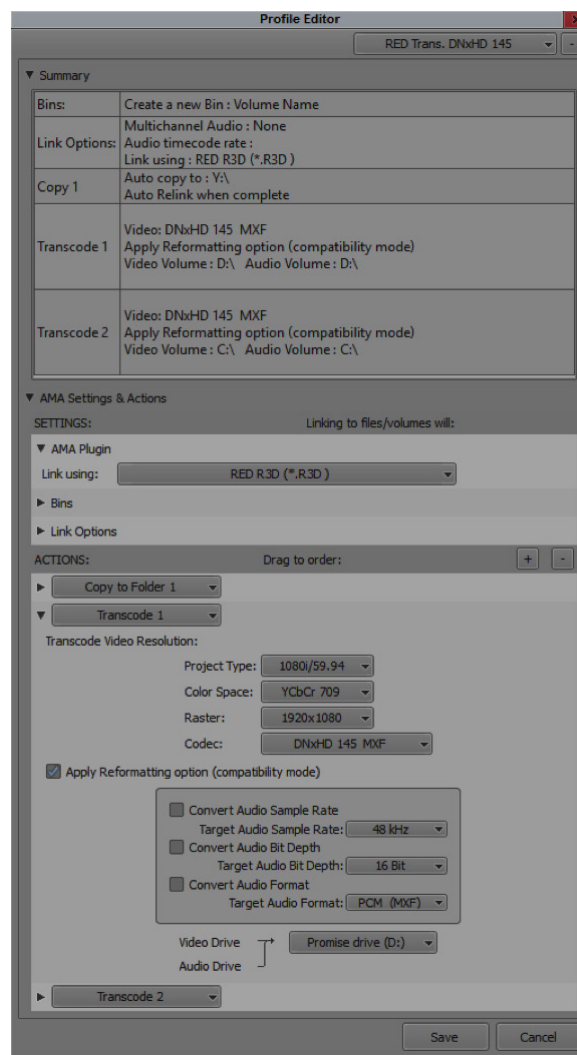


Figure 2 – DMF Profile Editor

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Once files have been placed in a DMF and/or processed, the user is notified in the timeline that new assets are ready to be acquired.

When the DMF window is opened, the user is shown which DMFs contain new assets. Clicking on the green bin button in the “Acquire” column will “pull” the new assets into Media Composer by populating a bin based on the AMA settings associated with the Profile (Figure 3). In this way, the editor is not disturbed and can choose when to acquire any new media that has processed in the background.

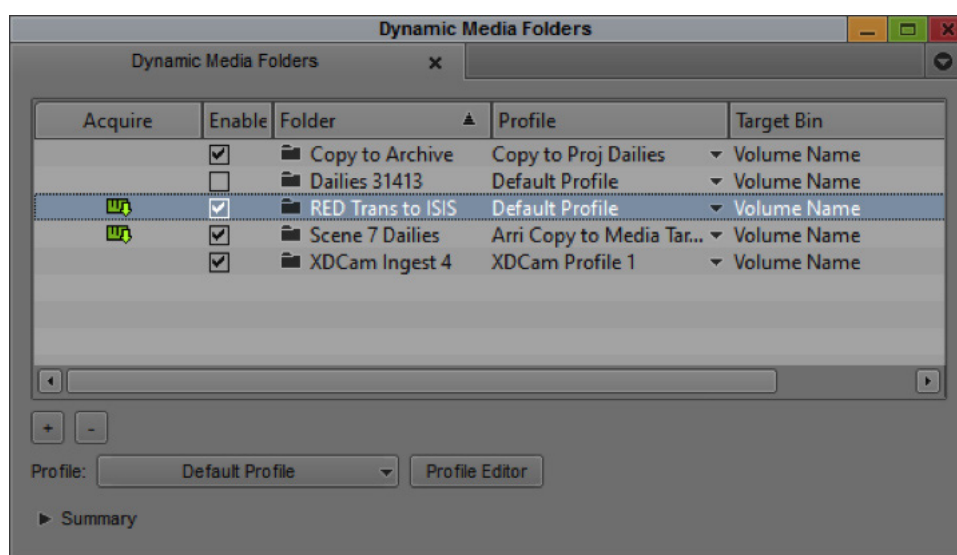


Figure 3 – Acquiring processed assets with DMF

All files that are placed in the DMF will then appear in Media Composer as AMA masterclips.

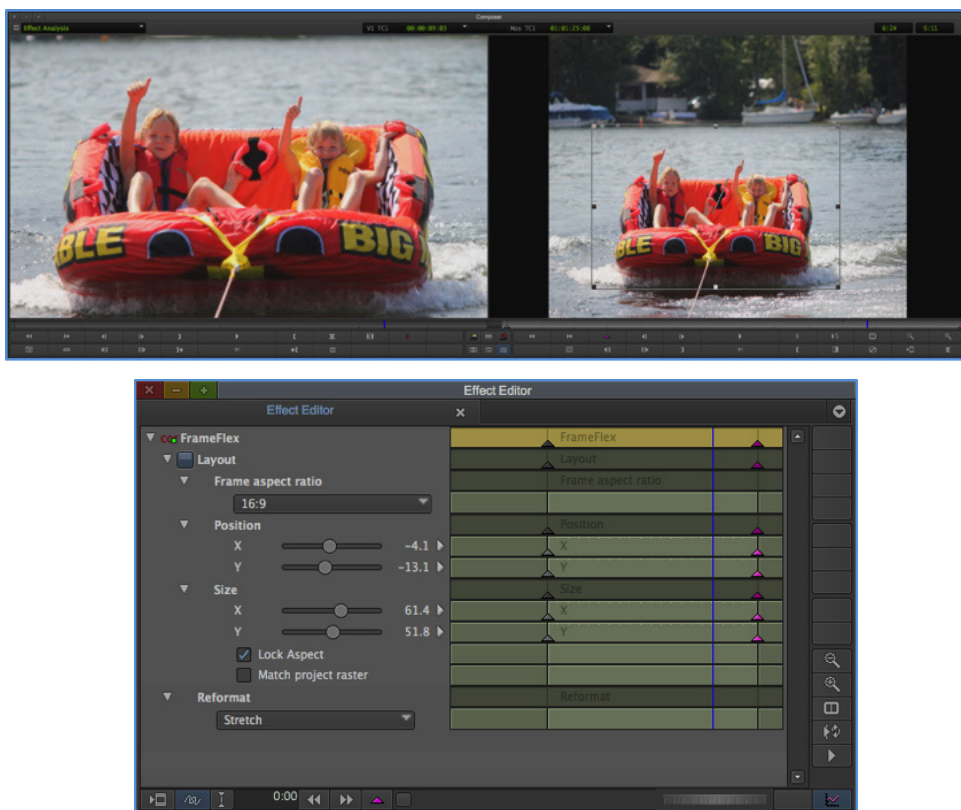
Once the media is transcoded to a lower resolution, the links to the original high-resolution sources remain, allowing the footage to be “re-linked” to the hi-res version when required for color grading and finishing.

Delivering HD Masters from high resolution media - FrameFlex

As previously discussed, productions routinely shoot higher resolutions than HD (2K, 4K, 5K, etc.) because it gives them the ultimate postproduction control for decisions around framing, color, and quality. However, the majority of productions outside of the cinematic market are still required to deliver HD masters. Recognizing that trend, Avid introduced the FrameFlex™ tool in Media Composer 7.

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Prior to Media Composer v7, it was possible to display images larger than the project target resolution through the reformat option. The media would be stretched, resized to fit, or cropped. However, there was no way to select a distinct area (region of interest) of the media so it would become the newly reframed clip. Using FrameFlex, editors can now control precisely which region of their high-resolution media—be it stills or video—is extracted for HD output. Using the effect editor, it's also possible to animate the framing box over time to pan and zoom across an image. This selective framing allows the editor to focus the viewer's attention while maintaining the original resolution of the source image. It's non-destructive and can be modified any time. According to some editors, productions are now purposefully shooting “wide” knowing that Frameflex will be used to re-frame in post production. This workflow, this effectively doubles the amount of camera angles that can be used. FrameFlex Metadata stays with the clip, so that even if resolutions are changed during a relink, the framing data is intact. For finishing, this assures that the resulting image is always derived from the highest quality source image.



A user can modify the framing of hundreds of clips simultaneously or modify them individually as needed.

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Frame rate mix and match

Projects are rarely acquired in a single format and frame rate.

Media Composer's mix-and-match timeline functionality allows editors to focus on storytelling by automatically applying the correct motion adaptor to any media not at the designated project rate for a high quality real time result. If certain results still aren't what the editor is looking for, the application allows an editor to customize the motion adaptive process to achieve the desired look. (Figure 4)

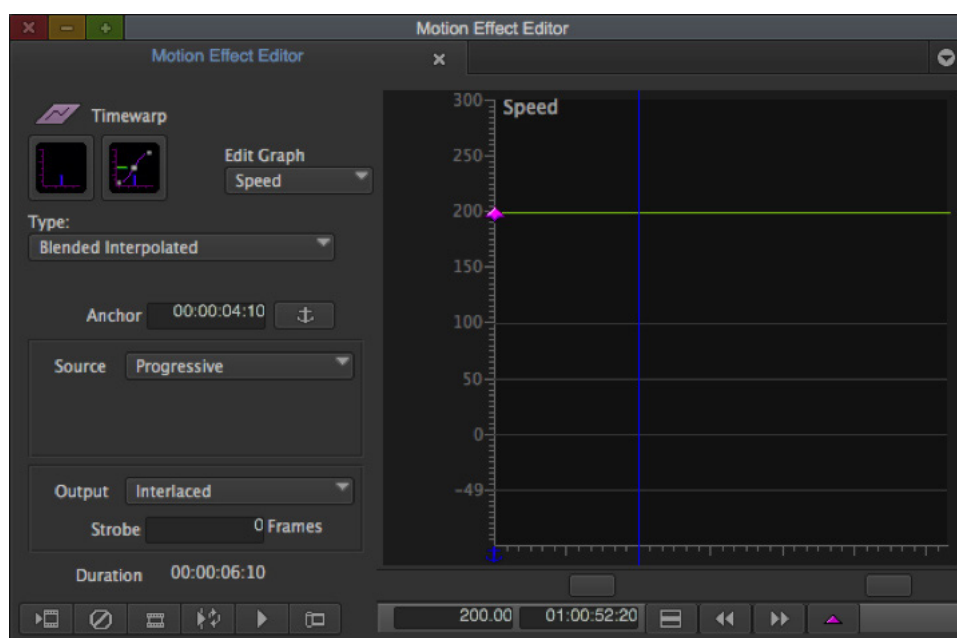


Figure 4 – Motion effect editor modifying a motion adapter

Color Management – CDLs and LUTs

As mentioned, when using modern file-based cameras, high resolution is not just about capturing more pixels, it's about capturing enhanced color and contrast detail as well. The goal of any camera system is to more closely mimic the perceptual range of the human eye in terms of contrast and color. Since the human eye doesn't "blow out" the whites and "crush" the blacks as easily as a camera can, manufacturers have created ways to store the sensor image data where more of this detail is retained. There are a few different methods for doing so, and consequently various camera manufacturers encode to different "color spaces" e.g., ARRI LogC, Canon C-log, Sony Slog2. Eventually, if consumers are going to see the correct colors on their HD screens, these alternative color spaces will need to be "mapped" back to the HD color space (Rec. 709). For an editor trying to concentrate on telling a compelling story, it would be better for the editing system to detect the color space on source material and automatically select the correct color space for output. In this way, Color Management is essential to ensure the correct colors are retained and maintained throughout the entire production and postproduction pipeline. Part of the color encoding includes "look up tables" (LUTs) that can

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be passed along with the media to ensure that a consistent color is applied to all related footage. The color management system will take the colors in an image and map them as accurately as possible to the color model chosen for the editing process. This color mapping is either done 'on-the-fly', or can be rendered (baked in) to new media after any effects are applied.

In Avid Media Composer, when this color information is embedded in file metadata from the camera, it can automatically be mapped to the REC. 709 HD color space. This not only saves time, but also guarantees the right choice by an editor or assistant. Otherwise, a LUT can be inserted as a manual "look" via the DP (director of photography). Additionally, the color information can be conveyed with a Color Decision List (CDL) by importing an Avid ALE (Avid Log Exchange) file or manually entering the data. It's possible that more than one LUT might be applied, and for this reason it's possible to change the order in which LUTs are applied creating a different end result. Throughout the process, the original color encoding data will remain with the master clip metadata for use throughout the editing pipeline.

Infrastructure

Since shared storage and asset management is a significant component of post-production workflows, it's easy to imagine the negative impact high resolution files can have on such infrastructure in regards to both storage consumed and impacts to performance. Enterprise class post environments and broadcasters realize great benefits from teams working in parallel on creative jobs and it's important not to sacrifice this advantage just to work with hi-res media. Yet, companies have struggled to find solutions to high-resolution workflows within the bounds of their current infrastructure.

Avid ISIS® and Avid Interplay® are smart storage and asset management systems currently in use in thousands of facilities around the world. Recognizing that high-resolution files can be a burden to networks, most users elect to transcode to a proxy resolution for editorial workflows. If quality is a concern, HD itself can be a suitable proxy for some workflows. Whether it is Avid's own DNxHD, Apple's Pro Res, or even an SD resolution, Avid Interplay can transcode in the background so editors can keep working. A frequent problem when working with large files is running out of allocated storage space. A unique feature to ISIS, Flexdrive is a tool that allows the storage to be dynamically sized up or down "on the fly" based on requirements. This flexibility is particularly unique in that it can be done while the system remains online and is only limited by the capacity of the storage group, meaning no one has to stop working for a configuration change.

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Remote Workflows

In a world of compressed schedules and budgets, it's important that teams have access to all the media wherever they may be located. Avid Interplay allows the entire team, not just the editor, to access and view footage via popular devices like iPads, iPhones, and even a standard web browsers like Safari or Chrome. With the high shooting ratios of some programs, logging is a full time job and now it can be done remotely from a simple browser interface. When an editor or assistant needs to edit in the field with Media Composer, the Interplay Sphere option streams compressed or proxy versions of higher resolution material over lower bandwidth connections like Wi-Fi or 4G. In this type of workflow, editors can mix local high-resolution media that's just been acquired in the field with media that resides on shared storage back at the facility on the same timeline. Footage can be set to automatically transfer back to the facility in the background for a seamless remote editing experience.

High Resolution Finishing Solutions

For programs that must be output at high resolution, such as 2K or 4K for cinematic release, metadata is an important aspect for seamlessly conforming the final sequence to the original high-resolution files. Avid's Media Composer produces an AAF (Advanced Authoring Format) file that can be conformed in multiple hi-res capable finishing systems from our partners. This industry standard file contains all the information necessary to conform and finish a program on any number of high resolution finishing systems such as:

- Autodesk - Smoke, Flame, Luster
- Black Magic Design – Resolve
- Digital Vision - Nucoda
- Filmlight – Baselight
- Quantel - Pablo

Typically, the output for theatrical release is to a DCP (Digital Cinema Package) file (a very large file at 4K), but as UHD TV approaches, the delivery requirement could be to an efficient codec format like HEVC (High Efficiency Video Coding), also known as H.265 or Google's new VP9 codec. For broadcasting and distribution of content over the Internet, it's obviously essential that the bandwidth be constrained.

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Future directions

It's clear that UHD TV is destined to become a standard distribution format for consumers in the future. Blu-ray formats and codecs for streaming and downloading (H.265) are all but standardized and delivery pipelines are being designed and discussed. As this next media evolution approaches, Avid is actively developing its infrastructure by moving all applications to 64bit for increased performance while creating a modularized media platform with common components shared by all Avid products and open to third parties. Running a high-resolution "pipeline" has to include all stages of production, postproduction and distribution. To that end, Avid continues to develop a media platform built to support such resolutions and accompanying metadata across the entire workflow. Future versions of Media Composer will be resolution independent, supporting more than just large rasters like 4K, but also color and frame rates across the entire postproduction pipeline. At the same time, additional efficiencies can be gained from continuing to automate processes and move them to the background where feasible (e.g. automatically setting image framing using camera metadata as set by the DP on location). Throughout all of this, Avid will openly work with its partners to deliver the best solutions possible to our mutual customers with the goal of not constraining any of the efficient processes already in place when working with these challenging new formats.

Conclusions

High-resolution images are enabling content creators to deliver higher quality, inspiring content, thereby motivating increasingly sophisticated consumers to act—whether it is purchasing a higher resolution version of their favorite program, buying a new device to enjoy it on, or being compelled by a quality advertisement, high-resolution acquisition and distribution will continue to evolve. In order to meet the challenges of these new formats and delivery requirements, Avid is taking a holistic approach by evolving its media platform to support all stages of a modern production pipeline from editorial and storage, to asset management, and review and approval. To answer the needs of productions working with hi-res projects today, Avid's products have been augmented with tools and technology to allow editors and assistants to work directly with hi-res media without sacrificing efficiencies with current workflow. Many productions will continue to deliver HD masters for the foreseeable future, while demands for UHD TV content will evolve to be part of delivery specifications for some programming. Avid will continue to provide proven and tested workflows to content creators and distributors wanting to realize the benefits of working with hi-res media for today's HD programs while actively developing solutions for tomorrow's higher resolution workflow challenges.



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