MEDIA COMPOSER 2019

The Advantages of using a 32-bit Floating Point Color Pipeline for Editing, Color Grading and Delivery in Media Composer

MAY 2019

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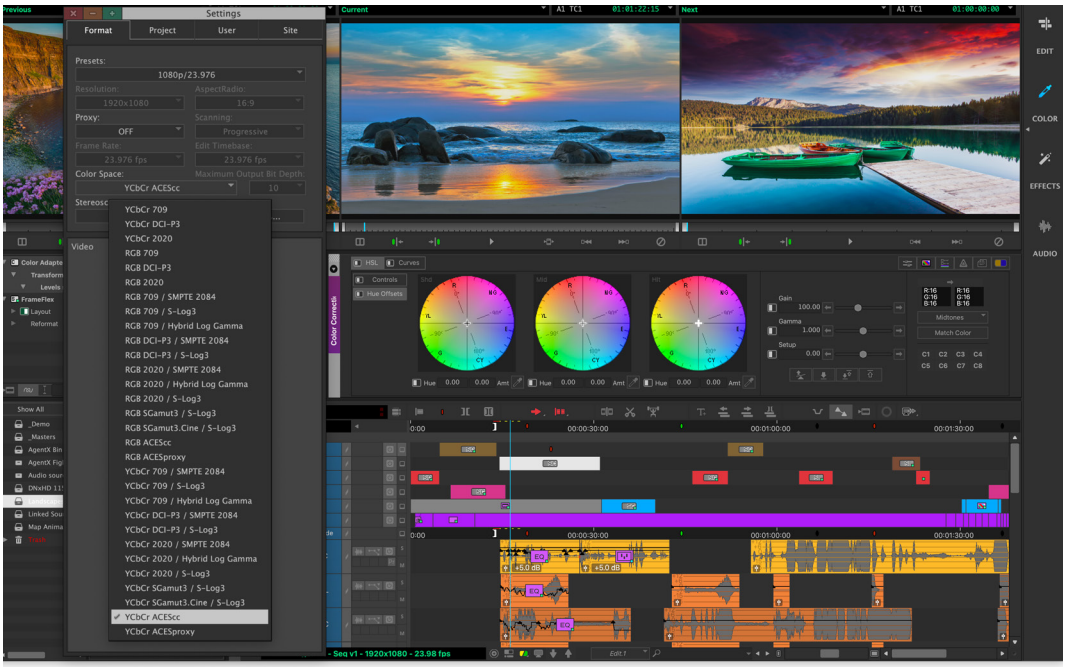
SUMMARY

This paper discusses the new 32-bit floating point color pipeline in the 2019 Media Composer® video editing software, which supports high bit-depth, HDR color grading workflows and video effects processing. In this paper, we will show you how the new Media Composer can increase efficiency and reduce churn in collaborative workflows, as well as streamline delivery methods.

Important topics include:

- The advantages of DNxHR and DNxUncompressed codecs when preserving color metadata and lossless collaboration.
- The importance and value of ACES (Academy Color Encoding System)
- IMF (Interoperable Master Format) when used to submit deliverables to broadcasters and other organizations that have a standardized master file delivery format.



UI MediaComposer 2019.6 Workspace Color with ACES compatibility

THE NEW COLOR PIPELINE IN MEDIA COMPOSER 2019

To preserve image and color quality throughout a modern, high-resolution HDR color workflow, we have significantly updated the Avid Media Engine in Media Composer. For Media Composer 2019, the resolution independent timeline can now support raster sizes up to 16K while processing images and effects in 32-bit floating point precision. The overarching goal is to provide a color management system that ensures color information is never lost or altered, even though monitoring devices and viewing settings may change.

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We know that modern production and post workflows demand that all underlying color data is preserved effectively "under the hood." Just as importantly, an editor should be able to concentrate on telling a good story, without worrying about damaging color information along the way. While there is plenty of "heavy lifting" going on in the background, it is important that editors invest some time and energy in learning how to properly set up a project in Media Composer with these new color options. These new settings will determine the working color space of the overall project - and ultimately influence how source/record monitors as well as external confidence monitors display the images. Whether you are color grading in Media Composer or in a 3rd party application, correctly setting the working color space ensures that all original color information is preserved throughout the process.

The Value of Avid DNxHR and DNxUncompressed

Processing images and effects in the timeline at 32-bit floating point precision is only half the equation. Since all of this additional data needs to be stored, a new breed of codec was required which led to the development of Avid DNxHR® an extension of Avid DNxHD®, which is color-space agnostic as well as frame-rate and resolution independent (DNxHD was limited to the Rec. 709 color-space at specific frame-rates and raster dimensions).

With DNxHR, media can be tagged at any color space, any frame rate, and any raster dimension with a 12bit resolution versus the original 10bit limit of DNxHD. DNxHR also supports multiple compression options from offline quality to 12-bit 4:4:4 finishing quality.

More recently, we developed a new DNxUncompressed codec for complete lossless interop and collaboration during VFX, grading and finishing workflows. Our DNxUncompressed codec supports media up to 32-bits of resolution thereby

preserving all color data. Editors and post supervisors wanted the ability to exchange a single high bit-depth, high-color, uncompressed MXF file with collaborators as opposed to generating massive DPX or OpenEXR image sequences to simplify transport and management.

In addition to storing uncompressed data, the Avid DNxUncompressed codec matches Media Composer's own internal image processing engine which not only enables 32-bit processing but also enables rendering and storing an increased range of mapped color and luminance values over previous codecs.

It's important to note that the SMPTE VC-3 specification, based on the Avid DNx family, has recently added the latest DNx codecs, DNxHR and DNxUncompressed, into the VC-3 portfolio. To further streamline media creation and organization, we also added the ability to export DNx codec variants as MXF OP1a further simplifying file interop and collaboration.

Color Spaces

With the advent of digital video, multiple image capture, and display technologies, it's more important than ever for cinematographers, directors of photography, and editors to acknowledge the importance of a production pipeline color space. It might have been acceptable in the past for an editor to not be fully aware that an HD video production was working in the Rec. 709 color space. Today, with the advent of DCI-P3, Rec 2020, and different ACES variants, it's critical that all collaborators discuss the color pipeline from the outset of production. This will be discussed in more detail below.

If a project is received from a different finishing or grading system, the color data can be transported using a free and open standard such as OpenEXR. Media Composer 2019 now supports reading of OpenEXR files and much of Media Composer's current color workflow remains the same when reading metadata for source side transformations and selecting output transforms for the viewers or the Avid Artist | DNxIQ I/O hardware.

HDR Workflows in Media Composer

Unlike an image's raster size (number of pixels in an HD/4K/8K/16K image), High Dynamic Range (HDR) focuses on improving the quality of each pixel with regards to color and contrast. Currently, there are three leading methods for encoding this additional information:

- HDR10
- UHD HLG (Hybrid-Log Gamma)
- Dolby Vision™

ITU-R Recommendation BT.2100 is the current standard for HDR video production.

Designed primarily for UHDTV and broadcasters, it includes the Rec. 2020 color space. In order to please multiple manufacturers and broadcaster requirements, two types of encoding curves (transfer characteristics that describe how the media is encoded) are allowed in BT.2100:

- PQ (used in HDR10 and Dolby Vision™)
- HLG (Hybrid-Log Gamma in use by the BBC, NHK)

Which brings us to the biggest difference between the two methods. PQ (also known as SMPTE ST 2084) is "display referred" – the way the signal is encoded directly dictates the luminance that should be presented on a PQ calibrated monitor. In this way, a specific value represents a certain level of brightness. We like to think of it in terms of a red Coca Cola can. If a monitor is PQ calibrated, then the can will have exactly the brightness that was intended by the content creator. The monitor is calibrated for certain values, and the signal is encoded in terms of presenting those luminance values exactly.

Conversely, HLG is "scene referred" – the signal is still an HDR signal, but the luminance is encoded with respect to the input signal. It can be looked at on any type of monitor, and as such, is more backwards compatible. However, the actual look can change based on the capability of an individual HLG monitor. In HLG, the range of display values will map across the luminance range supported by a given monitor (brightness).

Although the PQ curve method of encoding HDR is the basis of both HDR10 and Dolby Vision™, Dolby Vision™ adds another metadata layer beyond HDR10 that expands the range significantly. This metadata is part of Dolby's patented system to properly display colors on monitors of different luminance supporting Dolby Vision™. We've made sure that Media Composer 2019 supports HLG and PQ encoding, although the additional Dolby Vision™ metadata is not yet implemented as of this paper.

We recommend editing an HDR project on an HDR confidence monitor set to receive the chosen HDR signal type. Within Media Composer's settings, you can select PQ /2020 or HLG /2020 as the project color. Media Composer also supports log formats such as Sony Slog3, along with ACES which is discussed in detail below. Once the color space and HDR type is set properly in the project, Media Composer's color management system and the source settings will handle the conversions automatically if the identifying color space metadata exists in the media. It is also possible to add viewing LUTs in the software monitors as well as the HW output. These real-time conversions are non-destructive as no new media is created. To preserve the maximum bit depth precision, you can manually map your white point in nits (a unit of brightness). When color grading in Media Composer 2019, we also updated the vector scopes to show values for PQ levels in nits and for HLG, scopes can now show the value in respect to the HLG signal (0-12 in brightness).

Output options for an HDR master includes exporting an MXF file with DNxHR at 12bits to preserves the full precision that is required for PQ and HLG. Exports can also utilize the DNxUncompressed codec or a DPX image sequence. IMF masters are also possible utilizing the JPEG2000 codec.

The Importance of ACES

We've lived through profound changes in digital production techniques used in the creation of motion picture content. From camera to Digital Intermediary to presentation, digital technologies have become pervasive. This growth in technology led to new problems for production and post-production workflow. When production was done on film, all of the color science and color matching was done in a controlled environment in a film lab. Creative staff didn't have to think about this color science to any real degree since the labs used formulas given to them by Kodak, Fujifilm, Agfa etc. to produce consistent results (at least within the tolerances of a chemical process and its variables). These formulas became the "standards" that were used to ensure the results from one lab matched the results from another lab.

But as digital became the norm, much of the standardization was lost. Results from one visual effects house could vary dramatically from the output of its competitors. Issues multiplied when the output from one VFX house—such as a digitally created background scene—was used in a composite with content from another facility; you'd be faced with a background in the composite that could have significant color differences from the original input.

Recognizing this as a major issue in the workflow, the Academy of Motion Picture Arts and Sciences began to work on a replacement standardized image management infrastructure that would allow cinematographers, colorists, Digital Intermediate Technicians (DIT) and Visual Effects artists to focus on their creative process without worrying about the underlying color science. The result was a set of specifications for several color space transforms which no longer interfere with the creative process - and together make up a powerful color space pipeline for production. There are, in fact, some additional specifications in the set, but the transforms are by far the most important items. This set of specifications, taken together, is known as ACES (The Academy Color Encoding System).

A second target for the ACES team was to ensure that this new system would fulfill the archival needs of the industry. This meant preserving the maximum resolution imagery possible in order to maximize the possibility of re-use down the road. Many studios now archive (or re-archive) material using ACES-compliant processing.

ACES Color Space

When it comes to color space, one of the main benefits of an ACES workflow is that it is scene linear (as defined by the ACES 2065-1 standard), meaning that it represents

the original scene in a linear light space. This overcomes a problem with all film and digital cameras that "capture referred data" – i.e. they "bake in" their individual color space into the images they capture. With different sensors and electronics, it's easy to imagine why different makes and models of cameras might look different, even when you're shooting the same gray chart. This causes a big problem, simply because we need cameras to be neutral when it comes to color reproduction.

And this is where ACES adds real value. It solves this problem by utilizing an Input Device Transform (IDT) that requires ACES compliant camera manufacturers to deliver a precise description that informs the input transform on how to remove any color bias. With the input transform, systems can translate the image back to the pure linear light information that was in the actual scene in front of the camera, thus (theoretically) without any camera improvements/artifacts. Think about it this way - if you used a Canon C500, everyone's going to use the same C500 input transform for that media. That way, if the media is sent somewhere else, the new facility will use the same transform to preserve color integrity.

It's also important to note that ACES uses 16bit floating point representations of each of the color components, which allows it to encode to a color space so large that it exceeds any currently available media color space—including the current HDR standards. In fact, the ACES color space is so large that it exceeds the entire human visual locus. In other words, it can reproduce more colors than humans can actually see. (see Figure 1)

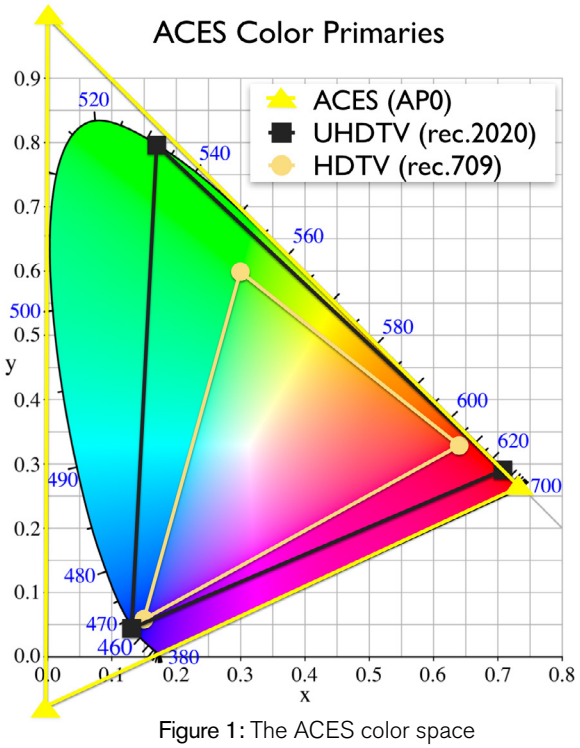

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Figure 1: The ACES color space

That's pretty amazing. And in addition to offering the highest fidelity for the processing pipeline, this huge color gamut is also fundamental to providing true "evergreen" digital archival copies.

ACES Components

As we previously mentioned, ACES specifies a number of transforms to be used in the production pipeline. We've outlined them here, in end-to-end workflow order:

1) The Input Transform
   The Input Transform takes the original camera data and converts it into the scene linear ACES color space.

2) The Look Transform
   This is applied after any digital processing and is the first of 3 transforms used to make up the ACES "Viewing Transform". The Look Transform provides a way to apply an overall look to a shot.

3) The Output Transform

   The Output Transform is the final step in the ACES "Viewing Transform". As part of the output process, the ACES render engine converts scene referred linear data to the ultrawide display-referred color space. The Output Transform then parses it for different devices and color spaces like P3 or Rec 709, 2020, etc.

The Output Transform does the same thing for all the variations that exist in displays, from Rec. 709 or Hybrid Log Gamma TVs, to SRGB computer monitors and HDR 10 capable projectors. Similar to the Input Transform that exist for cameras, but in reverse. The display referred data creates color consistency when viewing across the myriad displays in a typical post production pipeline.

It probably comes as no surprise to learn that within ACES there are a few variations such as ACES 2065 (the full linear version of ACES which includes colors we can't see) and ACES CG (full linear with a slightly smaller color space). ACES CG is still wider than any color space on the market and completely sufficient for grading and compositing. There's also ACES cc and ACES cct which have the same color ranges but are encoded as LOG (logarithmic scale) so you don't have to roll the grading ball for an eternity before the color changes significantly.

The key to the whole workflow is that color information is stored and processed in a controlled, but lossless way, regardless of:

- what camera is used;
- what monitors are used to view the images during post-production and finishing;
- and what type of output(s) are made.

Although you may need to change grading if the producer is not happy with the look, this is a separate issue. The color transformation has been set in stone and ensures

that the color pipeline is the same across the board. It is completely normal for color conversions to take place along the production pipeline, but as long as the color space has a wide enough gamut to store the results, nothing is ever lost and you can always return to the original essence.

While a tremendous amount of math may be at work below the surface, we believe that working in an ACES environment is fairly straightforward and brings huge benefits for collaboration between production, VFX, post, and finishing. The idea behind the ACES workflow is to avoid adding unnecessary complexity. The color process is very similar to the current source settings, display color space and project settings that have existed in previous versions of Media Composer. And while ACES may have been initiated by the Academy of Motion Picture Arts and Sciences to conquer color pipeline in the era of digital film workflow, it is just as relevant for video and television production.

Working with ACES in Media Composer

When it comes to setting up a Media Composer project for ACES, you are essentially telling Media Composer that ACES is your working color space. This means that everything Media Composer does to the media is processed and stored using 32-bit floating point and the DNxUncompressed codec, while preserving the full range of luminance values. And even though the "output color space" might be an sRGB computer monitor or a Rec. 709 monitor, and those monitors might clamp values that are beyond what they can display, all the color information is still there. You might even want to select a LOG version of ACES so color grading controls feel more natural.

In ACES mode, you can also apply a color LUT (Look Up Table), and it will be automatically assigned with a standardized CLF (Color Look Format). This way, any system can read and interpret the color correctly. The LUT transformations or Look Transforms are applied in linear fashion on the source side and are stackable. Any LUTs used must of course be ACES compatible and designed to work within the ACES 2065-1 standard for both input and output. Media Composer will automatically ensure that everything stays in ACES range.

When the time comes for you to deliver an HDR master in HLG for example, it's important to note that the gamut and luminance ranges might have to be reduced. This is because it needs to match the display technology at the very final step. In this way, working in ACES "future proofs" your project. Even though you may grade for HLG delivery initially, all the sources remain pristine and can be referenced by some future monitor technology that doesn't exist today but will likely have an even wider range and gamut.

ACES Logo Certification Program

Recently, we joined the ACES Logo Program as the first product partner in the new Editorial & Finishing product category. As a result, we will be working to implement ACES in conformance with logo program specifications for consistency and quality to provide our customers and users with a high-quality ACES-color managed video creation workflow.

IMF: The Interoperable Master Format

Distribution of programming has become massively more complex due to the sheer volume of deliverables and endpoints for media consumption. Companies used to transmit in a single language to a single geography for a single platform (the TV). Now content distributors and media entities, such as Comcast and Netflix, license much, if not all, of their content from other owners for distribution to multiple territories and playout devices. This leads to a number of problems, including dubbed audio and/or subtitles required for each language (and then for compatibility with multiple playout devices). In addition, certain types of content—nudity and/or profanity, for example—may need to be altered for certain geographies.

Thankfully, IMF (the Interoperable Mastering Format) was designed to streamline the management and processing of multiple versions of material destined for worldwide distribution. Key elements include:

- Support for multiple audio and video formats, with associated/language specific graphics, subtitles, captions, etc.
- Support for descriptive and dynamic metadata that is expected to be synchronized to an essence – media file(s).
- The use of existing technology—namely the MXF (Material eXchange Format) file specification—for wrapping media.

Anatomy of IMF

If you are unfamiliar, IMF is not a single file – it is instead a collection of files which together make up the content (be it a full-length movie, a documentary, or an episode of a series). Each version of a piece of content is called a “composition”, which is the set of all essence and metadata that makes up a particular deliverable. An example of a composition might be the U.S. TV version of the theatrical cut of a movie, or the German version of an episode within a series.

When you are playing back an IMF Composition, a device first looks for a file called a Composition Playlist (CPL). The CPL is a bit like an edit decision list—it defines the playback timeline for the composition and includes metadata applicable to the composition as a whole. One very important point here is that the CPL is not designed to contain essence but rather references external (MXF) Track Files that contain the actual essence (see Figure 2).

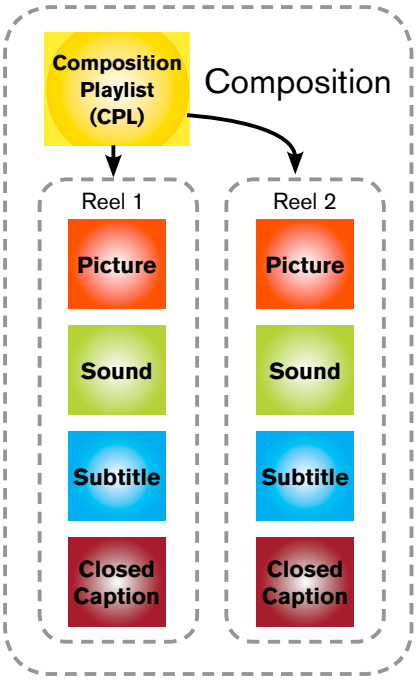

Figure 2: A CPL points to individual essence files

Using this mechanism greatly simplifies the versioning issue mentioned earlier: to create a different language version of a piece of content, you simply need another CPL that points to different audio files and different graphics files. All other pointers can remain the same (see Figure 3).

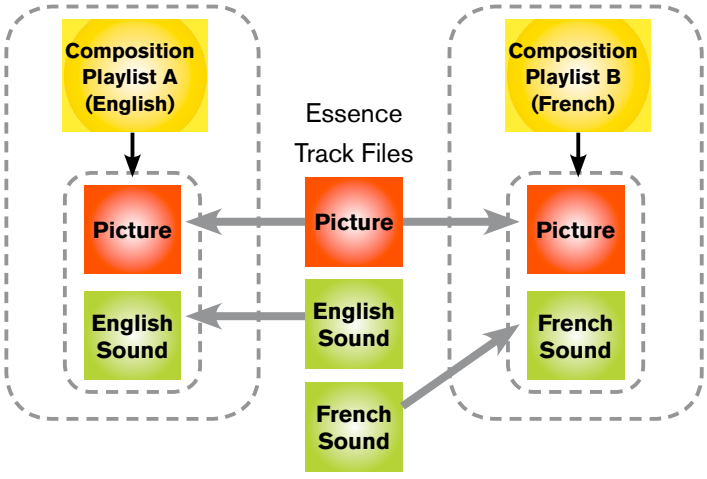

Figure 3: Multiple CPL versions share essence files

IMF also allows you to create different distribution formats from the same composition, if required. This is accomplished through another file, called the Output Profile List (OPL), which specifies the processing/transcoding instructions required for each distribution format. For example, you can change the display aspect ratio without generating any new media.

A concrete example of the value of this is the use of IMF in mastering the popular "House of Cards" TV series. In 2015, shortly before the release date for season 3, Netflix modified its opening logo to add sound. Unfortunately, all of the variants (languages, etc.) had already been mastered and delivered to the playout servers. Without IMF, it would have been impractical to update season 3 with the new opening logo, but with IMF, changing to the new version involved a trivial adjustment to the CPLs to point to a different opening "snipe" - and the change had no effect on audio/video/subtitle synchronization. No additional QA step was required, and the series released on its original schedule. You should note that Netflix, Disney, Hulu, and others require, or soon will require, all HD/UHD/4K material be delivered as an IMF package.

> *By using IMF, the overarching goal is to create a workflow that caters to the myriad versions of programs required now and in the future.*

By using IMF, the overarching goal is to create a workflow that caters to the myriad versions of programs required now and in the future. Proper implementation lets you focus on creative tasks without worrying whether a show will be rejected because it is improperly formatted for distribution. These are tasks computers are great at, so in the not too distant future, you will be able to download an IMF export profile, for Discovery as an example, load it into Media Composer, and have full confidence that the show and all required metadata will be exported correctly, the first time, and every time.

Delivering IMF Masters with Media Composer 2019

We built Media Composer 2019 to support direct export of a sequence to the IMF format. As part of this work, Media Composer 2019 exports a compliant JPEG 2000 file at resolutions up to 4K 60p. This export, also known as an IMF package, conforms to an IMF variant called Application #2E, or App 2E for short. You can even add additional descriptive metadata—such as who delivered the content—where it was created. Technical metadata, such as color space, dimensions, and frame rate are automatically added by the application in accordance with the delivery requirements of the spec. Although there's more work to do, the first phase of the IMF export development in Media Composer 2019 includes export and import of a simple IMF package conforming to App 2E.

CONCLUSION

Our industry is constantly challenged by shrinking budgets and time constraints. Thankfully, technical advancements—such as ACES and IMF—continue to evolve to meet those challenges. It's never been more important to increase efficiency and reduce churn in collaborative workflows while streamlining delivery methods. We developed Media Composer 2019 to address your challenges - putting the complex media transformation and conversion under the hood, allowing you to apply your craft without introducing additional technical burdens into the process. Ultimately, our goal is to free up your time to tell the greatest story you can, and let the machines handle the rest.

Discover the New Media Composer Now

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