Report from the American Society of Cinematographers Technology Committee

By Curtis Clark, ASC; David Reisner; Lou Levinson; Al Barton; Greg Ciaccio; Gary Demos; Don Eklund; Michael Karagosian; Garrett Smith; Michael Friend; David Morin

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ASC Technology Committee Officers
Chair: *Curtis Clark, ASC*
Vice-Chair: *Richard Edlund, ASC*
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Secretary: *David Reisner, dreisner@d-cinema.us*

Introduction

ASC Technology Committee Chair: Curtis Clark, ASC

From its inception in 2003, the American Society of Cinematographers (ASC) Technology Committee has been guided by its primary mission to engage and influence motion imaging technology developments in ways that better serve and protect the filmmaker's creative intent and the role of the cinematographer in realizing a creative vision that best serves that creative intent.

In the year that has passed since our last ASC Technology Committee progress report for the *SMPTE Motion Imaging Journal*, we have experienced an array of motion imaging technology developments that provide a promising view of our filmmaking future, but also present a challenging road map to achieve it. Central among these developments are technology advances in laser projection; new enhancements to digital display technology, i.e., High Dynamic Range (HDR) Reproduction aka Extended Dynamic Range (EDR) Reproduction for both monitors and laser projection; Ultra-high-definition-television (UHDTV), aka Quad HD, aka 4K TV; a new wide gamut color space, Rec. 2020, to accompany UHDTV; and, of course, Academy Color Encoding System (ACES) development. Details of the work being done by our ASC Technology Committee to address these developments is contained in our subcommittee reports that follow.

Digital camera technology continues to evolve with various vendors entering the production scene offering new 4K cameras. Although 4K workflow solutions have also been evolving, there is still the challenge of deploying high-capacity storage integrated with greater bandwidth for SAN and NAS infrastructure to manage large file sizes that accommodate 4K RAW. The transition to 4K workflows for both Digital Cinema and "4K" TV has generated renewed interest in highest quality compression codecs.

I'm delighted to report that our ASC CDL (Color Decision List) was recognized by the Academy of Motion Picture Arts and Sciences (AMPAS) with Academy Technical Achievement Awards presented at this year's Sci-Tech Awards ceremony to five ASC Technology Committee members: Joshua Pines; David Reisner; Lou Levinson; David Register; and me. This was a tremendous honor to add to the 2012 Primetime Emmy Engineering Award that the ASC received from the Academy of Television Arts and Sciences for ASC CDL development work done by our ASC Technology Committee. These awards should also acknowledge valuable contributions from numerous ASC Technology Committee members to ASC CDL development.

ASC Technology Committee member David Stump's important new book "Digital Cinematography" has recently been published.

I would like to thank all those who devote their time and expertise to support the mission of our ASC Technology Committee.

Secretary's Comment

ASC Technology Committee Secretary: David Reisner, dreisner@d-cinema.us

The ASC Technology Committee continues to be one of the leading voices for development, selection, and use of technology in support of creative intent and audience experience across the expanding and wide range of delivery platforms.

Judging by new products shown at NAB '14, 4K has become the standard expectation for cameras and workflows. There were the same range of variations in 4K cameras as seen in 2K cameras, including specialty items like high-speed (900 fps) cameras. We are also seeing broader recognition of the importance of viewfinders. 3G SDI interfaces are starting to appear in products. Both ACES and ASC CDL have continued to increase presence in cameras.

Hollywood has also been showing an increasing awareness of Big Data, for elements and proxies, although cloud production is not yet practically scaled for the tens or hundreds of terabytes of mainline feature production or archival. Television leads motion pictures in this area. NAB '14 demonstrated that Big Data's awareness of Hollywood has improved meaningfully. This suggests that the two may eventually find the right common ground, with impact on production and, hopefully, eventually, economic and highly reliable 100 year+ digital archival.

Worldwide, the significant majority of theater screens are now digital. For both theatrical and home television, and in a very wide range of applications in the world at large, work is being done with higher efficiency illumination sources, which frequently have narrow, "spiky" primaries. Particularly when combined with wide color gamut and high peak illumination, we do not have a good

understanding of how this interacts with the human visual system. With real-world materials there are remarkable demonstrations of significant color artifacts and we have observed some metamerism in theatrical application. LED is a common illumination for LCD televisions and one would expect similar issues, particularly as home televisions are often run at two or more times theatrical luminance and as we move toward a Rec. 2020, wide-color-gamut world. This is a topic that would benefit from some serious experimental testing.

UHDTVs are still early in product development, and the full Rec. 2020 color gamut is costly to implement. We are likely to see UHDTVs with a variety of wider color gamuts for some time. We also don't have a consistent way of delivering those signals to the home, especially at UHDTV's quad-HD resolution, and especially at 10-bit and higher accuracies. (The difference between an 8-bit signal and display and a 10-bit signal and display is easily seen.) If we want to actually deliver 10-bits and more to display panels, we will probably have to rethink how we are handling compression. To actually deliver 10+ bits, we will probably need to switch to floating-point computations in our codecs—a large leap from our current standards and hardware. While there is great potential, there is still development work to be done across a broad swath of the industry and infrastructure.

Digital Finishing Subcommittee

Chair: *Lou Levinson*
Vice-Chair: *Joshua Pines*
Secretary: *David Reisner*

In an environment of continuing change, with no slowing in pace, we would like to take a moment to thank all who have participated in our subcommittee's activities.

Once again the efforts of our subcommittee have received industry recognition, with five members receiving Academy Technical Achievement Awards for design of the ASC CDL: Joshua Pines, David Reisner, Lou Levinson, Curtis Clark, ASC, and David Register. We also want to note and acknowledge the work of our other award nominees: Jim Houston and Ana Benitez. But in reality the achievement is due to the work of our whole team of subcommittee members and many others in the industry who actively participated in the ASC CDL's development, deployment, and popularization.

The ASC CDL is currently being used at one or more steps in the production-dailies-post-visual effects (VFX) workflow of about 90% of motion pictures, 70% of scripted series television, and nearly 100% of VFX turn over. It has probably become one of motion picture history's most widely used pieces of technology. The ASC CDL is implemented in the vast majority of relevant (and potentially relevant) hardware and software systems. It is independent of dynamic range, gamut, and encoding, so we anticipate at least the ASC CDL's ten numbers will still be present in our HDR, wide color gamut, ACES future.

The ASC CDL is well-defined and stable. It has been adopted and proven useful beyond our expectations. We have been considering some enhancements to the metadata carried to aid correction libraries and coordination with some vendor-specific facilities. We have been pursuing codification in a SMPTE Registered Disclosure Document (RDD).

The subcommittee continues to provide support for the development of ACES, which continues to move from Trial phase toward release, which will be of great value to our industry. In the past year, our critical contributions included active participation in the design of ACESlog and ACESproxy—critically important components for the rollout of ACES during the possibly—extended transition from the existing environment of log-oriented systems and controllers to a future where internals are linear and interfaces provide log-style functions when and if useful. ACESlog and ACESproxy also allow ACES support in current and "transitional" systems with lower-bandwidth camera outputs and systems that cannot efficiently handle OpenEXR float computation. During the development of ACESlog and ACESproxy teams coordinated and anchored by the DI subcommittee conducted extensive set-to-post testing at the DMPC (Digital Motion Picture Center) at Sony Pictures.

Although we can't understand how our breathtaking current pace could be exceeded, we expect that in the future our world will continue to change at an ever increasing pace, and the DI/Digital Finishing subcommittee of the ASC Technology Committee will be on hand to advance the technology that supports the art of visual storytelling, regardless of resolution and frame rates.

To get the current ASC CDL specification, send an e-mail to asccdl@theasc.com; an auto-responder will send terms and instructions. For additional information about the ASC CDL or Digital Finishing subcommittee, contact Joshua Pines at jzp@technicolor.com, Lou Levinson at western.light@yahoo.com, or David Reisner at dreisner@d-cinema.us.

Motion Imaging Workflow Subcommittee

Chair: *Al Barton*
Vice-Chair: *Bill Feightner*
Vice-Chair: *George Joblove*
Greg Ciaccio

Current subcommittee focus: ACES

Since last year, the ASC Technology Committee's Motion Imaging Subcommittee has focused on helping educate and prepare the industry for the introduction of ACES in parallel with efforts by the AMPAS Science and Technology Council.

We have continued to work with filmmakers, motion picture and television studios, and post-production facilities to help demonstrate the pitfalls that often arise in currently common "snowflake" workflow approaches and the advantages of using an ACES-based workflow.

The subcommittee is composed of key individuals in a variety of positions involved in production and post, who provide valuable

real-world feedback. Since ACES benefits many areas of our industry, recent action items include role-specific marketing documents highlighting key advantages for each industry area.

As was outlined in the September 2013 Progress Report, the purpose of this subcommittee is to create several different documents that will cover the use of ACES and the ASC CDL:

(1) An overview of how ACES is used in workflows that is appropriate to present to executives in about 15 minutes. This will be an 80,000 ft view with enough information to understand the advantages of using ACES, without getting bogged down in the gritty details.

(2) A set of documents describing Best Practices for using ACES in ACES-enabled workflows. These documents will have an initial focus on the on-set and near-set area, since they are the "stake in the ground" point for setting the look of the image. The group will then continue documenting Best Practices that can be used throughout the process all the way to archival.

(3) The next documents will help answer questions in much greater technical detail as ACES becomes the de-facto standard used by the industry.

Our subcommittee continues to provide support for the development of the benchmark version of ACES, which will be of great value to our industry.

In the past year, ACES advances include updated RRTs (Reference Rendering Transforms) and the introduction of ACESproxy—reduced-precision 10 and 12-bit integer forms of ACES encoding that are intended for transmission over HD-SDI interfaces. ACESproxy represents the full range of ACES data, but with less accuracy.

ACESproxy is meant for viewing and on-set grading, not for dailies, finishing or mastering. ACESproxy should not be recorded. As such, there is no file format specification. It is, however, a critical component in an ACES-enabled workflow as it allows creative intent to be carried through the post-production process from a camera's live "video-tap" output.

More information regarding ACES is available at http://www.oscars.org/science-technology/council/projects/aces.html.

Advanced Imaging Subcommittee

Chair: *Gary Demos*
Vice-Chair: *Jim Fancher*
Vice-Chair: *Phil Feiner*
Secretary: *David Reisner*

The ASC Technology Committee's Advanced Imaging Subcommittee continues to work informally on key issues. There has been continued discussion and exploration of CIE 170-1:2006 in light of interest in widening color gamuts. High Dynamic Range (HDR) has also become very central to industry interest and discussions, partly stemming from the availability of Ultra High Definition displays (UHDTV). Supporting the UHDTV committee has been a key focus of our efforts.

A key area of consideration has been an attempt to extend the notion of Peak Signal to Noise Ratio (PSNR) to HDR and widening gamut. PSNR is used in evaluating codecs, but is not suitable for extended range images. An alternative approach using standard deviation (sigma) within each one-stop range seems more suited to guiding and evaluating codec performance. A tool that spans the dynamic range of the incoming HDR image and evaluates each stop of range is currently being tested. The tool is currently set to span as many as 32-stops of range, therefore covering extreme dark and light values. The tool also presents the behavior of negative numbers, which are often present in HDR data (and which can be useful if handled properly).

The limitations of 16-bit half floats, as are commonly used in EXR files, are also being evaluated. The latest high-end cameras are producing images in conjunction with HDR noise reducers that challenge workflows that make extensive use of EXR half-float processing steps. As a simple solution, the Digital Pictures Exchange (DPX) 2.0 file format is now being used with an extension ".dpx32" in order to convey 32-bit floating point pixel values. This augments these capabilities within the Tagged Image File Format (TIFF) and OpenEXR, using the well-tested DPX file header and format as extended from the common 10-bit usage to 32-bits using existing DPX header fields.

There has also been active discussion of various nonlinear functions that are being considered as alternatives to gamma, log, quasi-log, and linear (linear being gamma 1.0). It has been noticed that the denormalized low values of the half-float mimic the linear behavior of some modified video gamma representations near black. The relationship of the float's logarithmic-like behavior (due to the exponent) to a pure logarithmic representation has also been noted. At present there is very active debate about the extension of integers beyond 16-bits vs. the use of 32-bit floating point (and 16-bit half-floats).

Signal paths from computers to UHDTV displays are also an active area of exploration, including use and interoperation of HDMI 1.4 and DisplayPort 1.2, including audio support. There is also active exploration of using 8-bit, 10-bit, and 12-bit RGB values, at HDTV and UHDTV resolutions, via these connections. Clearly, there is a need to move beyond 10-bits, and perhaps to 12-bits or beyond, for widening gamut and for HDR.

Professional Display Subcommittee

Chair: *Jim Fancher*

Most of our work this past year has been with the Advanced Imaging subcommittee in looking at new 4K and UHD-1 displays. We made some rough measurements of a prototype of the new quantum dots technology display and were favorably impressed with the colorimetry in this display. We were able to verify input pathways on a number of available displays at different input resolutions, bit depths and frame rates. Input connections vary by model with displays supporting HDMI 1.4, 2.0 or DisplayPort 1.2. Gary Demos provided our test setup, so we were able to send to either HDMI or

DisplayPort at various bit depths and frame rates. We did extensive testing with the Samsung 84 in. display and were able to confirm the 10-bit pathway and processing to the 8-bit display. Since most of the displays we examined were LED backlight LCDs the actual display drivers are 8-bit. Sony also provided a demonstration of their, at that time, prototype of the professional OLED display. We are still waiting for a return match with the shipping unit in order to perform spectral measurements.

UHDTV Subcommittee

Chair: *Don Eklund*

The ongoing objective of this subcommittee is to inform ASC members on consumer display and distribution technologies; either released or in development. The further goal is to preserve artistic intent by recommending best practices on current devices and delivery systems and by influencing development in new technologies.

In the past year, the marketing of displays branded as UHD, 4K, Ultra HDTV and more has become common. These devices are being sold at similar prices to the high-end HD models from the previous year. These displays may become a source of consumer confusion as new standards are piecemeal-proposed in a number of organizations to increase color gamut, dynamic range and frame rate under the "UHD" designation.

Many demonstrations have been hosted at industry events showing dramatic display capabilities independent of resolution and, given viewer reaction, show that consumers will respond positively if these experiences can be brought into their homes.

Those who have been participating in public and private organizations have expressed concern that there is a lack of consensus on the methods and priorities that are necessary to inform specification development. Objectives for UHD have been expressed by the broadcast industry, digital service providers, studios, CE manufactures and others, but there is a troubling lack of alignment in these objectives.

Item with cross industry agreement:

- 3840 x 2160 resolution

Items with significant disagreement:

- Method to describe expanded color gamut
- Backward compatibility for legacy displays
- Merit and targets for expanding dynamic range
- Suitable bit depth for new gamut and dynamic range
- Electro-optical transfer function (EOTF) for efficient coding of high dynamic range
- Frame rates—fractional or whole
- Mastering display solutions
- Economic costs versus benefits of new systems

Through discussions with technology providers, there is evidence that solutions are available now or in the near future that allow the adoption of key features that the mentioned industries wish to pursue. The solution that has not presented itself is the catalyst to compromise to avoid a proliferation of vertically integrated delivery systems designed to meet the immediate requirements of individual manufacturers or groups.

The UHDTV subcommittee is ready to actively participate in developing practices around UHD and, in the coming months, we hope to have a greater role through the many strong relationships that exist with key industries. We continue to have concerns that while signal and display capabilities can bring new and powerful experiences to consumers, the tools and discipline to use such capabilities need to be available and understood.

Input to the group is welcome, provided that it can be shared on a non-confidential basis. Contact asc-uhdtv@d-cinema.us.

Laser Projection Subcommittee

Vice-Chair: *Steve Schklair*
Vice-Chair: *Eric Rodli*
Vice-Chair: *Michael Karagosian*

Vision of the Subcommittee

The ASC Technology Committee would like to influence the motion picture industry to take advantage of technologies that lead to brighter 3D pictures and, in general, technologies that lead to higher contrast and larger color spaces than found in cinemas today. Laser-illumination promises to achieve these goals. With this understanding, the subcommittee was formed to study and promote laser-illumination technology.

General Subcommittee Goals

The first goal of the subcommittee has been to provide education within the ASC in the area of laser illumination for the display of motion pictures. The focus of the group has been image quality, both 2D and 3D, and the benefits and impacts of this technology at the production and post-production level.

A few topics have occupied the group this past year:

- The potential for the perception and impact of metamerism over a broad population, and
- The possible benefit of applying a special color matching function (CMF) to laser-illuminated projectors to address differences from xenon P3.

Metamerism is an artifact of narrow-band primaries in the human perception of color. Its impact is non-uniform, e.g., the color response of one observer is not necessarily repeated in other observers. Notably, manufacturers take steps that may mitigate metamerism through means designed to improve other aspects of laser-illumination, such as the use of more than three primaries and solutions that mitigate speckle. Narrow and different primaries could also dictate the need for a different color matching function in laser illuminators from that used with xenon-illuminated projectors.

To explore these topics, the group observed several demonstrations of laser-illuminated projectors side-by-side with xenon-illuminated projectors. Laser-illuminated projectors are still in laboratories and not readily available for viewing, so the demonstrations provided the sole means to familiarize subcommittee members with the technology. Due to the nature of the demonstrations, the group did not have the benefit of viewing similar content in each one, nor content designed to expose metameric-induced problems. Some small differences in color match between laser and xenon were observed, much of which could be attributed to alignment. But in at least one demonstration, multiple perceptions of color occurred, where some observers experienced more cyan in the laser-illuminated images than in the xenon-illuminated images, while some experienced more magenta, indicating metameric mismatch. Following the demonstrations, the consensus of the group was that the metameric impact on image quality was small, and that the group should focus on other areas of image quality at this time. However, this does not rule out future studies of metamerism with laser illumination.

Laser-illumination technology is making its way into the marketplace. Three strategies for laser illumination are now being pursued either in the marketplace or in R&D laboratories:

- Cost-effective replacement of xenon projectors based on total cost of ownership,
- High-luminance 3D projection, and
- Higher dynamic range projection.

The ASC has set its target for 14 ft-L 3D, the feasibility of which is now greater with the emergence of laser illumination. Given the high cost of laser-illumination for high-luminance 3D, the ASC strongly encourages that such investments be made with the goal of achieving 14 ft-L 3D.

Regulatory approval of laser-illuminated projection in venues open to the public is still years away, although five-year waivers are possible for new installations. The Laser Illuminated Projector Association (LIPA) reports that certain progress has been made at the standards level, as evidenced by the newly-approved IEC 60825-1 Edition 3 specification. The revised specification carves out the ability for laser-illuminated projectors to evaluate risk assessment using the less restrictive rules under IEC 62471. This is an important step in the long journey toward changing government regulations around the world, regarding use of laser illumination in public places. With a revised IEC specification to point to, it is hoped that eventually government agencies will relax their rules.

Future Work

More discussion is needed regarding a special CMF for laser-illuminated projectors, and how it would be studied.

Speckle is observed as random variations in light intensity, caused by the interference of many waves of light of the same frequency at the surface of a projection screen. LIPA is working on a repeatable process for measuring speckle, and the subcommittee has offered to assist LIPA in its subjective assessment of speckle.

Much concern has been expressed for maintaining the uniqueness of the cinema experience. With this in mind, the subcommittee has discussed focusing future efforts in the determination of targets for dynamic range and contrast ratios. Color space is also a subject in future cinema. The subcommittee is leaning towards recommending the ITU-R BT.2020 (Rec. 2020) color space to laser original equipment manufacturers (OEMs), pending further discussion.

Over the coming year, the subcommittee expects to gain access to challenging new test materials, as well as improved access to laser-illuminated projectors, providing more opportunity to further study this new technology.

Digital Archive Subcommittee

Chair: *Garrett Smith*

The roots of the ASC stem from "The Static Club" that was formed approximately 101 years ago—when cinematographers from both coasts pooled their thoughts and experiences to solve the problems static electricity caused when using hand cranked cameras. (The American Society of Cinematographers was officially formed in 1919.) The ASC Technology Committee in 2014 is in many ways the 21st century "reboot" that connects to the roots of the ASC. As the variety of reports presented here show, we face many different kinds of "static" today.

The primary focus of the Digital Archive subcommittee is to explore the best solution for archiving movies in the digital age and to share that information with cinematographers.

I don't believe that in 1899, when Kodak started manufacturing nitrate-based film, anyone in the industry realized that nitrate film would begin to disintegrate (sometimes in flames) just a few decades later. Our industry was young and as we learned about the problems, the industry changed and evolved. Celluloid base solved many of the nitrate problems and as a byproduct it turned out to be a pretty good archival medium. If stored correctly, celluloid film could last 100 years or more, even with "benign neglect." By the end of the celluloid/polyester age, we learned that temperature and humidity control could greatly slow the chemical degradation of the film—most of the films from the past 50 years will be here a century from now.

Will our films from the first decade of the digital age be here in 100 years? How many will become "Digital Nitrate"? (We already know of a few films from the past 15 years, where the digital files are no longer accessible—but at least we have film copies from those files.) 2014 marks the first year in our history when the majority of films made will no longer have film copies available. (At the time of writing, FotoKem is the last remaining Film Laboratory in Los Angeles—Deluxe and Technicolor have closed their film developing labs and the transition from film to digital is entering a new phase where a few films are photographed on film negative; only a handful are finished on film and essentially none are released on film.)

We know that the new "constant" for technology in the digital age is change. Today, our tools and methods change and evolve at an ever increasing rate. In this rapidly evolving environment, the challenge

for filmmakers is also "What" do we archive—not just the "How." The ASC CDL (a major effort of the ASC Technology Committee) recently received a Technical Achievement Award from the Academy.

"The What" in relationship to archival, is being addressed by the industry through the development of ACES. Its focus on defining a "digital finished negative" that is clearly defined and holds additional information for future display technologies is paramount. Through the Academy, the industry has been working together for nearly a decade and several SMPTE standards have been written. This is great progress on the path to proper digital archiving, because we will know what the filmmaker's intent was at the time of their first digital release. (For reference, as electronic distribution grew over the past 50 years, motion pictures shot on film could be re-mastered and recorded on the current state-of-the-art platform: 2", 1", D1, HD, 2K, 4K or even 8K.)

ACES is an important step in creating the ability to have digitally finished negatives that can be created today and re-addressed when preparing for our future that may include UHD, HDR, Rec. 2020 and whatever else the future brings.

"The How" is another matter. We have all heard how digital "democratizes" and disrupts industries. In that process, our industry joins others with shared concerns over preserving data—Medical, Oil Exploration, Government Archive and the Intelligence (NSA/ Google/ etc.) communities to name a few.

We now face a much bigger problem than "static electricity." Some general statements coming from the above-mentioned groups include the following: "There has never, ever, been a successful archive media/medium that has not been visual, or where the method to retrieve the information is complex" and "Prior to the dawn of the computer age, this has never been an issue, because mankind never chose to save precious information in any way other than could be 'eye legible'."

The storage solution debate continues between various physical media (LTO vs. HD (hard disk) vs. solid-state drive (SSD)) and various configuration options (storage area network (SAN) vs. Cloud). We anticipate that this debate will continue for the foreseeable future and clearly falls into the category of "more than one thing can be true at the same time." For instance, some people believe that media migration is the answer to digital archiving, yet, Anne Siebert from the National Archive is quoted as saying: "How would libraries have been able to survive if they had to make copies of all of their books every five years?"

Earlier this year, the ASC Technology Committee got a very interesting look at a technology that was created near the end of the celluloid/polyester age: Digital Optical Tape Storage (DOTS). It has been "rebooted" for the digital age and ASC Associate Member Rob Hummel, CEO of Group 47, walked us through how they are reworking DOTS Bit Plane Images to store images without the burden of file format.

Clearly, it looks to be an interesting year ahead—even if it is as clear as mud!

Digital Preservation Subcommittee

Chair: *Grover Crisp*
Vice-Chair: *Michael Friend*

The ASC Technology Committee's Digital Preservation subcommittee continues to monitor developments in the field of archives, libraries, and asset management. Study and standardization are being pursued by committees of the AMPAS Science & Technology Council, SMPTE and various European agencies, the public archives sector (led by the Library of Congress) and internally at studios, service providers and manufacturers. The following notes are a synthetic overview of the asset management field for motion pictures, drawn from a wide variety of these resources.

The archive, whether capturing the digital source master of a new production or extracting images from the legacy film or video, is now a data-centric process. The impending collapse of film infrastructure (and the video infrastructure based on physical media) is fulfilling the prediction of the media-less archive. The go-forward archive for all assets is now almost completely digital. As a correlate, the archive is in a state of transition. An LTO-based (.dpx/.wav) model of DSM retention has emerged as a rough, de facto standard (with many variations) in the past decade. Many archives have reached a plateau in practice, which assigns archival data to LTOs and a regime of migration. But relative stability of the LTO system—physical and less fully featured with respect to wrapping and metadata—will be impacted by contemporary trends.

Data archives continue to grow through the capture of scans, remastering, and restoration of legacy formats—a process that will continue into the indefinite future.

As industry practices continue toward data-centrism, emergence of new file types (.exr) and workflows (ACES, IMF, etc.) an enhanced degree of documentation is required to optimize future use of material and to more effectively manage the archive. The public and private archival community is anticipating a push from the Academy to get industry-wide acceptance of ACES, which will have widespread ramifications for asset management regimes in archives and libraries.

Experience with 4K imagery has led to a greater interest in "future-proofing" assets by capturing raw camera files, which may contain more deployable data than the finished DSM, allowing the creation of a higher resolution version in the future to meet enhanced display requirements, or the creation of higher quality masters capable of better performance when combined with compression, encryption, and transcoding on the way to the viewer's screen.

The industry's exploration of new dimensions of the basic archival resource (higher resolution, dynamic range and frame rates—in addition to 3D and other forms of high-value data) is rapidly materializing as a challenge to the transitional archive, based on the LTO system.

Metadata development continues to be crucial to the evolution of a new asset management environment, and becomes even more critical as production workflows evolve and new data forms are created and archived.

The implementation of IMF systems for distribution, which supports massive de-duplication of distribution elements, also offers significant values for a more efficient, de-duplicated archive.

If we set aside issues of economics, there are three major problem sets for asset management in the near term.

While we will still conserve high-quality film elements—original negatives, YCM separations, for example—in our legacy archive and continue to make film elements, we will soon face the challenge of making preservation duplicates of legacy film productions without the original medium. Contemporary scanning allows us to normatively extract 4K resolution and 16 bits of dynamic range from a legacy film, with a corresponding workflow for getting those images to a viewer. But we do not know the ultimate data content of film resources—we have no metric that tells us we have extracted all of the significant data from a negative. We need to develop our extraction methods to the point where we have captured all of the data in a legacy element. This will mean larger data loads as well as the deployment of implements to assure authenticity and integrity of the original image.

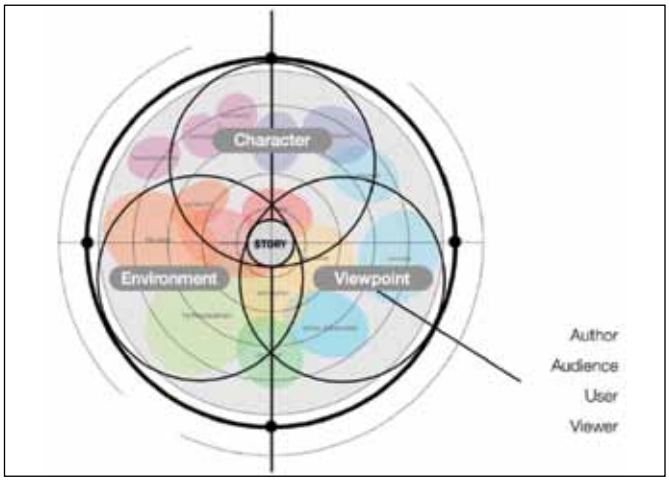
As production evolves, asset management needs to reconsider the map of deliverables that it acquires and archives from each production. This almost certainly includes the archiving of some camera files, and a more clarified notion of triage. With the loss of film as the "future-proof" core of the archive, a new list of standard deliverables is called for, and a reconsideration of the production archive is also necessary in order to derive best practices based on acceptable technical principles.

There is a need to re-conceptualize the archive and its functions, starting with the realization that permanence is a process, not a medium, and that migration of data is an essential feature of preservation for the foreseeable future. The data part of this new archive will be cloud-based. As an amalgam of platform-dependent legacies and media-less codecs, the new, hybrid archive presents many challenges that can only be addressed in a true digital asset management system. The new archive will need to track and control legacy film and video elements, deep storage resources (on LTOs or servers), duplication tasks and in-process data, and link these resources with legal, filmographic, and financial databases. Some archival functions (geographical separation, inspection, and verification, migration, preservation duplication) will be automated, while others (visual QC, restoration, reformatting and transcoding) will continue to require supervision. This will require the development of a single interface that supports constant monitoring, automated processing and direct control of technical operations on the data archive.

Joint Technology Subcommittee on Virtual Production

Chair: *David Morin*
Vice-Chair: *John Scheele*

As more movies are made using virtual production, the Joint Subcommittee on Virtual Production of the ASC (or Virtual Production Committee—VPC for short) ramped up its activities. The VPC continued its series of standalone case studies, but also broadened its proceedings to include more filmmakers.



Virtual production is a story-centric collaborative and interactive digital filmmaking process, which begins with virtual design and digital asset development and continues in an iterative, nonlinear process throughout production. (Second Mandala created by Alex McDowell/5D Institute.)

Alfonso Cuaron's "Gravity"

Within the period since the last SMPTE report, it is worth noting the critical and popular success of Alfonso Cuaron's *Gravity*, which won seven Academy Awards and generated $675M at the worldwide box office. The movie was a spectacular demonstration of the new imagery that can be brought to audiences using virtual production.

Winner of seven Academy Awards, the making of Alfonso Cuaron's "Gravity" demonstrated innovative use of virtual production techniques by Framestore. (Image copyright Warner Brothers Studio.)

The Virtual Production Committee held its *Gravity* case study on 3 October 2013 at Warner Brothers Studios, a few weeks before the movie was released, in the production screening room where the movie was made. Hosted by Chris DeFaria, president, digital production at Warner Bros., committee members were treated to a preview of the movie in perfectly calibrated 3D, followed by commentary and Q&A with some of the filmmakers. We learned about the many novel uses of technology employed by Framestore to produce the movie, such as digital prelight (a novel form of previsualization) and the corresponding on-set display of previs through the "light cube," a technique similar to Paul Debevec's light stage, repurposed to achieve digital lighting of actors and the replacement of green screen with a display of digital assets. As is always the case with meetings of the committee, a detailed report on this case study is available.

Separately, the Virtual Production Committee organized two more events: "An Afternoon of Virtual Production" in conjunction with the Visual Effects Society, and the "Virtual Production Track" at FMX 2014 in Stuttgart, Germany.

A series of five case studies on Virtual Production were presented on 15 March 2014 at the Ray Harryhausen Theater.

An Afternoon of Virtual Production

This half-day series of case study on Virtual Production took place on Saturday 15 March 2014 at the Sony Pictures ImageWorks Ray Harryhausen Theater in Culver City, CA. The following case studies were presented:

- Use of Virtual Camera on *White House Down*
  by Marc Weigert, Uncharted Territories
- New Developments in Virtual Production Technology
  by Mike Romey, Zoic Studios
- Virtual Production on *World War Z*
  by Dan Gregoire, Halon Entertainment
- Virtual Production on *Guerra dos Sexos*, *Pair of Kings*, and *Miss XV*
  by Eliot Mack, Lightcraft Technology
- New Solutions in on-location Virtual Production
  by Bruno Sargeant and Brett Inneson, Animatrik Film Design
- Virtual Production in the television series "Cosmos"
  Isaac Partouche, SolidTrack and Joe Lewis, Encodacam

A series of 14 case studies on Virtual Production were presented on 22-23 April 2014, at FMX 2014 in Stuttgart, Germany.

The Virtual Production Track at FMX 2014

This two-day series of 14 case studies on Virtual Production took place on 22-23 April 2014, at the FMX 2014 conference in Stuttgart, Germany. The Virtual Production track was co-curated by a team led by VPC chair David Morin, and included the following presentations:

- Previs and Animation in *Gravity*
  Max Solomon, Framestore
- *World War Z*–Previs through Postvis
  Daniel Gregoire, Halon Entertainment
- "Cosmos"–Exploring the virtual cosmos
  Pepe Valencia, Baraboom! Studios; Daniel Gregoire, Halon Entertainment; Isaac Partouche, SolidTrack; Joe Lewis, Encodacam
- *Captain America: The Winter Soldier*–from Previs to the Final Image
  Russell Earl, Industrial Light and Magic; Ron Frankel, Proof Inc.
- *Battlefield 4*–Cinematics with Frostbite
  Frank Vitz, DICE / Electronic Arts
- "Ryse Son of Rome"–Emotional Cinematics in a Realtime Environment
  Cevat Yerli, Crytek
- *White House Down*–Virtual Production
  Volker Engel, Uncharted Territory; Andrea Block and Christian Haas, LUXX Studios
- *300: Rise of an Empire*–Visualizing an Empire
  Chris DeFaria, Warner Brothers; Patrick Smith and Duncan Burbidge, The Third Floor; Thomas Zauner, Scanline VFX; and Don Parker, Shotgun Software
- Toward the next *Avatar*
  Jon Landau, Lightstorm Entertainment
- *Dawn of the Planet of the Apes*–Early look
  Andy Serkis, Actor & Second Unit Director
- *Gravity*–The Making of
  Tim Webber, Framestore; introduced by Chris DeFaria,Warner Brothers
- Application of Robotic Technology to the World of FilmMaking
  Tobias Kinnebrew, Bot & Dolly
- *Gravity*–Lighting R&D
  Paul Debevec, USC Institute for Creative Technologies

The Virtual Production Committee will continue to pursue its goal of educating and helping to define the new workflow, and is currently planning its meeting #9, along with other ancillary events, and the Virtual Production track at FMX 2015.

There is an ongoing Definition Workgroup. Publications Workgroup, History Workgroup and others may be created, when there is demand. Participation is encouraged. Those interested may contact:

David Morin, Chair, davidmorin@davidmorin.com

John Scheele, Vice-Chair, johnscheele@gmail.com

Inquiries regarding the ASC Technology Committee should be sent to Holly Lowzik: holly@theasc.com.

The Authors

Curtis Clark, ASC, studied theater at the Art Institute of Chicago's Goodman School of Drama and cinematography at the London Film School. He began his career by shooting numerous documentary films in Britain before transitioning to shooting feature films. Following on the success of his short film, *The Arrival*, Clark recently completed his highly praised short film *Eldorado*.

A member of the ASC Board of Governors, Clark is chairman of the ASC Technology Committee. Since its inception in 2003, the Committee under Clark's leadership has achieved a series of notable successes including its collaborative work with Digital Cinema Initiatives, LLC (DCI) to produce standardized evaluation material for assessing the performance of digital projectors and other elements of DCI standards-based digital cinema systems, as well as the 2009 Camera Assessment Series and 2012 Image Control Assessment Series.

The ASC Technology Committee, at Clark's instigation, embarked on the development of a groundbreaking project to create cross-platform data exchange for primary RGB digital color correction known as the ASC CDL. The ASC CDL was recognized by the Academy of Television Arts and Sciences with a prestigious 2012 Primetime Emmy Engineering Award. Clark also received an AMPAS Technical Achievement Award recognizing his work developing the ASC CDL. Clark was recipient of the prestigious ASC Presidents Award.

David Reisner received a 2014 Academy Technical Achievement Award and was recognized in a 2012 Primetime Emmy Engineering Award for co-development of the ASC CDL, used in the workflow of 90% of motion pictures, 70% of scripted TV, and 99% of visual effects turn over.

He was lead designer of the ASC-DCI StEM Standard Evaluation Material used to determine the quality required for the deployment of digital cinema, and vice chaired the SMPTE working groups responsible for the digital cinema imaging and security standards. 85% of theater screens worldwide now use digital cinema. Reisner had leading roles in activities, including production of the ASC-PGA CAS Camera Assessment Series and elements of the Academy Color Encoding System.

Reisner's "firsts" include portable computers; handheld video jukebox; and other computer and consumer electronics. He has produced concerts and trained killer whales.

Reisner is well published in books, technical articles, and has spoken widely. He is a member of SMPTE; the founding Secretary of the ASC Technology Committee and an ASC Associate; and a Member of the Visual Effects Society.

Lou Levinson is a long-time associate member of the ASC, and Chair of the Digital Finishing Subcommittee. A member of the ASC Technology Committee since its inception, he has been a frontline colorist from the "on the fly" analog era to today's advanced ACES and beyond digital pipelines, having worked with notables such as Woody Allen and Rob Zombie to name a few.

Al Barton has spent 29 years as a technologist in production, post-production, and manufacturing for television and feature films. Most recently he worked in production/post-production and distribution of feature films for Sony Pictures. Barton has participated in the International Organization for Standardization (ISO), the International Telecommunications Union (ITU), and Inter-Society Digital Cinema Forum (ISDCF) committees. He chairs the Workflow Subcommittee of the ASC Technology Committee. Barton also participates in the AMPAS ACES committees. He was a key member of DCI and helped create the digital cinema specification.

Greg Ciaccio is managing director of location services at Modern Videofilm, where he is focused primarily on finding new location-based technology and workflow solutions for their Motion Picture and Television clients. Previously, Ciaccio served in technical management roles for the respective Creative Services divisions for both Deluxe and Technicolor. Key developments include the first DP Lights deployments for Technicolor and full near-set dailies solutions for Deluxe Television.

Ciaccio is a member of SMPTE, ASC Technology Committee, AMPAS Sci-Tech Council, HPA, and DCS. He holds a BA degree in radio-television-film from California State University, Northridge.

Gary Demos has been a pioneer in the development of computer-generated images for use in motion pictures, and in digital film scanning and recording. He founded Digital Productions (1982-1986), and was awarded an AMPAS Scientific and Engineering Award in 1984 along with John Whitney Jr. "For the Practical Simulation of Motion Picture Photograph By Means of Computer-Generated Images." Demos also founded Whitney-Demos Productions (1986-1988), DemoGraFX (1988-2003), and Image Essence LLC (in 2005).

Demos is the recipient of the AMPAS 2005 Gordon E. Sawyer Oscar for lifetime technical achievement. Since 1990, he has been exploring layered compression coding and is active in preparing for future imaging and image processing technology. He is the chair of the ASC Technology Committee Advance Imaging Subcommittee and is involved in the AMPAS ACES project. Demos has presented numerous papers at SMPTE, and is a SMPTE Fellow.

Jim Fancher has consulted on next generation technology in digital asset management for Deluxe Digital Media in Burbank, CA. As chief technology officer for Technicolor Creative Services, the post-production arm of Technicolor, he was involved in the development of color management systems, image processing, and media asset management. Prior to his engagement at Technicolor, he was chief science officer for Pacific Ocean Post. Fancher has a Bachelor's degree in chemistry from Princeton University. He holds numerous patents and has been a member of SMPTE since 1974.

Don Eklund is vice president of business development at Verance Corp. in San Diego. He previously held an executive position with Sony Pictures where he helped execute the launch of DVD, UMD and Blu-ray.

Michael Karagosian is president of MKPE Consulting LLC, specializing in business development, strategy, and intellectual property for emerging technologies in cinema. His many accomplishments include the negotiation of virtual print fee subsidies for South America, Philippines, and Ireland. He consulted to the National Association of Theatre Owners for 11 years, leading exhibition input during the development of the DCI specification. He co-founded the CinemAcoustics division of Peavey Electronics in the 1990s, and led the development of cinema and studio products at Dolby in the late 1970s and early 1980s. Karagosian is a SMPTE Fellow and has chaired numerous SMPTE committees.

Garrett J. Smith is currently senior creative liaison at Entertainment Technology Consultants. He previously served as vice president, production technology and Digital Mastering Operations at Paramount Pictures. During his 24-year tenure at Paramount, Smith participated in the development of DVD, HDTV and DCI. Prior to Paramount Pictures, he worked in various post-production positions, including post-production supervisor for "Ripley's Believe it or Not," director, post-production for Columbia Pictures Television and manager, film services at CBS Television Network. Smith is a member of AMPAS and serves on the AMPAS Science and Technology Council. He is also an associate member of the ASC and an adjunct associate professor at the USC School of Cinematic Arts.

Photo Not Available

Michael Friend is the director of the digital archive in Sony Pictures Entertainment's Asset Management group and teaches at UCLA in the Moving Image Archives Studies Program.

David Morin is senior director, industry relations and business development at Autodesk Media & Entertainment. He chairs the Autodesk Film CTO Advisory Council, a product focus group composed of the 12 largest digital studios in the motion picture business. Morin is also chair of the Joint Technology Sub-Committee on Virtual Production, a sub-committee of six Hollywood-based guilds and societies, exploring the impact of virtual production on the motion picture production workflow.