American Society of Cinematographers (ASC) Technology Committee

By Curtis Clark, ASC; David Reisner; David Stump, ASC; Lou Levinson; Glenn Kennel; Grover Crisp; Gary Demos; Marty Ollstein

Introduction

Chair: Curtis Clark, ASC
Steering Committee Chair: Daryn Okada, ASC
Vice-Chair: Steven Poster, ASC
Vice-Chair: Richard Edlund, ASC
Secretary: David Reisner, dreisner@d-cinema.us

Through most of cinema's history, the American Society of Cinematographers has been the primary place where the art, science, and technology of making movies meet. The ASC has always worked with the industry to advance the theoretical and practical state-of-the-art and to share that knowledge widely, including publications like the *American Cinematographer Manual* and *American Cinematographer* magazine.

Founded in 2003, the ASC Technology Committee continues that historic commitment and extends it to encompass the revolutionary changes being brought about by the introduction of digital technology in pre-production, principle photography, post, and distribution and exhibition.

The ASC Technology Committee brings together some of the industry's best cinematographers, manufacturers, service providers, and studios, as well as art directors, editors, and producers to help identify, understand, and find ways to address moviemakers' needs in the art and business of creating movies, television shows, and commercials. The ASC Technology Committee is working closely with the Art Directors Guild, the Producers Guild of America, the Technology Committee of the American Cinema Editors, the Academy of Motion Picture Arts and Sciences Science and Technology Council, the Fraunhoffer Institute for Integrated Circuits, and many other important industry participants to develop how motion pictures are created in the new hybrid imaging environment.

When the industry was developing technical and quality requirements for digital cinema, the ASC partnered with the studios via the seven studio consortium DCI (Digital Cinema Initiatives) and, working closely with DCI's Walt Ordway and Howard Lukk, created the ASC-DCI StEM (Standard Evaluation Material) test footage. The ASC-DCI StEM is a short movie, shot and posted at the highest level of feature motion picture production, in a carefully monitored and carefully documented process. ASC-DCI StEM provides a known, available standard reference to use in evaluating projector and compression performance. Available in 4K, 2K, RGB, X'Y'Z' and other formats, it is widely used in the development and testing of post-production, display, distribution, and exhibition systems. StEM and the ASC's participation and input were instrumental in DCI's selection of image-quality parameters for digital cinema. (See www.dcimovies.com for information on getting copies of the ASC-DCI StEM.)

The film and digital hybrid imaging workflow combined with the many output formats—feature releases on film and digital, high and standard definition DVD, television in numerous forms, etc.—has presented new challenges to the industry. The ASC Technology Committee Workflow subcommittee is developing "best practice" recommendations to maintain artistic intent throughout the production process and help produce those deliverables more effectively and efficiently.

The Digital Intermediate (DI) subcommittee, whose members include representatives from many DI post facility and equipment vendors, has developed a proposal for an interchangeable Color Decision List—the ASC CDL. The ASC CDL has been implemented in many systems and allows basic, primary color corrections to be exchanged between different facilities running different platforms.

The Camera and Workflow subcommittees will soon be shooting the first round of the Camera Assessment Series (CAS). CAS will provide a regularly updated library of standard footage showing each new digital camera's best performance on a repeatable series of feature motion picture typical shots. Combined with a

parallel measurement-oriented series being conducted by the Academy of Motion Picture Arts and Sciences Science and Technology Council, CAS will provide cinematographers with a rich set of resources to understand and select cameras for their projects.

At NAB 2005, the Metadata subcommittee hosted a widely attended metadata summit. One key result was broad industry endorsement of The Golden Rule of Metadata: Add to, but do not delete metadata. The Metadata subcommittee is working on a survey of the current status of metadata in popular industry systems and how it is handled and organized in major production environments. Goals include identification of a key, small, core set of metadata and getting broad industry implementation of the Golden Rule.

The currently most active subcommittees summarize their work below.

Camera Subcommittee

Chair: Dave Stump, ASC

Vice-Chair: Richard Edlund, ASC

The ASC is in preproduction on a program called the ASC Camera Assessment Series (CAS)—a repeatable series of shots typical of those common in feature motion pictures, to show the characteristics and performance of the various digital cameras available for use in cinema. We have extended invitations to numerous manufacturers and/or rental companies to participate in the tests, and every attempt will be made to conduct the CAS in a fair, unbiased, and impartial way.

The ASC Camera Assessment Series will create a library of standard material from different cameras (including 35mm film stocks) that are available for use in large-screen cinema. Every attempt will be made to obtain the maximum performance out of each camera system—to give each camera its best opportunity to perform at the highest level possible—in order to determine each system's effectiveness for digital presentation and for output to film. Our aim is to give members of the community of cinematographers a resource to use in evaluating cameras for their task at hand and to generate an evolving data set for the benefit of cinematographers and other members of the motion picture production industry trying to decide which of the many camera systems available to use on any particular project.

The CAS is being designed to be consistently repeatable as new cameras become available. After the first round of shooting, we will create a cut-by-cut formula for a roughly six-minute digital "movie" to present the results from each camera. Each movie will present a consistent set of shots such as one might encounter in making a movie, TV show, or commercial. The shoot will be conducted on sets on Wisteria Lane from the popular TV series "Desperate Housewives," thanks to the generosity of the show's staff, including Art Director Thomas Walsh, ADG, and Co-Executive Producer George Perkins. Shots will also be done at night locations around Los Angeles.

The CAS shoot and post will be conducted in the presence of ASC cinematographers and with the active participation of the manufacturers and rental houses who know the cameras best. The shoot will be meticulously documented in writing, including all camera settings, menus, light readings, etc., and will include any and all technical notes and documentation of the procedures used in creating each movie as a metadata addendum. The shoot will be conducted with equivalent focal length lenses for each format of camera (actual lens length will depend on the camera's imager size). The CAS materials will be refreshed on an ongoing basis, roughly twice a year, in accordance with the development and evolution of the cameras and hardware available for testing.

The CAS is not a "shootout" between camera systems, and all precautions will be taken to ensure that it will not be presented as such. Rather, it is a method to enable ASC cinematographers and others to view the best performance of each camera in a variety of situations. In parallel, the Academy of Motion Picture Arts and Sciences—Science and Technology Council will take a set of scene-driven measurements of each camera to characterize behavior in numerically quantifiable ways. Combined, the ASC and Academy portions of the Camera Assessment Series will provide moviemakers with an opportunity to look deeply at each camera and evaluate appropriate selection for a particular project.

The CAS results will be archived for use by members of the American Society of Cinematographers and the membership of the Academy of Motion Picture Arts and Sciences. It will be viewed and treated with the respect demanded by those institutions.

Digital Intermediate Subcommittee

Chair: Lou Levinson
Vice-Chair: Joshua Pines

A report on the activities of the Digital Intermediate subcommittee of the ASC Technology Committee to our friends at SMPTE:

For a year now, the DI subcommittee has been focusing on what we call the ASC CDL—Color Decision List—project. The goal of this is to create a means of exchanging color correction information between the various available color correction platforms in a way that makes the CDL platform-independent. Currently, rudimentary edit decisions lists can be exchanged, but even these simple bits of metadata have problems being moved around. Our goal is to move a simple yet powerful set of color correction instructions freely between platforms. Realizing that the smaller our processing set was, the larger our chance of success, we created a set of three processes, each with separate R, G, and B operators that limits us to having to exchange nine numbers at most. In order to avoid any religious wars over what Lift, Gamma, and Gain are, we created our own processes called Slope, Power, and Offset, which we defined mathematically. While this may at first glance appear to be very rudimentary, we believe that one can attain up to 80% or more of final color, and given the appropriate environs, such niceties as printer point emulation can be implemented as well.

We have had all of the major color correction vendors participating, including many of the new software-based products.

We have achieved a general consensus on the mathematical definitions of our operators. We have done tests with non-picture data sets to allow the individual vendors to prove they are doing the basic math correctly, and at this point, most if not all vendors are getting the right answers.

At this year's NAB, we did a "guerilla" test in which we captured some still frames with a Viper FilmStream camera, created some color corrections with the ASC CDL, and passed the source pictures, the CDL instructions, and the final pictures around to various volunteer vendors to see how real-world images were affected. (Many thanks to our friends at Thomson for supporting this.) We have had several vendors pass this hurdle successfully and are sure more will, as we get more results back.

We now face the hard part: getting a consensus on how to move the CDL between platforms. This may happen by putting it in with the edit decision lists, which already move back and forth. It may be by creating XML packages, which can be exchanged. It may be we put the nine numbers in the headers of the frames to be processed themselves. Or some combination of the above. We look forward to helping (herding??) the vendors come to some agreement and have a real, cross-platform tool to help cinematographers and others wrestle with the color management issues that confront us all.

For any SMPTE members who are curious about what we've done, or may want to participate in some way, please contact Joshua Pines at jzp@asctech.org or Lou Levinson at JoeBeats@postlogic.com.

Digital Display Subcommittee

Chair: Glenn Kennel, glkennel@sbcglobal.net
Co-chair: Steven Poster, ASC
Co-chair: Jerry Pierce

As projection and compression-oriented test footage, much of the coordination and planning for the ASC-DCI StEM was conducted under the umbrella of the Digital Display subcommittee, during Jerry Pierce's term as chairman. More recently, the focus of the Digital Display subcommittee has been on investigating the requirements for digital dailies and the supporting workflow. We started by looking at current practices in the industry. Last year, Ascent Media/Company 3 hosted a tour of their facilities in Santa Monica, and we have extended requests to other service providers who offer digital dailies.

Currently, we are engaged with the Workflow subcommittee in defining the requirements for digital dailies and color calibration in support of workflow best-practice recommendations and the Camera Assessment Series. This includes a look at the calibration methods and viewing conditions for reviewing dailies, plus methods (including the Color Decision List) for communicating artistic intent between the cinematographer on set and downstream activities.

Experience has shown that video dailies viewed on a small monitor are not effective. However, there are some recent production examples in which HD dailies presented on a calibrated digital projector can be much

more effective, even with a 2000-lumen 720p "home theater" projector on a 10-ft wide-screen.

However, there are many other displays used in post-production where projectors and dark viewing conditions are impractical. While not all of the functions are color critical, creative decisions like editing are influenced by the contrast and color of the pictures. The ubiquitous CRT reference monitor is about to be phased out, but what will replace it? Although today's digital picture monitors all have limitations, there are some promising improvements on the horizon. It is important that manufacturers of these future digital reference monitors understand the requirements for stability, performance, and calibration, as well as the utility of emulating various outputs through selectable look-up tables.

Workflow Subcommittee

Co-chair: Al Barton
Co-chair: Gary Morse
Co-chair: Howard Lukk

The Workflow subcommittee is the point where the work of the other subcommittees meets. The Workflow subcommittee is working on best practice recommendations for the hybrid imaging workflow. Recognizing that different facilities will have different capabilities, needs, and preferences, we are crafting recommendations that can be usefully applied in many situations. For new and improved open-architecture workflow solutions to be successfully deployed, they must be embraced by multiple industry players (filmmakers, studios, and service providers) and what is becoming an increasingly diverse group of technology suppliers. The ASC, through its Technology Committee, is providing a critically needed forum, bringing manufacturers and service providers to the table and asking them to support new initiatives to create effective, efficient open-architecture workflow solutions. The Workflow subcommittee is working to thoroughly analyze current hybrid film-digital imaging workflow practices while looking at ways to optimize the workflow, with a view to recommending open-architecture solutions.

One of the key topics facing post facilities and cinematographers, from on-set and in dailies through post, is display environment and color gamut. Much of today's mastering and dailies viewing is done on displays that are not capable of displaying either the full digital cinema reference projector or film color spaces. While we are used to the situation for film and have developed practices and skills to address adequately, digital cinema adds significant additional variation.

There are viewing environment and workflow needs for monitoring on-set, in dailies, during post and mastering, and to support teams that may already be working on the next projects in other countries. Effective handling is critical for Look Management—the communication and maintenance of creative intent. Some of these issues are addressed in a relatively new area of study—Image Appearance Modeling.

Mastering for output to multiple formats—cinema release on film and digital, standard, and high-definition DVD and broadcast, specialty markets including airplane and hotel, trailers, advertising, etc.—puts new demands on project data management, image manipulation, and workflow. Consistent data formats, color spaces, and communications between all project members from preproduction through mastering gives new opportunities for savings across an entire show.

Digital Preservation Subcommittee

Co-chair: Grover Crisp
Co-chair: Garrett Smith

At a point early on in the meetings of the ASC's Technology Committee, it was decided that a subcommittee be created to look into issues related to preservation of motion pictures that are created digitally. The initial impetus for this discussion involved the Digital Intermediate workflow processes, which have become predominant in the production and post-production environment.

The subcommittee, co-chaired by Grover Crisp of Sony Pictures Entertainment and Garrett Smith of Paramount Pictures, decided that new ways of addressing preservation out of the Digital Intermediate workflow needed to be researched and tested. Some of the key initial goals of the subcommittee include ensuring that the archived digital files of the Digital Intermediate are capturing all the data required to replicate the process again (should it be necessary), and identifying what means—whether digital, photo-chemical, or even a combination of both—are best for preserving and retrieving that data.

Although there are many Digital Intermediate facilities in the industry right now, only a few were actually trying to deal with the issues of preservation of the DI process

when the subcommittee began. The subcommittee actively sought testing and potential resolutions from a few companies, including both traditional film laboratories and Digital Intermediate facilities. Pacific Title and Technicolor put forth plans, differing in approach but pointed toward the same result. Sample materials and data from several studios were supplied for testing.

This first project, which was the creation of digitally generated Black-and-White Color Separation Masters, or Digital Separations, using data derived from the DI, was completed at Pacific Title. Results were presented to the ASC Technology Committee, ASC members, industry executives, and others. The concept of Digital Separations was also more formally advanced as a key preservation component for the Digital Intermediate process at the Joint Technical Symposium in Toronto in June 2004. Since that time, Technicolor, Ascent Media, EFilm, and other DI facilities have developed Digital Separation processes, each varying to some degree in composition and design, but many refinements have been made in the last year. An update on all these initiatives was presented at the Reel Thing Technical Symposium in Austin in 2005, and again in Sao Paulo in April 2006 at the annual conference of the International Federation of Film Archives (FIAF). Digital Separations are now becoming a standard deliverable for preservation of DI-created motion pictures.

The Digital Intermediate represents a new problem for preservation. The data files out of the DI facility are often captured on LTO2 or LTO3 data tapes and have been vaulted at production companies, laboratories, studios, or in archives in untested form. However, these files offer the possibility of recording out black-and-white color separation masters at the same resolution as the digital intermediate, without registration issues related to traditionally-produced separations. Working from the data tapes provides both a confirmation and verification of the DI data itself, as well as a physical element for preservation, something that is clearly still of value in the film-and-digital hybrid that represents the current DI process. But these elements should only comprise part of a comprehensive preservation scheme for the Digital Intermediate. How to preserve the data itself, developing a migration plan to new platforms, and allowing for long-term storage and retrieval without loss or degradation are key components to preserving all the data related to digitally-created or mastered motion pictures.

The Science and Technology Council of the Academy of Motion Picture Arts and Sciences has created a project that intersects with the interests of the ASC subcommittee on preservation. One of the Council's first initiatives is the Digital Motion Picture Archival Project, which is a project to investigate issues related to preservation of motion pictures that are digitally-originated. Members of the ASC Digital Preservation subcommittee are taking part in the Council's project, which is considered an important step toward developing policies, procedures, and eventually standards in digital archiving of motion pictures.

Advanced Imaging Subcommittee

Chair: Gary Demos

Vice-Chair: Phil Feiner

The Advanced Imaging subcommittee takes a somewhat longer view on our production and imaging processes, looking both at and beyond current practice. The subcommittee takes a more rigorous science and engineering-oriented approach to understanding the behavior of current imaging systems and what we might want to do in the future in support of the moving image art forms, as well as how current practice can be improved.

One area of interest is the characteristics of trichromatic—three primary—color systems, like RGB and X'Y'Z'. Most trichromatic systems in use today define their primaries and color characteristics using xy coordinates, which are part of the color system based on the 1931 CIE two-degree observer. For example, the standard color "horseshoe" diagram used almost universally to illustrate color gamuts is a representation of the 1931 CIE gamut. Essentially all monitors are calibrated using xy measurements. But 1931 CIE is known to have problems. Some are numerically small but some are significant. These problems may cause a particular set of CIE coordinates to represent visually different colors to different observers. For example, one well-respected colorist who participates in our subcommittee sometimes sees the same trichromatic stimulus as different colors with his right and left eyes. Several colorists in the same room are almost guaranteed to perceive trichromatic colors differently. We do not presently know the practical effects of these errors

in cinema production. Are they large enough and serious enough to interfere with the normal process of making motion pictures? The ASC Technology Committee Advanced Imaging subcommittee and the Academy of Motion Picture Arts and Sciences Science and Technology Council are looking at this issue.

To be clear, this problem is, in part, characteristic of trichromatic systems in general and partly an issue with the particular specifications of 1931 CIE. Reliable, accurate presentation of colors to a variety of observers (without characterizing each observer and customizing color presentation) may require a system with more than three primaries. At the extreme, a system that gives a full spectral representation for every color (70 primaries is a close enough approximation) will present the same color to every observer. Of course there are significant practical problems using such a system, but it is desirable to keep track of it as our reference.

Another area of significant interest is the industry-wide practice of (at best) informality in terminology used to describe numerical coding in color systems. To do accurate work in a post-production environment it is absolutely necessary to correctly identify the digital values being used to describe light.

Linear light values are proportional to the photon counts of light in the scene or striking the camera imager or on the display or projector. For example, light meters, spectral radiometers, and chroma meters all use linear light values. But the term "linear" is often misused to describe nonlinear signals containing video gamma.

It is common practice for video signals to be processed using a nonlinear exponent, known as gamma. A typical video system *gamma* is 2.222, though gammas in standard definition and high definition differ. Linear light is exponentiated to the power of the inverse of gamma (e.g., 1/2.222) to create the nonlinear video signal. The video signal is converted back into linear light by exponentiating the nonlinear video signal to the power of gamma (e.g., 2.222), usually as part of the monitor or projector. (Note that the DCI digital cinema gamma is 2.6—a "pure" gamma as opposed to video signals, which usually have a linear "toe" segment near black.)

Happily, all forms of video gamma representation, when precisely specified, can be converted to and from linear light.

Logarithmic representations of linear light include pure logarithmic and quasi-logarithmic representations. An example of a pure logarithmic representation is the log of the linear photon count of light at each pixel. At all luminances, all pure logarithmic representations vary by an equal percentage for an equal step in value. For example, an increase of 30 digital units might represent a 10% increase in the photon count. A 30-unit increase then represents a 10% linear light increase for any digital value, so 500 to 530 represents a 10% increase in light, just as 783 to 813 is a 10% increase. An example of a quasi-logarithmic representation is the Viper Camera's logarithm of the linear light value plus a constant.

All forms of logarithmic representation, when precisely specified, can be converted to and from linear light.

Logarithmic Printing Density is the density of a film negative, as used in printing and scanning. It is usually collected by scanning a film negative. Cineon and DPX formats most commonly use a density range of 2.048 using 10-bit (1024) units to specify the red, green, and blue densities of film negative.

Because film emulsion characteristics are quite complex and densities will vary from lab processing run to processing run (temperature, state of the chemicals in the film bath, etc.), accurate conversion of logarithmic printing density to linear light is more complicated. Conversion usually requires use of a three-dimensional cross-color Look-Up Table (LUT), or a cross-color matrix/LUT combination, constructed by a combination of engineering and art. 3-D cross-color processing is required to encode the interaction between the color primaries.

Image resolution terminology has also become indistinct. For digital cinema, 4K means 4096 but is often loosely used to reference 3840 or 3556 (4K minus sound track). Similarly, 2K is 2048 and not 1920 or 1778.

We are also considering precision in digital moviemaking systems. In order to preserve an image, the noise floor must be considered. The image noise floor is generally a function of both color and brightness (e.g., typical noisy or grainy blacks). For example, concatenated 10-bit computations may only preserve 8-bits. Compression is sometimes used in production (e.g., HD-CAM and DVC-ProHD) and distribution (e.g., JPEG-2000). The statistics of compression errors and precision errors are best considered in relation to the noise floor of the image. In support of understanding image precision, we

have created a test-sphere object with 16-bit precision at gamma 2.6 for use in evaluating processing systems (such as compression or color adjustment) and projectors and displays. All contour bands that are created are the result of processing, since there are no contour bands in the moving sphere source image. The color of contour bands is also revealing.

Another area of active discussion is the white point used in digital cinema mastering and display. You see the white point in specular reflections—the brightest points in the scene—normally the largest code values for digital displays or Dmin (the areas of minimum density) for film.

The standard for film projection's white point is 5400K—a point on the black body color curve defined by the spectrum of a black body radiating at 5400°K (not by a 1931 CIE xy coordinate). Film projectors in the field actually have a scatter of white points, often but not always in the vicinity of the standard. The white point being considered for digital cinema is an xy coordinate to the green side of the black body and daylight curves (generally near D60). This provided better light efficiency for DLP projectors.

In theory, the human visual system will adapt to perceive a reasonably large range of white points as natural. This happens every day as the sun rises, progresses across the sky, and sets. But if a movie scene is mastered with a warm feel and the specular reflections show green-ish, there is a conflict within the single scene and it will not be possible to adapt. The scene can be mastered so that the brightest points are not at full code values, and thus not at the full brightness of the projector, but this is different from current practice. It might be better to choose a more neutral white for the digital cinema white and gray point, carefully chosen based upon the practical experience of cinematographers and other movie experts.

There must also be an awareness of the complexities of human vision and visual perception. Our human visual resolution and dynamic range and color perception capabilities are fundamental to digital image technical considerations. For example, current models under development for perceiving color appearance suggest that moving the white point of a scene requires complex processing.

This is a sampling of the topics we are addressing and the approaches we are taking.

Digital Primer Subcommittee

Chair: Marty Ollstein, martycine@gmail.com

Vice-Chair: Levie Isaacks, ASC

The Digital Primer is designed to make the work of the ASC Technology Committee accessible to the general membership of the ASC, and eventually, the rest of the industry and the public.

The mission of the Digital Primer subcommittee is to create and publish reference material that will provide a comprehensive foundation to all aspects of digital technology that relate to digital motion picture production. With the support of committee member specialists in the related fields, Chair Marty Ollstein has completed writing the first stage, entitled "The Digital Primer Overview." The Overview is a compact, practical, but detailed quick-start guide for digital cinematography. It includes an explanation of the principal concepts underlying digital cinematography, as well as a step-by-step description of the new hybrid film/digital workflow that has recently emerged in the industry. The intent of the Overview is to identify the decisions that need to be made by cinematographers embarking upon this new digital workflow and provide enough information to allow them to make informed choices that maintain quality and preserve their creative intent.

The next phase of the development of the Digital Primer is the creation of in-depth chapters on each subject, which will result in a comprehensive book on digital motion picture production. The substance of the text will be drawn from the ground-breaking work being done by the ASC Technology Committee and all of its subcommittees, and will include technological advances, product developments, and best-practice recommendations developed by the Committee. Each step of the workflow will be covered—from Pre-Production Look Development through to the final Digital Intermediate grading session, as well as the Mastering and Archiving of a production. There will also be a discussion of the work of the Advanced Imaging subcommittee, which is taking a key role in the development of new cutting-edge technology to solve problems and expand opportunities in the field.

The Digital Primer will be a living document, updated routinely, and interim reports may be made available on the web and other electronic media.

Affiliations: David Reisner, D-Cinema Consulting; Glenn Kennel, Laser Pacific; Grover Crisp, Sony Pictures Entertainment; Marty Ollstein, Crystal Image.