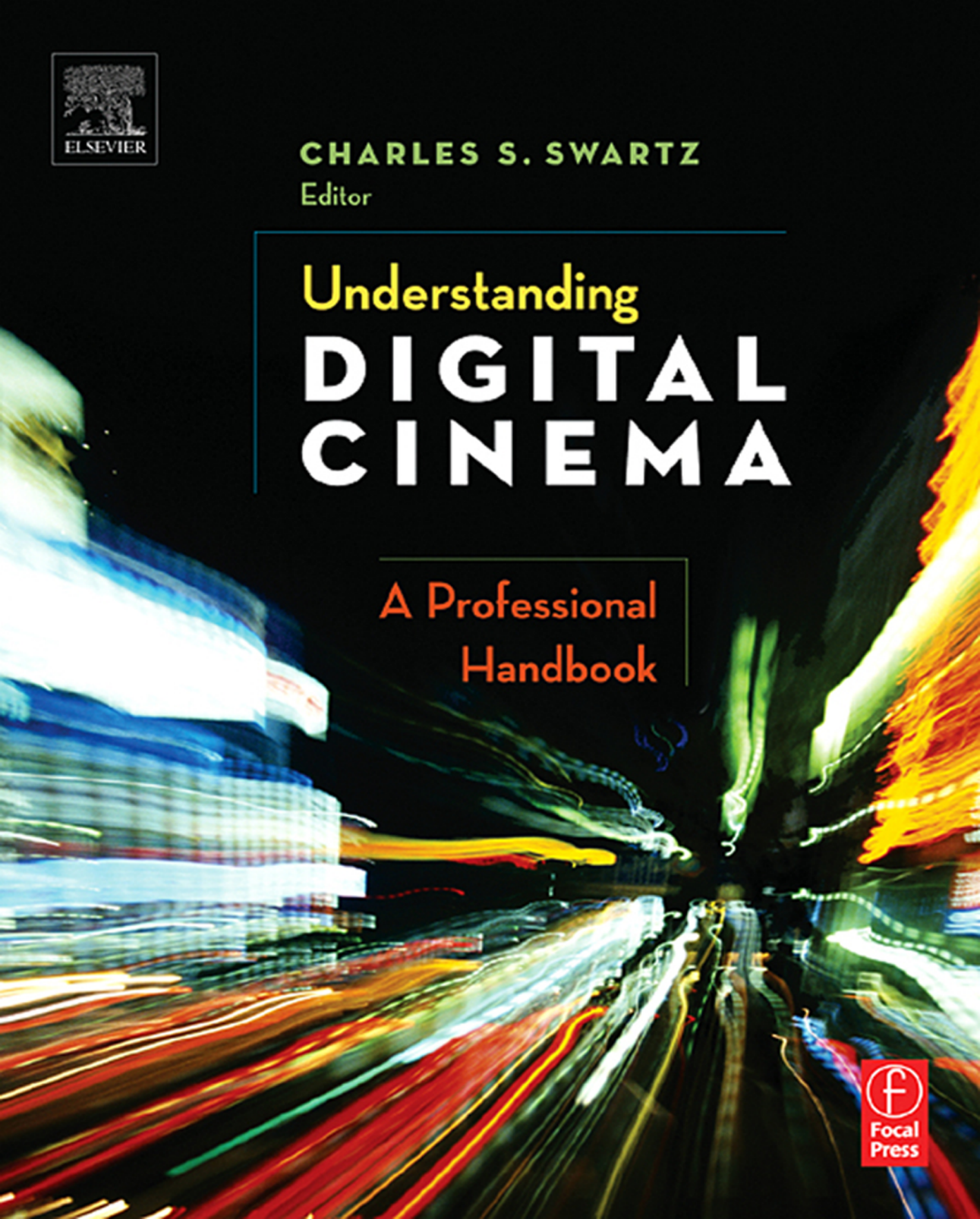
ELSEVIER
CHARLES S. SWARTZ
Editor
Understanding
DIGITAL
CINEMA
A Professional
Handbook
Focal
Press

Praise for Understanding Digital Cinema:

"First, let me say that this is possibly the only 'comprehensive' and complete gathering of information on Digital Cinema that has been written to date. I emphasize the 'comprehensive' aspect as it is clearly written by experts who have gone out of their way to simplify and summarize in laymen's terms what could have easily become a collection of highly scientific and academic theses, filled with mathematical equations and techno-geek jargon only decipherable by learned and passionate technicians. Instead, it manages to deal with sometimes complex technical processes in a very clear and straightforward fashion. The century-old business of making movies carries a lot of baggage in terms of processes and workflows that have evolved over time. Filmmaking is like house building; the end result is the outcome of many skills and trades that have worked together harmoniously to deliver what was originally conceived in someone's mind. Trying to bundle all the subtle complexities of this business into a flowing yet thorough explanation is what has impressed me most with this book. This book manages to describe clearly and concisely every aspect of the Digital Cinema workflow that will become the new way of making, delivering, and seeing movies. Charles Swartz has managed to pick the best people in the business to detail every one of these steps. I found this to be an 'easy read.' It is a 'crash course' in filmmaking as well as a 'primer' on new technologies that have influenced our industry in the last decade.

Because of its simple and straightforward approach of dealing with every component of the Digital Cinema workflow in a distinct fashion, it gets the reader to assimilate and understand the essential elements as well as the critical aspects of each phase. Whatever the field of expertise or specialty you're in, this book will 'fill in the blanks' that you missed in understanding the ultimate benefits and challenges of Digital Cinema.

This book will fill a big gap in many film & media reference libraries and should be a must for anyone entering any field of the filmmaking industry today."

—René L. Villeneuve
Villeneuve Media Technologies, Inc.

"*Understanding Digital Cinema* is an impressive compilation of information covering both the complex technical and operational aspects of Digital Cinema. The book brings together the collective insight of some of the field's most knowledgeable experts. It is the single most comprehensive book ever written on the topic."

—Brad Hunt
Sr. VP, Chief Technology Officer
Motion Picture Association of America, Inc.

"*Understanding Digital Cinema* is a book that inspires professionalism and instills a sense of meaning for the present and future career of the reader. Finally, a book that really shows how the supply chain of Digital Cinema works. Through an effective and easy-to-follow structure, this book translates the complex patterns of Digital Cinema into practical insights and guidelines to help Professionals. This book is a company's most important asset for the roll-out of Digital Cinema."

—Dr. Angelo D'Alessio
President
MIC – Moving Image Center

"Digital cinema represents a revolutionary change in the delivery and presentation of entertainment in movie theatres. The same technology has been in place for 100 years and is about to undergo a major transition. This book details in an easy-to-read way the technical and business issues facing this transition from some of the many pioneers leading this change."

—Douglas Darrow
Business Manager
Commercial Entertainment
Texas Instruments

Understanding Digital Cinema

A Professional Handbook

Charles S. Swartz, Editor
Entertainment Technology Center
University of Southern California

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AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Focal Press is an imprint of Elsevier

Focal Press

Focal Press is an imprint of Elsevier
200 Wheeler Road, Burlington, MA 01803, USA
Linacre House, Jordan Hill, Oxford OX2 8DP, UK

Library of Congress Cataloging-in-Publication Data
Application submitted

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

ISBN: 0-240-80617-4

For information on all Focal Press publications

visit our website at www.books.elsevier.com

04 05 06 07 08 09 10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

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Foreword

How New Technology Has Shaped Motion Pictures: A Short History

Richard P. Crudo, ASC
President, American Society of Cinematographers

In 1978 I was a college student whose after-school job was as an assistant cameraman for a documentary/newsreel cinematographer based in my home town of New York City. I loved what I was doing and saw it as the first step on the road to someday becoming a shooter myself. Our work was done in 16mm film format, generally for network television presentation under the auspices of such programs as CBS News' *60 Minutes*. One afternoon my boss and I were dispatched to the Plaza Hotel to photograph an interview with a visiting European dignitary. Upon arrival at the appointed suite, we were met by a second camera crew whose purpose was to simultaneously cover correspondent Mike Wallace's angle and thus help speed things along.

Never mind that the subject before our lens was to be the Italian Prime Minister. The initial thing I noticed about the busy situation was that my counterpart on the "B" camera—Phil—was an uncommon character for our line of employment. As a group, assistant camerapeople at that level tended to be of the young, go-getter variety. Phil looked nothing like me. He was much older, close to retirement, in fact, and had a hard, grizzled air about him. Though he moved with assurance as he unpacked his cases, there was no doubt he would have preferred to be spending his time some other way. On top of that, the burning stump of a cheap cigar dangled from the corner of his mouth. Suffice to say no one had the nerve to tell him to put it out, even among the rare company of our foreign statesman and his entourage.

After an unremarkable shoot during which we exposed what seemed like several miles of Eastman Kodak 7254 negative, Phil and I found ourselves back downstairs on East 59th Street loading the gear into our cars. I had given him a wide berth as the cameras rolled because it was plain that he was infinitely more experienced, and I respected him for that. But I was still one of those eager go-getters. Before we went our separate ways, I couldn't resist asking if he had any advice. Phil slammed the trunk hard and turned to utter his only complete sentence in the eight hours I'd known him. Oddly, his tone was gentle. "Kid, what you're trying to do right now is like trying to become a blacksmith at the time the automobile was invented."

With that, he hung his head and walked away. I never saw him again.

Talk about dashing someone's dreams. In retrospect, this should not have been unexpected. I could sense the greater significance of what he was telling me. The threat of our beloved photochemical process being replaced by video, or some other electronic medium was breathing down everyone's neck. This turn of events would mark the end to a way of life I had already become deeply attached to. No jobs. No opportunities. Worst of all, no hope.

My choices at that moment were clear. One would have had me retreating to the fabled Oak Room inside the Plaza, ordering a double vodka and figuring out a new career path. The other was more sensible and truer to heart. Rather than let the prospect of circumstances that might or might not occur within the industry intimidate me, I chose then and there to welcome new technologies as they came. This didn't just mean embracing them regardless of form. My rejection of easy cynicism also held a nod in Phil's direction. Picturing myself in the company of the many cinematographers I admired, my endorsement would go only to those items that helped me do my job *better*.

Allowing that Phil spoke from some shred of fatherly concern, I'm thankful I had the wherewithal to not heed his veiled suggestion. Twenty-five years later, I see that I was driven by something much more profound than ignorance of the hard road I might be facing if I'd elected to stay the course. Instead, as with so much of the story that relates technology and its effect on the moving image, what motivated my decision came down to something drawn from the opposite side of the brain. It came down to passion.

The idea that emotions and machines are in some way intertwined is not an unusual one. What is unique is that the tools that help put a film together come to life only in creative hands. This is where many so-called experts continue to go wrong in their approach to the subject. They forget that

technology is the means to an end, not the end itself. Without an initial, passionate impulse to translate an idea—a *feeling*—into concrete form, that state-of-the-art equipment on display at the rental house, laboratory, or post facility amounts to nothing more than a fascinating conglomeration of metal, plastic, rubber, and glass.

In a similar vein, every so often the industry gets caught up in a frenzy that finds us trying to reduce complex situations to a rote phrase. Lately, for example, it seems all we're hearing is that we're living in a time of "great change." The truth is that we're always living in a time of great change. On the heels of this are two questions: "How does change affect what we do?" and "What role does creative passion occupy in the process?" By trade, cinematographers are both artists and scientists. As a member of their ranks I can attest that the answers are found in hundreds of examples from the rich history of our profession. What follows are a representative few.

Keep in mind that today images are created for the cinema through what is essentially the same set of procedures that brought them to light 100 years ago. For the most part, only the hardware has evolved and in slow, steady increments at that. Along the way, a pattern has emerged that has yet to flag in its predictability. Whenever something fresh appears on the scene, there is a misguided tendency among filmmakers to believe that "new" automatically equates with "improved." The device or method is then overused for a time—misused, actually—until its proper application is found. Most recently, the emergence of digital technology has been noted as "revolutionary." For this to be true, the essence of how and why movies are made would need to have been changed. This hasn't happened. The ball that represents the kinds of tools we use has merely been pushed a bit farther up the field. And in keeping with that, it has no doubt been best for cinematography that to date it has never been subject to a single event of catastrophic technical upheaval.

If only that were true for the rest of the industry.

Short of the sudden appearance of some on-call hologram-based system in which lifelike representations of performers act out a story in real space and in real time, there's no way for us to imagine the impact talking films had when they arrived in theatres in late 1927. Until then movies existed as a purely visual medium, distinct in their popularity and universal in their ability to communicate. Literally overnight, sync-sound erased a pan-cultural language from the face of the earth. Actors and directors were the

first to feel the repercussions, often in sad or tragic ways. Cinematographers, on the other hand, weathered the shift in the most ironic of fashions. Everything about their art and craft changed in an instant, yet all of it remained the same.

One immutable fact that helped smooth the transition was that they had already established a long habit of being at the forefront of technological advancement. Beginning in the 1880s with Thomas Edison's research assistant, W.K.L. Dickson (in some corners acknowledged as the "first" cameraman), virtually every one of the early cinematographers was also known as an inventor, a builder, a tinkerer, always reaching for the next new thing. Whenever the current state of affairs conspired against handy realization of an on-screen effect, the solution came from hours of experimentation in one of their garages or at basement workbenches. The result of this habitual striving not only brought better physical experiences to audiences, it expanded film's possibilities and helped define the medium. What's even more amazing is that these men followed no road map. They made it all up as they went along. Should there be any doubt as to the momentous nature of their achievements, consider the not atypical example of Johann Gottlob Wilhelm "Billy" Bitzer (1872–1944).

Best known for his 16-year collaboration with legendary director D.W. Griffith, Bitzer's contribution to motion pictures cannot be overstated. Prior to that time, while working alone as both director and cameraman, many of the aesthetic innovations that grew from his prodigious development and application of technology remain part of our daily convention. In addition to photographing what is believed to be the first movie under artificial light, *The Jeffries-Sharkey Fight of 1899,* Bitzer's short recording of actor Joseph Jefferson in *Rip Van Winkle* (1903) contains the first known use of the close-up. Later, he became expert in filming dramatic chase sequences and was regularly stringing together scenes that used wide establishing shots immediately followed by close shots. Though it's impossible to separate his other ideas from those encouraged by Griffith, during their time together Bitzer invented many new ways of moving the camera. He also originated split-screen photography, perfected the in-camera fade and dissolve, built special filters and lenses that enabled soft focus work and invented the device that allowed for iris-in/iris-out effects, which entered the grammar of film as transition tools. At the same time, he also contributed to the development of three-point lighting by being the first cinematographer to employ backlight.

Despite his genius, Bitzer never became a rich man. In fact, well into the 1920s, at a point during which the Bell & Howell Model 2709 had become accepted as the standard production camera, he stuck with his old Pathe—and was often ridiculed for it. This little cruelty goes to the crux of the issue. Bitzer understood that the tool itself meant nothing without the inspiration and intellect that found ways to use it, to make it sing. Even at that early stage, technology was shaped as a conduit to personal expression. Whether or not today's audiences realize it, their debt to him will continue as long as motion pictures exist.

Bitzer was hardly alone in his pursuits. Indeed, the 1919 merging of New York's Cinema Camera Club with the Static Club of Los Angeles to form the American Society of Cinematographers (ASC) heralded a major event in the evolution of the screen image. For the first time, cameramen joined together as a group with the specific purpose of elevating standards for what they did. Guided by the motto "Loyalty, Progress, Artistry," such pioneering cinematographer/inventors as Karl Brown, Linwood Dunn, Karl Freund, Tony Gaudio, Arthur Miller, Jackson Rose, Charles Rosher, John Seitz, Leon Shamroy, and Karl Struss made their own outstanding contributions to the growth of visual storytelling. In unison with the Society of Motion Picture Engineers (the appearance of television would later spark their reformation as the SMPTE) and the Academy of Motion Picture Arts and Sciences (AMPAS), the ASC has been party to almost every improvement in emulsion, lighting, camera, lens, laboratory, and projection. The work of all three organizations still goes on.

The Mazda Tests of 1928 offer further insight as to what this sort of cooperation signified.Between January and March of that year, suppliers, studio executives, scientists and members of SMPE, AMPAS, and ASC all joined together to carry out a series of studies to determine the effect of incandescent (tungsten) lighting on panchromatic film. Prior to this time, arc and mercury-vapor lamps served as the main lighting sources on the majority of Hollywood sets, but as the General Electric Company began to step up emphasis on their incandescent "Mazda" units, cinematographers saw a way to expand creativity while helping producers cut costs and increase efficiency. Incandescents, though not common, had been around for decades but the crudeness of their fixtures led to unreliable performance. Another goal of these tests then became the discovery of information that would lead to solid standards across a broad spectrum of technical and manufacturing processes.

The eight-week effort was massive. On a set constructed within the confines of a specially designated Warner Bros. stage, 40 ASC cameramen exposed nearly 800 hours of negative. All the leading figures of the time clamored to be involved. Among the service firms contributing to the tests were General Electric, Mole Richardson, Bell & Howell, Eastman Kodak, DuPont, and Agfa. Even make-up specialist Max Factor had a stake in the outcome.

In terms of substance, the set that was photographed for the Mazda Tests was of a type commonly seen in silent films throughout the 1920s. With its fireplace, piano, plush chairs, ornate tables, fine woodwork, and high ceiling, it was essentially a mock-up of a rich man's home. Detailed records were kept for each lighting unit as to how and where it was employed. Closely related to these were notes on exposure and laboratory processes. No item was left to chance.

The ASC took the lead in analyzing some 450,000 feet of raw footage and supervised its editing down to a viewer-friendly 8-reel configuration. The results obtained from screenings held at the Hollywood Chamber of Commerce clearly showed that the consortium of suppliers, enablers and creators was on the right track. Incandescent lighting was deemed superior to all other forms of illumination for motion pictures and was immediately marked as the industry standard. In addition to being convenient and clean, it was economical. More important to cinematographers, tungsten sources were consistent. Over time, they became so dependable that they are still the main choice for use in the majority of filming situations.

This sea change did not go unnoticed on the screen. After the Mazda findings, the widespread deployment of incandescents and panchromatic negative led to a somewhat more diffuse style of photography. Cinematographers' aesthetics had begun to expand, but part of this was due to the different characteristics of the units themselves. The older arc and mercury-vapor lamps produced a light that was harder and more brutally defined on surfaces. Softening the quality of that light to a point where taste was pleased while exposure requirements were met called for great effort on part of the cameraman. Although capable of delivering a sharp-edged beam under the right circumstances, the tungsten filament substantially modified the game. With its inherently gentler throw, less work was needed to achieve a diffuse look. In likely response to the visual texture of the era's most successful films, a trend toward soft lighting then took hold. Though it would be several years before the approach assumed its rightful place in the cinematographer's toolbox, this

instance illustrates one of the least known examples of how evolving mechanics affected this mechanical art form and vice versa.

That motion pictures moved so quickly to a point where the Mazda Tests were necessary is no surprise, yet there's something much more resonant to be noted beyond a minor (and relatively transient) shift in photographic style. Besides showing the first recognition of the need for industrywide standards, the organization and execution of the Mazda Tests created a template for advancement so invaluable that it remains in place to this day. As part of the progression that began with the work of Bitzer and the other pioneers, the notion of economic feasibility was set in stone. Transparency to an audience also took on a primary role, guaranteeing the best possible effect onscreen while condemning radical departures to failure. But a third factor trumped all as far as cinematographers were concerned. Rather than allow manufacturers to dictate improvements on a presumptuous and speculative timeline, the Mazda Tests showed that cameramen could drive the effort through their own creative demands. Newly charged by the industry as "guardians of the image," cinematographers thereafter enforced an unwritten code that until the late 1970s went largely unchallenged. By causing technologists to think as end-users, artistic passion gained a subtle yet intractable stake. The acid test for widespread approval was summed up in reply to a basic question: *Does it help us do our job better?* In today's foggy environment the answers continue to make themselves plain. The introduction of improved high-speed negative stocks would qualify. Repurposing an ENG camera as a cine camera would not.

This little truth is by no means intended as a knock against the current wave of innovations. To the contrary, digital technology is the future of motion picture imaging. But there has lately been a disconnect with regard to whether some of these tools actually help us create more freely and effectively. The chief failure among suppliers has been the refusal to acknowledge that photochemical science and electronics exist in two separate and distinct physical realms. They only appear to do the same thing. During this hybrid stage in which a variety of elements overlap, we need to guard against losing a quality of audience experience whose value is matched only by its marvelous intangibility. Issues of taste and artistic sensitivity dominate here, and rightly so. Without them there would be no reference for the passion that has underpinned all our significant progress. But to ensure the transition reaches its full potential—that everyone involved actually does gain

something worthwhile—digital technologists would do well to remember the history that's brought us this far.

Giving the Mazda model its due, this means the highest possible photochemical standard must continue to be seen as the minimum point from which to grow on all fronts. Along with improvements in such areas as dynamic range, resolution, color space, black levels, and archival potency, a standard of quantifiable repeatability that will last over the long term must also be established on the electronic side. Without the option to measure for consistent results from start to finish, the artist is forced to deal in random possibility, and that's untenable. Cameras need to be made smaller, lighter, and more robust, free of cables and other encumbrances that limit their mobility. Other items, such as the optical viewfinder, would be welcomed additions. Chip size, as it relates to depth of field, must also be addressed. Then, as higher benchmarks are inevitably achieved in each area, these same technicians must respond to the needs of the artist and be ready to leap forward yet again.

If all this sounds daunting, it's really not. The good news is that images created and delivered through the best of what digital technology offers right now most likely represent the worst of what an audience will ever see. A successful balance has existed for over 75 years among those with an interest in furthering the ways and means by which movies are made and exhibited. Sidestepping that framework of checks and balances, or worse, tossing it away in the interest of narrow, short-term gain, will leave us with something no amount of passion will be able to salvage.

Whatever the future holds, some things are forever certain. Writers will still need to dream up wonderful new stories. Producers will gather the people and resources that make everything possible. Directors will direct, actors will act. Cinematographers will continue to compose their shots, light them, and use their expertise on the set and in post. Audiences, on the other hand, will be under no such obligation to fill our theatres.

The ethic of Bitzer and those like him guaranteed a level of excellence that not only kept them coming, but created a limitless archive of precious images.

Now, more than ever, it's incumbent upon us to remain faithful in their wake.

CHAPTER 1

Introduction

Charles S. Swartz
Entertainment Technology Center
University of Southern California

The process of distributing and exhibiting a motion picture has changed little, in its essence, since the Lumière brothers presented the first motion picture to an audience in 1895. Using a negative, positive 35mm film prints are exposed and developed, and then shipped to theatres, where the images are projected onto the screen. This analog photochemical process is capable of producing screen images of great beauty and expressive power, but in practice the moviegoer's experience is too often degraded by the wear and tear of the mechanical process, which can result in worn, scratched, and dirty prints. The process of manufacturing and shipping prints is also costly; the film industry globally spends more than $1B annually. Recently the industry's attention has turned to digital technology and its potential application to distribution and exhibition, because distributing digital files would theoretically yield great benefits in terms of image clarity and quality, lower cost, greater security, and more flexibility in the cinema.

This Handbook is devoted to an examination and explanation of this new process and the issues that arise in designing it.

Terms

Digital Cinema describes the packaging, distribution, and exhibition of motion pictures in digital form. This term does not specify how those motion pictures are originated, produced, and finished. For the foreseeable future, movies will be shot using mostly film but also digital cameras, edited using a variety of digital (and rarely, analog) devices, and post produced in a variety of ways—depending on issues of capability, flexibility, and cost.

However movies are created, they can flow into a Digital Cinema pipeline. So while this book does not deal with the merits of film versus digital cinematography per se, the decisions made in production, post production, and mastering profoundly affect the way the *Digital Cinema Package* (DCP) is created, so those decisions and the resulting implications are discussed throughout.

The terms *motion picture, movie,* and *film* are used interchangeably in this book to describe the completed work, not the medium in which it is originated or distributed.

Why Do We Need Digital Cinema?

Digital Cinema is at a crossroads. Current trials have demonstrated that today's interim process of digital mastering, distribution, and display in the theatre can create a presentation that moviegoers find compelling, especially when compared to an ordinary release print after multiple showings. At the same time, technology demonstrations provide a window into the future through which we can see a Digital Cinema that equals or even exceeds the quality of a first generation print (an *answer print*).

But obstacles lie ahead that cloud that vision unless they are addressed: we need global interoperable standards; we need a system that enables mastering to a single color reference, with assurance that the images in the theatre will look exactly as creative decision-makers intend, regardless of the projection technology in place; and we need a scalable and extensible deployment that will encourage theatre owners to adopt the system and not penalize them as quality improves.

ADVANTAGES AND CHALLENGES OF DIGITAL TECHNOLOGY FOR MOTION PICTURES

Advantages and Opportunities

Why use digital technology? Its advantages fall into four main areas:

1. *Copying*: In the digital domain, we can copy without deterioration, because every copy is a perfect clone of the original.

2. *Changing*: We can easily transform shape and color, with much more precision than in the photochemical world of film. And we can seamlessly composite elements from both original cinematography and *computer-generated imagery* (CGI).
3. *Controlling*: Digital technology enables us to make the motion picture much more secure from pirates, allowing us to encrypt the digital file and then decrypt it in the theatre—by validated users only—with the appropriate keys.
4. *Delivering*: Digital permits non-physical delivery to the viewer, e.g., Digital Cinema and Video-on-Demand. There is no need to manufacture copies unless desired.

What Opportunities Are Enabled by Digital Technology?

First, a high-quality digital master can preserve creative intent and ensure consistent presentation quality because all versions of the motion picture, including those for the home, can be extracted from this master with minimal adjustment. That saves money as well.

Second, motion pictures are called show *business* for a reason, and dollars will always loom large in any decision to change such a major system. Digital Cinema could enormously reduce the cost of prints and shipping. According to the Motion Picture Association, which tracks costs from the seven major studios and their subsidiaries, the studios collectively spent more than $631 million on prints in 2003 in North America (excluding French-speaking Canada).[1] Add independents and foreign releases in the United States, plus all print distribution internationally, and *Screen Digest* estimates that well over $1 billion is spent annually worldwide on prints and shipping.[2] That's a powerful motivator for change in any studio executive's eye.

Third, independent filmmakers and distributors face a challenging road. Reducing their costs of distribution can help create more diversity in the distribution pipeline. However, it is important to remember that prints account for only about 12% of total *P&A* (Prints & Advertising),[3] so marketing is still the biggest battle for independents. To address this problem, many independent filmmakers envision a network of theatres that would feature independent films released and exhibited digitally.

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[1] www.mpaa.org
[2] "Digital Cinema Business Models: The Global Outlook," Chapter 4: "Print Cost Savings" *Screen Digest,* June 2003.
[3] www.mpaa.org

Fourth, digital distribution would provide much more flexibility for both distributors and exhibitors. The single Digital Cinema Package—think of it as a "digital print"—will contain multiple subtitled and dubbed language versions, permitting a single theatre to meet the varied language needs of its audience on different screens. Sellout films could easily be expanded to more screens, provided those companies distributing the low-grossing films agree. And many more versions of trailers could be made, permitting filmmakers to try more varied marketing approaches and to match trailers to the demographics of a particular audience.

There is an additional, perhaps more controversial idea: assuming directors and distributors agree, and given credible enforcement by the exhibitor, an R rated film could run on one screen of a multiplex, while the PG-13 and NC-17 versions run in others.

Fifth, presentation quality improves. Once digital projection can equal film in all respects—and many believe it does already—a higher quality presentation will result because the digital presentation is rock-steady, never dirty or scratched. And the audio is uncompressed, with many more channels available.

In summary, the benefits are:

- For the consumer: a heightened experience, with improved presentation and choice.
- For the director, producer, and creative team: an improved presentation, with greater assurance their creative choices translate to the screen.
- For the distributor: an improved presentation and significant savings on distribution costs.
- For the exhibitor: an improved presentation and greater flexibility in scheduling.

Challenges

Although its proponents won't always say so, there are disadvantages of using digital technology for Digital Cinema as well. They fall into four main areas. Digital technology is:

1. *Immature*: This means it is undergoing constant change and improvement. Why cite this as a disadvantage—isn't improvement good? Yes, but

not when it results in shifting sands of uncertainty, preventing manufacturers from introducing new products because of the fear they will rapidly become obsolete. To address this problem, Digital Cinema awaits agreement on standards (a topic discussed later in this chapter).

2. *Expensive*: Digital technology is hardware-intensive, and the knowledge of how to make it work well is in the hands of only a few gurus. The idea of a computer in the projection booth of a theatre gives some experts cause for concern.
3. *Complex*: Digital Cinema requires a seamless integration of hardware and software to work well—or even at all. Furthermore, digital doesn't fail gracefully. With analog image creation, there is a range of failure that cinematographers often exploit to create expressive effects that further the story. Even in the theatre, a degraded image is still viewable. With digital, failure will produce a dark screen.
4. *Impermanent*: Digital is impermanent for two reasons. First, the formats of recording the data are changeable; even the operating systems change over time, sometimes rapidly. Second, the media itself on which the digital data is recorded is vulnerable to deterioration and data loss.

What Issues Result from These Challenges?

First, while film technology is mature, digital technology is continually evolving and improving. A requirement of a Digital Cinema system is interoperability: all the components of the system should be modular so improved versions can still work with existing pieces. This requires standards.

A second issue is economics. What about the cost of converting theatres to digital? Since the overall system for digital distribution has not been agreed on, cost estimates are just that. To get a sense of comparative costs, Chris Cookson, CTO of Warner Bros., has pointed out that if we calculate how frequently a typical theatre changes films and how much is spent on the average print, it costs distributors about $13,000 to service one screen for a year. If Digital Cinema distribution could eliminate 75% of this cost—or roughly $10,000 a year—it would take about 7 years, using a conversion cost of $70,000, to pay for it from the distributors' savings alone. And this estimate does not take into account potential contributions from exhibitors or financial advantages in depreciation gained by a third-party entity. So while the issue of how to pay for the conversion remains to be worked out, it does not appear at this time insurmountable.

Third, what about the system that must be created? This is an enormous challenge as well. For several years, the *Society of Motion Picture and Television Engineers* (SMPTE) has been studying Digital Cinema, and they have embarked on the standards-setting process (see the next section, *Who Is Working to Develop Specifications and Standards?*).

Fourth, security is a vital issue for filmmakers, distributors, and exhibitors alike. A robust security system is a requirement to deter piracy, and it needs to be flexible so that, if it is hacked, it can immediately be changed.

Fifth, where do we set the threshold of quality? Early in its development, some reasoned that as long as digital display is as good as the average release print, it would be good enough, and delaying implementation to define standards for the future would only set back the cause. Others argued that if we are to replace 35mm film, which has served so well for more than 100 years, we should standardize on an even higher-quality threshold than we can achieve today in a first-generation answer print. They reminded us that we may be setting standards for the next 100 years, so Digital Cinema should exceed 35mm film in quality.

The work of *Digital Cinema Initiatives, LLC* (DCI), the seven-studio consortium formed to issue a technical specification, points toward a consensus position between these two earlier viewpoints. DCI has described its consensus as a scalable 2K/4K solution.[4] Detailed explanations of how this scalable solution will work are found in the chapters that follow. The important point is that this path will both encourage rapid deployment today and at the same time drive presentation quality improvements for the future.

Finally, none of the theatre installations will matter—indeed, they will certainly not occur—if there are no motion pictures released in digital format. Doug Darrow of Texas Instruments, maker of the DLP Cinema chip that is in all today's projectors in theatres, observes that since the release of *Star Wars: Episode II* the number of digital theatres has tripled, whereas the number of digital releases has barely doubled. A substantial base of digital theatres and a substantial flow of digital releases must go hand in hand.

What steps can be taken to create this future scenario? First, DCI has issued its final performance specifications as version 5.0. Second, all the work described must move forward to build a distribution infrastructure.

[4] www.dcimovies.com

Finally, filmmakers themselves can help by insisting on a digital release for their pictures along with the conventional film release.

WHO IS WORKING TO DEVELOP SPECIFICATIONS AND STANDARDS?

A number of groups and organizations are addressing the issues of creating specifications and standards for Digital Cinema.

1. *SMPTE.* In 1999, SMPTE created a technology committee for Digital Cinema, called DC28.[5] SMPTE committee work is done by volunteers as individuals, some employed at companies who may or may not be interested parties and some freelance consultants and interested observers. For its first 4 years of existence, the chair of DC28 was Curt Behlmer, who played a key role in early Digital Cinema installations and now chairs the *Digital Cinema Providers Group* (DCPG).[6] The current chair is Wendy Aylsworth, Vice President, Technology, Warner Bros. For more information on DC28 goals, see the Appendix.
2. *DCI.* DCI was created in March 2002, as a joint venture of Disney, Fox, MGM, Paramount, Sony Pictures Entertainment, Universal, and Warner Bros. Studios.[7] Led by Chuck Goldwater, CEO, and Walt Ordway, CTO, DCI's primary purpose is to establish and document voluntary specifications for an open architecture for Digital Cinema that ensures a uniform and high level of technical performance, reliability, and quality control. The Introduction to the final version of the specifications, with permission of DCI, states as follows:

   A number of significant technology developments have occurred in the past years that have enabled the electronic playback and display of feature films at a level of quality approaching that of 35mm film release prints. These technology developments include: the introduction of high-resolution film scanners, digital image compression, high-speed data networking and storage, and advanced digital projection.

[5] For information about how to become a Participant or Observer in DC28 activities, see www.smpte.org/engineering_committees/. For information about obtaining existing SMPTE Standards, see smpte.org/smpte_store/standards/
[6] dcpg.com/
[7] www.dcimovies.com

The combination of these digital technologies has allowed many impressive demonstrations of what is now being called "Digital Cinema." These demonstrations, however, have not incorporated all of the components necessary for a broad-based commercially viable Digital Cinema system. These demonstrations have created a great deal of discussion and confusion around defining the quality levels, system specifications, and the engineering standards necessary for implementing a comprehensive Digital Cinema system.

Digital Cinema Initiatives, LLC (DCI) is the entity created by seven major studios: Disney, Fox, Metro Goldwyn Mayer, Paramount Pictures, Sony Pictures Entertainment, Universal Studios, and Warner Brothers. The primary purpose of DCI is to establish uniform specifications for Digital Cinema. These DCI member companies believe that the introduction of Digital Cinema has the potential for providing real benefits to theatre audiences, theatre owners, filmmakers and distributors. DCI was created, recognizing that these benefits could not be fully realized without industry-wide standards that all parties involved in the practice of Digital Cinema can be confident that their products and services are interoperable and compatible with the products and services of all industry participants. The studios further believe that digital film exhibition will significantly improve the moviegoing experience for the public.

3. *ASC.* The American Society of Cinematographers was founded in 1919 for the main purpose of advancing the art of narrative filmmaking. There are some 215 cinematographers and visual effects artists in the organization today and another 135 associate members who work in allied sectors of the industry. Its current President is Richard Crudo, ASC (see Foreword). In May 2003, it formed the ASC Technology Committee, chaired by Curtis Clark, ASC, with the goal to "recommend standards and practices for emerging technologies that affect the art and craft of filmmaking." The committee includes more than 50 cinematographers and technology thought leaders from all sectors of the industry. In September 2003, ASC, under the auspices of the Technology Committee, and DCI announced plans to produce *Standardized Evaluation Material* (StEM) for evaluating the performance of digital projectors and other elements of Digital Cinema systems.[8] The StEM was shot in August 2003 and mastered over the following six months. It has been used extensively by DCI and ASC for testing in the Digital Cinema Laboratory (see point 6 that follows) and shown at numerous conferences, including the NAB 2004 Digital Cinema Summit, Cinema Expo 2004, and the 2004 Naples Cinematography Forum.[9]

[8] dcimovies.com/press/09-24-03.tt2

[9] For details about how the StEM was produced and mastered, as well as information about how copies of the StEM can be obtained for non-commercial purposes, see www.dcimovies.com.

4. *MPAA*. The Motion Picture Association of America (MPAA) and its international counterpart, the Motion Picture Association (MPA), serve as the voices and advocates of the American motion picture, home video, and television industries. Founded in 1922 as the trade association of the American film industry, the MPAA has broadened its mandate over the years to reflect the diversity of an expanding industry. Its members are the seven major studios. In August 2000, under the leadership of its CTO Brad Hunt, the MPAA issued "Goals for Digital Cinema," listing ten goals "critical to the successful implementation of a Digital Cinema system that provides real benefits to all stakeholders."[10]
5. *NATO*. The National Association of Theatre Owners is the largest exhibition trade organization in the world, representing more than 26,000 movie screens in all 50 states and in more than 20 countries worldwide. Its membership includes the largest cinema chains in the world and hundreds of independent theatre owners as well.[11] NATO's president, John Fithian, has spoken many times on the important issues surrounding Digital Cinema from the exhibitor point of view.[12] NATO's "Digital Cinema User Requirements" is discussed in Chapter 10 and appears on the website of MKPE Consulting,[13] NATO's Digital Cinema consultant.
6. *Entertainment Technology Center at USC (ETC-USC)*. The Entertainment Technology Center was founded in 1993 as an Organized Research Unit of the University of Southern California's School of Cinema-Television, with the mission to help understand the impact of new technologies on the entertainment industry.[14] Its executive sponsors include all seven major studios, LucasFilm, and several leading technology companies. In 1999, ETC-USC created the Digital Cinema Forum, which produced the concept of creating a neutral laboratory for the testing and evaluation of

[10] mpaa.org/dcinema/
[11] www.natoonline.org/
[12] For example, see his speech at the Digital Cinema 2001 Conference, hosted by the National Institute of Standards and Technology at www.infocusmag.com/presidents.htm, and his letter co-authored with his European counterpart, Jan van Dommelen, President of UNIC, at www.natoonline.org/.
[13] www.mkpe.com/articles/
[14] www.etcenter.org

Digital Cinema products and solutions. In October 2000, with the support of NATO and MPAA, the *Digital Cinema Laboratory* (DCL) opened in the historic Hollywood Pacific Theatre. With the most up-to-date film and digital projection and sound, the DCL serves as a test bed for demonstrations and evaluation as well as a high-quality screening venue. In December 2002, DCI announced the Lab as the official site to test Digital Cinema technologies and to work with DCI to establish uniform, open, and voluntary standards for digital movie release that will be scalable into the future. ETC-USC also works with international organizations and consortia to promote greater understanding of Digital Cinema.

7. *ISO.* ISO, the International Organization for Standardization, is a network of national standards institutes from 148 countries working in partnership with international organizations, governments, industry, business and consumer representatives. ISO was founded in 1947 and has its headquarters in Geneva, Switzerland.[15] ISO Technical Committee ISO/TC 36-Cinematography had its first meeting in 1952 in New York. SMPTE serves as Secretariat through the American National Standards Institute (ANSI). The current Chairman and Secretary is Mr. C.V. Girod, P.E., the SMPTE Director of Engineering. The scope of ISO/TC 36 is standardization of definitions, dimensions, methods of measurement and test, and performance characteristics relating to materials and apparatus used in silent and sound motion picture photography; in sound recording and reproduction related thereto; in the installation and characteristics of projection and sound reproduction equipment; in laboratory work; and in standards relating to sound and picture films used in television.
8. *EDCF.* The European Digital Cinema Forum was formed in Stockholm in June 2001 to promote the creation of a technical and business framework for the harmonious introduction of Digital Cinema in all its forms in Europe.[16] Made up of three modules—Technical, Commercial, and Content—it is led by a Management Committee whose current President is Åse Kleveland, Director General of the Swedish Film Institute. Because of its wide-ranging activities in Europe and liaison with SMPTE and other groups, its website is a rich source of information of Digital Cinema developments.

[15] www.iso.org/
[16] www.digitalcinema-europe.com/pages/objectives.html

9. *DTB@NFT.* June 2003 saw the launch of the Digital Test Bed at the National Film Theatre in its premiere cinema complex on London's South Bank.[17] The National Film Theatre is a renowned part of the British Film Institute (BFI), established in 1933 to promote greater understanding, appreciation, and access to film and television culture. Established by the Department of Trade and Industry (DTI) in conjunction with BFI, the DTB@NFT is the main UK and European facility for exploring the digital distribution and exhibition of film. Its aim is to act as a neutral research laboratory in the search of universal standards and compatible technology solutions. The Test Bed hosts seminars, training sessions, interactive forums, and special demonstrations.
10. *MIC.* The *Moving Image Center* was established in Italy in 2003 by Angelo D'Alessio.[18] Its key goals are to analyze and study Digital Cinema and advanced media technologies, and their applications and business models, and to prepare tools and methodologies for the education and training of teachers and professional people. The MIC will comprise multiple laboratories, devoted to asset management, content security, audio, mastering, assessment of quality, and the preservation of digital content. In addition to the Italian Center of Excellence that will be an integral part of this effort, it plans to pursue the concept of an International Center of Excellence, with a desire to connect its work with that of the Entertainment Technology Center and others worldwide. The MIC's upcoming projects include "Methodologies and Tools for Education and Training of Professionals Involved in Digital Cinematography" and "Preservation and Management of Digital Cinema Content."
11. *DCCJ.* The Digital Cinema Consortium of Japan is a nonprofit organization formed to contribute to the promotion of culture and art through the development, test, evaluation, and standardization of very high-quality Digital Cinema formats and related infrastructure.[19] Its Board of Directors is headed by Chief Director Tomonori Aoyama, Professor in the Department of Information and Communication Engineering, Graduate School of Information Science and Technology of the University of Tokyo. DCCJ has organized demonstrations of the

[17] www.bfi.org.uk/features/dtb/
[18] *angelo.dalessio@infinito.it*
[19] www12.ocn.ne.jp/~d-cinema/index2.htm

NTT-built 4K Digital Cinema projector, using the JVC D-ILA chip, in Japan, Europe, and the United States.

12. *CST.* The Commission Supérieure Technique de l'Image et du Son (CST) is a French regulatory body established by legislation. The CST has the authority to set and enforce the design standards for Cinema Auditoria.[20]

More information about the international organizations above, as well as numerous additional initiatives, can be found in Chapter 11, International Perspectives.

Goals of This Handbook

Because Digital Cinema is currently in a nascent state, this Handbook cannot present a final view of a settled topic. Its goals instead are to present a snapshot of the present and a vision of the future. Both of these goals are bounded by continually evolving technology and business developments. But if "the best is the enemy of the good," then it follows that waiting until all questions are answered would provide no information and guidance during this crucial formative period when readers most need exactly that.

Furthermore, the fluid nature of current developments inevitably can result in differing views about a given topic. While each chapter focuses on a specific area of the proposed Digital Cinema process, authors' views do not always mesh. But from these differing views, which at times may even clash, will come the standards we all seek.

While this Handbook is designed to meet the needs of the technical reader, my hope is that those new to the field can read the Introduction to each chapter and gain an understanding of the fundamental issues.

[20] www.cst.fr/

From the birth of the movies until 1916, dozens of film formats and sizes existed and no standards prevailed.[21] In 1916, SMPE (the original organization name before Television added the "T") standardized 4-perforation 35mm film as its first task. Since that date, this single system has acted as an umbrella for significant and continuous improvements in emulsions, lenses, cameras, and processes—all of which serve to enhance presentation quality. In the same way, Digital Cinema requires a system design based on interoperable standards globally deployed and at the same time flexibly capable of improvement as technology permits. Only in this way will the promise of Digital Cinema be achieved.

Acknowledgments

My interest in motion pictures began as an undergraduate at Yale. Jacques Guicharnaud, Professor of French and a lifelong filmmaker and critic, agreed to oversee my senior essay in History, the Arts, and Letters. I wrote about Orson Welles' *Citizen Kane*, and I was thereafter forever hooked on film. Bernard Kantor, then Dean of the USC School of Cinema-Television, provided a scholarship and continuing encouragement for my graduate study in production. And through winning the Warner Scholarship, I had the good fortune of working at Warner Bros. for 3½ years, where writer-producer Jim Barnett was a mentor and always stimulating colleague.

During the years I was designing the professional education courses in digital media at UCLA Extension, Dick Stumpf was my patient and frequent breakfast companion, spending many hours educating the educator. A longtime SMPTE leader and studio executive, he continues in retirement to share his enthusiasm and wisdom with the Entertainment Technology Center at USC.

The true value of this book resides in the contributions of the respective contributors, who have each taken on the challenge of explaining a topic that is at this moment fluid, a task not unlike nailing down mercury. My thanks to Richard Crudo, Leon Silverman, Charles Poynton, Chris Carey, Bob Lambert, Bill Kinder, Glenn Kennel, Peter Symes, Robert

[21] See "Inventing Entertainment" on the Library of Congress site memory.loc.gov/ammem/edhtml/edhome.html; "One Hundred Years of Film Sizes," www.gregssandbox.com/gtech/filmsize/filmsize.htm; "The Complete History of the Discovery of Cinematography," www.precinemahistory.net/.

Schumann, David Gray, Darcy Antonellis, Matt Cowan, Loren Nielsen, Michael Karagosian, Peter Wilson, Patrick Von Sychowski and Wendy Aylsworth. I am also grateful to Walt Ordway for his guidance.

The members of the Entertainment Technology Center Executive Board and Technical Advisory Board have encouraged and supported my understanding of Digital Cinema. I want to acknowledge especially Dean Elizabeth Daley, Jerry Pierce, Bob Lambert, Chuck Dages, George Joblove, Andy Setos, Dave Schnuelle, Brad Hunt, Garrett Smith, and Leon Silverman. Lastly, Phil Barlow was my earliest guide through the perplexities of the subject.

Joanne Tracy, Senior Editor at Focal Press, originally proposed this book, and she has provided guidance and insight throughout its development, always with good judgment and good humor.

Finally, my thanks to Stephanie Rothman, my filmmaking and life partner, from whom I have learned so much.

Sherman Oaks, California
June 13, 2004

CHAPTER 2

The New Post Production Workflow: Today and Tomorrow

Leon Silverman
LaserPacific Media Corporation

To many, post production is mysteriously confusing; a black art performed in darkened rooms, which when executed with a high degree of art and skill, literally becomes unknowably transparent in service to the story. Though its importance to the filmmaking process is undeniable, the fashioning of disjointed bits of picture and sound into a finished work is often eschewed as a lesser and certainly lower-paid skill when compared to the highly visible and better-compensated writer, director, or cinematographer. Post production can often help make marginal work better and cement great work as a timeless masterpiece. It is interesting to note that many directors pose for photographs, pictured in front of editing devices or sound mixing consoles, albeit with nary an editor or mixer, their necessary collaborators and oftentimes saviors, in frame.

The rallying cry of "We'll fix it in post," uttered in reverential tones, although usually without much notion of what actually happens in "post," has helped to urge on countless productions or assuage the horror of the best laid plans gone awry. Post production, which encompasses both creative expression and the technical details of the filmmaking, manufacturing and delivery processes, has been undergoing dramatic technological change over the past 20 years. Electronic and digital tools have helped to point the way to increasing numbers of new processes, which not only have changed the creative character of motion pictures, but also are changing the forms and methods from which the cinema of the future will take shape.

The creative and workflow impact of new electronic and digital tools and "toys" that are the hallmark of "the look" of commercials, music videos, digital animation, and visual effects, has also influenced the motion picture post production process as well, altering the practice that has been decidedly film-based since the beginning of cinema. These new evolving tools and methods will help hasten a merging and blurring of film and digital processes, ushering in the era of what might be called "the modern motion picture."

The stage is currently being set for a cinema of the future that may include digital cinematography, will most certainly utilize an increasingly digital post production process, and is destined to be distributed into what the industry is grappling to envision as the Digital Cinema.

The challenge for many working in the industry today, especially for those who have been tapped to lay the technological groundwork for future cinema, is to ensure that an uncompromised, robust, and extensible technical pathway can be built. For film, when considered as technology, in its relative simplicity and its 100-year endurance, is unquestionably quite elegant.

THE TRADITIONAL POST PRODUCTION WORKFLOW

Regardless of technology or terminology, post production usually does not begin "after production" but more accurately is concurrent with production. Typically and traditionally, post production encompasses the process of preparing, editing, and "finishing" both picture and sound as well as creating the intermediate and final elements necessary for distribution.

The process is usually overseen by a group of post production professionals, some who work for the studio and some who work for the producing entity or the film itself. The management hierarchy extends from the studio or production company VP of post production and his or her staff, through line producers, producers, associate producers, post production supervisors, post production coordinators, editors, assistant editors, and the various people associated with the "vendor community" of laboratory and sound. These relationships are sometimes strained when creative, financial, or scheduling needs clash as the editors, who are often aligned with the creative filmmakers, find themselves in the middle of a tug of war.

The complexity of the post production process is little understood in most studio executive suites and indeed by many producers and production managers, who are responsible for creating post production schedules and budgets and sometimes have precious little knowledge of the intricacies and nuances of the process. The pressure to shave costs and time from a film can often result in the squeezing of post production, as production or *above the line* (story rights, script, actors, director, and producer) costs and issues are oftentimes sacrosanct.

Certain recent developments put an even greater strain on the process of completing motion pictures: the need to create a big splash in a short time at the box office, the fear of piracy, which has contributed to the acceleration of worldwide distribution, as well as the requirement to ready video delivery elements for earlier *windows* (phases of distribution on different formats). The impending need for Digital Cinema elements will further articulate new post production methods that might help to meet the challenges and pressures of today's motion picture delivery needs.

To begin to discuss how these technological and marketplace changes might affect these processes, we must first outline the traditional post production workflow.

Dailies

It all begins with *dailies*, the process by which yesterday's footage is readied for viewing by the creative filmmakers and studio as well as editing. So-called because it happens every day, the importance and timeliness of this step that feeds and enables the post production process can be even better understood when referred to by its name outside of the US: *rushes*. Dailies inform the filmmaking process by enabling the various disciplines involved in motion picture production to gauge the progress of a film.

The film shot during each production day is delivered to the film laboratory where it is processed overnight (except for Saturday and sometimes Friday nights when most labs are closed). For dailies that will be screened on film, commonly referred to as the *workpicture*, the processed negative is *broken down* or separated in the lab into "*A*" and "*B*" negative. The "A" negative, or *circle takes*, includes the takes the director wishes to have printed for viewing and editing. The director asks for them to be circled, or marked as "good," on the camera report that is delivered with the film to the lab.

The "B" negative is vaulted at the lab in case the director or editor later wishes to see an *outtake* printed. The "A" negative then heads to the *timing* department. The dailies *timer* will evaluate the negative film's exposure and determine the proper *timing lights* that need to be applied to the film for it to be properly printed.

Film Timing

The primary tool of the film timer is a device rarely called by its official name, the color analyzer. Instead, it is almost universally known by the name of the company, *Hazeltine*, that designed and made the most commonly used analyzer, sometimes even when the analyzer is made by different company. The Hazeltine made its way into the industry in the 1960s and was hailed as a significant development. As a foreshadowing of the importance of utilizing electronic display and color calibration technology for film, the Hazeltine is a precursor to both the modern *telecine* (a device used in television to transfer film to video) and the digital color timing systems that dominate our industry today.

Named for Professor Alan Hazeltine, who in 1923 invented a new, more easily tunable circuit that became widely used in the broadcast, medical, and photographic industries, the Hazeltine company went on to become a major defense contractor and developed significant technology for radar, mine detection, and electronic defense systems. The analyzer represented a show business dalliance for Hazeltine, which nevertheless ended up winning an Academy Award for its efforts.

The color analyzer is an electronic device that displays the film (similar to a crude telecine) on a monitor and provides timers with the ability to alter the image using values of red, green, and blue and *density* (which simplistically can be thought of as contrast). It is set to a reference called the *LAD* (Lab Aim Density), a standard means to control color and density in the timing process, whose purpose is to calibrate the analyzer so that by changing the values of color and contrast, these characteristics can also be altered in the film print. The LAD contains an image of a woman's face, which helps to establish a flesh tone reference, as well as red, green, blue, and various shades of black and gray patches that serve as a visual reference for the experienced timer. Unlike a telecine, which can display a *WYSIWYG* (what you see is what you get) rendition of a scene for a video transfer, a color analyzer's image is not as visually intuitive in relation to the end result.

Some refer to the process of printing the negative each day as *one light dailies*. This refers to the notion that the timer determines the proper *printing light*—values of red, green, and blue and density—and applies this one light to the entire camera roll for printing. The more accurate description of the dailies timing process might be *best light dailies*. The timer creates a timing value for each unique lighting setup and determines the best light for printing the scene. Cinematographers want to know their printing lights in order to verify that they are exposing the film correctly relative to their own expectations. This is an important reference and calibration tool for them to understand how the exposure of the film correlates to their understanding of their goals when shooting it.

Printing

Once timed, the film is sent to the printing department where it is printed at the lights that the timer has determined. From the printer, the film is usually viewed on a high-speed projector by a representative of the lab. This *lab contact* will communicate with the cinematographer about what he or she saw in the cinematography, commenting on exposure and other issues with the film. The lab contact might order a retiming and reprinting of certain takes if it is felt that they are not accurate representations of the look of the film. All of this activity happens during the wee hours of the morning in time for the assistant editor to pick up the resulting print as early as possible to begin the process of syncing the sound with this silent film workpicture.

Production Sound

The sound that was recorded during production makes its way overnight on a separate path from the film. In the past, the most common method had been to transfer the production sound to 35mm film, which is coated with a magnetic surface, called *mag*. The assistant editor then uses a *synchronizer* to synchronize the mag with the workpicture. This is accomplished by aligning the exact film frame where the slate's *clapper stick* closes with the sound of the closed clapper on the mag. When no sticks were used, the assistant editor must create sync manually by aligning the actor's spoken words with his or her moving lips, or some other reference in the frame. *Syncing dailies* has always been one of the most important tasks of the assistant editor.