CHAPTER 2

Painting with Digital Light

Prolific Hollywood cinematographer Leon Shamroy worked for nearly a half-century and won two consecutive Oscars for cinematography. His work included such key genre pictures as You Only Live Once (1947), Twelve O’Clock High (1949), The Snows of Kilimanjaro (1952), The King and I (1956), and Planet of the Apes (1968). In 1947, Shamroy wrote a prescient article for American Cinematographer in which he predicted that the medium’s future would be electronic. He envisioned an electronic camera more sensitive than present film stocks that would send its image over a cable feed to a remote storage and viewing station. Rather than waiting for dailies, the director could view the images as they were being captured, and image variables could be adjusted during production rather than afterward. “Electronic monitor screens connected into the system will make it possible to view the scene as it is being recorded. Control of contrast and color will be possible before development.”

Shamroy had glimpsed the future. Cinema’s photochemical domain began shrinking in the 1990s as digital imaging tools reconfigured the work of filmmaking. To the public, the most visible profile assumed by these changes included startling new visual effects, as found in Jurassic Park (1993) and Forrest Gump (1994). But the changes were deeper. The shift to digital modes ended the era in which visual effects were “special,” that is, were allocated to a domain of trick photography regarded as being separate from and peripheral to the main stage of production. A better term today is “visual effects,” designating an expanded domain of image manipulation carried out with digital tools. This may include the creation of fantastic, attention-grabbing creatures prevalent in everyday conceptions of what a movie special effect is, but visual effects go beyond this. Most often they are subliminal and invisible to viewers, and by no means are they confined to genres like science
fiction and fantasy. In 1995, the American Society of Cinematographers and Eastman Kodak sponsored a seminar examining the emerging relationships among cinematographers and digital effects artists. Speaking as a panelist at the seminar, Andrea D’Amico of Pacific Ocean Post (What Dreams May Come [1998]) described digital imaging as a kind of toolset offering filmmakers expanded creative opportunities: “I see [digital] as a huge expansion of opportunity . . . by allowing people to do things they really couldn’t do before or as easily as we can do now.”2 Visual effects encompass much more than what the term “special effects” has designated. They encompass all variety of digital manipulations carried out upon cinematic images. As cinematographer Marvin Rush emphasized, “‘Digital,’ or what we’re calling digital, should be taken out of the realm of visual effects. We should look at digital as a concept for something besides visual effects.”3 Although Rush was advocating an entirely new terminology, his philosophical point is sound—digital imaging is about more than the creation of monsters and spectacle. In contrast with Rush, I believe the terminology of “visual effects” is suitable for creating the necessary distinction with “special effects” and for pointing to the larger domain of digital image manipulation that the present study examines. It also tracks with current terminology as employed in the industry. Audiences notice special effects. Most often they fail to notice visual effects. Greg McMurray, a visual effects supervisor at VIFX, an effects-house that has contributed work to From Dusk to Dawn (1996) and Face/Off (1997), identified two kinds of images that his company and similar firms provided to filmmakers—effects that people see because they are elaborate and fantastic and effects that no viewer notices. “I think the digital revolution has broadened that second category incredibly.”4

While scholars, critics, and viewers have tended to see digital imaging in terms of fantasy effects—the things that people notice—filmmakers gradually came to understand that the new tools enabled cinema to incorporate important dimensions of visual realism. Neil Krepela of Boss Film (True Lies [1994], Starship Troopers [1997]) pointed to the connection between digital imaging and realism. “The effects in films are becoming more and more realistic, rather than the fantasy elements. I think this is one of the great powers of digital effects in general, that we can make things a lot more seamless and realistic and not so much ‘in your face.’”5 Forrest Gump may not be a film to which many viewers would attach a term like realism. Its story is a tall tale in which hero Gump (Tom Hanks) experiences numerous improbable adventures, such as meeting three U.S. presidents in scenes where actor Hanks was matted into archival footage of Presidents Kennedy, Johnson, and Nixon. These were clearly visual effects sequences, as were the Ping-Pong matches
Among the most famous of the early-generation digital effects was Lieutenant Dan's missing legs in *Forrest Gump* (1994, Paramount Pictures). Although many viewers knew this was a digital effect, it conveyed an undeniable perceptual realism. Frame enlargement.

between Gump and his Chinese opponents featuring digitally animated balls with appropriate motion blur.

But the feather drifting through city streets in the film's famous opening sequence was not a CGI element, though many viewers may have thought it so. The three Phantom F-4 jets that drop napalm in the Vietnam sequence were CGI elements, but they didn't look like such. Although most viewers probably knew that Gary Sinise's appearance without legs, playing Lieutenant Dan, a vet wounded in Vietnam, was a digital effect, this awareness did not disturb the perceptual realism of scenes in which Dan maneuvers himself, or is carried, through spaces too small, narrow, or confined for a fully limbed man to fit. The physical reality depicted in such scenes onscreen is true and cannot be perceptually denied in spite of a viewer's awareness that it is dependent on digital effects. In a pre-digital era, scenes with actors playing handicapped characters never achieved such visual credibility. Viewers were always aware that the actors had one limb tucked behind their backs or hidden below a specially constructed table or chair. (Even in *Gump*, some scenes with Lieutenant Dan were done with a trick wheelchair.) Stephen Rosenbaum, the film's graphics effects supervisor, said that "most of the effects in the film were designed to enhance reality," and Ken Ralston, another of the film's visual effects supervisors, noted that using digital methods to achieve such realism is actually harder than doing something outlandish. "The toughest thing... is trying to recreate reality. The more surreal an image is, the more leeway we have to fake our way through because people can't identify with it. This show was firmly based in reality."
Although the feather that drifts through the opening sequence is not CGI—it is, instead, a real feather photographed and then matted into the scene, with some digital tweaks to marry the two—digital compositing enhances the scene’s perceptual realism by making the join between the foreground feather and the background environment virtually imperceptible. Digital compositing, and its widespread adoption by the film industry in the 1990s, played an essential role in the developing abilities of filmmakers to enhance the realism of their visual effects and a viewer’s sense of the authenticity and veracity of a scene’s depicted content. I begin this chapter by examining optical and digital compositing and then consider the transformation of cinematography with the onset of digital intermediates and digital capture, and I conclude by examining attributes of the new aesthetic that these tools helped to enable.

Optical Compositing

Throughout the history of cinema, visual effects images have been composited, that is, composed of at least two elements separately created and then layered together to produce the final synthetic image. (Initial instances of combining images were accomplished using multiple exposures on original negative.) Compositing is the industry term for this process of joining image layers. The first all-digital composite performed by Industrial Light and Magic occurred in Indiana Jones and the Last Crusade (1989) during a scene showing the destruction of the Nazi villain Donovan, whose corpse shrivels, desiccates, and collapses into a heap of ash. Director Steven Spielberg didn’t want to do the scene in the usual manner by cutting away from an actor as makeup changes are applied. “I didn’t want to do a series of cutaways so the actor could be advanced in make-up. We’ve all seen that, and I think people have a high level of expectation with these movies.” As in Jurassic Park, he wanted to offer viewers a different kind of aesthetic. The camera, therefore, holds on Donovan as he crumbles away, and the effect was achieved using three animatronic puppet heads, each more decayed than the other. They were shot as bluescreen elements and blended using morphs, and all the main elements were digitally composited. Morphs had been introduced on Willow (1988) as a technique involving digital image blends, used in that film to depict a character who transforms from goat, ostrich, and turtle to tiger and then to human form. (A morph is produced by warping two images, such as a goat and an ostrich, so that pre-selected major features in each image become graphically similar. The computer then calculates the intermediate stages of transformation that will take each image through a sequence to its final warped state, reverses the sequencing for the second image and adds a
dissolve to connect them.) But even though Willow employed morphs, the film's effects shots were finished as optical composites, one sign of the movie's transitional status. Disney was the first studio to move toward all-digital compositing. In 1989, Disney began converting traditional cel animation to an electronic format called CAPS—Computer Animation Production System—and did an all-digital composite on The Rescuers Down Under, continuing with the animated features Beauty and the Beast (1990), Aladdin (1991), and The Lion King (1993).

Prior to the digital era, compositing was performed optically. Digital methods soon put the optical printer into mothballs. (Like the veneration for vinyl records often felt by audiophiles, however, some film-based experimental filmmakers remain devoted to the optical printer for its ability to produce traditional kinds of effects.) For generations, optical printers had served as the workhorses of studio effects departments. They featured an interlocked process camera and a process projector known as the printer head. Master positive footage of effects elements—models, traveling mattes, animation—were loaded into the printer head and run through and photographed frame by frame by the process camera. (A process camera is one used in the laboratory for effects work, in distinction to a production camera used to film live action.) The final composite (the finished effects shot) was gradually created by this process of rephotographing each of its components. The composite negative would have to be rewound in the process camera so that each component could be photographed. Thus an optically printed effects shot yields a dupe negative, a copy of a copy. The more elements an effects shot contained, the more elaborate this process became. Two- and four-head optical printers enabled the photographing of multiple image elements in one pass, speeding the work of compositing. Linwood Dunn, who became head of RKO's photographic effects department, designed the Acme-Dunn Special Effects Optical Printer, which was widely used throughout the studio era. In 1934 he published an article in American Cinematographer in which he claimed that “during the past four or five years there has not been a single production released that did not utilize the services of the optical printer to a considerable extent.”

Dunn gave photographic examples of numerous editing transitions created on optical printers as well as examples of using the printer to alter scenes so as to modify, correct, or extend their shots. “Almost anything in the broad spectrum of modifying a filmed scene can be done.” Dunn estimated that at least 50 percent of Citizen Kane had been optically printed. The shot where Kane appears as a tiny figure framed in a distant doorway at Xanadu after his wife Susan leaves him was composited from three elements.

Kane appears as the background element, achieved as a miniature rear projection. The midground area depicting the hallway is a matte painting, and the foreground elements—an open door and doorframe—were photographed from physical props. Dunn composited these image elements on the optical printer. It’s worth noting that the matte painting included Kane’s reflection on a tiled floor, and, as we will see, digital compositing offers numerous opportunities to create lighting effects that can tie image elements together.

Optical printers could create the impression of camera movement by moving the printer head toward the camera. Swinging the printer head sideways past the camera created a curtain wipe in which one moving image appears to push another off screen. Dunn used both techniques to extend camera moves in *Citizen Kane*. In the scene introducing Susan Alexander, the camera makes an elaborate move across the roof of the nightclub set (a miniature model) and through its sign (a breakaway prop), then descends toward the skylight and appears to move through the skylight and continue via a crane down to the floor below. Dunn subliminally connected the two camera moves (one on the rooftop set, the other inside the club) by moving the printer head to create optical zooms on the tail of the first shot and the head of the second and then hid the cut by creating the impression of a lightning flash. In the scene set in the Thatcher Library, an apparently unbroken camera move travels from the bust of Thatcher (a miniature model) to an inscription on its pedestal (a set), and then to a wide framing of the reporter Thompson speaking with the librarian. The miniature of Thatcher had not been filmed, and Welles decided he wanted it in the shot. Dunn supplied it and the camera move that connected it to the scene. He said, “I had a statue made—about two feet high . . . and I made a straight shot of it, and on the optical printer I made a motorised pan-down from it. Then I made a pan from the scene with the girl and I matched [the two] with a travelling split-screen.”

I have described the contribution of optical compositing to *Citizen Kane* in some detail in order to make the point that filmmakers routinely practice an art of elegant misdirection. The screen worlds that viewers watch tend to be constructed domains. This point can be illustrated clearly with regard to traveling mattes, a fundamental visual effects technique that digital methods have greatly facilitated. Achieved on the optical printer, traveling mattes enabled filmmakers to insert a moving foreground element over a background set, such as Superman flying over New York City. The process involved printing the foreground and background elements with a matte and counter-matte (so-called male and female mattes) in order to prevent a double-exposure
that would show Superman as transparent with the city visible through him. A matte prevents this by allowing exposure in one area of the frame while blocking it in others. The male matte (aka a hold-out matte) is a length of film with an opaque area in the shape of the foreground element and is transparent everywhere else. The female matte is the reverse—transparent foreground element, all else opaque. The effect would be created on the optical printer by printing the background element with the male matte to create a shot on the composited negative of the background element (the city) with an unexposed hole corresponding to the foreground element (Superman, in this case) that will be inserted. Then the film in the process camera is rewound and the foreground element is printed with the female matte. This inserts our flying Superman onto the background and prevents additional light from hitting the background, which had been exposed on the negative during the first printing pass.

Numerous methods evolved for extracting the matted elements, most of which involved photographing the foreground action against colored screens and then printing the footage with filters or as high-contrast black and white images to generate the male and female mattes. But matting artifacts—black outlines or colored haloes around the foreground element—tended to detract from the final result, and the capability for staging action in depth was quite limited. Cameras were kept locked down to minimize problems of image registration during printing. Moreover, complex shots, like those in *Star Wars* (1977), required printing hundreds of elements, which tended to wear down the dupe negative in the printer from the stresses of running it backward and forward. Richard Edlund, who helped create the effects on *Star Wars* and *The Empire Strikes Back* (1980) and who designed sophisticated optical printers, noted that the optical approach was fundamentally flawed because too many variables affected it. “The quality of the chemical bath being used by the lab to develop film that day, voltage changes, weakening lamps, fading filters, and on and on and on. There are just so many variables that even with the best equipment in the world, a good optical composite relied partly on science and skill, and a little bit on good luck.” John Knoll, one of the creators of Photoshop and an ILM visual effects supervisor, said, “Some of these elements would just eventually wear out, and any problems with the B.C. [the ‘black center’ produced by the holdout matte] would be immediately evident. You thread them up through the optical printer enough times [that] they start getting scratches or other problems. In an optical composite if there’s some flaw, and if the shot is ninety percent of the way there, there’s not much you can do.” By contrast, if the image is digitized, “it’s putty in your hands, and you can do anything you want with it.”
Linwood Dunn wrote that Welles used the optical printer like a “paint brush,” and Dunn looked forward to the day when “the Electronic Optical Printer” would offer filmmakers an even greater range of creativity. Digital compositing is Dunn’s Electronic Optical Printer, and the tools it furnishes have enabled filmmakers to actually become painters; the metaphor is no longer a poetic fancy.

Digital Compositing

Just as they have been in earlier periods, films today are an amalgamation of miniature models, matte paintings, and live action, but the digital compositing of these elements alleviates many problems that were inherent in the photochemical methods of the optical printer. Rather than using light to blend image layers by continuously rephotographing them—and thereby introducing problems of excessive grain, resolution loss, and physical damage to the image surface occasioned by running celluloid through a machine—digital compositing works by numerically transforming data according to mathematical functions called operators. A compositor has many operators available for blending image elements, which include add, subtract, multiply, and so forth. Inserting a matted object into a background merely involves adding or multiplying relevant pixels in the image sequences and introduces no visual degradation, unlike the optical printer. Creating mattes is much easier, as is blending the lighting and color values of the layered elements.

Moreover, a digital compositor can work selectively on image layers, enabling greater precision and much finer manipulation and control of the shot. Multipass compositing proceeds by rendering image layers in separate passes or operations. (Multipass compositing existed in the analog domain as well. Return of the Jedi [1983] was optically printed, and some of its elaborate battle scenes included more than one hundred image elements, rendered as separate passes.) Digital multipass compositing offers dramatically enhanced artistic tools. These include image channels that can be manipulated separately, such as the alpha channel (specifying pixel transparency and used for generating mattes) and the Z-depth channel, which is in grayscale and specifies where image objects are along the Z-axis. The brighter a pixel in this channel, the farther away it is from the camera. By using brightness to measure distance, the Z-channel furnishes a depth map of the shot, which can be used for 3D matte effects, enabling complex interactions amongst matted objects. A squadron of CGI jets, for example, can fly with individual planes passing in front of and behind mountains or buildings, which themselves are matted CGI objects. Z-depth matting overcomes the planar representation of
space that often afflicted traditional optical compositing, and it also furnishes
an effective means of establishing depth of field in a computer-generated
shot. Other passes in a multipass composite will operate on layers containing
lighting information. A beauty pass will build the CGI object with its greatest
level of color and detail. A diffuse pass renders the diffuse light in the scene,
which reflects evenly from objects according to their orientation toward the
light sources. An ambient pass builds the ambient light in the environment,
and an “ambient occlusion” pass is useful for generating soft shadows. A
specular pass establishes the positioning and size of reflected highlights.

In Spider-Man 2 (2004), for example, the fight scene on the elevated train
between Spider-Man and the villain Doc Ock was composed using separate
renders of all elements—the city background, buildings and train tracks, the
train, and the characters. The compositor consulted with the cinematogra-
pher on lighting and color preferences and used beauty and multiple lighting
passes to control reflections, highlights, and shadows within the scene. Reflec-
tions on the shiny train surface of passing buildings and of Spidey and Doc
Ock were added as separate elements and then subjected to a diffusion pass to
blur them and to a “dirt pass” to dull them down by adding a layer of grime
to the outside of the train. A reflective occlusion pass served to block building
reflections when the characters, fighting outside the train, come between it
and the surrounding buildings. A matte pass used the RGB channels in the
image to apply selective color corrections. The red channel, for example,
served to isolate the train wheels. Z-depth passes created depth of field by
blurring distant elements, such as the furthermost end of the train. Changes
in camera exposure were added in relation to virtual camera moves relative
to the light source. Grain and lens distortion were also added to blend shots
across the sequence. 15

Although the fight scene in Spider-Man 2 is mainly CGI, digital compos-
iting also offers great flexibility in handling live-action elements. In Peter
Jackson’s King Kong (2005), a major climax occurs when Kong saves Ann
Darrow (Naomi Watts) from a hungry Tyrannosaurus Rex. The scene takes
place in a rocky clearing with mountains in the distance. Its elements were
composed of Watts as the live-action element filmed against bluescreen, Kong
and the T-Rex as CG elements, CG foliage in the foreground, and a digital
matte painting representing the distant mountains. When Watts was shot on
bluescreen, the CG characters and environment had not yet been built, and
the lighting on Watts failed to match what was subsequently created for the
CG elements. Watts looked flat when placed against the high-contrast lighting
on the CG creatures. This disparity undermined the representational realism
the sequence required and provided a clear tell for viewers about the scene’s

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artificial construction. The solution was to relight Watts as a digital figure. Matchmoving, a procedure that maps the movement of live action and a live camera to a computer-modeled environment, generated a digital replication of Watts as Ann Darrow. This was relit using a normals pass, which employs surface normals—vectors perpendicular to the surfaces of an object (in this case, the digital figure of Ann)—to analyze the light distribution in a scene. The illumination of the surface normals tells the compositor how light will be distributed across the surface of the object. Based on this information, reflection mattes and ambient occlusion mattes were used to increase the lighting on Watts’s key side and lower it in her shadowed areas. The result was a convincing distribution of light throughout the scene. The digital relighting of Naomi Watts created a subliminal join of live action and computer elements. Based on the visible evidence in the lighting, Ann Darrow became an organic part of the scene’s action.  

As this example indicates, a great deal of the work performed in compositing involves lighting and color, which traditionally has been the domain of the cinematographer on a production. Digital compositing and the use of digital intermediates have reconfigured the professional role of cinematographers. Cinematographers and directors, along with visual effects supervisors and digital compositors, now work together to create lighting (along with other camera variables, such as movement and composition), and the process spans production and post-production. Before examining this change in detail with regard to the use of digital intermediates, let’s spend a bit more time looking at the nature of digital lighting in a computer-generated world.

Lighting Naomi Watts in post-production during compositing enabled a more convincing blend of the actress with the scene’s matte paintings, miniature models, and digital creatures. King Kong (2005, Universal Pictures). Frame enlargement.
Digital Lighting

A digital lighting design can be achieved using local or global illumination methods. Using a local illumination approach, a visual effects artist works with the same categories of light as a real cinematographer. Key lights, back lights, fill and rim lights are created and positioned in virtual space, and their levels and spread must be defined in relation to the surface textures and objects in the scene. Creating local illumination is a labor-intensive process. Global illumination algorithms, in contrast, will calculate the inter-reflections of light between and across surfaces in an environment and do not require setting individual light sources. Much digital lighting in cinema is now accomplished as global illumination.

The digital realm affords many opportunities for cheating the behavior of light and shadow in ways that real-world cinematography has a harder time accommodating. Orange firelight would have made the blue-skinned Na’vi in Avatar (2009) look gray, an undesirable outcome, so the filmmakers decided to implement a policy they called “spectral compensation,” in effect ignoring the interaction of orange and blue light in this context. Digital lighting designs are found in environments that are all CGI, such as WALL-E (2008), Up (2009), and other animated films by Pixar, and in situations where CG objects are added to live-action scenes or vice versa. In most cases, the digital design strives to emulate the physical behavior of light in a perceptually convincing manner, unless a more dramatically satisfying cheat is required. As visual effects researcher Paul Debevec recognized, “This difficult task requires that the objects be lit consistently with the surfaces in their vicinity, and that the interplay of light between the objects and their surroundings be properly simulated. Specifically, the objects should cast shadows, appear in reflections, and refract, focus, and emit light just as real objects would.”

Accomplishing this is a challenging task because light and color interact with the environment in variegated ways. Marcel Minnaert’s classic study, Light and Color in the Outdoors, demonstrates the physics of light under many different environmental conditions, which include reflection, refraction, diffusion, contrast phenomena, halos, coronas, curvature effects produced by the atmosphere, and the luminous properties of plants and animals. The variety of environmental lighting effects produced in nature has generated volumes of research by the computer graphics community on how to replicate this information in ways that are economical and efficient. Many of the scholarly papers presented at SIGGRAPH deal with methods of modeling light and representing reflections and shadows. Ray tracing, for example, has been an effective and widely used approach that is useful for representing
specular highlights and hard-edged shadows. The method traces rays of light from the virtual camera to objects in the scene and follows the ray’s path from the object to a light source, noting whether it bounces off other objects along the way. Pixar used ray tracing extensively in Cars (2006) to model the shiny exteriors of the cartoon automobiles and their finely detailed, reflective geometry.

Ray tracing, however, is not very good at emulating soft-edged shadows, which show a gradual transition between light and dark, or at capturing the ambient light that diffuses throughout an environment. Moreover, the needs of many scenes go beyond what fixed, point-source lighting can provide. Global illumination models can emulate point-source lighting as well as diffuse and ambient effects. Global illumination deals with the reflected and transmitted light on all surfaces in a scene. Many complex CG environments—the streets of 1930s New York, for example, as rendered in Peter Jackson’s King Kong, dense with vehicles, store signage, and pedestrians—must convincingly depict situations where there may be too many light sources to make it feasible to set up individual virtual lights or to ray-trace illumination paths. To model global illumination in such cases, environmental maps are used to calculate the global behavior of light. If the scene features live action and incorporates CG effects, a reflection ball can be photographed on location to provide a lighting reference useful in re-creating the scene’s visual parameters in a CG environment. (I say more about the use of reflection balls in chapter 5 in the context of high dynamic range images.) The information on its reflective surface can be unwrapped to produce an environment map of reflected light distribution throughout the scene, and this can be used to model the computer objects that will be added to the scene. ILM refined this approach to include methods of occluding unwanted reflections and of modeling ambient light. The approach was developed for Pearl Harbor (2001) and quickly gained currency in the computer graphics world. ILM’s “ambient environment” method included two components—creation of ambient light sources and of ambient occlusion, the soft-edged shadow effects produced from the distribution of ambient light. As an ILM artist explained, “It’s . . . necessary to provide shadowing from the surrounding [live action] lighting environment. Points not fully exposed to the environment need to be attenuated properly. This process is known as ‘Ambient Occlusion.’” ILM’s ambient environmental lighting proved to be fast and efficient. The scene in Pearl Harbor showing B-25 bombers on the Doolittle raid taking off from an aircraft carrier was a live action–CG blend. The CG portion used only a key light and global illumination derived from the environmental map. An ILM
effects artist noted, “Not every shot goes this smoothly but it is a testament to the ease of using this simple but effective lighting setup.”

Other kinds of environmental maps used to calculate light distribution include texture maps wrapped around scene geometry and that are designed to capture light and shadow information. Shadow mapping, for example, is a method for calculating hard and soft shadows and point-source shadowing. Occlusion Interval Maps, similarly, use texture mapping to create intervals that show when a light source is visible and when it is occluded. Z-depth mapping can also provide a useful approach for calculating shadow distribution.

**Lighting Food in *Ratatouille***

Pixar’s animated film about a gourmet rat working as a master chef in a high-class restaurant had many scenes showing delicious food being prepared in the kitchen and served to guests. Successfully visualizing the properties of good food required that the digital animation seem real, that is, it had to correspond with the finely tuned physiology of the human food response. As the film’s visual effects artists noted, “We as humans have a built-in sensory system to know what looks right to our eyes and stomach, and finding that acceptable (and tasty) look was the main focus” of the film’s food lighting. Proper lighting and coloring provided a means for cuing a viewer’s physiological food responses, and the filmmakers determined that good food appeal depended on carefully visualizing the factors of softness, reflection, and saturation. “Food needs to be colorful as this indicates ripeness or freshness. The surface should appear wet, dry, waxy or soft as appropriate. These things are visual cues of its taste, texture and feel. A fleshy or translucent appearance is essential for certain foods. It lets you know how ripe or juicy the food is.” Subsurface scattering provided an essential means of evoking a fleshy or translucent appearance. This technique, used in *The Lord of the Rings* movies to make Gollum’s skin look naturalistic, deals with the way that light penetrates below the surface of an object, is scattered, and then exits in a different location than its point of entry. This shading technique was applied to soft and translucent foods like scallops and grapes. The latter were given a very naturalistic appearance through a careful control of scatter, diffusion, color shifting, and specular highlights. “We used tinting of scatter (with warmth), lightly patterned surface diffuse color, and allowing more translucency to dominate over the diffuse. Each grape was offset individually from the bunch by a random color shift in hue and value. We also used a very subtle diffuse blur, and a sharp reflection.” All these elements enabled the lighting to create
"an appealing image.\textsuperscript{27} With regard to denser foods like cheeses or meats, blurring their diffuse light gave them an appropriately fleshy look, and taking the diffuse blur on cheeses to the point where details were lost contributed the right kind of waxy look.

Soft lighting made the food look appealing, even if it meant cheating the physics of the source lighting. "We always made sure that light fell on food at an angle that best revealed the broken texture of bread or the smooth sheen of sliced tomatoes, even if that meant diverging somewhat from what the rest of the set lights are doing."\textsuperscript{28} In a scene, for example, where a wedge of cheese sits beside several thin slices, the key light on the cheese should create more subsurface scatter in the thin slices, but the animator might decide that the shot’s aesthetic appeal demanded that more scatter appear in the large wedge relative to the slices. The Pixar artists designed a new type of light, which they called Gummi light after the fishes from \textit{Finding Nemo} (2003). This light conveys directional transmission through an object rather than by scattering. It was used to visualize translucent objects like a glass of wine and depicted the differential absorption of varying wavelengths as light passes through the object. It complimented subsurface scattering and added color complexity and shape to areas shadowed by a key light. The ability to cheat source lighting or to invent a wholly new kind of light points to a difference between digital lighting and cinematography that is performed with real lights. A real-world cinematographer is more constrained by the physics of light. To serve an aesthetic goal, its properties can be manipulated but not altered, as can a CG lighting scheme in which shadows or light diffusion may be cheated. In a CG environment, the objectives of an aesthetic design can nudge out the physics of actual light behavior. In this respect, the Pixar artists maintained

Throughout \textit{Ratatouille} (2007, Pixar), digital lighting establishes the physical properties of food, making it look good enough to eat. Frame enlargement.
that they were not going for photorealism in lighting and texturing the film's food because that would be distracting from the stylized world of the story. They wanted to bring viewers into that stylized world, where rats can cook and talk, a world that was not photorealistic but which needed to accommodate the recognizably real properties of appealing foods. Visual effects achieved through digital lighting served the twin goals of advancing the film's stylized fantasy and evoking the sensual properties of food in ways that were visibly true for the viewer. Photorealism is often not the goal of digital aesthetics—careful cheats in the interests of style and tone are often more important than the simulation of camera or lighting reality. We will see in the next chapter that a temperate and skeptical attitude toward photorealism by effects artists plays a major role in the aesthetics of digital performance.

The Digital Intermediate

Digital lighting effects are not confined to computer-generated environments. The ability to digitally alter light and color in movies that were shot on film using real actors and locations offered cinematographers an exciting and daunting expansion of their creative horizons. It made lighting more like painting than it had ever been. Cinematographer John Alton published a book on the art and craft of cinematography in 1949 entitled Painting with Light. Alton was one of Hollywood's most expressive and radical cinematographers, pushing shadows, depth of field, and single-source lighting to extremes that most of his peers didn't attempt. But expressive as his work is, his analogy of cinematography with painting was mainly a metaphor. A cinematographer creates color by working with real light; a painter does not. The painter creates color by applying pigments to a surface. Color in film is subtractive; color in painting is additive. And once shooting wrapped, a cinematographer had minimal ability to adjust and correct color in post-production. The painter can endlessly tweak and fiddle with color schemes. Cinematography as it traditionally existed was an image-creation process. The image was created and defined largely according to the decisions made during production, such as the manner in which costumes and sets were lit or the imaging characteristics of the particular stock of film on which the movie was shot. After the production phase ended, abilities to intervene and modify the existing images were highly constrained.

Scanning celluloid to a digital file has helped to alleviate these constraints. It enabled cinematographers and directors to alter colors and other image elements by working directly on the hues of pixels in what was now an additive color system in place of the subtractive system that film employed. And
they now had a painter's fine control over minute image elements. What had been an image-creation process was now an image-capture process because many of the creative decisions about cinematic image definition shifted to post-production. And by expanding the capabilities of digitally manipulating photographic images, these changes made digital visual effects, broadly defined, coextensive with all of filmmaking. Digital visual effects were not the exclusive province of dinosaurs and other fantasy creatures and domains. They now could exist everywhere.

During most of the 1990s, movies originated on film and stayed there. Digital effects were created in the computer and then were scanned to film to be integrated with existing sequences. The results were printed photochemically in the lab for distribution on celluloid to theaters. Commercial advertisers and music video producers at mid-decade were digitally manipulating colors and creating other effects, but they worked in short formats. When a completed film was transferred to videotape via telecine for distribution on home video, opportunities for color control arose that did not yet exist for filmmakers during production or post-production. The telecine operator could adjust primary color channels (red, blue, green) and make adjustments to overall brightness (gain), black levels (lift), and mid-tones (gamma). Limited secondary controls enabled some adjustments of specific colors independently of others.

Outside of telecine work for video, color correction in cinema had been an analog process and had remained unchanged for generations. The director and cinematographer would view an edited work print of the film with a color timer from the lab assigned to the project and would reach agreement about where colors needed to be shifted or modified, either for dramatic purposes or to maintain consistency and continuity across shots. The lab then generated a color-timed trial print using an intermediate negative (not the camera original) and Hazeltine printing lights. The printer used a beam splitter to divide white light into the three primaries, and timing occurred by adjusting the levels of red, green, and blue light as they printed the negative. Adding blue light, for instance, would make the print look more yellow (because the negative sees in reverse, the change occurs in the complementary color). Adding more red increases the cyan level in the print. Adjustments were made on a range of 1 to 50, with an interval of eight representing one full stop of light. Thus a mid-range balanced print, ideally, would have printing values of RGB 25–25–25, though a cinematographer might wish, for instance, to have a more yellowish cast to the image, in which case the RGB values might be 25–25–30. Overall print density could be increased by raising the RGB values equally, producing a darker image. In one sense, the method was
very precise. After viewing a trial print, a cinematographer who requested additional corrections might ask for two more points of red and would know exactly how this calibration would look. It would not depend on the color timer making a subjective judgment about how much red to add. The cinematographer thus retained control over color decisions, a prerogative that seemed less secure with digital timing because it lacked the Hazeltine’s objective scale for calibrating color.

On the other hand, however, the method was less precise. It offered little opportunity to fine-tune individual colors. A cinematographer color-timing a film print had fewer choices than when supervising a film-to-tape telecine where, as we have seen, individual colors might be corrected without altering the overall image. Hazeltine timing could adjust the color balance but not individual hues or selective parts of the image, a major limitation on the potential for cinematography to be like painting. Moreover, prints released to theaters were always several generations away from the original camera negative (OCN). Theatrical release prints were struck from internegatives that, in turn, had been made from an interpositive that was, in turn, derived from the OCN. The generational loss of visual information was compounded by the inherent differences between the responses of negative and positive film to light. Negative film has a more gradual light curve (known as the sensitometric curve), with a longer shoulder (registering highlights) and toe (registering shadows). Positive film (printed from negative) has less latitude—a more steeply sloped curve, with less gradation in the shoulder and toe. (Video has even less latitude and a stronger tendency for shoulder and toe to reach their limit and clip or lose information.) The significance of these differences is that a print viewed in theaters could never reproduce all the visual information that was contained in the negative. Information was always, inevitably, lost. The full range of information in the negative was inaccessible. Film images remained luminous and beautiful, but the medium also claimed a quality that was astonishing to contemplate in a digital era—its images were virtual, that is, as viewed they were simulacra of a more complete but inaccessible original. An original camera negative included image information that was unrecoverable by the traditional process of photochemical printing. (Ironically, scanning that negative to a digital file enables the recovery of information that photochemical printing cannot extract.) As a Kodak image scientist expressed it, “The purpose of the negative is to capture a virtual scene, but there is no practical way to reproduce those same luminance ratios.”

Virtuality, it turns out, is not a claim uniquely made by digital media. The photochemical heritage of cinema had always retained this characteristic.
The digital intermediate offered a new approach to color timing. By scanning film to a digital file, color timing and numerous other image corrections could be performed electronically and with greater precision and nuance than by using traditional one-light printing. As noted above, Disney was an early innovator in using a computerized scanning system to transfer animation drawings to a digital format where they could be painted and where multi-plane camerawork could be created electronically. *The Rescuers Down Under* (1990) was the first animated feature to undergo this transition and to be digitally composited. In 1993 Disney used Kodak’s new Cineon system to scan *Snow White and the Seven Dwarfs* (1937) at 4K resolution (4096 x 3072 pixels) so that the film could be digitally restored for a new release. In 1989 Kodak had begun researching a means of porting film into an electronic world, which it provisionally termed an Electronic Intermediate System, featuring a 2–4K scanner, a laser recorder for outputting to film, and a software file format for storing the data. In 1993 Kodak introduced the Cineon system, which Disney used on *Snow White*, and the ability to scan film at high resolution quickly moved visual effects away from optical printing and made digital compositing the new norm. As Douglas Bankston notes, Cineon “caused a radical shift in the visual-effects industry. In just a few short years, the traditional, labor-intensive optical died out.”

In 1999 and 2000, *Pleasantville* and *O Brother, Where Art Thou?* marked the onset of the digital intermediate in Hollywood. “Digital intermediate” (DI) referred to the electronic interval in which image adjustments were made on digital files before all corrections were exported back to film for release printing. *Pleasantville* used the technique for special effects purposes. Gary Ross’s film portrays two teenagers, Jennifer and David (Reese Witherspoon and Tobey Maguire), who inexplicably find themselves trapped inside the black-and-white world of a 1950s-era television sitcom. As their presence changes the simplified moral world of the sitcom, the black-and-white world gradually transitions to color. Jennifer rebels against the constraints of the sitcom world, and her skin tones resume their normal appearance, leading to broader changes in Pleasantville. The sweater of a passing black-and-white coed glows a vibrant red. The town artist begins painting in color. An unsatisfied housewife (Joan Allen) begins to question the terms of her life, and she transitions to a color figure. The color changes symbolize social changes occurring in Pleasantville, as its denizens grapple with new gender and political issues that never before existed in its simplified television world.

Ross’s symbolic use of color to shift a fantasy world closer to reality could not have been accomplished via traditional film timing. Only a digital intermediate process enabled him to work selectively on individual colors. Thus
the entire film was shot in color, and the sequences set in the TV world of Pleasantville were scanned at 2K resolution (some 163,000 frames) so that color could be removed except for the isolated instances in which it would appear.31 In contrast, O Brother, Where Art Thou? did not use a digital intermediate for special effects purposes. The manipulations in DI were subtler. The use of DI on O Brother enabled the filmmakers to solve some very immediate and real problems. The directors, Joel and Ethan Coen, envisioned a dry, dusty look and one that resembled slightly faded, hand-tinted postcards, but the film was scheduled to shoot in Mississippi during the summer when the foliage would be wet, lush, and green. Cinematographer Roger Deakins explored traditional photochemical solutions, such as bleach-bypass, which retains silver in the positive print and has the effect of desaturating colors and reducing exposure latitude. While it would bring down color levels, bleach by-pass did not provide a means for controlling selective colors, such as the lush Mississippi greens that were going to be the main problem. No photochemical tool seemed equipped for the job. Deakins was aware of what had been accomplished on Pleasantville and, after running tests, he and the Coens agreed that the film would be digitally graded (color corrected). “Quite honestly,” he said, “it was the only way we could see of achieving the look that all three of us wanted.”32 He spent ten weeks digitally grading the film, and the changes were relatively modest. “We affected [sic] the greens and played with the overall saturation but little else. We only used windows, for instance, on a couple of shots.”33 By “windows,” Deakins is referring to power windows, a selecting and masking function that enables artists to work on one part of an image and leave the rest unchanged. Some cinematographers prefer to avoid extensive use of power windows, while others embrace such corrective measures. Peter Jackson, for example, used power windows to make extensive changes throughout The Lord of the Rings and King Kong, bringing up highlights in Naomi Watts’s eyes, for example, in Kong or changing a scene shot in a monochromatic tone to one with more color differentiation.

With a digital grade, cinematographers began making changes to their work that previously had been beyond consideration. When Jack Green shot the rainy climax of Clint Eastwood’s The Bridges of Madison County (1995), he wanted an overcast day but the weather didn’t cooperate. So the scene was shot at dusk, which required constant lighting changes to balance the actors’ faces against the diminishing background light. On Twister (1996), the storm scenes were shot in broad daylight, the actors brightly lit to provide background balance, and the images were printed down during Hazeltine timing to give them the darkness the story situations required.34 A digital grade can help to modify constraints imposed by weather or time
of day. On *King Kong*, Jackson routinely altered the color cast and density of scenes to suggest a particular time of day when the action was occurring. On *300* (2006), cinematographer Larry Fong shot numerous scenes under identical lighting at a mid-range color temperature and then in the digital grade warmed the color to suggest daylight or cooled it down to suggest dusk. He deliberately crushed all detail from the shadows and clipped the highlights in order to create the look of the Frank Miller graphic novel that was the film’s source.

Digital grading replaced custom laboratory processes. Clint Eastwood likes very dark shadows, and on *Mystic River* (2003) and *Million Dollar Baby* (2004) he had used the photochemical process of ENR to desaturate color and intensify the blacks. ENR deepens shadows and mutes colors by adding an extra development bath during the processing of a positive print. The extra bath redevelops the silver in the emulsion, adding density to shadow areas (where most of the image-retaining silver halides are clustered). Eastwood had never done a DI prior to *Flags of Our Fathers* (2006), and when cinematographer Tom Stern ran tests comparing ENR with comparable results achieved digitally, he and Eastwood resolved to go with a DI. It gave them more creative power than working photochemically. Because ENR is applied during the creation of a positive release print, the smallest increment in which it can be used is one lab reel (about 10 minutes of film), and it cannot be varied within that unit. In contrast, working digitally Stern could not only replicate the ENR look but could vary it dynamically within a shot, changing its intensity from one corner of the frame to another. Portraying the American landings on Iwo Jima in *World War II*, the film has a severely monochromatic, desaturated look that is part of its ENR aesthetic, but the look wasn’t achieved in the lab. Digital grading enabled Stern to modulate the film’s chromatic minimalism with assertive but subtle color manipulations achieved using power windows. “There’s a science to understanding where the eye will go first in a given composition. I wanted to enhance that effect by using power windows to lessen some of the contrast, or to really punch up other elements that would help control the audience’s eye.”35 To avoid key details from becoming washed out by the film’s black-and-white look, the digital grade retained color density in skin tones and in the blood erupting from soldiers hit by gunfire. The black of the beach sand was darkened to suggest Iwo’s volcanic soil. In the American flag raised over Mount Suribachi, the reds were subtly increased.

After doing a digital grade on *Flags of Our Fathers*, Eastwood never looked back to a photochemical finish. His next films—*Letters from Iwo Jima* (2006), *Changeling* (2008), *Gran Torino* (2008), *Invictus* (2009), and *Hereafter*
(2010)—used a DI finish, and he joined numerous filmmakers and cinematographers who found in digital grading an essential tool of image control. Vilmos Zsigmond, who had pushed cinematography in historically important directions with his flashed negative for Robert Altman’s McCabe and Mrs. Miller (1973), embraced digital grading after first trying it on Brian DePalma’s The Black Dahlia (2006), a 1940s-era film noir. “I realize now that if we hadn’t done a DI, I could not have done as good a job with the period look,” he said. “The DI gives us a lot of tools that allow us to do practically anything, and I don’t think I could do another movie without one.”

The magnitude of the changes instanced by the digital intermediate alienated some prominent cinematographers. John Bailey (Ordinary People [1980], In the Line of Fire [1993]), for example, warned that the industry’s widespread adoption of digital grading threatened to erode the cinematographer’s creative domain. As directors, stars, and studio executives work their way into the digital coloring suites, offering their own input into coloring, the cinematographer’s prerogatives would diminish. “I fear we cinematographers may have unwittingly begun to write our own epitaph on the subject of image control.” Bailey asserted that a photochemical finish yielded better-looking prints than did a 2K or 4K digital finish. While industry consensus supported the view that scanning in 2K entailed a loss of film resolution, not all of Bailey’s peers believed that such was the case in 4K. In a column countering Bailey’s criticisms, Roger Deakins wrote, “A print taken from a 4K master of a Super 35mm negative is surely superior in terms of resolution and saturation to one taken from an internegative of the same material.” While 2K scans were the norm in the early years of digital intermediates, at the time of this writing 4K scans have become the norm, and it is not unlikely that soon 6K will be the standard. (Baraka [1992] was given an 8K scan for Blu-ray release.)

Studios have embraced the DI because it economizes on the expenses incurred in post-production. When films are finished photochemically, a separate scan and color timing still have to be done for video and other ancillary markets. But a DI produces film and video masters at the same time, which is a cost savings for the studio. New Line told Bailey that he could have a photochemical finish on He’s Just Not That into You (2009) but then changed its mind. Colorist Stefan Sonnenfeld, who worked with Bailey on the film’s DI, pointed out, “There are too many ancillary deliverables these days that require digital manipulation to make a strictly photochemical finish practical... The good thing about the DI is that you control the look of all deliverables from end to end.” A photochemical finish falls outside this evolving workflow.
Another effect of the industry’s preference for the DI is an increased use of Super 35mm in production. Super 35 uses the full aperture of the 35mm negative frame, including the area normally masked for a sound track, and the image can then be formatted for release in a variety of aspect ratios. A “scope extraction,” for example, is commonly performed to produce a 2.35:1 image for theatrical release in anamorphic widescreen. James Cameron’s *Aliens* (1986) was shot in this manner. Before the DI, however, the scope extraction was accomplished with an optical printer, enlarging the image and anamorphically squeezing it to produce an internegative for release prints. This often resulted in increased grain, as can be seen in *Aliens*. With a DI, no optical printing is involved. The scope extraction is digitally scanned, the DI is performed, and the result is printed out to film with no generational loss of image quality. As a result, most Hollywood filmmakers working in widescreen have adopted Super 35 rather than shooting true anamorphic. Moreover, Super 35 uses spherical lenses that are faster, cheaper, and sharper than anamorphic lenses. In this regard, industry preference for the DI has helped shape the emergence of a new mode of widescreen filmmaking.

A key component of a digital grade is its subliminal character. Typically, viewers do not perceive image alterations performed in a DI as being changes to the image as photographed. It is doubtful, for example, that viewers of *The Proposition* (2005), an Australian western, thought that they were watching a visual effects film. They were, because a DI was used to stylize the color design, accentuating the beige tones of rocks, sand, and foliage in the desert landscapes and leaching most color out of the sky. Viewers of *The Duchess* (2008), starring Keira Knightley, might have thought they were viewing scenes as they had been photographed, inside sumptuous eighteenth-century historical mansions. Many of the mansions and grounds were real, but a narrative arc had been created in the lighting during the DI. As the film’s colorist explained, “There’s a curve to the lighting through this film—it changes as the story develops.” Georgina (Knightley) moves from idealism to disillusionment as she sees the coarseness and brutality of the world. “The lighting and the tones transition from brightness and color to a faded and colder tone at the end.” These are invisible digital effects. Viewers do not see them as they do dinosaurs and spaceships, objects that moviegoers know are instances of movie magic. As invisible effects, image changes achieved in a DI represent a category of digital imaging that is more extensive throughout modern cinema than the effects intended to be seen as special. As such, images emerging from the DI toolbox arguably exert a more pervasive influence on contemporary film than do the more obvious kinds of effects imagery. Although the latter is
Subtle alterations in color and lighting are employed throughout *The Duchess* (2008, Paramount Vantage) to create a character curve visualizing the changing fortunes of Georgiana (Keira Knightley). The digital intermediate facilitates filmmakers' abilities to establish a narrative arc through color changes. Frame enlargement.

what media reporters, movie critics, and scholars often focus on, the digital imaging capabilities examined in this chapter—digital compositing, digital film scanning and printing, the DI—have altered production methods and professional relationships, have changed cinematography to an image capture process, have made it more like painting, and have greatly enlarged the expressive capabilities of film artists.

But the magnitude of these changes has elicited a measure of suspicion and resistance not only amongst filmmakers but scholars as well. John Bailey's declaration that he “will shoot movies on film in the anamorphic format and finish on film as long as I am able” is a matter of record.41 Steven Spielberg, too, has said that he will shoot and edit on film as long as he can. Joe Fordham reports, "*Indy 4* VFX supervisor Pablo Helman told me that film was the first time Spielberg has agreed to use a D.I.—pretty remarkable when you realize how impressionistic some of Spielberg's films have been, working with [cinematographer] Janusz Kaminski on film negative."42 Scholars, too, have been nostalgic and have shown some resistance toward the digital intermediate. John Belton explored the changing aesthetics of color made possible by the DI and reached a pessimistic conclusion. He points out that *Pleasantville* changed the way that color/black-and-white hybrids, such as *The Wizard of Oz* (1939), had traditionally maintained a careful separation between chromatic and achromatic domains. Dorothy's Kansas is black-and-white (sepia, actually) while Oz is color, and the two are not intermixed as they are in *Pleasantville*. He writes that this aesthetic change is both a threat and
a violation. "Clearly, [digital] color manipulation poses a potential threat to our traditional understanding of chromatic and achromatic color systems and their creation of a credible narrative space." Pleasantville's combination of color and black-and-white in the same frame results in "violating the integrity of the image. The image is revealed as not whole, but made up of parts. Of pixels." His claims rest on a reading of André Bazin's famous essay "The Ontology of the Photographic Image," in which Bazin asserted that photographic images are uniquely credible because they have a spatial wholeness resulting from their existential connection to what was before the camera lens. Belton argues that digital images threaten "our traditional understanding of the photographic image as homogenous, as a whole constituted by the frame that groups its contents together." This is because digital images involve stages of manipulation that are potentially much greater than is the case with traditional photographs and, furthermore, because it is difficult for viewers to see the extent of such manipulation. "To cast this in the language of motion-picture technology, photochemical imaging practices necessarily treat the image as a whole; digital-imaging practices necessarily treat the image differently." We will encounter numerous versions of this argument as we move forward here.

It is true that digital compositing enables visual effects artists to manipulate and control many more image layers and elements than is possible when working with celluloid on an optical printer. As well, the DI facilitates global as well as selective kinds of image changes. Without question, digital tools have expanded the array of creative choices available to filmmakers. The difficulty, however, in claiming that digital undermines the photochemical integrity that cinema once possessed, and in using Bazin's discussion of photographs to make this case, is that photographs are not at issue. It is difficult to see where this photochemical integrity might be found in cinema. Moving images arranged in sequences to tell stories are not a photograph. Bazin's claims about the nature of photographic truth do not easily generalize to a medium that assembles an array of ever-changing images in order to provoke motion perception. Even if we grant Bazin the validity of his claims, he overlooks the rich tradition of composite photographs and of darkroom practices such as dodging and burning that use masks to selectively lighten or darken discrete areas of the image. These practices are not qualitatively different from anything that may be accomplished digitally. Because he neglects this tradition, Bazin at times made erroneous claims about aesthetics. As I noted earlier, some of Citizen Kane's deep-focus effects were achieved using mattes and optical printing. The famous shot of Kane bursting into Susan's bedroom after she attempts suicide gives us an apparently deep-focus composition, with Kane in the doorway in
the far background. Susan on the bed in midground, and a drinking glass, spoon, and medicine bottle looming in the extreme foreground. The shot was an in-camera composite that matted the foreground elements to the separately filmed midground and background. As Robert Carringer perceptively writes, "Bazin's point is valid, but his underlying premise was wrong: The shot reveals Welles not as a photographic realist but as a master illusionist."

The stylistics of cinema do not favor homogenous image spaces, nor have most filmmakers treated images as whole units. Quite the contrary. Cinema is a history of techniques for creating synthetic images, for duping, matting, masking, compounding, and kaleidoscoping camera reality. In-camera mattes, traveling mattes, matte paintings, glass shots, Schufftan shots, rear projection, front projection, composite process projection, the Zoionic technique, rotoscoping, stop motion, Go-Motion, miniature models, hanging foreground miniatures, makeup, pyrotechnics, and optical printing are commonly used methods of counterfeiting what was before the camera. These pre-digital methodologies proliferated throughout the early history of cinema. In many cases, viewers did not perceive them as manipulations of physical reality. The hanging miniature set extension used for the chariot race arena in *Ben-Hur* (1925) creates a perfect illusion of unbroken space, as do the matte painting set extensions used in *Gone with the Wind* (1939). Effects images produced using these techniques are not rare instances; they are commonly found in nearly all films of the pre-digital era (especially if optical printing alone is considered). It is difficult to see how digital technology changes any of this, apart from the ways enumerated in this chapter, namely, in an expansion of creative possibilities. Cinema remains now what it always has been, a synthesis of discrete elements that collectively simulate the representational space of a depicted world. Writing in 1929, Fred Seres, who headed the art department at the William Fox Studio, pointed out the ways that matte shots enabled filmmakers to draw closer to their artistic visions. Seres described numerous methods for combining sets, miniatures, actors, and painted elements. He declared, "The use of a matte enables a cameraman to make the picture he visualizes. He is no longer limited by the size of the set, poor light, etc. It makes it possible for him to create and carry out the ideas he has for the enrichment of the production." Little of this has changed in the digital era.

**Digital Image Capture**

After Thomas Vinterberg shot *The Celebration* (1998) according to Dogme aesthetics on digital video, numerous filmmakers began exploring and using digital image capture as the principal method of film production. George
Lucas filmed *Star Wars II: Attack of the Clones* (2002) using Sony’s CineAlta HDW-F900, shooting 24p with a resolution of 1920 x 1080 pixels. Brad Anderson had used the CineAlta a year earlier on the low-budget horror film *Session 9* (2001). John Bailey used standard-definition cameras to shoot *The Anniversary Party* (2001), as did Zacharias Kunuk on *Atanarjuat: The Fast Runner* (2001). In a few years, Lucas had been joined by Michael Mann, David Fincher, and others attracted to the different look created by digital video relative to film and to the benefits offered by the format during production.

Two important differences offered by digital video formats relative to film were the ability of video to see into shadows and its hyper-clarity, which could make colors pop and create an almost three-dimensional look on screen. John Bailey was struck by the different way that video handled the toe of the light curve. After shooting *The Anniversary Party*, he remarked, “It’s my feeling that video tends to fall off more slowly than film in the shadow end. . . . I think that the inherent greater latitude in film is at the high end [i.e., highlights], rather than in the dark areas.” Michael Mann was especially impressed with this characteristic and chose to shoot *Collateral* (2004) on HD for night-exterior scenes while using film mostly for interiors. The movie, about a hit man (Tom Cruise) who recruits a Los Angeles taxi driver (Jamie Foxx) to ferry him from killing to killing, was shot on location in the city, and the HD format enabled Mann and his cinematographer to view the night as if it had a kind of glowing illumination. As the cinematographer remarked, “We were able to shoot Los Angeles at night and actually see silhouettes of palm trees against the night sky, which was very exciting.” The movie is a modern film noir, but its vision of the city at night is starkly different from that established by classic noirs such as *The Big Combo* (1955) or *Chinatown* (1974), where blacks are rich, deep, and dark. Black areas in the night exteriors of *Collateral* are gray and semi-transparent, turning the night into a kind of milky film that hangs over the city. Darkness does not conceal and hide as it does in traditional noirs, nor establish a sense of menace or mystery. Night becomes twilight in *Collateral*, a light-toned dusk, a translucent screen rather than a cloak. The look is strikingly different and not always pleasing. Mann and cinematographer Dion Beebe frequently had to boost the gain on their Thomson Viper Filmstream cameras, which brightened the image by raising its black levels. At times this introduced considerable noise into the image. Noise is the video equivalent of film grain, an artifact of electronically processed images, and its visible presence makes some of the night exteriors in the film look coarse and harsh. They tolerated its presence in the urban backgrounds but found it too distracting in close-ups of Cruise and Foxx during scenes taking place in the taxicab. Video has less exposure latitude than film, which can comfortably
handle more stops of light. Mann and Beebe found that shooting a mere 1½ stops below mid-range produced close-ups of Cruise and Foxx that were too noisy. To eliminate the noise, they overlit the actors and then, in the DI, used power windows to bring the light levels on them back down, creating the proper look of a cab interior at night.

Beebe and Mann had to contend with the noise problem when they collaborated again on Miami Vice (2006), shooting virtually all of that film on HD using Thomson Vipers. This time they brought the exposure levels up approximately one stop to minimize noise but found that holding the highlights—bright exteriors and skies—and keeping them from blowing out constrained many of their choices. They decided to expose for the highlights and then overweight interiors to bring them into balance. Shooting on film would have enabled up to a four-stop difference between a bright exterior and a key-lit actor indoors. HD video gave them 1–2 stops, a far narrower range, requiring the cinematographer to carefully study the exposure monitor.

This is a key change that digital video formats have introduced into cinema. Shooting on film, a cinematographer relies on a light meter to calculate exposure. This makes the cinematographer into a kind of alchemist, according to Uta Briesewitz, who has shot on film and video. Based on light meter readings in the traditional film world, the cinematographer knows how things will look; no one else does. “The director sees the set and says, ‘This is what it’s going to look like?’, and the cinematographer will say, ‘Wait till you see it on film.’ And it’s magic.” Cinematographers shooting on video don’t use light meters; they consult a waveform monitor that displays the amplitude of the video signal and indicates where highlights and shadows are clipping or losing information. They can also view the scene displayed as a video image. As can others. Briesewitz notes, “Anyone can gather around the monitor and make an opinion known. That’s a very different dynamic, for a cinematographer in particular.” While this dynamic may pose issues of creative control depending on personnel, most filmmakers desire to have the ability to view their images in real time. As David Fincher said, “I will trade four or five stops of high-end shoulder exposure for the ability to have a 25” HD monitor that allows me” to view footage without delay.

In spite of efforts to control highlights, numerous exterior scenes in Miami Vice feature blown-out clouds and skies, lending a harsh look to landscapes that film could comfortably handle. But Mann liked the abilities of HD to see into the shadows, even though efforts to control the highlights meant that the blacks on this film would be deeper and darker than those in Collateral. As a result, the night scenes have a more traditional appearance than the slightly surreal look attained in the earlier film. Mann continued his usage of HD...
video, collaborating with cinematographer Dante Spinotti on *Public Enemies* (2009), aiming again to illuminate shadows and night exteriors and making considerable image adjustments electronically on set. This was another advantage that Mann felt HD gave him. The Thomson Viper and other top-line video cameras enable filmmakers to shoot in uncompressed RAW files. Thomson’s FilmStream mode captures HD images in RAW mode, meaning that the camera applies no image-processing software, then down-converts image data to a 10-bit logarithmic format for storage. A log-encoded image looks very different from a normal RGB video image. It resembles the image on a frame of developed film negative—it looks gray and flat and has minimal contrast. Like printing a positive image from a film negative, processing a log-encoded image produces the desired levels of brightness, contrast, and color saturation. A cinematographer on set viewing footage as log images on a monitor sees scenes that look very flat and sometimes have an off-color cast. Because this can be disconcerting, Mann chose on his HD films not to work in RAW format but to use the camera’s image processing software, the Viper’s VideoStream mode, which compresses the image data but enables the filmmaker instantly to adjust color, contrast, and other basic image variables. This is a huge change relative to the film world, where filmmakers have lacked the ability to view final image characteristics in real time, and it can help solve problems. On *Collateral*, for example, the wide range of exterior lighting in Los Angeles created potential difficulties for a location shoot. As Beebe noted, “L.A. has a lot of mixed color at night—sodium vapors, mercury vapors, tungsten light, neon and fluorescents—and when mixed together within a frame, they often created an image that Michael thought looked too ‘fruity’ and detracted from the mood of the scene.”52 Using the image monitors, Mann adjusted the color levels the camera was capturing, alleviating the “fruit-bowl” problem.

The Viper—like the Panavision Genesis and the Red One—is a “data camera” because it enables filmmakers to capture images in an unprocessed, uncompressed mode, the idea being to save all image processing for post-production (though filmmakers like Mann may choose not to do this). These cameras operate like computers: they crunch huge amounts of data, require a process of rebooting after they are shut down, and get regular software and hardware updates. When Steven Soderbergh used the Red One to shoot *Che* (2008), the camera was an early-generation build; at the time of this writing it has gone through more than twenty upgrades. Using the Viper in VideoStream format, as Mann did on *Collateral* and *Miami Vice*, defeats the purpose of a data camera. Cinematographer Newton Thomas Sigel used the Genesis on *Superman Returns* (2006) and learned to mentally translate what
the somewhat flat image in RAW mode would look like when fully processed in its final form. He likened the process to learning the characteristics of a new film stock.

The luminous, sumptuous imagery in *Che* (2008) and *Zodiac* (2007) show what can be accomplished with the new generation of data cameras, making these among the most beautifully rendered digital films yet produced. Soderbergh shot *Che’s* two parts (part 1 depicts the Cuban Revolution and part 2 depicts *Che’s* subsequent, hapless campaign in Bolivia) using the Red One, which captures images in RAW format at 4K resolution (4096 x 3072 pixels, as compared with HD’s 1920 x 1080). This is known as an extra- or ultra-high definition format. Although at the time the camera was still somewhat experimental, Soderbergh wanted to use it because of its portability and sensitivity to light and because he felt that working digitally would give him more control over the work. A digital workflow, from image capture to editing to color correction, enabled him to retain control over the image files. (The workflow is also convenient. David Fincher shot *The Social Network* [2010] using the Red One and remarked, “It’s light and small, and I could walk away from the set at the end of the day with a wallet full of GF cards, take them to the editorial department, download them, and go back and use them again. I call it a righteous workflow.”)53 The Red One beautifully renders *Che’s* landscapes and lighting tonalities, and the film’s color pops with carefully modulated intensity. While some of the night exteriors show noise, this is less excessive and more closely resembles film grain than what appears in Mann’s films. *Che* has a very filmlike appearance, a product of the camera’s ability to handle tones, shadows, and highlights with impressive dynamic range. Indeed, in its current build, the camera has been tested to handle thirteen stops of light and with minimal noise at the low end. Without already knowing so, a viewer would be unlikely to identify *Che’s* video origins. Disparities of resolution and exposure latitude between film and digital video have been narrowing. To a perceptive viewer, the giveaway of *Che’s* digital origin is its hyper-sharp clarity of detail and an occasional harshness in the highlights. Soderbergh indicated that even he found the clarity of super-high definition at times to be distracting and that he prefers the film’s first part, which he shot with anamorphic lenses that produced a slight softening in the image relative to the second part that was shot with spherical lenses for a 1.85 aspect ratio.

Fincher and cinematographer Harris Savides shot *Zodiac* with the Viper in FilmStream mode, and Fincher, unlike Mann, was determined for the blacks to be rich and deep, a decision that helps give *Zodiac* a more filmic look than *Collateral*. *Zodiac* is a historically important film because it places digital effects in the service of banality rather than spectacle. The film is a procedural
about the effort by police and newspaper reporters to learn the identity of the Zodiac killer who was terrorizing the San Francisco area in the early 1970s. As a procedural, the film's tone emphasizes naturalism, authenticity, and the mundane aspects of daily life and police work. Camera movements are uninhibited, and no Steadicam is used. Lighting is natural and motivated by onscreen sources. 

Zodiac is a digital effects-intensive film, and because these effects are in service to a story told with documentary-like veracity, a viewer can watch the movie and never suspect how extensively its locations and visual designs are digitally engineered.

Fincher's respect for the tonality of darkness helps to establish the film's naturalism, in distinct contrast to the visible stylization of Collateral and Miami Vice. In researching the period look of San Francisco, Fincher watched such shot-on-location movies as Bullitt (1968) and Dirty Harry (1971) and was struck by how little one saw in the backgrounds of the night exteriors. He told Savides to accomplish something similar, feeling that CGI environments—of which the film has many—tend to look synthetic because they are often overlit. Going in the other direction helped to make the digital locations more credible. Savides shot numerous dark scenes at low F-stops with the lens wide open. This helped decrease depth of field, preventing viewers from seeing very far into the backgrounds, and also helped offset the deep-focus bias of the Viper. Depth of field reduction can be a challenge when shooting in HD because the camera image sensor is smaller than a frame of 35mm film. The Viper and Sony's CineAlta cameras use a 2/3 inch sensor, 11mm in diagonal as compared with the 27.5mm diagonal of 35mm film. This produces 2.5 times the depth of field for the same angle of view and f-stop as when shooting 35mm film. Often on Zodiac when the filmmakers wanted a soft background behind the performers, they established depth of field and then placed the actors at the rear border of this area. Night exteriors in Zodiac are dark and deep and without the excessive noise that plagues Collateral and Miami Vice. While Fincher achieved what Mann did not, he also used the Viper at times to counter the look of film and to create a subtle aesthetic tension within the visible surfaces of the movie. Like many HD cameras, the Viper produces images that are hyper-sharp. (Sharpness and resolution are not the same thing. The resolution of film is superior to that of HD, but its inherent grain produces a softer-looking image. Moreover, some HD cameras compress the image captured by the sensor to a degree that degrades resolution.) Savides thought the images looked synthetic because they captured so many details of the surface textures in scenes. “With the Viper, the audience will see more than what they normally see in a movie—literally, the pores on people's faces and every hair on the heads—so it may have an almost immersive effect.”

This
effect can be quite startling. Jake Gyllenhaal, as San Francisco Chronicle editorial cartoonist Robert Graysmith, stands in the background of a wide frame showing a group of editors assembled in conference with police. Gyllenhaal’s face pops out of the background with a remarkable, even distracting, level of detail. Fincher uses the remarkable detailing of HD as a metaphor for the search for truth and understanding. Graysmith, fellow reporter Paul Avery (Robert Downey Jr.), and detective Dave Toschi (Mark Ruffalo) spend years delving through an avalanche of information, tips, and leads that take them down winding, often dead-end pathways. In the end there is no catharsis. A suspect emerges—Arthur Lee Allen (John Carroll Lynch)—who seems to be the guy, but there is never enough evidence to charge him. And when a witness does come forth many years later and identifies Allen as the man who attacked him, Allen dies of a heart attack before he can be questioned. The denouement is mundane and anticlimactic, yet the irresolute nature of the horrific case remains powerfully haunting. Forensics and empirical investigation provide insufficient illumination—none of the investigators can see very far into the moral darkness represented by Zodiac. Fincher explicitly equates HD’s hyper-focus with the quest for truth in a scene where Toschi and two other investigators question Allen at the factory where he works. Fincher had a digital film restoration company interpolate sub-pixel information from this scene to subtly increase the resolution of the imagery beyond even what the rest of the film was showing. Savides remarked that “it makes you study the image more intently . . . it draws your eye even further into the drama.” But the viewer, like the investigators, will be denied the catharsis of a case successfully closed. The density and hyper-clarity of the HD imagery metaphorically contrasts with the opacity of the case and its events, and this disparity points to an epistemological paradox inhering in our desire to know and our believing that we can know and the utter resistance of the case to being known. The clarity of HD seems to promise answers, and yet none are forthcoming.

The aesthetic design of Zodiac, in which the heightening of image resolution visibly manifests the epistemological desire to know truth, would not be possible had Fincher shot the picture on film. And for this design to be appreciated, it must be viewed digitally. While film negative has impressive resolution capabilities, these quickly degrade through the multigenerational process needed to generate a release print that can be exhibited in theaters. In 2001, the International Telecommunication Union did a study in which a resolution test pattern presenting a maximum of 2,400 lines of information per picture height was photographed on color negative film and then printed in the usual way to generate an interpositive, an internegative, and release
prints. The latter when measured were found to display a maximum of 1,000 lines of resolution that degraded further to 875 lines when projected. The best way to view Zodiac, therefore, is digital projection. The film’s HD images display best in this format, and appreciating the film’s aesthetic design requires it.

**New Visual Aesthetics**

The shift to digital imaging has enabled moviemakers to explore new aesthetics and alternative optical domains to those established over generations using the traditional methods of celluloid-based imaging. I conclude this chapter by examining some recent striking examples in *Speed Racer* (2008), *300* (2006), *WALL-E*, and *Children of Men* (2006). This is a diverse range of movies. Not all are equally successful—and probably few critics or scholars would find *Speed Racer* particularly worthy of attention—but each film is insistently iconoclastic in its efforts to use digital methods to craft images in novel ways or to expand the boundaries of more traditional aesthetic designs.

*Speed Racer* is the Wachowski brothers’ homage to the popular Japanese anime character, and in the film they aimed to fuse anime aesthetics with a design that subverted camera optics. They aimed to create the deep-focus look of anime graphics and make it insistsent and stylized in a manner that could not be achieved through the optics of traditional cinematography. The film was shot with a Sony CineAlta camera, and the extreme deep-focus shots are the product of digital compositing. Visual effects supervisor John Gaeta noted, “When we looked closely at Japanese animation, we noticed that a lot of it is done with a large painted background and modified layers on top of

Faux-lens perspectives in *Speed Racer* (2008, Warner Bros.) include exaggerated depth of field, achieved in the compositing. Frame enlargement.
that, like traditional cel animation. It puts everything in focus. To create a cinematic equivalent, the filmmakers shot separate foreground, midground, and background elements in crisp focus and then combined these as a digital composite. The resulting perspective and hyper-deep spatial articulation look very different from what would have been achieved using conventional methods. Early in the film, for example, young Speed (Nicolas Elia) drives his go-cart into his father’s garage where his brother Rex (Scott Porter) is repairing an engine. The compositions place Rex in the close foreground, Speed in midground, and the house across the street as background. The spatial planes are crisply focused and layered like cel animation, and there is no attempt to evoke naturalism or photorealism, although the depth cues in the image are assertively presented in a way intended to evoke an extreme version of three-dimensional space. The depth cues are hyper-articulated. Changes in object size, for example, suggest an extreme recession of space far beyond what a suburban neighborhood street typically would engender.

The film is rife with designs that subvert camera optics. The filmmakers referred to these as “faux lensing,” that is, “literally inventing optical properties that aren’t physically possible.” Because foreground and background elements were created separately, like animation cels, their optical relationships could subvert camera reality and go beyond what camera perspective could accommodate. When young Trixie sees that Speed is going to crash his go-cart, she is presented in a shallow-focus composition, the background soft. As she grows alarmed and calls out to Speed, a rack focus occurs to bring the background into clarity, but Trixie’s focal plane remains unchanged. When a real camera lens is rack-focused, the focal plane shifts so that areas that were clear become soft or vice versa. Speed Racer, instead, flaunts the paradox that rack focusing needn’t alter a shot’s foreground focal plane. In a subsequent scene, Speed’s father (John Goodman) sits in profile in the garage in the foreground of a shallow-focus shot. When Rex walks into the background, a rack focus brings him into optical clarity without losing the focus on Speed’s father. In other ways, the optical perspective within shots assumes photographically impossible forms. Many of the film’s deep-focus shots incorporate paradoxical perspectives—spatial planes are mismatched, as when wide angle and telephoto perspectives are combined within the same shot. The background of a shot might be done in deep focus while the foreground is in telephoto perspective. A common artifact of lens perspective is “bokeh,” the photographic term for the distinctive blurring that occurs in the out-of-focus areas of an image. Different types of lenses—spherical or anamorphic, for example—produce characteristic bokeh effects. The Wachowskis play with bokeh throughout Speed Racer, as in a scene where young Speed and Trixie
realize they are in love. Each is filmed in shallow focus, and the spherical background blur assumes the shape of a cluster of Valentine’s hearts.

Depth of field in Speed Racer is a composited effect whose aberrations point self-consciously toward its normative construction in celluloid-based cinema and the physical constraints of the optics from which camera-defined depth of field derives. The composited deep-focus shots are presented as playful subversions of camera reality, and as such they clearly depart from photorealism, as do other elements of the film. These include its intensely saturated color images and the eccentric ways that focal planes within a shot move in relation to each other. Used as a narrative tool, the focal-plane shifts enable scene transitions to occur. Background planes behind characters slide across the screen, a lateral movement perpendicular to the camera’s line of sight. A new location displaces the old, signaling the scene transition, while lighting and focus on foreground characters remain unaltered. The effect is comparable to multiplane camerawork in cel animation, and it represents a 2D simulation of 3D space. Depth cues are clearly artificial and are conveyed on a 2D axis using the lateral shift of background and foreground elements. The effect flauts the paradoxes achieved by visually disconnecting spaces that as narrative elements remain integrated in the represented action of a scene.

Critics of digital effects sometimes complain that they represent a limited aesthetic to the degree that they strive for photorealism. John Belton, for example, writes that “digital imaging technology . . . tends to simulate older, analogue, image-making conventions, not to create radically new perceptual modes.”79 Julie Turnock writes that the dominant style that ILM established is one that seeks “perfectly executed, seamless photorealism,” creating a “perfect illusion” of the real.60 These scholars are correct in pointing to photorealism as an effect that can be achieved digitally, but it is not the only goal of digital effects. Sometimes it isn’t a goal at all. As we have seen, effects artists delight in revealing new optical domains. Moreover, photorealism is a slippery and somewhat misleading term. As an art-form of composited images, little about cinema is realistic if such a term is understood as corresponding with camera reality. Tromp l’oeil is deeply embedded in cinema as one of its essential characteristics.

Willful departures from photorealism are quite evident throughout 300, a retelling of the Battle of Thermopylae that models its images on the ink and watercolor paintings produced by Frank Miller for his graphic novel, from which the film is adapted. Shot largely in a greenscreen studio with minimal sets, the locales are computer-generated, and the filmmakers never seek to persuade viewers that they are seeing landscapes that could be photographed.
The digital skies are monochromatic and toned like a watercolor wash, rocks and mountains are minimally textured, and oceans, storms, and the Persian foes are depicted in a surreal fashion. Distant vistas are digital matte paintings presented as 2D constructions. The film’s landscapes do not include realistic depictions of atmospheric perspective, namely, visual haze and a color shift toward blue. *300* was shot on film, which creates the soft tones necessary for the watercolor style, but in the DI the blacks were crushed (detail in shadow areas was eliminated) and the highlights were clipped. The resulting effect looks very different—more velvety, less harsh and hard—than what HD video would have achieved. But none of the film’s stylistic attributes seeks to persuade viewers that they are real. Stepping into the film, viewers imaginatively enter a digitally painted domain, in which the small spaces on set are opened up as digital set extensions but with minimal effort to provide credible 3D depth cues. The painted and two-dimensional qualities of the matte backdrops are unconcealed.

When depth cues are vividly rendered, they count among the film’s most extreme departures from photorealism. One of the film’s especially flamboyant effects employs digital zooms to create the appearance of an extended moving camera shot; the zooms actually conceal a series of cuts. The zooms create depth of field effects and hide the cuts in a way that maintains the viewer’s phenomenal impression of seeing a stream of action unbroken by editing and contained within a single shot. The effect is displayed most strikingly during the first battle scene between the Spartans and their Persian foes. King Leonides (Gerard Butler) charges into the fray hurling a spear and using his sword to lop off the limbs of his enemies. A moving

*300* (2006, Warner Bros.) avoids a photographic look even though it was shot on film. Instead, it emulates the distinctive painterly style of the Frank Miller artwork on which it is based. Frame enlargement.
camera follows him as he defiantly rushes across the battlefield, slaying his antagonists. At key moments—as he hurls a spear or slashes at foes—the shot abruptly and rapidly zooms in to provide a close view of the action, then quickly zooms back out, and these optical changes are accompanied by speed changes (known as “speed ramps”) during which the action slows down to a few frames per second in order to highlight details, such as a blood spray or flying limb. The abrupt zooms and speed ramps give the shot a hyper-kinetic quality, a herky-jerky, spasmodic energy, a degree of artifice so pronounced that the viewer is forced to take notice.

The “shot” actually contains twenty-seven cuts and incorporates footage assembled from two takes. It was created using a special three-camera mount that filmed the action simultaneously from three lens perspectives—wide, medium, and long—each aligned on the same axis of view. The zooms are digital creations used to cover the cuts from one lens perspective to another, and morphs blend the views imperceptibly. Thus a zoom-in to highlight a detail such as a sword thrust by Leonides is actually a cut between a wide-angle shot and a telephoto shot, with digital frame interpolations used to simulate the zoom effect and provide the lead-in and lead-out of the join between the shots. The speed ramps were created during compositing, and they are more dynamic than what might have been achieved using celluloid methods. When shooting film, a modest speed change can be achieved within a shot by altering the camera’s speed (or, after filming, by using the optical printer), but the ramps in 300 are more extreme. A technique called optical flow, a form of motion analysis, enables the computer to analyze the motion vectors occurring across the frames in a sequence and from these to generate new frames that can be used to shorten or expand the action. This method creates perfect image blends and models the alterations of motion blur that correspond with the speed changes. Acceleration produces greater blur, deceleration less. The other tool necessary for the sequence to work was matchmoving, a method of analyzing a live-action camera move and live-action elements such as actors and using this data to create corresponding moves in a CGI environment. Gerard Butler charged into action on a greenscreen set; in the finished shot the CG backgrounds have been carefully matchmoved so that the camera’s simulated optical perspective on them matches what happens in the live action.

What emerged from these manipulations was a digitally realized long take. The action appears to be covered in a single camera move, and this appearance conceals the actual basis of the sequence that lies in montage. The wholeness of space here is a digital palimpsest, but one that advertises its constructed origins through the insistent artifice of the speed ramps. Imperceptible simulations of a long-take aesthetic can be found throughout
Children of Men (2007), a futuristic tale about a time when the human race has become sterile. Director Alfonso Cuarón wanted to compose the film in a series of extended moving camera shots, a long-take style that he felt would lend the story the immediacy and credibility of a pseudo-documentary such as The Battle of Algiers (1966). Unlike the extended camera moves in 300 that present themselves as part of a visual effects sequence, the long takes in Children of Men unfold in a more naturalistic manner and are perceptually indistinguishable from true long takes. I make this distinction because, while Cuarón did shoot the film with extended takes, he lengthened these by digitally conjoining several takes to create scenes that seem to unfold in a single, unbroken camera perspective. The joins between the shots cannot be seen even if a viewer knows where they are. The digital stitching is that perfect.

A striking example occurs in the film’s first scene. The hero, Theo (Clive Owen), is in a coffee bar listening to a newscast about the death of the world’s youngest citizen. He leaves the bar, followed by the camera in a Steadicam shot. He walks out the door and down the street, through a throng of pedestrian traffic, as the camera follows close behind. He pauses by a newspaper box to pour some liquor into his coffee. As he does so, the camera circles around to show him in the foreground; in the background is the street he has just walked down and its coffee bar. At that moment, a bomb blows out the front of the building and Theo ducks to the ground. The camera rushes past him toward the ruined building as a woman staggers out clutching her severed arm.

Subtle compositing of multiple takes creates a sustained optical flow that connects Theo (Clive Owen) with the exploding coffee bar that he has just left. The digital long take enhances the abrupt and shocking effect of the scene’s action. Children of Men (2006, Universal Pictures). Frame enlargement.
The shot is composed as a continuous camera move, and its emotional effect—the bomb destroying the building from which Theo has just emerged—depends on a viewer’s subliminal sense that the shot has unfolded in real time and within a space that is whole and contiguous as presented in the long take. The continuous optical flow that has connected Theo and the coffee bar makes the sudden explosion more shocking than if the scene had cut from Theo in the street to the building blowing up. But while the shot’s design works well in this regard, the basis on which it is achieved is deceiving. The long take is constructed from two shots, and the scene was filmed over two days. The reason was entirely pragmatic. The bar had to be fitted with an effects explosive, its extras recostumed as wounded patrons, and this was easier to accomplish if the shot cut at the point where Theo leaves the bar, enabling the set changes to be made for the next day’s shooting. The “cut” is imperceptible. It occurs as Theo steps through the doorway into the street. The camera briefly pans away from him toward the door as a double-decker bus passes by in the street outside. The two takes were joined at that moment, with matchmoving used to align the backgrounds of the door in each take. The passing bus enabled the compositor to apply a traveling matte as a digital wipe. As the bus passes, its bulk blocks the camera’s view of the street, and the rear edge of the bus effectively becomes the blade of an optical wipe, enabling the compositor to insert the street background from the second day’s filming. This background is revealed as the rear edge of the bus crosses the screen. The solution enabled the views of London’s Fleet Street, with different traffic patterns over the two-day shoot, to blend perfectly.

Numerous other scenes in the movie create long takes as digital conjunctures of separately filmed material. A bravura six-minute moving camera shot depicts action in which Theo and his ex-wife Julian (Julianne Moore) reconcile while driving in a Fiat van; they are then attacked by thugs who chase their van; Julian is shot and killed; Theo flees in the car; he is then stopped by police; and he must flee again when an accomplice kills the officers. The shot was not done as greenscreen. It was filmed over eight days, in three separate, real locations, and was broken apart as six small sequences for filming. Numerous digital transitions blend background plates of different locations into what appears to be a single passing landscape, and digital blends were used inside the car to hide sections of the action that were discontinuous because they were shot at different times. The Fiat had no roof so that the camera could descend into the car and film the actors, and the camera crew sat atop the open-roofed vehicle. To hide the crew, a CG car roof was used, and digital lighting effects simulated the look of an enclosed vehicle.
During the attack, a Molotov cocktail hurled by a thug and the fiery explosion are digital effects, as is the bullet strike through the windshield. Julian's head when she is shot is a digital model tracked onto Julianne Moore's shoulders. When Theo hits a pair of pursuing motorcyclists with the Fiat, the stuntmen fall into the underbrush, but the flipping cycles and victims are digital creations, as is the splintering, crumbling windshield. When police stop the Fiat and Theo gets out, a digital matchmove centering on the open door enables the camera to look back (in another take) at a real Fiat without a camera crew on top of it.

Like the digital blend that joins the two views of Fleet Street in the earlier scene, none of these manipulations are apparent. Viewers experience instead an unbroken extension of time and space, dramatic action unfolding within a continuous optical perspective. The long take aesthetic is a digital achievement, and as such we should ask whether its visual effects sleight-of-hand is consistent with the kind of realism that Bazin famously claimed for long takes. Bazin argued that a long-take aesthetic was counterposed to montage aesthetics. The latter, he wrote, is anti-cinematic because it does not respect the unity of space. It creates meanings derived from image juxtaposition rather than from the content of an image itself. He wrote that montage is "an abstract creator of meaning," one that "preserves the state of unreality" demanded by spectacle. It would be far too easy to claim something similar for digital effects, that their use in *Children of Men* preserves a spectacle-based state of unreality. Quite the opposite, in fact, is the case.

In contrast to montage, Bazin emphasized the ways that deep focus and extended takes preserve a unity of space that he believed was an essential constituent of realism in cinema. He held that the continuity of dramatic space, achieved via these techniques, was a cinematic analogue for the spectator's experience of the real world. To the extent that cinema could model that experience, it drew closer to reality. He praised, for example, Renoir's use of camera movement to extend shot duration, regarding this as an important alternative to montage. "It is based on a respect for the continuity of dramatic space and, of course, of its duration."

If a filmmaker can model the continuity of dramatic space and its duration in a fictional screen world, does it matter how this is accomplished? Does it make any difference if the long takes are existentially real or are digitally simulated? Much depends on the context of a scene, of course, but if spatial continuity is what counts, then surely there are many routes to its attainment. Cuaron filmed *Children of Men* in long takes; they simply aren't as long as what is represented on screen. These long takes indeed exist in the film as a stylistic alternative to montage, even if their construction involves a process
of montage as the various digital elements are assembled. A viewer watching the digital long take has a phenomenological experience of duration and not montage. Cuaron uses visual effects in order to respect the integrity of space. That space is often simulated, but the stitching between shots or other visual effects elements does not show. The unity of space is perceptibly whole, and it is sustained across complexly choreographed dramatic action. The film is utterly Bazinian in its preference for creating scenes as large blocks of action sustained without a fragmentation of the represented dramatic space. What is cinema in *Children of Men*? It is a medium of digital realism or, to be more precise, a medium in which the Bazinian ideals of realism are sought and digitally attained. The aesthetic design is consistent with that found in the work of all Bazin's heroes—Welles, Renoir, Rossellini, Flaherty—while representing as well an approach to spatial unity that was technologically beyond Bazin’s horizon of filmic experience. *Children of Men* demonstrates that long takes can be virtual and remain consistent with the aesthetic of realism to which they historically have been attached.

Criticism of digital imaging on the basis that it strives for photorealism overlooks a prime motivation on the part of effects artists when they do seek a photo-real appearance. Such an appearance minimizes the artificiality of computer-generated imagery, and it creates continuity with the historical traditions of cinematic imaging that are photographic. Pixar’s *WALL-E* (2008) exemplifies this quest to create an all-digital world on screen that is fanciful and fantastical yet evokes the conventions of cinematic perspective familiar to moviegoers. These serve to soften the tendency for computer images to look overly calculated and excessively designed, cold, and hard. The film’s director, Andrew Stanton, said, “Life is nothing but imperfection and the computer likes perfection, so we spent probably 90% of our time putting in all of the imperfections.” Jeremy Lasky, the director of photography, emphasized the strategic value of designing imperfections into the film. “The little inconsistencies that you can put in CG … make it feel like [objects] were really filmed and not studied pixel for pixel, month after month, which is what we do.”

The imperfections mostly involved the proper replication of anamorphic lens perspective and the flaws that distinguish it from spherical lens perspective. Many of these involved depth-of-field simulations to emulate the focusing characteristics of anamorphic lenses. (As with lighting a CG environment, the difficulties of representing depth of field in CG have elicited numerous algorithms and methods of simulation.) Stanton wanted the movie to look reminiscent of 1970s-era anamorphic widescreen science fiction films. Pixar’s virtual camera package, as used on films such as *Ratatouille*, calculated camera variables, such as f-stops, depth of field, focal lengths, and created
optical perspectives consistent across these variables, but these lens perspectives had always been spherical. The package was not equipped to emulate the look of an anamorphic film, even though many Pixar movies were in a 2.35:1 aspect ratio. The films had always had a spherical look as if they had been a Super 35mm scope extraction. Cinematographer Roger Deakins worked on the film as a consultant, showing Pixar’s artists the subtle distinctions between spherical and scope perspective and also demonstrating how a cinematographer might light some of the film’s scenes and locations. Successfully replicating the appearance of anamorphic cinematography required redesigning the studio’s virtual camera software so that the optical distortions found in anamorphic movies would be on display in WALL-E. These include elliptical-shaped bokeh and lens flares, barrel distortion, astigmatism, field curvature, and optical breathing artifacts.

When filmed with a spherical lens, point-light sources that are out of focus appear round, whereas blurred light sources filmed anamorphically appear as horizontal or vertical ellipses. This effect is especially evident in the close-ups of EVE, the sleek robot with whom our hero, WALL-E, a discarded waste removal robot, falls in love. In the close-ups showing her from WALL-E’s perspective inside his trailer, the background Christmas lights assume the characteristic elliptical form that would be found in an anamorphic movie. Anamorphic lens flares tend to spike horizontally, and this effect is simulated in the glare of the rocket engines when WALL-E hitched a ride on the spaceship carrying the surviving Earthlings. Barrel distortion is visible as the outward curvature of straight lines, especially when filmed at wider focal lengths. The film’s evocation of barrel distortion is especially subtle and can be seen at the edges of the high-rise buildings in many wide shots. Astigmatism is one of the most serious problems found in anamorphic lenses and makes it difficult to achieve fine focus across the field of view. The outermost quadrants of the frame tend to go soft, and WALL-E is especially attentive to the peculiarities and defects of anamorphic focus, particularly evident in shots involving close-focus distances. An extreme close-up of WALL-E gazing at his companion cockroach, for example, does not resolve cleanly across the width of his face. The limited focus points to the constraints on anamorphic depth of field and the lens’ relatively small “sweet spot,” the area capable of delivering fine-focus imaging.

Simulating anamorphic field curvature—the warping of lines and objects as they move across the curvature of the lens—required Pixar to construct a different type of virtual camera because the studio hitherto had relied on one that was nodal. A nodal camera is specially mounted so that it will pan around the optical center of its lens, creating a shifting view but no change in perspective. It is often used in visual effects work employing foreground
miniatures because it permits limited pans. These do not create the perspective shifts that would reveal the presence of the miniature model. Most tripods are not nodal. Cameras mounted on them do record changes in perspective during a panning shot. These perspective changes were a new level of visual information created for WALL-E. Throughout the film, panning shots cause objects in the scene to warp as they move across the frame. A related type of object displacement, visible as a focusing artifact, is the phenomenon of optical breathing. Large focal changes, as when racking focus from a very distant object to a very near object, produce changes in field position. In the film’s last act, when WALL-E is hiding in the spaceship captain’s cabin, a large rack focus shifts from EVE in the far background of the shot to WALL-E in the near foreground. As EVE is defocused, her position in the frame changes as a result of anamorphic lens breathing.

All these effects in the film are fairly subliminal and are probably felt by audiences more than seen. Lasky believed that they would be noticed subconsciously by viewers and would help audiences to “feel like there’s a camera in the CG space.” The realism induced by these artifacts is not a first-order level of realism in the way that ambient occlusion establishes the impression of 3D space by representing the soft shadows cast by environmental light. It is a more derivative form of realism, tied to the peculiarities of anamorphic optics as these were instantiated in cinema by generations of films, most especially during the high period of anamorphic widescreen that lasted until the 1980s. By emulating the eccentricities of this optical system, WALL-E locates itself in this distinct period. It is a paradoxical gesture. This is a futuristic film in a double sense—its story world is a science fiction set in the future, and it is

The animation in WALL-E (2008, Pixar) emulates the characteristic look of anamorphic cinematography, which includes features such as this horizontally spiking lens flare. Frame enlargement.
an all-CGI film in which nothing was photographed—yet its aesthetic design looks toward the past and the way that films were once composed. With this backward glance, the film distinguishes itself from the spherical cinematography that is commonly found in modern cinema and that digital imaging tools have helped to make more prevalent, and it aligns itself with a format that emerged in the 1950s as a means for cinema to compete with television. It is photorealism in a very restricted sense. The objective is not to convince audiences that what they are watching is real, but rather to suggest that WALL-E could have been filmed by a cinematographer working in anamorphic widescreen. Audiences know that the film is all-CG, but this visual conceit serves to introduce a historically grounded aesthetic perspective into the film, ironically, by connecting it with the mechanical imperfections that once were rife in cinema and that lens manufacturing has worked very hard to overcome.

Berys Gaut has written that the long dominance of photographically derived images in cinema has led scholars to identify the characteristics of photography with those of cinema. But the advent of digital imaging tools has moved cinema away from its near-exclusive reliance on photography. He writes that the task now is "to disentangle systematically which aspects of photographic films depend on their photographic nature, and which on their being moving images." As moving images, Forrest Gump, Zodiac, Ratatouille, Speed Racer, 300, WALL-E, and the other films examined in this chapter incorporate a photographic aesthetic but also go considerably beyond this. Digital imaging tools enable filmmakers to extend the visual properties of cinema in ways that are consistent with photographic images and also in ways that subvert, alter, or otherwise depart from what the optical system of camera machinery dictates. This flexibility opens up new creative freedoms without destroying the old ones. Martin Scorsese's Shutter Island (2010), for example, contains nearly 650 visual effects shots that simulate the island location using bluescreen mattes, digital painting, and 3D computer effects. But the final shot of the film employs a hanging miniature, one of the oldest and most traditional of visual effects techniques. Digital imaging coexists with cinema's traditional aesthetics, but it is not confined or constrained by them. Using its tools, filmmakers have taken audiences to new visual domains foreclosed by the optics of real, nonvirtual cameras. Cinematography has been transformed in the process, and light—a filmmaker's most basic tool—has retained the physics of its behavior while becoming a virtual energy, one that is infinitely malleable.