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CINEMATIC STYLE:

THE EFFECTS OF TECHNOLOGY

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The Path of Light

Cinematography is defined as the art or technique of movie photography, including both the shooting and development of the film. Due to the nature of this craft there is basic technical understanding needed of the tools that Directors of photography use to control light. Before dissecting the technological developments that allowed and limited aesthetic choices, there must be a basic understanding of how this technology worked. Cinematography is essentially the control and manipulation of how light reacts chemically with the emulsion of the film stock. Discussing the effects of film stocks and sensitivities, lenses, motion picture cameras, lighting, and camera support would benefit from an introduction to how those tools are used to control light.

The most common type of light used in movies is daylight. The sun projects daylight onto the earth, which we see because of the reflective behavior of all the objects around us. Different materials have different reflective properties, including luminosity and color, which change the wavelength of the light, allowing us to see. Besides daylight, cinematographers employ artificial light. There are many different types of these lights ranging in design and power. Typical cinema lights are either open-faced lights, lensed lights, or soft lights. [1] These differ in quality of the light

[1] Lights are built to utilize bulbs with different wattages for different intensities, ranging from 150 watts to 18,000 watts. They also vary in color temperature, lights being either tungsten-balanced (3200 degrees Kelvin) or daylight balanced (5600 degrees Kelvin).

beam and one's ability to control the light. One aspect of this thesis will examine how the evolution of technology has allowed for greater control of light.

Light passes through the lens which is attached to the front of the camera. Lenses were built initially to imitate the human eye. There are three main aspects of lenses that allow for control: the size or focal length (measured in millimeters), inherent speed, and aperture. Different size lenses have varying glass elements in them which are spaced out down the barrel of the lens creating different focal lengths such as 35mm, 50mm, 85mm, and so on. Lenses with low focal lengths are considered wide-angle lenses; high focal lengths are considered telephoto lenses. Lenses also have varying speeds. This refers to how quickly the light passes through the glass elements and on to the film frame. Lenses are built with an iris or aperture that can be manipulated to let in more or less light needed for exposure. One mechanically opens or closes the iris to create a certain size of a hole through which light will pass. The size of the opening is measured in "f stops". The human eye works very similarly. The pupil opens wider in lower light conditions to allow more light to pass, and closes down under brighter conditions.

After the light passes through the lens, it now enters the camera body. The film rests in the "magazine," a light-locked case attached to the camera body. Film passes through the camera in an area known as the gate.[2] A spinning disk with missing portions – the shutter – allows light to be blocked or allowed to pass to the film stock

[2] Gate sizes vary according to the gauge of the film stock – e.g., 8mm, 16mm, 35mm, 70mm.

in the gate.[3] The "claw" advances the film through the gate as the shutter is closed.[4] The registration pin holds the film steady in the gate as the shutter is open and a frame is exposed to light. Film is therefore alternately 1) exposed to light and 2) advanced in the camera through the precise coordination of the shutter, the claw and the registration pin. This happens at a chosen rate, called the "frame rate".[5] This is where the projector becomes part of the equation. If an action is recorded at any given frame rate, and projected at the same rate then it will have a real-time play back. However, if it is recorded at say 48 frames per second and played back at the normal 24 frames per second then it will have the illusion of slow motion, by half of the time the action actually took place. To summarize the process, the film begins at the unexposed reel, is pulled through the magazine to the gate, the claw moves out, pulls it down and the pin comes out at the same time to hold a single frame into place. The shutter is then removed from the front of the film and light is allowed to expose the frame. Once the shutter is replaced the frame is removed and continues on to the take up reel.

Three major developments for cameras were the size of the camera, the noise that the camera itself made, and the speed that the camera could advance film. Generally, cameras that were smaller were more portable and could fit in spaces where

[3] The shutter opening can vary. This was manipulated by cinematographers to create the illusion of smoother or choppier images as well as allow for proper exposure when executing slower or faster motion recording.
[4] The claw is connected to two or more motorized cams that drive it in a nearly circular motion to move up, hook onto a perforation hole in the film stock, and pull it down so that the frame is placed in front of the gate.
[5] Until cameras were motorized frame rates varied. Silent film eventually standardized at 16 frames per second. Today's standard is 24 frames per second.

an angle was needed but a larger camera could not fit. The silence of the camera was also particularly important during the transition to sound films. During early filmmaking, the sound of the film running through the camera tended to be considerably loud. Last, the speed of the camera is a factor in camera quality. Variable shutter speeds and frame rates made cameras more versatile and practical when shooting for special effects.

Finally there is the film stock itself. Film stocks also work on a "speed" scale that measures the stocks inherent sensitivity to light.[6]

The film is made up of chemicals, which react on a speed and color scale. The celluloid film is usually made up of a base and an emulsion. The base is transparent and is what the emulsion sits on top of. The emulsion is made up of silver halide granules in a colloid gel. This is the part of the film, which is light sensitive and reacts to the light to create the image. In color film, there are typically three layers of emulsion that react to wavelengths corresponding to yellow, green, and magenta, which blend for a color negative. There are a few different processes for the development of the film. Once exposed the film is what is called a negative from which it is processed by a lab into a print. The "speed" scale is represented by a number known as its "ASA". In perspective, a 500 ASA is particularly fast and is used for very low light shooting, due to its sensitivity, while a 50 ASA film stock would be a good choice for mid-day exterior shooting in sun as it is a slower stock

[6] Variously referred to as the EI (Exposure Index), ASA or ISO, film stocks range from the ultra slow 12 ASA to the more modern fast 500 ASA. The slower the speed of a stock, the more light needed for proper exposure.

which will not react to the same amount of light as quickly. The last basic variable to understand about stock is the color balance. Color films are balanced to daylight, 5600 degrees Kelvin, or tungsten, 3200 degrees Kelvin.[7]

This is where filtration comes in. When a film stock is balanced to say daylight that means it will read all the light waves with a temperature of 5600K as "white" light. However, since there tends to be a mixture of light a decision is made by the cinematographer of what white should be. Take the example of a room with windows and a desk with a lamp that is turned on. The cameraman may decide that daylight should be "white" and use a tungsten-balanced film, he would have to put a filter that is balanced for tungsten to filter the daylight to match the balance of the film. These are just a few ways that the film stock is used to control the light that will eventually be projected onto the screen.

The last part of this study will include camera support. This will discuss the ability to place the camera in the position to record the light. The most basic form of support is a tripod. Support typically deals more with framing and through history there have been numerous inventions that allow cameramen to place and move the camera wherever they want. These inventions include tripod heads for smooth panning and tilting. [8] The history of cinematography is marked by ever increasing

[7] The Kelvin scale is based on a color spectrum measured by wavelengths. It is a measurement of the color temperature of a light source. As the Kelvin number and color temperature increase, a light source becomes bluer or cooler. By decreasing the Kelvin number and color temperature, a light becomes warmer and more orange. For example, match light or sunsets measure 1700 degrees Kelvin. Overcast cloudy light measures 7000 degrees Kelvin.

[8] Panning – camera movement on the horizontal axis (i.e., left to right). Tilting – camera movement on the vertical axis (i.e., up and down).

sophisticated methods of moving the camera. Initially, this was done in moving cars or boats or trains. Eventually, devices like film dollies and cranes were designed which allowed for precise and controllable camera movements through space. Recent developments include helicopter mounts and the Steadicam.

Part I. Early Cinema

1835-1913

The beginning of film and film technology can be traced back to a parlor trick known as the Stroboscope. This was essentially a strip of drawings of a sequential action that would be arranged on the inside of a cylinder and spun. The cylinder would have a hole to look through just big enough to see one drawing at a time. However, based on the principal of persistence of vision, the sequential drawings created the illusion of continuous motion. This is the principal that the entire motion picture industry is based on.

In the beginning era of still photography, around 1820, the films being used could not be exposed fast enough to capture a moving object. Eventually, about midway though the 19th century, the light sensitivity of film stocks became fast enough that taking a photograph of a moving object became possible. Edweard Muybridge, a photographer working in San Francisco, used this to his advantage to win one of the most famous wagers in history. With $25,000 hanging in the balance, Muybridge placed 24 cameras on trip wires in a line in order to photograph a horse galloping. When projected it became the first moving picture shot on celluloid film.

Enter the Camera

During the 1800s, there were many attempts at creating a camera that could take successive photographic images fast enough for them to be played back and form a moving sequence. The challenge here was to construct a device that would hold still a single frame of a film strip in front of the camera gate long enough to achieve a properly exposed image, while at the same time moving the strip quickly enough that the projected frames which had been exposed would give the illusion of motion. Eventually, the famous inventor, Thomas Edison, found a solution to this problem. At the end of the 19th century, Edison with the help of William Dickson had developed the Kinetographe. This was a hand-cranked camera that recorded sixteen distinct photographic frames per second using teethed gears to advance the film down and hold it in front of the gate while simultaneously moving and replacing a shutter to create an exposure. The kinetoscope (Fig. 1) was also a single-person viewing box that played the short moving pictures that Edison had made. It ran on an electronic variable speed motor that projected films at 46 frames per second. This device turned into an attraction in which people would drop a penny into the large hard casing and be able to watch short moving pictures. The filmstrips were typically less than 50 feet and would therefore create a moving image for less than 30 seconds. The kinetographe became what almost everyone else based camera designs on.

R.W. Paul designed a camera based on the kinetographe. However, there was a major difference. Edison's camera ran on a single gear solely in a forward direction.

Paul's design incorporated two synchronized sprocket gears that drove the film on both sides of the gate. This allowed the film to be rewound to open up possibilities for double exposure, and superimpositions to be created within the camera. This allowed for cinema's first special effects. Unfortunately, the camera had problems with poor registration, meaning the film could not be held steady while passing through the gate. Two French brothers, Auguste and Louis Lumière, developed their own camera in 1895 (fig. 2). They instituted the claw and pin system that would be used in movie cameras, for the most part, for the rest of film history. The claw would reach up and grab the film via the sprocket holes and pull it down frame-by-frame, while the registration pin held a single frame in place in front of the gate where the frame would be exposed to light. The claw would then move in a circular motion to release the film after exposure and reach up again for the subsequent frame. The Lumière camera was hand cranked and one full rotation of the crank exposed 8 frames. This meant that cameramen would have to develop a sense of timing where cranking and projection would match up for a real-time recording.

None of these early cameras were equipped with view finding systems. Framing and focusing had to be performed prior to loading the film. To frame and focus the shot, the camera operator would have to open the camera and look through a hole in the back of the gate prior to filming.

By 1900, technical developments in cameras really began to accelerate. Robert Dickson had left the Edison Company and joined two other inventors to create a company that eventually became known as the Biograph Company, the oldest movie company in America. At this point, there were issues surrounding film stock durability. The original gear system put too much strain on the film, and there were problems with it breaking during filming and projection. Woodville Latham discovered a way to release some of the tension, which he patented as the Latham loop (Fig. 3). Biograph purchased the patent for the Latham loop after Edison disallowed them from licensing some of their mechanical patents. From this point on, just about every camera utilized the Latham loop. One such camera was the Pathé studio camera (Fig. 4) developed in 1903 which was designed to be very much like the original Lumière camera. It was much bigger and but still utilized a wooden construction. The size was created out of a need to hold longer filmstrips of 400 feet, to film longer actions. The camera had a ground glass that was used to focus the lens, but required a magnifying glass to use. This camera also had a viewfinder, which was useful for framing during the shot. At this point, however, viewfinders were not extremely accurate and also formed an inverted image on the ground glass, which made camera moves difficult. The Pathé camera would grow as one of the more consistently used cameras until 1911.

The Biograph camera was particularly interesting because instead of using the claw pull down system on perforated film it used a friction pressure system on filmstrips without any perforations. It used rubber rollers that were cut in half to pull the film down and stop while the film would be exposed. During the exposure process, the filmstrip would have holes punched into it. This would cause irregular perforations that would not run with standard projectors so a specialized printer was developed to compensate for the perforations. Interestingly enough, the camera had better vertical registration, but somewhat unsteady horizontal imaging.

At this time, cameras were hand-cranked, with a crank on the operators right side of the camera. The Williamson camera, developed in 1904, was largely responsible for this design. These cranks would be replaced by motorized cameras in 1912, like the Debrie Parvo camera. The Debrie Parvo camera became the smallest professional camera to incorporate a metal, rather than wooden, chassis. The film, loaded in 400-foot spool boxes, traveled through the gate into a take-up box. The camera had a viewfinder in the back of the camera used to frame and focus. The camera did have a scope on the side for use during the shot but it was inaccurate and not particularly useful. This camera set a new standard for early professional cameras.

The camera that was responsible for propelling movies out of the "early cinema" stage would be the Bell & Howell camera. The B&H 2709 camera (Fig. 5) debuted in 1912. It was made entirely of cast aluminum, and was much more durable than its wooden predecessors. It was large (about 15 inches tall by 15 inches long by 7 inches wide) and weighed about 27 pounds[9]. New to this camera was a variable shutter opening, which could be adjusted to allow for fade-ins and fade-outs. It is important to recognize that all the major camera companies were competing with each other, generally using the same technological theories and designs. A main area of concern in camera development at the time was maintaining registration, keeping the

[9] In perspective, the Panavision Panaflex Millenium, when it first came out in 1997, weighed about 18pounds

film steady during exposure. The Bell & Howell camera had the best registration to date. Biograph tried to compete, however, the non-perforated film proved to be an inconsistent method of maintaining registration. The Biograph camera did, however, have a turret with which the operator could mount four lenses at a time, making lens changing much easier and more efficient. It also had a viewfinder mounted on the side that made focusing much easier.

The famous director D.W. Griffith and his cinematographer, Billy Bitzer, worked for Biograph for years shooting hundreds of short films. The industry standard for shooting as well as projection was 16 frames per second, One note to consider would be that many of Griffith's films were shot at 14 frames per second due to Biograph's effort to economize on film budgets. This cost-saving measure was ultimately responsible for giving many of Griffith's films a slightly sped-up effect.

Lenses

Most cinema lenses had been used earlier by still photographers. At the turn of the century, the standard focal length (measured in millimeters) for lenses ranged from 50mm to 75mm. Lenses wider than 50mm were rare and suffered from a lack of quality. Telephoto lenses with focal lengths of 100-150mm also were generally of inferior quality and primarily used only in actuality filming. Another particular characteristic of early lenses was the fact that they had to be specifically fitted to specific cameras. There were no universal lens mounts so lenses could not be interchanged between cameras. These early lenses had no focusing scales engraved on the lens barrels requiring that all focusing had to be done through the gate. One particular issue with the pre-1900 lenses was that they were limited to maximum apertures of f4.5 - f5.6[10]. Combined with the low light sensitivity of the early film stocks[11], large quantities of light were needed to travel through the lens to create a proper exposure. In the early cinema days, artificial lights were not particularly powerful which meant mainly daylight was the primary light source in shooting movies.

By 1913, Carl Zeiss lenses were available in 35mm and 40mm focal lengths. The Zeiss Company is the oldest optics manufacturer in the world. It had originally been founded in 1846 created optical devices for scientific use. At the time, 40mm lenses were considered wide angle and came with a maximum aperture of f4.5. Other lens manufacturers at the time were Taylor-Hobson[12] and Dallmeyer. The Dallmeyer Company actually created a lens with an aperture of f1.9, but it had poor image quality and was used only for actuality filmmaking. Generally, lens development at this time left filmmakers with the ability to film with a wider angle of view, but still required a large amount of light for proper exposure.

[10] Standard lenses open up to 1.4 and 2.8.
[11] Early film stocks would be considered extremely “slow” by today’s standards. The term “slow” refers to the amount of time that an emulsion takes to expose when introduced to light; usually fractions of a second.
[12] In 1998 Taylor-Hobson becomes the famous lens manufacturer Cooke.

Lighting

As mentioned above, artificial lighting was not highly available, leaving daylight as the primary source of light. Up until about 1894, films had to be shot outdoors. Edison's famed Black Maria studio brought shooting indoors (Fig. 6). Built in 1893, the Black Maria is considered America's first movie studio. It was a small, tar-paper-covered building built on a turnstile. The ceiling of the studio was actually a large pane of glass which was covered by a retractable roof. During the day, sunlight could pour into the studio and create a light level which suitable for exposure. The turnstile allowed the building to rotate so that depending on the time of day the room could be illuminated. In 1902, Pathé studios would diffuse their windowed ceiling to create a softer light; Biograph would follow soon after.

Edison would use the first artificial lighting in his New York studio. Utilizing overhead lamps was more reliable than the constantly changing qualities of daylight. The ability to place lights gave cinematographers greater control over the image. These lights were mercury vapor tubes with a mercury gas encased in quartz arc tubes that were about three feet long and three inches wide. The lamp would glow when electricity ionized the mercury vapor gas. They were actually very blue colored lights, but because film stocks of the time were only black and white, color temperature did not have an effect on picture quality. The company Cooper-Hewitt was responsible for making and supplying these lights, and they resembled modern fluorescent lights. Some films which can be seen using these lights would be *Why Jones Discharged His Clerks(date), Mystic Swing, and Uncle Josh in a Spooky Hotel,* where racks of these tubes would be hung from the ceiling or placed on stands to illuminate the subjects. This was mostly occurring in New York. The smaller emerging studios in California were still utilizing the diffused daylight method where the better weather allowed for more consistent daylight. Around 1907 the mercury vapor would be replaced with sodium vapor.

Another type of artificial lighting that was used during early cinema was the arc light. These lamps were similar to the streetlights of the time, and were placed in reflector cans to direct the light down onto the set. They looked a lot like a large version of a heat lamp of today. Vitagraph was able to hang the arc lights overhead because they were lightweight and easily movable. The arc lamps also became the preferred method for effects lighting because they could fit into small spaces and would create interesting shadow patterns that could be used to attain separation in the frame.

Overall, lighting in the days of early cinema was confined to finding ways of using available sunlight, whether it be direct, diffused, or bounced off reflectors. Artificial lights were considered supplementary simply to gain an exposure level, with the exception of a few instances, as well as interesting effects.

Camera Support

For the most part, the early cinema years were confined to little to no camera support. Prior to the 1920s, cameras were fastened directly to tripods, much like those of early still cameras. The tripods were fashioned from wood and cameramen used crude leveling techniques, like lengthening and shortening legs.

Alexandre Promio was actually the first to create a panning shot[13] by putting the camera on a gondola in Venice, France. It wasn't until 1897 when R.W. Paul created the first panning tripod head that this was possible to execute a pan the way that it is done today.

Given the fact that tripods were basically bare bones versions of what is used in filmmaking today, cameramen used other sorts of techniques to create tracking[14] shots. Mostly, this consisted of putting the camera in a car and driving the car to follow an action, or to move the camera during a shot. A great example of how early operators created camera movements can be seen in the film Dziga Vertov's *The Man with the Movie Camera* (1929). It would not be until the 1920s before the major advancements in the way cameras were supported and moved would take place.

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[13]"Panning shot" is a term for a type of camera movement where the camera is turned horizontally while independent of its position in space. The word "pan" is derived from the term "panorama". Conversely, a "tilt" is a term for a type of camera movement where the camera is turned to face either down or up independent of its place in space.
[14]"Tracking shot" is a term for a type of camera movement where the camera maintains a fixed position on a tripod or support, but is moved in a horizontal plane through space.

Film Stocks

Still photography had already been around for years by the time that motion picture film stocks had begun to be developed. George Eastman, however, attempted to switch from wet collodion plates to gelatin dry plates, which were less cumbersome and chemically difficult. In 1885, Eastman and William Walker invented a roll holder, which held 48 exposures in a roll of sensitized paper, to replace the plate holder on still cameras. In 1888, Eastman built a camera with a built-in roll holder that could take up to 100 exposures. This came from the marketing need to make photography simpler and easier for public use. In 1888, the Kodak name was put on the market under the slogan "you push the button-we do the rest". Finally, in 1889, he created the first commercial transparent roll of film for the Kodak camera, which came in a 200-foot roll, By the following year, a 1000-foot roll was in distribution.

Early in the production of motion picture celluloid a few other companies attempted to compete, such as Pathé, which bought the English company Blair. Pathé tried to recoat old film stock for re-use, but suffered terrible quality. Agfa, a German company, began manufacturing film stocks, but none of their stocks were as fast as the Kodak stocks. The Agfa stocks were also only sensitive to blue light. Kodak stocks were orthochromatic, meaning it responded well to green and blue light, (and modestly to yellow light), making the stock more dynamic and faster.

Originally, the stocks were not made with sprocket holes (i.e., perforations). The perforations were punched by whoever was using the stock. This was true until Bell & Howell decided to distribute perforators in 1908. These became extremely popular and to compete, Kodak bought up a bunch of the perforators. Kodak began to make pre-punched film stocks, which lead to the creation of the 35mm standard for size, shape, and spacing of the perforations, which continues today.

Part II. The Silent Era

1913-1927

This period marked the transition from experimentation in creating the ability to shoot film to using this ability. This was due very much to the growth of the American film market. People were spending money on films that had more shots, better acting, and better story. The industry was realizing that it could benefit financially from condensing films to only interesting sections. The audience became more concerned by story continuity than purely looking at something happening. Cinematographers began finding ways of stylizing films to tell stories through mood and imagery which lead to a new system of visual storytelling.

Camera

By World War I, the Bell & Howell camera would replace the Pathé studio camera as the most popular camera. The newest camera advancement, however, was the Akeley camera in 1917 (Fig. 7). This camera was different because it incorporated a few new advantages. It had the ability to tilt and pan using pivots that were gear driven. These gears smoothed out unevenness in the movements. It had two identical lenses mounted on the camera next to each, one the primary lens, the other, the secondary lens. The primary lens was used for actual filming, while the secondary lens was used as the view-finding lens, which could be used to focus the primary lens. This secondary lens fed a viewfinder attached to the camera, which displayed an upright image, as opposed to previous viewfinders, which showed inverted images. This helped make panning and tilting much easier, because cameramen had a better reference of what they were filming. It also made focusing the lens during the shot possible. Weighing only 22 pounds, it was primarily used for wildlife and war filming and remained in use up until the sound era. Probably the most famous film shot on this camera was Robert Flaherty's *Nanook of The North* (1922).

Another major camera innovation occurred in the Mitchell camera (Fig. 8). It was designed by John E. Leonard and was an upgrade on the Bell & Howell camera. This was one of the first studio cameras that had a viewfinder system which let operators focus and view the shot at the same time. The camera, however, did not have any registration pins until 1928. Instead, it used a third cam that was used to clamp the pressure plate down to hold the frame in place during exposure. This resulted in uneven registration for this camera.

During the silent era, cameras began making use of metal bodywork, as well as top mounted reel magazines. Also, since sound was not yet an option the camera didn't have any noise constraints, so they could keep the size of the camera to a minimum due to not having to load it with sound dampening features. In the next few years, however, this would change.

Lenses

One way that the silent era gave way to stylistic changes was with lens choice. Films like Thomas Ince's *Civilization* (1916) and D.W. Griffith's *Broken Blossoms* (1919) showed a new trend of shooting close up shots with longer lenses to give a more shallow depth of field (Fig. 9). Cinematographers were able to isolate the character by keeping sharp focus on the actor while leaving the background and foreground blurry and out of focus. The trend became more and more popular throughout the silent era.

In 1920, lens manufacturers began providing wider focal length lenses of 25mm and 30mm. This meant that cameramen could put the camera in tighter spaces and capture wider fields of view. Lens companies began to compete to create the most practical lenses with the greatest picture quality. In 1920, the Taylor-Hobson Company manufactured a 50mm lens, which opened up to an impressively fast f2. In 1925, Zeiss built the Tachars lenses, which opened up to f1.8 and f2.3. Unfortunately, these lens speeds were confined to the wider lenses. Lenses with longer focal lengths, like 100mm, maintained slower speeds of around f3.5.

Lighting

Artificial lighting devices saw dramatic development during the silent era. The Kliegle brothers designed a spotlight style light capable of generating powerful intensities. These lights were large, oblong lights that were lensed. There was an inefficiency to the lights as some of the generated light would be scattered and lost in the light's housing. It required a significant amount of electricity pulling anywhere from 60 to 120 amps[15]. The Kliegl light was a carbon arc light. Its bulb was made of two carbon electrodes which, when electricity was run through, would ignite the air in the bulb and burn to create light. When the lamp was first struck, the electrodes would have to touch to allow for the flow of electricity to begin. Then the electrodes would be pulled apart to create the electric arc. The heat of the lights resulted in many crew members and actors getting eye inflammations – the Kliegle eye - due to dust being burnt off the light. These lamps would need to be adjusted over time because the electrodes would slowly burn away during use, which meant that these lights would need operators during shooting. In 1917, it became a common practice to use these lights as an overhead backlight for characters.

By 1918, a new time of arc spotlight was built. The film industry used the military searchlight as a basis for this new model. These new spotlights were known as "sunlight arcs" (Fig. 10) because of how powerful they were. They were an open-faced light with a large parabolic mirror behind the arc, which made spotting the beam

[15] Amperage is the amount of power that will be pulled from a circuit depending on the wattage of he light. Mathematically Amps=watts/volts. For example, on a modern home, only a certain amount of lights could be run off a standard 120volt circuit. If the circuit breaker is rated for 20amps then only 2400 watts could be run off that circuit.

a possibility. Cinematographers used diffusion screens, and ripple glass to control these lights to give them a softer, more diffused look. All in all these were a new, very efficient type of spotlight.

Camera Support

In 1926, the True Ball friction head was invented, which allowed for panning and tilting the camera during the shot. It worked similar to the friction heads of today. They used the pressure of the operator's hand on the panhandle to move. Much like current tripod heads as well, operators had the capability of adjusting the amount of friction the head would hold against the movement to create slower or faster pans and tilts. Outside of the new friction tripod heads, there were very little advancements in camera support during this period. Any tracking or moving shots had to be improvised using cars or boats or whatever filmmakers could think up.

Film Stocks

In 1917, Kodak released its Cine Negative film type E and F. An improved version of stock that had been used previously, it was an orthochromatic stock and became the new standard for filming.

In 1920 Kodak released its X-Back stock. This was an invention designed to reduce the build-up of static electricity in the camera during filming. Early cameramen had issues with black streaks on the print caused by tiny sparks being created from the film being pulled from the reel. This was mainly a problem on the East Coast because of its cold weather and the greater likelihood for static electricity. The X-Back stock did not completely eliminate the streaking, and also had the disadvantage of being much more opaque than other stocks. This meant that the focusing method cameramen used, looking in the back of the gate, would not work with this stock.

Kodak also came out with a new "Super Speed Cine Film" in 1922. The film had to be special ordered and received little use due to a necessity for immediate filming after it was made or the treatment on the stock would wear off. Another special order item was the Kodak panchromatic stock. This became a standard item and was pushed on the market by Kodak advocating its capabilities in shooting skies and day-for-night[16] because of its sensitivity to blue. However, it received little use in the market because combined with costume tone changes, not many cameramen had a need for special day-for-night stocks since night scenes tended to be tinted blue anyway.

Kodak struck gold, however, with its 1923 release of 16mm reversal film stock. It was put on a cellulose acetate safety base and Kodak released the first 16mm camera and Kodascope projector. The introduction of this package brought the

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capability of motion pictures to amateur moviemakers. This resulted in the creation of numerous processing labs with which Kodak would make printing available to the world.

Also in 1923, Kodak manufactured the matrix stock. This was specifically made for the two-color Technicolor process and camera. The Technicolor process involved the use of a beam splitter splitting the light through red and green filters and onto two frames of black and white film simultaneously. They would be red and green negative prints which would then be processed to green and red positive prints. The base would then be glued together and the colors would complement each other to give the viewer the illusion of full color film. This was the second attempt at this process after the failure of using the beam splitter behind the lens to split the red and green light. The failure came not because of the shooting process but of the projection process which required a technician to monitor two strips of film which would run simultaneously through a special projector that used a beam splitter to center both images. Process one was debuted in 1916, while process two came out in 1922.

Kodak's last innovation for the time period was the introduction of duplicate negative film in 1926. This made it possible to create dissolve effects in the editing room, which added to the capability of cinematographers to rely on special effects as a means of storytelling.

Part III. The Studio Era

1927-1950

The development of the studio system coincided with the advent of sound films. The use of sound by the studios would create complications for other technologies, particularly camera and lighting. During this period, America would slump into the Great Depression and as a result, theater attendance declined and the drive to create new technology was sluggish. Many studios focused their attention on using sound as a selling point for the films. Unfortunately, the emphasis on sound had an adverse effect on the cinematography of the period. Microphone placements required cameras to remain static and in soundproof booths. The drive to develop new technologies came out of a necessity to create solutions for the problems that sound films brought with them.

Camera

The addition of sound meant that filmmakers had to create quieter cameras. The noise from the film running through the camera was loud enough that the microphones could pick up the sound while shooting. The first solution to this problem was to move the camera into a soundproof booth. The booth was essentially a separate room where the camera would be placed, and a window that the camera could record the action through. This left cameras with uninteresting shot angles and composition.

The solution was a camera "blimp" (Fig. 11). The blimp was a large, metal, soundproof box encasing the camera and allowed for increased mobility. This allowed for cameras to be removed from the booths, however, left the cameras with a bulky exterior encasement that could not easily fit into small places. The Mitchell Camera Company was able to adapt their cameras to fit into these blimps. However, Bell & Howell could not follow suit which gave the new Mitchell BNC camera the opportunity to become the camera of choice starting in the late thirties.

The BNC cameras (Fig. 12) were also the first generation of cameras designed to be quieter and operate outside of the blimps and sound booths. This camera was what cinematographer Gregg Toland used on *Citizen Kane*. MGM acquired one of the BNC cameras that Toland used because of Mitchell's need to test the new camera. The ability to move the camera more freely while separately recording sound helped Toland achieve the amazing level of cinematography that makes up this great American masterpiece.

In 1937, Arriflex came out with a camera that operated nearly the same as current Arri cameras that are used today. It came equipped with a viewfinder that looked through the lens using a rolling mirrored shutter. When the light would travel through the lens, while the shutter was closed it would be reflected up into the viewfinder. This camera also used the single claw and pin system that ran on a motor charged by a battery pack. The camera was ideal for war filming because of the ability to preload a magazine and change it in about two seconds. Also, the Arriflex had good handheld ergonomics, which led to a preference to this camera over its competitors.

The new name of the game was quieter cameras. Companies like Mitchell, that could find ways to dampen sound emission from the camera were to survive. Blimps made the cameras cumbersome and tricky to work with, so the search for a camera that could be used with a microphone was on.

Lenses

Right before the 1930s, lenses with focal lengths shorter than 25mm were experimented with, but suffered from poor quality. This was the result of a growing interest in "deep focus" photography. Anyone who really attempted to make a lens wider than 25mm resorted to experimental photography, for example Gregg Toland in *Citizen Kane* when he put a piece of glass in front of the lens to create a "fisheye" look.

Other experiments included the concept of "zoom" lenses. The goal of the zoom lens was to have a single lens with a range of focal lengths, allowing for "zooming" in and out of the action in front of it. The early attempts were quiet unsuccessful, though. These lenses generally had a maximum aperture of f11, which meant that it was a poor choice for any sort of low light situation. Also, the focus and zoom level had to be adjusted simultaneously. Last, these lenses were not the ideal choice for studio work because they were not compatible with the design of the blimps; they were too large to fit inside of the housing.

In the thirties, studios began to instill a system of shooting which determined lens choice. The general rule was "the wider the shot the wider the lens". Long shots could typically be found using a lens with a focal length of about 40mm, and close up shots would usually be filmed with a 75mm or 100mm lens. Because of the design of the camera blimps, lenses wider than 25mm could not be used; the wide angle would allow the edge of the blimp window to be seen, which is one reason for the 40mm lens choice. Due to lighting situations in the studios, lenses were usually used at their maximum aperture, which was generally around an f2.8, this resulted in a shallower depth of field and helped establish the "studio" look.

In 1940, the first lenses were given an anti-reflective coating on the outer glass element. Lenses would be coated with a microscopically thin layer of magnesium fluoride that would increase lens's inherent speed by up to 40%. The loss of light was common. It occurred as a result of reflections within the barrel of the lens, bouncing light off internal glass elements and back out the front of the lens. The coating worked by reflecting that light back into the lens. The coating was only about ¼ of a light wavelength thick and would be applied using an evaporation method, which took place inside of a vacuum. This method would help overall increase the sharpness and speed of lenses for the remainder of filmmaking.

Lighting

Prior to sound, and resulting from the use of panchromatic negative film, many cinematographers took an interest in using tungsten lights. The theory was that the increased sensitivity to red light caused the film to be faster when used with the tungsten lights, which lean more towards red on the light spectrum. The tungsten lights were also more efficient lights, required less manpower, and were ultimately more reliable. Arc lights, however, tended to work much better with the film stocks that manufacturers were producing.

Unfortunately, as the popularity of sound films grew, the arc lights were discarded because of high sound levels. Incandescent floodlights were fitted with large tungsten globes replaced the Cooper-Hewitt lamps. These floodlights used large, bowl-like, reflectors around the bulb to direct the light, and were built as open-faced floodlights, as opposed to lensed "theater" style lights. This movement was guided by, now industry leading, Mole-Richardson, which occurred as they officially, founded their name in 1927.

By 1931, all of the studios returned to using arc lights. Developments in circuitry allowed for the hum of arc lights to be silenced. However, the majority of lighting done was still tungsten. In 1934, Fresnel lights were developed as spotlights and used for key lighting[17]. Fresnel lights are designed to have the bulb placed in the

[17] A "key light" is a term used for the main lighting source when lighting a person, based on the 3-point lighting principal. That is, a "key light" for initial exposure, a "fill light" opposite they key light to

middle of the lamp with a parabolic mirror behind it reflecting light back through a lens in the front of the lamp. These lights were much more efficient and controllable. They came with an ability to spot and flood the beam, which means that operators could focus the beam to create a sharp centralized spot of light, or they could widen the beam giving the light a wider beam with a diffused effect. This accomplished by controlling the distance between the bulb and the mirror in the back of the lamp. The spot-flood function became the most groundbreaking development of the time; lensed Fresnel lamps are still the most popular type of light used in films today.

The Mole-Richardson company recognized the industry's desire to shoot with smaller fixtures around 1940. There was a growing trend to shoot with faster stocks in lower light. This is where the solar-spot, inkies, and dinky inkies came into play. These lights were of 1,000 watts of power and under.

As the trend to create efficient lighting sources continued one of the most considerable inventions in was the photoflood bulb by General Electric. These were bulbs that had a reflective coating on the inside of the glass covering half of the bulb. They were desirable for interiors because of the even flood lighting that they gave and their ability to give more light than other bulbs using the same wattage. The disadvantage, however, was that they only lasted a few hours before they would burn out. Nevertheless, the industry was fulfilling the need to become more efficient and giving cinematographers the option of using smaller lighting systems.

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control the contrast of the light ratio, and a "backlight" placed behind the subject to create a ring of light around the back of the subject.

Camera Support

Under the supervision of Paul Fejos, Universal Studios built the first camera crane. It was 25 feet long and was big enough for two cameras. It implemented a counterweight system to hold the camera up and achieved movement using a pivoting column mounted on a wheeled base that ran on electric motors. This crane was first used on the production of *Broadway* in 1929.

By the 1930s, the use of the large crane movements was generally reserved for musicals. Rarely, would there be a use for crane shots in a more dramatic film. More popular, instead, were tracking shots. These were achieved with the addition of small steerable dollies that were usually fitted with thick rubber wheels and a support column in the middle for the camera. Originally, this column would not move, however, in 1932, Bell & Howell developed the "rotambulator" which, on top of other things, allowed for a rising a falling column. This dolly was a small 3-wheeled version of the present day crab dollies. It came with a built in geared head for cameras, however, only allowed a minimum lens height of 3 feet, which was common with all dollies of the time. The last innovation of the studio era would be geared tripod heads. In 1930, Mole-Richardson developed the first version of a geared head that would become a model for the current heads being used today. However, with the exception of these three elements, camera support would go mainly untouched until the 1960s.

Film Stocks

The most significant change in the world of film stocks before 1930 was the change from orthochromatic film to the new panchromatic film stocks. In general, the panchromatic film was a better stock in terms of color exposure. Since the stock was a black and white stock, this means that it would expose a wider range of colors on the visible light spectrum, almost the entire spectrum. This is to say that the grayscale that the film emulsion developed had less contrast in the black and white, giving skin tones a nicer silver look in middle grey. This is in comparison to the orthochromatic stocks that were more sensitive to blue than red and therefore shortened the length of the visible light spectrum that it could expose, which in turn gave the stock much more contrast in the image.

By 1931, the Kodak Supersensitive stock had made it into the industry. The film was much faster than the stocks of the time, which had an ASA rating of about 20[18]. It had an increased amount of grain in the image, but it was also the first stock to come with an anti-halation backing. Kodak applied an opaque backing to the film to

[18] In comparison, one of the most common film stocks by Kodak today is the Vision series which comes in an ASA rating of 500, meaning it is 25 times faster than the Supersensitive stock of 1931.

prevent light from going through the film and bouncing back giving a halo effect on parts of the image that were particularly bright, such as lights. During development of the negative, the backing would dissolve off so that during projection there were no problems with brightness.

In 1934, the Agfa Company introduced a faster stock called Superpan which had an ASA of 32. This lead to a light battle for the fastest film stock between Agfa and Kodak until Kodak released its Plus X and Super XX stocks. These stocks came in 80 ASA and 160 ASA, and were much superior in terms of image quality. Interestingly enough, instead of cinematographers using the fast stocks to close down the aperture on the lens and achieve a greater depth of field and sharper image, they decided to implement smaller lighting systems, which is where Mole-Richardson comes in again.

MGM and RKO studios used these stocks slightly differently. They utilized a system of overexposing the stock, and then giving a reduced development to the negative. The effect was a flatter image with a higher ratio of middle grey tones that picked up into the late 'thirties. Where as studios like Twentieth Century Fox used the faster stocks to their advantage and demanded that everything being shot on an interior set be shot at an f3.5 for greater depth of field. This can be seen a few times in *The Grapes of Wrath,* which was somewhat of a precursor for the interest in deep focus photography that Gregg Toland would use in *Citizen Kane*.

The system of rating film stock speed was put in place in 1941. The ASA scale required cinematographers to use light meters on set to achieve a proper exposure. The most popular of which was the Norwood incident meter (Fig. 13). Unlike the earlier reflected meters of the Weston style that measured foot candles, the Norwood meter took a general reading from all directions and used a system to calculate the intensity before giving the operator an exposure. This became one of the most useful tools that a cinematographer could use on set to create a proper exposure.

Part IV. The Adaptive Era

1950-1970

Camera

During the 1950s, there were two major additions to the camera world, the first addition being the introduction of 16mm film. After the war, the Arriflex 16s camera made its way to America. New to the Arri cameras was a frontally located claw, which is in contrast to the previous placement by other camera companies of claws in the back. The 16s was similar to the 35mm camera except for the film reel magazines. It was built to originally run 100-foot daylight spools of film. However, Arri created a new line of magazines, which would carry 400-foot reels. These magazines were adapted to be mounted on top of the camera (Fig. 14). There was a change in these magazines, though; the sprocket drive that was usually built into the magazines was actually built straight into the camera instead. Unfortunately, the camera did not make much of an impact on the documentary market, for which 16mm cameras were intended.

The second and more important innovation of the fifties was the Auricon Cine-Voice camera. This camera allowed tape recorders to operate in conjunction with the camera, but without a connecting cable. This camera spearheaded the ability to shoot "direct cinema", a style of documentary, while at the same time bringing a new way of shooting news footage to the forefront.

The original Auricon camera would drive Richard Leacock and Donn Pennebaker to develop lightweight camera adaptations which, at the same time, were silenced enough to record sound. Since the Cine-Voice camera (Fig. 15) was the lightest, they modified the internal magazine, which only held 100-foot spools, to use an externally mounted magazine that could hold 400-foot reels of film. This was done out of a necessity to film more at one time without having to change reels every three minutes. These lightweight sound cameras were aimed directly at the documentary market where a guerilla shooting style is more common, where time could not be wasted changing reels very often and hand-holding of the camera is almost unavoidable.

In the 35mm camera world very little was new. Mitchell switched to a dual mirrored reflex shutter in their design of the Mark II, which is different from the majority of other cameras using a single shutter for both exposure and reflection into the viewfinder. The major problem with this camera was the fact that it was much noisier than most cameras, such as the BNC, which made it somewhat undesirable. It also wasn't much lighter than previous cameras which gave no advantage in hand-holding. Because this camera had particularly good registration, the Mark II was found to be more useful making TV commercials where effects like titles and graphics were used. In addition, commercials did not generally require synch sound recording, so the amount of noise created by the camera was not much of a problem.

Lenses

The needs stemming from TV created a more intense demand for lenses capable of shooting in low light, as well as a need for simplicity. This seemed to be the era of the zoom lens. A few lenses came out in the fifties that were wider and faster than previously released. These lenses were mainly for 16mm cameras, such as the 25mm Angenieux which had a maximum aperture of f0.95 and came out in 1956. In the 35mm camera world a new 14mm lens was available in 1959 which had a 108 degree horizontal field of view. The zoom lens, however, was being developed by a few companies that saw the value in the efficiency of fast lenses with multiple focal lengths.

In 1954, The Zoomar Corporation came out with a variable focus zoom lens. This lens only had a 3 to 1 ratio and was created for 35mm cameras. The design was adapted from an earlier lens built for 16mm cameras. A greater improvement was the SOM-Berthiot zoom lens out of France in 1956. For 35mm cameras, the lens had a 4 to 1 zoom ratio and made with a focal length range of 38.5mm to 150mm and a maximum aperture of f3.5. In 1958, Angenieux would come out with a lens based on the SOM design.

In 1963, Angenieux released a zoom lens with 10 to 1 zoom ratio for 35mm cameras. This meant a zoom range from 25mm to 250mm and a maximum aperture of f3.2. The 16mm version where the zoom range was 12mm to 120mm became the most successful lens of all time. This is because the convenience of the lens completely outweighed the loss of image quality, which was not so great that it was particularly noticeable, except when the lens was used at its extremes. The lens was also made with the reflex view-finding system built in. This allowed the lens to be used with the Mitchell BNC and the Auricon camera. Although zoom lens designs began to compete on the market with prime lenses, the image quality was still a noteworthy issue when it came to narrative film production.

Lighting

As with so many other products on the market, television began to create a demand for lighting equipment. In 1951, the cone light was introduced. It was built out of a need to create a large amount of light to fill the action without creating shadows. This was obtained by using a ten thousand watt bulb inside of cone shaped lamp which was painted flat white on the inside of the cone to bounce the light onto subjects while at the same time diffusing it. It eliminated direct beams by placing another piece of white in the center of the lamp and in front of the bulb to shield the light[19]. These lights were suspended from the ceiling to cast what little shadows they

[19] The "cone light" design resembled that of the modern "soft lights", however, found little use in film production.

produced onto the floor. This created the ability to use multiple cameras at one time to capture different angles and speed up television production.

Outside of the technical developments, of which there were few, there were new stylistic changes during the fifties. With the improvement of color film the popularity of backlighting decreased. This came from the ability to create separation in the image using colors as opposed to lighting principals. Overall, simplicity was the goal. As studio sets shrank to mimic real dimensions, so too did the number of lights that could be used on the given set. The trend followed black and white film production as well, though not to the same degree. In an attempt to create a more natural look, daytime exterior shots even began to eliminate supplementary lighting.

The 1960s, however, brought a new approach to lighting style as well as tools with which to create this style. Because sets were becoming smaller, and film stocks were becoming faster, the need for large powerful lights decreased slightly. In 1960, Ross Lowel came out with a new small, lightweight, controllable light. The light housed a 500-watt reflector bulb, and weighed only 10 ounces. The light also came with detachable barn doors for control and was small enough to be hidden in discreet places. These lights were primarily used for documentary and news work, but the Lowel name would eventually find its way into modern narrative production.

Colortran began replacing their old system with new quartz-iodine or tungsten-halogen bulbs placed inside of Fresnel housings. These new housings weighed only a few pounds and utilized “spot” and “flood” options. This meant that a parabolic mirror was placed behind the movable bulb and that a lens was built into the housing and placed in front of the bulb. When moved closer to the lens, the lamp would be at full spot, which would focus the beam through the lens and create a harder light. In contrast, when moved further away from the lens, the light would be at full flood which created a softer beam of light.

The third new light of the sixties was the Minibrute, also known as the “niner”. This was because it contained three groups of 650-watt lights on three adjustable panels. It was a small alternative to the Brute lights and found use on large exterior sets. The drawback of this light was that if the actor were near a wall it would create multiple shadows, so it was really only capable of supplementing exterior light.

The general trend of this era was towards soft lighting. This grew out of a European strive for naturalism and simplicity. During the sixties cameramen began to use a system of bounced light by aiming lights into the ceilings above windows, which mimicked the natural light pouring through windows. This was found more often in French films of the time, but Americans attempted to accommodate the style as well. Unfortunately, in the American studios of the time, the white walls and smaller rooms of the location interiors, that the French used, were not a possibility. Americans adapted by using large white boards to bounce light, thus recreating the soft, diffused lighting style. This was only possibly due to the newer faster film stocks because a great deal of light is lost when it is bounced and only the fast stocks could expose for the light loss.

Camera Support

One of the most important additions to the camera support world at this time was the advent of the hydraulic fluid dampening system for tripod heads. The release of the new heads could not have come at a better time. This era saw an amplified use of longer focal length lenses that could not hide the small jerks and uneven movements when panning or tilting to follow action. The earlier friction heads were simply not strong enough to smooth out these movements with lenses of over 200mm However, the fluid heads developed by O'connor could achieve this smoothness. At this time, geared heads, commonly used by studios, were available and were also capable of supporting cameras dawning longer lenses, but were cumbersome and inefficient for any sort of location shooting. They were also more difficult to use and made following a change in action difficult to cope with.

The tendency to shoot on location in America meant that equipment needed to be more movable. This included dollies, and the Moviola crab dolly became the primary dolly used in America (Fig.16). The large, rubber, pneumatic tires were its main selling point. The tires could absorb cracks and bumps much better than the competitors, including the Colortran dolly. The Colortran dolly only weighed 222 pounds, and was slim enough that it could fit through doors, but the hard rubber tires caused problems when used without the use of a dolly track.

In 1964, the Tyler camera mount was released for helicopters. Originally, the vibrations were limited, but in 1965 the Dynalens was released which removed *all* of the vibration. It worked due to a flexible prism that was controlled electromagnetically and would deviate the image by the exact amount needed to take the vibration out. Although this technology was available in 1965, it made its mainstream debut in the 1968 Olympic Games.

Film Stocks

In the 1950s, color film began major development. After World War II, America brought back stocks that had been manufactured by the Agfa film Company called Agfacolor stocks. These were a single strip color film which had an ASA rating of about 12. In 1951, Kodak began producing their own single strip color film based on the Agfacolor system and process. Problems with the Agfacolor process were speed and insufficient color reproduction. Kodak created a "color mask" which would correct for this problem, particularly with blue and green colors. They also incorporated an intermediate process which improved the film speed to about 16 ASA by finding a way of duplicating negative and positive stocks. This was compared to other color stocks which had to go through black and white separation positives.

The speed of Kodak's new color film was still not yet a match for the Technicolor process, which boasted an inexact rating ranging from 50 ASA to 100

ASA. However, in 1953, Kodak improved the process by creating new intermediate negative and positive stocks. They also changed the camera negative to a tungsten balance, which brought it into the realm of 50 ASA. This color negative stock became the dominant stock chosen for film production, now surpassing the superior image of Technicolor because of its speed, and convenience. In 1955, Technicolor stopped making film stocks for the specialized camera and focused on the laboratory process that could be carried out using the Kodak color negative stock. This meant that no specialized camera or lenses was needed to shoot color film, and that wider angle lenses could be utilized in color productions. This had not been the case previous to the introduction of this Eastman Kodak stock.

The sixties were a time of improvement in the film stock world. As with the rest of this era, television drove the need for the ability to shoot in low light situations. This meant Kodak continued to look for ways to make faster color films. The two biggest additions to Kodak's capabilities were actually not with the color negative stock, but with the Ektachrome stock. The development was not even necessarily the stock's speed, but the ability to "force develop" it; film could be shot in under-lit situations and in the lab the film would be developed at a higher temperature and at a faster pace which would in brighten the image up. This would work for about 3 stops until image quality began to be compromised with grain structure becoming apparent.

The second big step Kodak took was the invention of the Color Reversal Intermediate stock. This stock allowed for a second negative to be created from the original camera negative, without any image quality loss. Previously there had been a need to create a positive print before going to the negative. This helped improve the quality of fades, but it also gave way for the use of "liquid gate" printing. During this process, the negative film would pass through the gate in the printer which was submersed in a clear liquid while light passed through it. The liquid had the same refractive index as the emulsion, allowing it to fill in scratches and would keep the scratches from being transferred to the positive print. This process became very popular when creating a 35mm print from an original 16mm negative which was a growing trend in the sixties.

Part V. The Hollywood Renaissance

1970-1980

The Hollywood Renaissance era can be described as one of the most historically innovative times for film production. As with every moment in film history, the surrounding times have a major impact on the films being made, both in story and style. This era was particularly subject to a new style that was made possible by a new crop of cinematographers and directors working to create films which had never before been imagined. The boom of technical advancements gave cameramen a whole new world of tools with which to create the atmosphere and emotion which the stories of this era demanded.

Camera

Camera development and design reached an historical climax during the seventies. The two most important developments were by the Arri and Panavision camera companies.

During the seventies, Arri decided to abandon the earlier designs for 35mm cameras and adapt a design much like the French Éclair NPR camera of 1971. The camera underwent a number of prototypes in an attempt to quiet the camera down to 25 dB, which was realized in 1980 with the Arri 35 BL Mark III. This came after a number of blimped models, changing the camera to cast aluminum, and creating a quieter claw and pin system. It also came with a coaxial clip in a magazine that could be pre-loaded and replaced with efficiency. One of the seemingly insignificant changes that Arri made was to the balance of the camera. At 15 pounds without film, the camera was not particularly heavy, but Arri was the first company to attempt to balance the weight of the camera to be directly over the operator's shoulders to improve hand-held operating.

A major advancement made by Arri was in 16mm camera development. In 1975, they released the Arri 16SR (Fig. 17). The camera was very similar to the 35 BL, but weighed only 11 pounds. It carried 200' coaxial magazines, and for the first time came with a built in, through-the-lens light meter. It also had a completely adjustable viewfinder that allowed cameramen to operate with their left eye in greater comfort. The Zeiss 10-100mm zoom lens was the standard lens fitted to the camera. Similar to most new cameras of the time, the SR came with a crystal controlled motor to control camera speed ranging from 8 to 40 frames per second. The controllability of the 16SR made the camera one of the more popular cameras of the seventies.

In 1972, Panavision released the Panaflex 35mm camera (Fig. 18). Originallya lens company, Panavision became the most desirable camera for big-budget and studio film productions. The camera was lightweight (weighing only 34pounds) with a magazine capable of holding 500 feet of film that could be mounted on top or on the side. In 1976, they developed a magazine capable of holding 2000 feet of film. It ran on an electric motor, as most cameras did at this point, which was part of a drive system that was based on the Mitchell system, but was an updated version that also helped to reduce the weight. The first Panaflex was used on Steven Spielberg's *The Sugarland Express* (1974) where hand-held synchronized dialogue was shot during a moving car sequence, which had never been done before.

Aside from the two main companies designing cameras there were three smaller companies pushing the envelope of camera development. Those companies were Cinema Products, Moviecam, and Aaton. Cinema Products was started by Edmund DiGuilo who left the Mitchell Company in 1968. By installing reflecting 45 pellicle mirrors in front of the shutters he began converting BNC cameras to reflex cameras. Cinema Products developed the CP-16, which was inspired by the Auricon camera, and mounted with the Angenieux 10-1 zoom lens. In 1973, it was fitted with a reflex shutter and became the camera of choice for TV studios, surpassing the Auricon. In the 35mm market they designed the X35R which weighed 93 pounds without a lens or film. It was essentially an improved version of the Mitchell cameras. The X35R competed with the Panaflex as the major studio camera, mainly because Panavision only rented out equipment and required a royalty on the footage, which was too much to ask for some producers. The Moviecam 3N and Aaton NPR are also both notable cameras of the decade. Moviecam created the quietist 35mm camera and also had a "digislate" that printed the scene number onto the negative stock, as well as a capability for a plug in time coding accessory. The Aaton camera company created the Éclair NPR which became the most popular super16 camera of the decade.

Lenses

Television pushed for the most efficient lenses. Competing with Angenieux for control of the zoom lens market was Taylor-Hobson. They released a 5 to 1 zoom lens that was 20mm to 100mm and a maximum aperture of T3.2[20]. It also had a close focus of 0.34cm. This lens was also fitted with a focus ring that was convenient when adapted to 16mm cameras while being used to cover news footage.

At this point in history, Canon decided to enter the lens world with its own 5 to 1 zoom lens. In 1971, they released a 25mm to 120mm zoom lens which opened to a T2.8. The big releases were the anamorphic zoom lenses and the particularly fast prime lenses. Canon began to replace internal glass elements with synthetic fluorite crystal, and used computers to cut the element and eliminate the abnormalities in the curve. This, combined with numerous coatings of anti-flare coatings, made it possible to create lenses with maximum apertures of T1.4. These lenses were similar to the new Zeiss Superspeed lenses, which opened up to a maximum aperture of T1.3. The only faster lenses of the time were specially adapted from still photography 50mm

[20] T Stops are another measurement for lens aperture. However, it is a measurement that takes into account the inherent light loss caused by the lens when the light travels through it.

lenses for Kubrick's film *Barry Lyndon,* which opened up to f0.7. This was in order to film in the extreme low light created by Haskell Wexler's completely candlelit interior scenes. Zeiss also introduced "floating" elements, which meant that the internal elements would move in proportion to the external elements when changing focus. This was based on the same theory as the movement of elements in zoom lenses.

Angenieux continued to improve on its own designs but began releasing lenses with a wider range of zoom capabilities, and capped the competition from Cinema Products' 20 to 1 zoom lens with a 25 to 1 at 25mm to 625mm in 1980. However, with the trend continuing to move towards location shooting and low light situations, cinematographers tended to lean towards the faster prime lenses, particularly for feature film production.

Lighting

A number of new lights made their way onto sets in the seventies. The first of these was created by Xenotech Inc., which modeled its new xenon arc lights after military tank spotlights. These lights produced a 6,000 degree Kelvin color temperature, which came close to the 5,600 degree Kelvin temperature of daylight. The xenon lights were about the same size as the arc brute but were able to run on 4,000 watts from a 30 volt D.C. circuit. The drawback of these lights was that they were known to have exploding bulbs while on set.

The next lighting innovation was the HMI bulb. HMI lights were capable of putting out a lot of power at 5,500 degrees Kelvin from a small lightweight lamp, making them ideal for location shooting. Unfortunately, there were a number of initial problems with HMI bulbs. The drawbacks included fragile bulbs that would break or die easily; they also had problems with light flicker when used with A.C. circuits. The flicker problem was remedied using frequency-regulated generators and adjusted ballasts. In Europe Arri and LTM were building HMI bulbs, while in 1974, Mole-Richardson began producing these bulbs.

The last addition to the lighting world was the smaller lights that Lowel had continued designing, including the Tota (Fig. 19) and Omni lights. These were small, less than 7pounds, 1000-watt lights that were ideal for location news and documentary shooting because of their portability. The Tota light was a small bulb with two reflective barn doors that would fold in when packing the light away. The Omni light was an open-faced light comprised of a bulb in front of a parabolic reflector with spot and flood functions, and controlled by removable barn doors. These lights would become a standard for small-scale productions because of their low cost and the ability to light small scenes with only four lights.

Camera Support

The computer played an essential part in the development of camera support during this decade. Just as essential to the computer, however, was the stepping motor. This programmable motor was used to control the computerized crane and dolly movements. This motor allowed operators to set exact points in a movement that the crane and dolly could then exactly reproduce as many times as desired. The newest version of this crane was the Louma crane (Fig. 20). This looked much like a large microphone boom which extended to 23'. The camera was mounted at the end on a mechanism run by stepping motors and remotely controlled. . The crane was fitted with a video assist system, which displayed a video feed from the film camera. It utilized a beam splitter to send part of the light that would otherwise go through the viewfinder to a video chip wired to a separate monitor, allowing operators to not have to look through the viewfinder framing and focus. Although there is some debate over who officially invented video assist, comedian Jerry Lewis seems to be the deciding vote, it being used on the film *The Bellboy* in 1960. Stanley Kubrick is said to have used a primitive version of the system; unfortunately, there are few accounts of exactly how it was designed.

The age of computers also allowed for improvements on helicopter shooting. These improvements, created by the Canadian military, were originally used for surveillance. The technology was built by the Westinghouse Company and was effectively called the Wescam. This mount consisted of a fiberglass sphere that surrounded the camera with a window built in for the lens to shoot through. The sphere was then mounted outside of the helicopter and controlled by servomotors. The system had some sort of video assist setup allowing for remote viewing while controlling the motors via some sort of joystick mechanism.

One of the most utilized tools of the seventies was developed by inventor Garrett Brown and is known as the Steadicam (Fig. 21). The Steadicam was a body-mounted apparatus that utilized a vest, a spring arm, and a center-post with attached gimbal joint. The camera was placed on the top of the center-post and was balanced at the gimbal joint, effectively lowering the center of gravity of the camera, which aimed to eliminate unintended panning and tilting. The gimbal was connected to a spring arm which was designed to absorb bumps created from walking. And the spring arm connected to the operator via a padded vest. The goal of the Steadicam was to create the ability to make completely smooth hand held camera moves. The intended look was much like a dolly movement; however, the convenience of a body mount meant that tracks were un-necessary, as were cranes for shots moving up and down stairs(for example). The only major downfalls of the Steadicam was that it was difficult to use, requiring training, and a certain amount of strength due to the increased stress put on operators by the weight.

Film Stocks

The major addition of film stocks at this time was by Fuji in Japan. In 1973, it released a motion picture color negative stock with an ASA rating of 100. This meant that it was as fast as the Kodak color negative stock. Shortly after its release, Kodak came out with a new, (what they thought was) improved, color negative stock. However, because of an increase in color saturation, many cinematographers rejected the stock. This problem was quickly remedied in 1975 by a new stock that found immediate use in America. During this time, the Fuji stock would have been a preferred stock by some cinematographers, however, it really found its way into the TV market due to its lower price compared to Kodak.

The seventies also saw a transition in preferred 16mm stock. Documentaries tended to use the Ektachrome reversal stock, but that changed when Kodak replaced its own upgrades with the Eastman Video News Film. The stock was generally a better stock, with a decrease in grain, and an increase in color detail.

Part VI. The Modern Age

1980-current

Camera

During the eighties only a few major camera companies remained. These were Panavision, Arri, and Moviecam. Panavision had made a deal with Aaton in efforts to fill the void left by the absence of lightweight cameras to its arsenal or professional motion picture cameras. Meanwhile, it supported the time-code system developed by Aaton. The Arri 35BL eventually became the Arri 535 camera which was built to compete with the Panaflex camera. It had a built in SMPTE time code generator, as well as illuminated frame markings which were used for framing in low light situations. The most important aspect of the new camera was the interlinking between the variable shutter and aperture diaphragm. This meant that if an operator changed either setting, the camera would automatically change the other. This made sure that exposure was always kept constant through the camera.

At this time there was growing activity in larger film formats, which required cameras designed specifically for that film. Arri designed a camera based on the 35BL called the 765. This camera was able to run 70mm film at speeds between 2 and 100 frames per second. The 70mm format was used for IMAX presentations which have gained much more momentum in the 2000s.

In 1996 Arri released the 435 which was designed much like the older Arri cameras with the magazine mounted on the slanted back of the camera. The camera was also used for non-synch shoots and could run up to 150 frames per second. In the nineties Arri had become the leader in technical advancements for cameras. In 1999, Panavision followed suit with the Millenium Panaflex camera which had many of the same electronic options as the Arri concerning shutter and film speed controls.

Aaton continued to focus on the 16mm market as they could not compete with the larger Arri and Panavision companies. Originally Aaton had a dieresis over the second "a" in its name, however, this was removed during the nineties to put the company alphabetically ahead of Arri, most likely for marketing purposes, particularly in the age of the internet.

The 1990s were a decade of dominance for the large 35mm. camera producers. However, as the 2000s continue the underlying trend for video cinematography has been coming to the forefront. Currently, there has been a major growing trend to use High Definition video cameras for feature cinematography. The Panavision Company has recognized the growth and entered the digital HD market with the Genesis. The camera claims to have all the advantages of film, however, recording onto solid state magazines capable of holding gigabytes of information which is recorded by a sensor chip, which replaced the historical gate in the camera as the light sensitive feature. Coinciding with the digital age is a move of productions away from studios to independent filmmakers who utilize the cheaper solutions to the same goal of full HD recording. The most revolutionary camera of the decade could be described as the

RED One camera (Fig. 22) made by the RED company. This camera is capable of recording images greater than full HD, with plans to increase its abilities in the future. It was built to be adjusted with mounts and adapter to make using numerous cinema lenses possible. It is also lightweight, weighing in at about 10pounds and being only 6" tall and 12" long it is a particularly small camera. The trend in creating small cameras has been taken over between 2009 and 2010 by the DSLR market. Digital Single Lens Reflex still cameras have adapted to being able to record a full HD image as well, the most powerful of which was released by Canon as the 5D mark II. The benefits of which include in-camera image adjustments, as well as ISO, the DSLR version of ASA, which can be cranked up to 6,400. Downfalls of this camera, however, include increased noise, the digital equivalent of grain, and a particularly complex post-production workflow before creating a final film print for projection. But this camera has recently dominated the independent market because of its amateur photographer affordability, and an increased drive in digital media mediums such as the internet and Blue Ray discs.

Lenses

Lenses continued to be improved during the eighties out of competition in the market. With the use of lens design programs companies were using computers to design lenses to exact measurements. Glass elements had also begun to be replaced by fluophosphate glass, as discovered ealier this lead to a high refractive index, making the lens inherently faster. This decade, Panavision also released its own lenses which were both spherical and anamorphic. The famed Primo lenses were released in 1987 but as with all other Panavision equipment, productions could only rent these lenses. The were built to compete with the Zeiss Superspeeds, but in recent years have seemed to surpass the Zeiss company in image quality. Also During the eighties Taylor-Hobson changed its name to the now famous Cooke lens company. Meanwhile Canon and Nikon had begun adapting lens for motion picture use.

In 1992 Clairmont Camera company introduced the newest innovation to the lens world, swing/shift lenses. These lenses were built in specially made rigs which kept the lens off axis, in turn, creating a difference in focus at the same plane of depth. These lenses were used as more of a special effect than for straight forward viewing.

As with the pattern of cameras moving into the digital age during the 2000s, so did lenses. Mainly the cameras would be adapted to use cinema lenses, however, in smaller scale production, video cameras had began using mini35 adapters which were mounted on the front of the video lens and used a system of reflection to translate the use of cinema lenses into the video lens. This was done to create the opportunity to use shallow depth of field, which created separation and made low budget productions look more professional. Popular brands that build these adapters were P+S Technik, Brevis, and Letus. The downfall to these adapters, though, is unreliability with the internal ground glass element, as well as a need for further support rod systems to hold up the adapter on the front of the video lens. At the same time, within recent months of 2010, during the DSLR boom, independent manufacturers have begun fitting DSLR cameras with cinema lens mounts, such as PL mounts, so that cinema lenses could be used during HD filming.

Lighting

The eighties saw an increase in powerful lights that used metal halide arcs. They ranged from 6,000 watts in 1981 to 18,000 watts developed by 1989. HMI bulbs had found their place in the market as one of the more popular bulbs for daylight lighting. One light that utilized the HMI bulb was developed in America as the Musco Mobile light. This light consisted of 15 lightweight lamp heads, each holding a 6000 watt HMI bulb. The lamps were placed on a grid and hoisted above the action using a crane. The power source for this light, which became commonplace as lights grew larger, was a separate electricity generator which sat at the base of the crane. Also, since the lights would be up so high they would be controlled by an operator with a remote who could change the angle of the light according to the needs of the shot.

In 1987, the Kino Flo lighting system was introduced. These were lights comprised of rows of fluorescent tube bulbs that were controlled by ballasts. The tube bulbs were also designed to glow particular color temperatures aside from the green that is generally associated with fluorescent lighting. Typically, daylight and tungsten were how tubes were balanced. The Kino Flo lights were used as a type of soft light that was particularly useful except for a major detail. When using Kino Flo lights, much like the earlier HMI lights, there was a stroboscopic effect that was noticeable when filming. This was due to the pulsing frequency of the electronic current. A ballast was designed to eliminate the effect but really only minimized the issue to the point where it was not noticeable on the film.

Other new lights of the time period included new HMI parabolic lamp designs. They HMI "PAR" lights were a good source of high-powered light that could be focused into a beam with a narrow width giving it a spotlight-like quality. In the early 1990s, a development known as the "dedolight" was released. This was a very small Fresnel light with a convex lens on the front of the housing. This created a small beam of light which had a sharp fall off outside of the hard beam. These lights were ideal because they were only 100 watts, coming out with a 300 watt model later, which could be placed in small places without melting anything surrounding it, lending itself to shots involving cramped interiors, like cars. Lastly, during the nineties, was the addition of Chimera lights. These were not necessarily lamps and bulbs, but a cloth-like covering which was mounted to the front of a light and would extend out about three feet to create a reflective surrounding around the face of the light. The opening would then be covered with an opaque, white cloth that wouldn't burn, but would in turn create a diffused effect. This became a means of creating soft, natural light without the hassle of stands and silks.

In the modern 2000s, few lights have been invented, instead improvements have been made to existing lights, particularly those with electrical issues, such as HMI and Kino Flo lights. One new light, however, is the Kobalt brand HMI light, which claims to be an all-weather lamp. Kobalt claims that the light can be placed outside during rain and other atmospheric elements, and it will not short out the light. This becomes very convenient when shooting on location where rain is either necessary or unwanted.

Camera Support

At this point, very little camera support had been innovated. Instead, current dolly systems had been improved upon. Such as the Elemack Cricket dolly, which was equipped with a hydraulic pump that allowed for the camera to rise and fall according to the dolly grip's operation. The hydraulic system helped to insure smooth movements while going up and down. At the same time, the Dutch Egripment company released the Tulip crane and its upgrade, the Piccolo jib. These cranes were made of lightweight materials which eliminated the need for motors to control them. Instead they used an operator at the opposite end of the camera to manipulate the rise and pan of the jib, which could reach about fifteen feet high. These were ideal for small shoots where large movements were involved because of the ability for them to fit on small dollies to combine tracking motion into the camera move.

The three main additions in camera support during the nineties were the Glidecam, the Technocrane, and the Cablecam. All three of which are currently used in only a slightly updated form. The Glidecam originated out of the Steadicam build after the patent ran out in 1994. However, even in the 2000s, when compared to Steadicam and other stabilization providers such as the new PRO/GPI, and MKV, the Glidecam leaves much to be desired. This is especially true in the category of accessory availability and compatibility. The Technocrane is a more precise improvement on the early versions of programmable crane and dolly movements. Now controlled by computers, as opposed to electric motors, the precision was desired for motion control systems, which was used for special effects. Lastly, the Cablecam was a system was introduced during the nineties. This was a system of cables which were mounted by remote controlled rigs that carried cameras in straight lines while at the same time having the ability to pan and tilt. These are very frequently seen at sporting events where footage must be captured from above, but the freedom of where the cable is placed allows for the opportunity of different perspectives.

Film Stocks

There have also been improvements in film stocks during the past twenty years. During the eighties, Fuji had begun to compete with Kodak. They did so by creating a fast color negative film, 250 ASA, which was the same as Kodak, but Fuji, as well as Agfa, was willing to sell the film for cheaper. Kodak promptly responded with improved stocks and the companies continued competing for the fastest stock with the best color quality until Kodak devised a new type of emulsion. The change was created in the shape of the silver halide crystals that they had been using in the celluloid. Before then the crystals had been in the shape of random naturally formed crystals. Kodak developed what they named "T-grains" which were silver halide crystals in a tube shape. These would then fit together in a pattern which reduced the amount of light photons that could possibly pass through the film without activating a crystal, thus making the film more sensitive with a better "resolution".

In 1995, Kodak premiered the Vision line of film stocks. This quickly became the most popular film to use in the world, with its 500T stock, a 500ASA tungsten balanced stock, debuting in 1996. Eventually, Kodak would release a Vision2 and Vision3 series of stocks, based on the first Vision line. This group of film stocks, however, is still the preferred stocks of the majority of big budget studio films.

The one movement that is eliminating the wide usage of film is HD. Solid-state memory for video cameras has become the preferred format for most independent films being made in America. The cost efficient video cameras capable of recording images at a 4K resolution are outweighing the image quality created by celluloid. Only a few cameras, however, have been used for theatrical purposes, and those cameras are used because of the possibility of a film transfer after the editing and post production process. For example, the RED One camera can record a digital HD image with a 4K resolution, which, in theory, matches, or at least comes very close to, that of film. So, after shooting on a cheaper camera, with cheaper lenses, and getting a "film-quality" image, ideally that image would be then transferred to a release print on celluloid to be played in theaters. Outside of a full 4K, which means that the image is over 4,000 pixels wide, it is particularly difficult to transfer an HD image, that being a 1920:1080 ratio, to film format.

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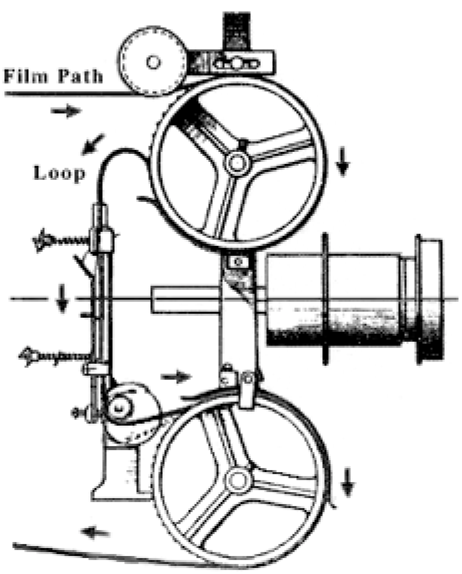

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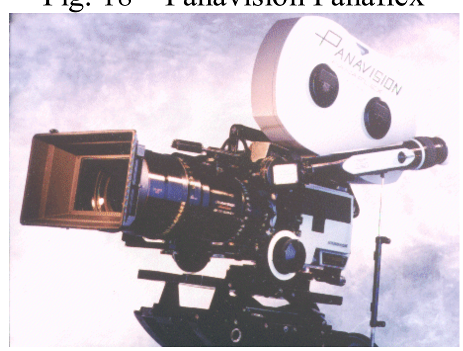

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