Rebirth of the Cinématographe:

The Zinematograph as a challenge to gourmet filmmaking

by

J.R. Wudel

MEDC 4620 Senior Overview

Juraj Bohus

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"After more than a century, film is finally dying" (Molloy). Film critics, scholars, and filmmakers long discussed the death of the traditional film format in light of emerging digital technologies. In the past, the development of new technologies forced a change in the manner in which we appreciate media communications. Television, its electronic technology and rise in popularity, impacted other forms of mass media. For the film industry, this meant that television stole the bulk of Hollywood's audience (Vivian 135). With the development of digital technology the chemical medium of motion film once more faces a challenge as many low-budget producers turn to digital formats as a means to cut production costs. However, the quality of film and its pleasing esthetics remain superior to the emerging digital formats for many critics—"there is no doubt that digital cinema lacks the romance of celluloid" (Molloy). The degradation of media stored as a digital file, compared to that stored on celluloid, also bothers some critics. Can one exploit the photographic advantages of the chemical medium, the dining equivalent to a plate of porterhouse steak and a glass of Romanée Conti, in an effective and elegant manner, and with a budget comparable to a meal of rice and a nice Zinfandel?

The following answers that question by chronicling the growth process of personal discoveries while attempting to rebirth the cinématographe—the "first motion-picture apparatus, used as both camera and projector" ("Cinématographe")—as a means of cutting the costs associated with 35mm film production. The process began by considering the conception of motion film technology. The germinal stage observed the current literature and review of the professional opinion of this media, with special attention placed on its future. The embryonic phase examines the difference between film and video. The fetal stage matured with an understanding of the fundamental technologies of the two mediums, and opinion concerning the chemical medium's future, in order to understand of their qualities—which affect the decisions faced by filmmakers and industry executives when choosing what format to use based on their esthetic and economic differences. The birth phase consisted of secondary research that examined the primary research and revealed a motion camera design that blends classic and modern technologies to enable affordable and creative expression via the 35mm motion image. The final analysis offers the codling of a baby that could one day dine on a dish made of rice and a nice

Zinfandel with just the right amount of nourishment. Its sweetness of complex sugars promise to reward the most discerning gastronomist—or in this case, fan of the cinema.

Background Information

With the cost of film production comparable to a gourmet dinner of porterhouse steak and a glass of the most expensive red Burgundy, Romanée Conti, film critics, scholars and filmmakers long discussed the death of the chemical film format in light of emerging digital technologies. The film v digital debate fights over the grounds of budget and esthetics. To better understand the implied passing of the chemical medium and the rise of the digital format requires understanding of the technology behind these forms of motion photography. Their different technologies impact the economic and esthetic choices producers consider when deciding to use one technology over the other.

The Future of Motion Photography?

“The final credits are rolling for film” (Molloy). In the photographic industries film cameras rapidly give way to digital cameras, cinematographers shoot in digital formats rather than the more expensive 16 or 35mm film and the majority of professional photographers now shoot all their work in digital formats (Molloy). “In only a few years, it seems the industry has moved from the equivalent of stone knives and bear skins of chemical film production toward a fully electronic origination, post production and distribution system” (Wiedemann). In 2002, George Lucas released *Star Wars: Episode II - Attack of the Clones*, “the first feature film with a complete digital delivery chain [from the studio] to the home” (Wiedemann). In July of 2005, the major Hollywood studios released specifications for the digital projectors they supported with their new-release films, enabling the distribution of movies electronically rather than shipping and distributing expensive 35mm prints (Molloy). "High-definition digital is another nail in the coffin… Now they are able to create that lovely film feel—the contrast ratios, the control of depth of field. Film is not going to win the race" (qtd in Molloy). These details led many to believe in the death of film.

As digital technology begins to inherit the workload of the motion picture industry, we enter a new era concerning the films that we watch and the way that we watch them. “Though film projection is the traditional way movies have been shown in theaters, as digital cameras and large-screen video projectors improve, it is not unlikely that video will at some point replace it" (Ascher 43). To some, this sacrifices the art of cinema. "Projecting is a craft—getting the film in frame, in focus—it's all part of the magic of cinema and it becomes a passion… Digital projection will steal a lot of that" (qtd in Molloy). However, others see digital film production as a benefit to the industry. "The lower cost of making digital films means independent filmmakers are getting access to wider audiences" (Molloy). Digital projection equipment allows cinema owners to project limited-release independent films to a wider audience (Molloy). "Some commentators suggest that home theatres will eventually replace cinemas… shifting movies into private spaces rather than public arenas" (Molloy).

Currently, the industry represents the interdependence of the chemical and digital mediums. Filmmakers shoot in one format, edit in another and release the movie in several others (Ascher 32).

> Adding to the flexibility and/or confusion of our time the traditional definitions of video, audio and film have fallen apart. Digital "video" camcorders can be used for still photography. Computer-generated graphics can be combined seamlessly with video and then transferred to film. Sounds can be digitally sampled and transformed beyond recognition. The term *digital media assets* is sometimes used to refer to digitized material that may have been acquired—and may be used—in any number of ways (Ascher 32).

With this in mind, and the future of the chemical medium still in doubt, we will examine the individual technology behind these two formats. An understanding of their technologies reveals the choice modern filmmakers make during the production process and the framework for the design of a camera that incorporates the most cost conscious elements of motion photography.

Technology of Motion Photography

"The impression of continuous movement in a motion picture is an illusion" (Ascher 3). Through the phenomenon of persistence of vision, humans retain and remember images longer than their exposure to them. "Exposure to two successive images causes the eye and brain to blend them together creates the appearance of motion in film and video" (Ascher 3). Developers of motion picture technology discovered that "to maintain the illusion of smooth motion in the reproduction, at least 10 to 14 pictures must be presented to the eye every second" (Wheeler 47). As a result, early silent films were shot at 16 frames per second—a rate safely above the minimum. With the incorporation of a photographic sound track to the filmstrip, this rate had to be increased to 24 frames per second, which remains the standard (Wheeler).

Regardless of the frames per second, "all forms of modern cinematography depend upon the photographic image" (Wheeler). A photographic image results when capturing a scene lit by a source: the sun, electric lights, etc. The camera lens focuses the light from the scene to a plane within the camera. Typically, the placement of a shutter between the lens and the focal plane of the image within the camera acts as a window-like mechanism capable of allowing the light to reach the focal plane for a controlled amount of time and expose the piece of film located there. An emulsion coats the film that when properly developed creates a representation of the scene. "It is important to realize that a chemical change occurred within the film emulsion immediately as it was exposed to the rays of light passing through the camera lens" (Wheeler 16). Black and white film emulsion comprises "thousands of minute silver bromide crystalline grains which would automatically blacken (or tarnish) if exposed to light for a considerable time" (Wheeler 16). "The first movies, made in the 1890's by Thomas Edison, were shot on cellulose nitrate base film that was about 35 millimeters wide… The 35mm film gauge remains the most commonly used in theatrical filmmaking"(Ascher).

Although Thomas Edison holds credit as making the first movies in the 1890's, the French Auguste and Louis Lumière "gave the movies their first birthday" (Smith I.4). By using much of Edison's technology, as he didn't take out foreign patent rights, the Lumière Brothers built the Cinématographe—capable of operating as camera, developer or projector with a few simple modifications (Smith I.4). The Lumière Brothers hold the title as the first to project their captured motion images before a paying audience. They "drew the obvious conclusion that one screening for three hundred viewers paying 300 nickels is better than one screening for one viewer with one nickel" (Smith I.4)—like Edison's films. The Cinématographe projected images onto the theater screen by opening a hatch located at the rear of the camera (Fig.1) and shining a high-powered lamp behind a glass globe filled with water acting as a coolant and magnifier of the light beam through the film negative and lens.

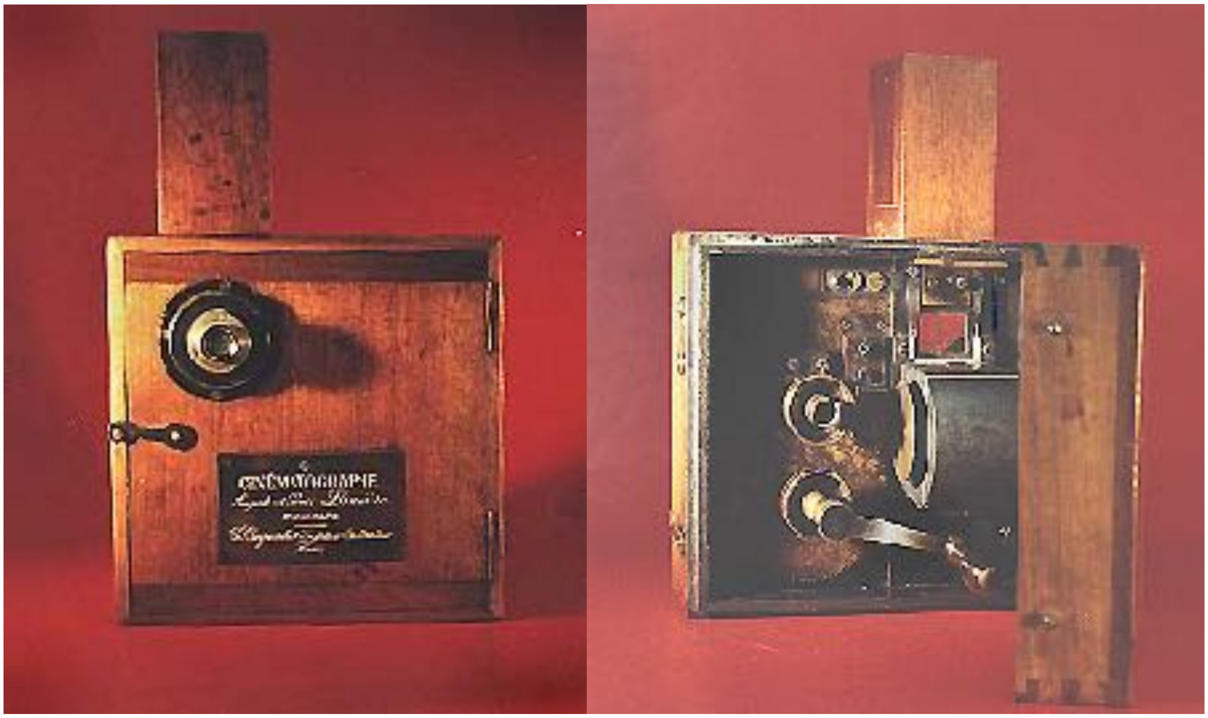

FIG. 1 The Lumière Cinématographe, front and rear images ("Wood…").

All motion film camera mechanisms share ten common elements (Wheeler 46). First, they possess a surface finish that does not scratch the film—resulting in easily accessible and cleanable felt or velvet light traps and the avoidance of painted surfaces in the film path that might flake-off during use. Next, the film take-up should create no stress on the film via the aid of a friction clutch driving mechanism, and all film should be housed in a light tight container such as a film magazine. Continuous motion sprockets facilitate film movement between the feed magazine, intermittent and take-up magazine that engage the film only at points that will not compromise areas of the film that record image or sound. Fourth, the intermittent mechanism moves the film forward an amount equal to the height of one picture, brings it to rest, then returns to a point ready to repeat the cycle. A continuously revolving shutter must be geared to the intermittent mechanism. Also, the camera possesses a lens mount that will accept a range of objective lenses. These lenses will be scaled in F-stops. The camera should be fixed with a viewfinder enabling sight of the field of view captured by the lens. There should be an indicator noting frames-per-second, and the camera should possess a footage counter.

"The heart of any cinematograph camera is the intermittent mechanism" (Wheeler 47). This also applies to the cinema projector (Wheeler 293). The intermittent mechanism turns a still camera into a motion camera by enabling the capture of successive images on the film stock. Motion cameras have a fixed revolving shutter, and the intermittent mechanism creates the start and stop motion of the film strip with a claw that grips the strip by its perforations, advances it one frame, holds it still for exposure, and then withdraws from the perforation to a point ready for the next exposure (Wheeler).

The film projector functions similarly, "but rather than focusing light from the surroundings onto the film, it projects the filmed image onto a screen using a bright light behind the film path… As long as the projector runs at the same speed as the camera, motion will appear normal" (Ascher). Unlike the motion camera, motion projectors usually employ a sprocket instead of the claw and pilot pin (Wheeler 293). The projector undergoes more wear than the camera, and the sprocket will less likely come out of alignment. The sprocket more accurately engages and advances film that experienced pitch reduction as a result of the developing process. Finally, the the sprocket allows more time for the film to remain still while passing through the film gate, more necessary in projectors than cameras (Wheeler 293).

> In camera mechanisms the film is usually at rest of approximately one-half of the total cycle and, being in motion during the remainder of the cycle, must be protected from exposure by a rotating shutter—usually for approximately 170°. If such a shutter were used in projectors the image frequency on the screen would be at the rate of 24 every second, and the duration of individual pictures would cause

> very noticeable flicker since the threshold below which flicker is apparent is 48 interruptions per second when the light and dark periods are of equal duration. The threshold below the flicker is seen when the time of opening is not equal to the time of closure rises to approximately 60 interruptions per second (Wheeler 293).

As a result of this, "the camera claw may therefore take half of the complete cycle to move the film, but the projector intermittent must complete this movement within one-quarter of the cycle" (Wheeler 293). The Geneva mechanism, Maltese cross or star wheel, three different names for the same component, produces "the intermittent rotation of a sprocket wheel… almost exclusively throughout the industry" (Wheeler 293).

Other accepted standards concern the film's aspect ratio—the size and shape of the image recorded on the film stock expressed by the proportion of the width of the frame divided by its height (Ascher 6). The traditional standard format for film and video/TV has been an aspect ratio of four to three, or 1.33:1 (Ascher 6). The Academy of Motion Picture Arts and Sciences named this ratio the Academy Aperture, defined by the aspect ratio of the full frame for sound film (Ascher 6). "Though the Academy frame was once standard in theaters, and is the 'traditional' standard for television, it is considered too narrow to satisfy contemporary theater audiences" (Ascher 6). As a response to the rise in popularity of television, moviemakers introduced the widescreen aspect ratio CinemaScope (Vivian 136). With an aspect ratio of 2.35:1 "CinemaScope seemed more realistic than the earlier squarish screen images" (Vivian 136). CinemaScope uses "anamorphic lenses to 'squeeze' the width of the image being shot so that it will fit on the film frame… Most widescreen systems work by cropping out the top and bottom of the Academy frame" (Ascher 6). This caused films shown in American theaters produced with normal, nonanamorphic lenses and an aspect ratio of 1.85:1 (Ascher 6).

Aspect ratio relates to negative pull down and directly effects the movement of the intermittent mechanism. Negative pull down "refers to the number of film perforations that each frame occupies" ("Negative…"). The Academy aperture requires the length of 4 perforations to fit the negative space of 35mm film ("Negative…"). "The 4-perf system, where each frame of

35mm film, is 4 perforations long… was (and remains) the traditional system" of the 35mm format ("Negative…"). Using the current 1.85:1 theatrical standard aspect ratio with spherical lenses, while still relying on the 4-perf negative pull down, results in a negative image with the top and bottom cropped from the full shape of the Academy aperture ("Negative…"). "Therefore, a fair percentage of the film is wasted, because the cropped top and bottom are never meant to be shown" ("Negative…). Changing the camera gate and shutter mechanism so that each frame is 3 perforations long solves this problem of film wastage ("Negative…"). "The three perf image is 1.78:1, which makes it both ideal for widescreen television and very close to 1.85:1" ("Negative…"). The three perf negative pull down used together with the Super 35mm film theatrical format, achieves a ratio of 1.85:1 by removing the optical analog sound track printed alongside the image frame and extending the frame into this otherwise occupied space ("Negative…).

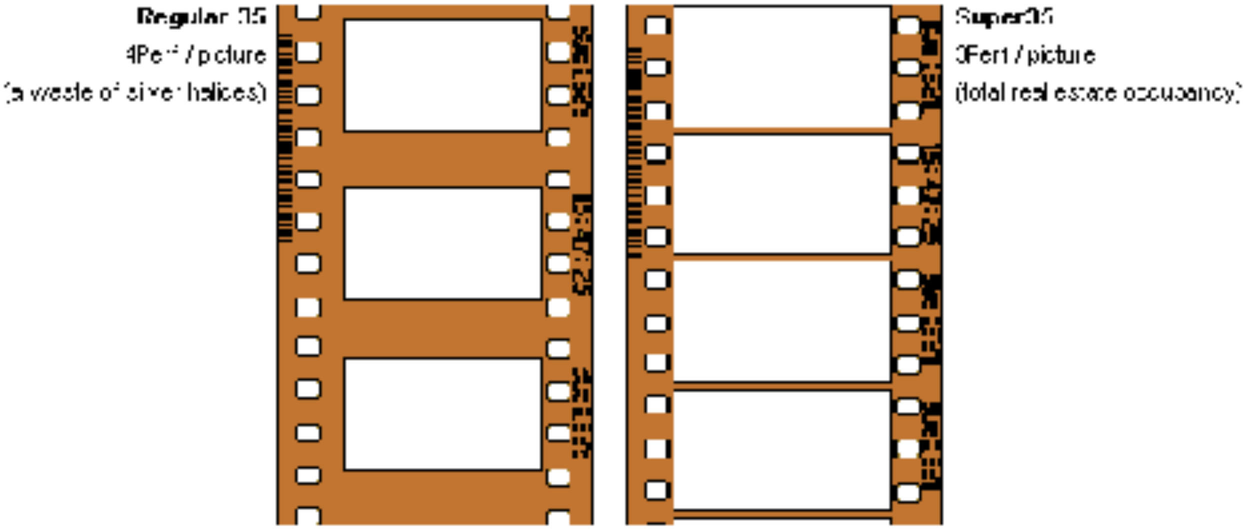

FIG. 2 Comparison of traditional and Super35 negatives with a 1.85:1 aspect ratio ("3 perf").

"Like film cameras, video cameras use a lens to bring an image of the world into the camera" (Ascher 16). However, in place of cellulose video cameras focus the picture on a light-sensitive computer chip called a CCD, or charge-coupled device. "In digital recording, the video or audio signal is represented by a set of numbers, which are recorded as simple on-off pulses" (Ascher 20).

> In North America, traditional broadcast video systems use a standard developed by the *NTSC* (*National Television Standards Committee*). NTSC video uses 525 horizontal lines, scanned in an interlaced pattern. A new field is scanned 60 times a second. Since the two fields make up one complete frame, this results in video that runs at about 30 frames per second (Ascher 18).

"For years, *HDTV (High-Definition Television,* also called *HD* and *Hi-Def*) represented the holy grail of video quality… HDTV represents a quantum leap in resolution over traditional, analog systems and results in an image that rivals 35mm film in clarity" (Ascher 26-27). The Hi-Def digital format uses more than twice the number of scan lines as the NTSC video format (Ascher 27). It records with an aspect ratio of 16:9: only slightly less wide than the widescreen standard for U.S. theatrical release films (Ascher 27). "Very few segments of the production industry are questioning the future viability of HDTV and most are planning for migration of services away from chemical film systems" (Wiedemann).

Chemical v Digital

"There is no doubt that digital cinema lacks the romance of celluloid" (Molloy). Despite this heart felt statement, the reproduction of the motion image in both the chemical and digital mediums must be acknowledged. "In cinematography the recordings always exist in recognizable form whilst in other systems… the stored information may be said to exist in coded form… In every case the system succeeds in ultimately reproducing the illusion of moving pictures" (Wheeler 15). Since both mediums achieve the goal of reproducing the motion image with different end results concerning quality, cost and compatibility, professional filmmakers consider the characteristics of each medium across three phases of the production process: capture, postproduction and distribution (Ascher 32).

Capture refers to the means by which the filmmaker initially records the image (Ascher 32). The look of the movie becomes the key esthetic concern of the capture phase. “How a movie looks has an enormous impact on what the movie means to the audience… and there is no doubt that the medium itself plays a large part in how we understand a movie’s content and experience its emotional impact” (Ascher 32). The 35mm film format “is capable of an extremely sharp image with subtle color variations and the ability to handle a wide range of contrast from dark to light” (Ascher 32-33), while “Images originating from typical (standard-definition) video cameras are generally much less sharp, have cruder color rendering and have a much more limited range from dark to light”(Ascher 33). Motion Picture Film has none of the artifacts, or noise, associated with a video image due to the exposure of each film frame all at once (Wiedemann). Also, film lacks pixel structure—with film, randomly placed grains of the film emulsion serve as the smallest area of exposure, and a new grain structure appears with each new frame, randomizing the successive image structure (Wiedemann). Comparing the video news or documentary footage feature film to films’ 35mm footage gives one an idea of their differing image qualities. “There is a noticeable difference in terms of the emotional ‘feel’ and texture of the scene” (Ascher 33). This led one photographer to comment, "I do miss the warmth and lustre of film" (Molloy). Technical elements such as sharpness, contrast, brightness, resolution and depth of field present measurable physical qualities that impact the emotion and texture of the image.

“Resolution refers to a system’s ability to capture fine detail; in this sense, resolution plays a part in how sharp the image can look” (Ascher 33). In technical terms, resolution applies to the amount of information, or data, stored in each film or video image (Ascher 34). “As a crude rule of thumb, the higher the resolution, the finer the detail in the image and the more information (or storage space) is needed to record it… For example, 35mm is higher resolution than 16mm; if you take a ruler and compare the surface area of 35mm and 16mm frames, the 35mm image is over four times bigger” (Ascher 34). 35mm film renders finer detail than standard video (Ascher 33). “The film image makes a more gradual transition from areas of the picture that are sharp to areas that are out of focus [resulting in an image] in certain ways *softer* than video” (Ascher 33).

“When a scene has a great range from dark areas to light, the film image will usually capture more detail and look better, even if the film is later transferred to video” (Ascher 37). Contrast ratio equals the range from dark to light. “Kodak estimates that many of their color negative film stocks can accommodate about a ten-stop range of brightness (a *contrast ratio* of about 1000:1 between the brightest and darkest value). Video cameras can generally handle a more limited range, some as low as about five stops (40:1)” (Ascher 189). This led some filmmakers to believe that digital formats "don't yet deliver" (Molloy). Filmmakers who shoot “very raw, black and white images… blow things out a lot and use strong highlights” (Molloy) with the goal of manipulating the final expression of their images.

In January 2000, Sony and other companies released equipment constructed to the 1080p/24 HDTV video standard (Wiedemann). The 1080p/24 Hi-Def camera captures images in a progressive fashion, a full frame image, much like film and shoots at the same speed (Wiedemann). “The resultant image is stunning and can easily outperform 35mm film in a variety of areas” (Wiedemann). George Lucas used a prototype Sony-Panavision 1080p/24 camera to shoot several scenes in *Star Wars: Episode I—The Phantom Menace* without releasing to the public which scenes. The lack of the video artifacts of these scenes, intercut within the film material, resulted in few noticing the difference (Wiedemann). “The success of that test drove the decision to shoot the next two installments of the Star Wars series completely in the 1080p/24 HDTV format, not in film” (Wiedemann).

> With the low 24 fps frame rate, 1080p/24 would not be suited for fast action sports photography… At the 24 fps frame rate, the 1080p/24 HDTV system takes on the "veil of separation" that film has. This is appealing to feature film cinematographers who rely on that veil to suspend belief. At higher frame rates, the viewer experiences a telepresence that would trash the mood 24 fps film provides, a primary blow against 30 frame/60 field television acquisition.

Ranking the formats in terms of resolution yields a list with 35mm and HDTV offering the highest resolution, then 16mm film, Digital Betacam, DV and super 8 film, followed by the analog systems Betacam, Hi8, S-VHS, and VHS (Ascher 34). “As a rule of thumb, film and video formats that are capable of high resolution cost more than systems that work at lower resolution” (Ascher 35); Hi-Def cameras cost more than DV cameras (Ascher 37). “On the other hand, if you need a high-definition image, you may be able to capture it acceptably using 16mm film, which might cost less than producing in HDTV” (Ascher 37). However, as the technology of Hi-Def evolves the cost will lower (Ascher 37).

“In these days of HD vs Film debate, 3Perf/pict is the future of film origination: image quality up, cost down” (“3 perf”). When comparing three perf to four perf technology the same amount of film footage will give twenty-five percent more shooting time and “another 4% economy is added by the reduction of the wasted short-ends induced by longer running magazines,” ultimately saving money on the cost of film stock (“3 perf). “The camera will run more quietly because less film is moved through the camera per frame; and the Super 35 variant allows for a larger negative area, which can help compensate for increased grain when using higher-speed film stocks” (“Negative…”) reducing lighting costs. Unfortunately, the theatrical projection of three perf requires its transfer back to a 4-perf system resulting in “the same wastage problem as before” (“Negative…”). Three perf still utilizes less film footage during production and remains a viable option to reduce negative costs (“Negative…”).

The complexity of motion cameras’ price to the consumer includes separate costs for the camera body, its lenses and the other accessories necessary to its function. Although these prices constantly fluctuate. Surfing the internet provided the following idea of the present cost of high end and low end used 35mm motion film cameras, a new professional quality HDTV camera and a new professional quality DV camera.

The modern ARRIFLEX 535A silent studio camera with all the bells and whistles:—capable of shooting 4-perf or 3-perf in standard or Super35 with the proper modifications, a 270° swing-over viewfinder, 100/50/0 video beam splitter, contrast filter ND2, ND6, built-in deanamorphoser, ArriGlow, 11.2-180º variable electronic shutter, film loop adjustment, dual LCD display, Timecode module, variable pitch, able to shoot 3-50 frames per second, an SWA eyepiece, VSU-1 variable speed unit, field lens, gate with 18.6 x 24.9 full-aperture format mask, CEI Color IV video assist, two 1000 ft magazines, CCU and an extension viewfinder—recently sold at a price of $67,450 (“CinemaTechnic…”).

Alan Gordon Enterprises, Inc. offers their non-reflex, Alan Gordon Slam-Cam, “a 35mm motion picture camera specially designed for point of view and crash-camera [where the camera is often destroyed during filming] cinematography,” for $8,250 (“Film Cameras – 35mm”). The Slam-Cam’s design compares to the well known, “and practically indestructible” (“FILM CAMERAS [Page 1]…”), Bell and Howell Eyemo motion film camera. It accepts a 100 foot daylight load spool, has digital speed and footage readouts, runs on a 12 volt battery, and weighs 7 pounds. Alan Gordon offered an actual, used, Bell and Howell 35mm Eyemo, non-reflex, motion film camera with a 100 foot film capacity and powered by a hand-wound spring motor, for around $1500.

In the HDTV arena, Panasonic High Definition cameras span the price spectrum. At the high end, costing $65, 900 is the AJ-HDC27F VariCam: “The ONLY HD Camera with variable frame rates from 4-60 fps,” capturing in 720 lines progressive and chosen for use in the “multi camera Marc Burnett produced show ‘’Casino’” (“Camera Sales…”). For $5,295 producers can shoot HD Cinema with Panasonic’s AG-HVX200 (“Camera Sales…”). The AG-HVX200 shoots in multiple interlaced and progressive formats, and, among a host of other features, can also record the Mini-DV recording format (“Camera Sales…”).

“The professional series XL2 camcorder replaces one of the most successful and iconic products in Canon’s history—the XL1S—as the company’s new digital video camcorder flagship” (“Camera Sales…”). For $3,999, plus the price of a lens, the camera shoots in the Mini DV format utilizing the XL2’s features—including a choice of 60i, 24p or 30p frame rates, 4:3 or high resolution 16:9 aspect ratio, and 680,000 pixel progressive scan CCDs (“Camera Sales…”).

“Old can be good too” (Ascher 44). The evolution of technology means that older technology and used equipment becomes less expensive (Ascher 44). Also, “one advantage of film equipment—both cameras and editing equipment—is that formats haven’t changed much over time, so the gear can be used for many years. Video equipment becomes obsolete much faster” (Ascher 44). Film students working with older film cameras discover that they “may be 40 years old, but they produce beautiful images” (qtd in Molloy). Often, when students see the prints of what they have shot, they “have never before seen images they have produced that are so clear and that have such depth and detail. It inspires them to learn more about aesthetics, lighting and framing" (qtd in Molloy).

“Some of our greatest photographers and cinematographers warn that with the loss of film comes the loss of something less tangible but more precious: the quality that results from the discipline and skill required by a more stringent medium” (Molloy). Without the benefit to immediately see what they’ve shot, filmmakers must plan and practice their scene (Molloy). Documentary filmmaker Bob Connoly says "My shooting was a lot better on film than it is on tape" (qtd in Molloy). Film costs several dollars per second to expose, process and print while tape is “so cheap, you can reuse it" (Molloy). "In documentary filmmaking, shooting ratios have gone up about 400 per cent… That causes trouble down the track in the amount of time you've got to spend dealing with that amount of material" (qtd in Molloy).

Postproduction involves filmmakers editing the initial images in regards to picture manipulation and involves their technology choice (Asher 32). Digital, non-linear editing is replacing traditional film and videotape editing (Ascher 41). “Digital information is very “robust”—it is not susceptible to tape noise and you can make many generations of copies without any loss in quality (digital copies are called clones)” (Ascher 20). As a result, for “a well-funded film or TV project, nonlinear is usually by far the best way to go” (Ascher 41). However, for independent filmmakers with a thrifty budget, editing with the traditional linear editing equipment can save a lot of money (Ascher 41). “Though nonlinear systems are rapidly dropping in price, they can still be a sizable investment when all the software, computer and storage needs are figured in” (Ascher 41). On the other hand, used film editing equipment “can be purchased for the cost of a few weeks’ rental of a fully equipped digital editing system” (Ascher 41).

A final consideration for filmmakers when choosing between the chemical and digital formats, impacting each aspect of the production process, concerns degradation: what some have come to refer to as the *digital dark age*. “Photographic plates of the Civil War still make excellent reproductions but a 20 year old video tape may, or may not, play in a machine - if you can find a machine” (Wiedemann). While motion images captured on film stock at the turn of the century, and given particular care in terms of handling and storage, still exist in recognizable form, the longevity of digital images “can be limited both by media deterioration and by technological obsolescence” (Hartke). The implications of the following material have many doubting the long-term capability of the digital medium, “so shooting film now is thought to ‘future-proof’ the show”(Ascher 42).

Degradation and deterioration refers to the breakdown of the storage medium to the point where the video player can no longer properly read it. In the consumer market CDs and DVDs have become the preferred medium for storage of digital information because of their affordable cost, robust construction, and the ratio of the amount of information they can store to their relatively small physical size (Care). “Because these products are sold as commodities, users may find that performance claims originated by marketing departments may not be supported by accurate test results” (Hartke).

“Manufacturers generally claim 50-250 years life for the disc, although anecdotal evidence points to 10-20 years being more realistic” (Cockfield). Factors such as type, manufacturing quality, condition of the disc before recording, quality of the disc recording, handling and maintenance and environmental conditions affect disc life (Care). Exposure to radiation, inks and other chemicals, water or pollutants causes degradation (Hartke). “The technology is changing and evolving however, but we should still bear in mind that master copies recorded today may not work in 10 years time” (Cockfield).

The evolution and dominance of digital technology led some theorists to warn, “This era could become a ‘digital dark age’—a part of its collective memories forever lost” (Jesdanum). This notion is derived from the “common misperception about digital lasting forever. It comes out of the fact that a digital copy is a perfect copy" (qtd in Jesdanum). The computer files may survive but the computers and programs that read and display the files may not (Jesdanum). “Product support cycles are typically 5-10 years, while computer system use rarely exceeds 20 years” (Hartke).

Several examples support this phenomenon. Scholars could still read the 1,086-tome version of the Domesday Book, a collection of photographs, writings and other snapshots of life in 11th Century England, while the software and hardware of the digital version created in 1986 keeps breaking down from old age (Jesdanum). Digital data from only 20 years ago has already being lost. Similarly, NASA's space records of the 1976 Viking landings on Mars stored on magnetic tapes, a now obsolete format, have become unreadable to modern scientists (Jesdanum). This also applied to businessmen who can't read old electronic records needed for lawsuits and professors that have lost old research papers (Jesdanum). MacKenzie Smith, associate director for technology at Massachusetts Institute of Technology Libraries, recalls, "Every now and then, a faculty member would come in in tears having some boxes of completely unreadable tapes… They've lost their life's work" (Jesdanum).

The process of preserving information in a digital format consists of more than just saving them to CD or DVD—the computer also needs to read the information's file structure (Jesdanum). This relates to "moving away from the once-common WordStar format and always using the latest version of Microsoft Word, because even the newest software reads only a few versions back" (Jesdanum). The transfer between formats often causes the loss of some information like color and structure (Jesdanum). "The spacing of the characters and stuff on pages may be off, so lines get a little bit longer and carry over onto the next line" (Jesdanum). Similar problems have plagued the conversion of the popular JPEG format (Jesdanum). "More vexing are the social considerations, such as the legality of copying and adapting obsolete software" (Jesdanum). "If your aim is to have something lasting 1,000 years from now, you can't plan on electronics doing the job" (Jesdanum).

Summary of Background Information

Supremacy of the digital medium of motion photography over the traditional chemical medium will prove to be a function of evolution. The feature film industry currently transitions from the chemical medium—introducing E-Cinema, a completely digital production and distribution chain, into their operations. The release of *Star Wars: Episode II – Attack of the Clones*, completely shot in Hi-Def video and digitally released in several theaters, proved E-Cinema could be financially successful. As the cost of the Hollywood approved digital projectors becomes more affordable to cinema owners, the number of E-Cinema theaters will grow. Likewise, as the cost of Hi-Def digital cameras and the computers that process their recoded data lowers, film will be phased out as the dominant medium for high quality image reproduction—regardless of the opinion of some that digital technology sacrifices the art of cinema.

The art of filmmaking must take into consideration the technical capabilities and cost of the two mediums throughout the capture, postproduction and distribution phases. Hi-Def digital technology rivals 35mm film in its ability to capture images with the greatest resolution and contrast ratio—especially as the technology develops and its cost lowers. Filmmakers consider video easier to shoot than film due to the smaller size of the camera and affordable nature of capture medium. However, this ease can sacrifice a project's planning and production value.

Commonly, film and video coexist throughout the feature film production process—most noticeably in the postproduction phase when footage originated on film is digitized, blended with computer-generated graphics, and edited with non-linear, digital workstations. Digital technology possesses a breadth of capabilities in the post-production process—however, its cost can hinder many low-budget filmmakers. Film has long been the favored format for distribution due to its quality and compatibility with foreign markets, although Hi-Def might change this due to the cost of distribution prints and the technical problems often associated with film projection.

However, digital technology brings with it its own problems moving into the future. Degradation of digital storage media may occur much sooner than manufacturers claim and evidence exists of the failure of hardware and software to read digital files as new digital technologies make the old obsolete. As a result, shooting film might future-proof the work.

The literature review established the groundwork of the argument concerning the doubtful future of the chemical motion film medium as a result of its high cost, established Hi-Definition digital video as its rival, explored the technological differences between film and video and covered the choices made by filmmakers, and other industry professionals, concerning esthetic and economic reasons behind the format they use. However, it remains clear that the chemical medium still has merit. Does the possibility to exploit this merit, while limiting its main detriment—cost—exist? Now, primary research will reveal a camera design developed to fulfill the requirement of recreating the motion image through the romance of celluloid, on a budget of rice and a nice Zinfandel.

Report of Primary Research

How does one go about reducing the cost of chemical motion picture production to its barest minimum? The answer to this question involves a synthesis of early and modern motion film technology. With the goal of capturing the motion image with a budget comparable to a diet of rice and a nice Zinfandel, cost reduction lay on two factors. First, omit unnecessary camera design elements that, although making the production process more easy, efficient and professional, do not affect the primary function of the motion camera and projector—to capture and project the motion image. This meant a return to basics resulting in the design of a silent-era cinématographe, hereafter referred to as the Zinematograph. The Zinematograph would not possess a motor, electronics and other complex mechanical components. Nor the ability to capture an optical sound track. Second, incorporate into the design a way to reduce the major cost of the film budget, that of the celluloid itself—including its acquisition and processing. This would be achieved via incorporation of the 3-perf, Super 35mm format. The budget for this endeavor aimed below the current purchase price of a commercial 35mm motion film camera. Therefore, since a used Eyemo film camera costs around $1500 dollars, the budget topped out at $1000. A detailed explanation of the choices made during the design process of the Zinematograph, that incorporates these points, follows.

The classic Debrie Le Parvo silent-era motion film camera influenced the general design and layout of the Zinematograph. Developed in 1908,“The hand-cranked *‘Le Parvo’* [meaning ‘compact’ and of small dimension] was at one time the most popular European camera”, used by both F.W. Murnau—on his silent film *Nosferatu, eine Symphonie des Grauens*—and Leni Riefenstahl—*Olympia Part One: Festival of the Nations* and *Olympia Part Two: Festival of Beauty*—among many others (“Film

FIG. 3 Wood Le Parvo (“Wood…”).

Cameras [Page 1]…”). “The original models were constructed from polished hardwood (Fig. 3), but the *‘Le Parvo’* series also included metal bodied cameras” (“Film Cameras [Page 1]…”). “The wood Debrie cameras were lighter than the metal ones” (“Wood…”). The gears, film gate, intermittent and other working components were mounted on metal framed chassis (“Film Cameras [Page 1]…”) (Fig.4).

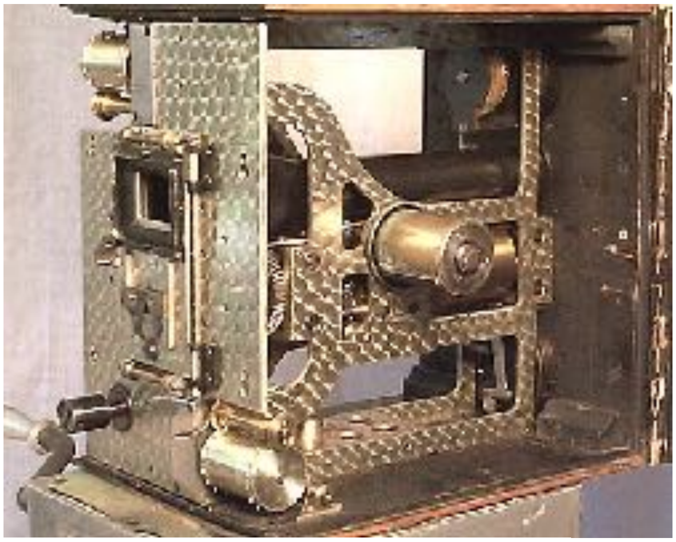
FIG. 4 Le Parvo’s Chassis (“Wood…”).

The camera housed one 400 foot feed magazine and an identical take-up magazine on either side of its metal chassis (Fig 5).

The Debrie Le Parvo has three planes. Thus, the feed magazine, film gate, and film take-up magazine are in different planes (Figs. 5 and 6)—as opposed to the single plane design most commonly employed by film cameras and projectors, or double plane like that found in the ARRIFLEX SRII. The hand crank normally operated the camera at 8 frames per each 360-degree rotation (“Wood…”).

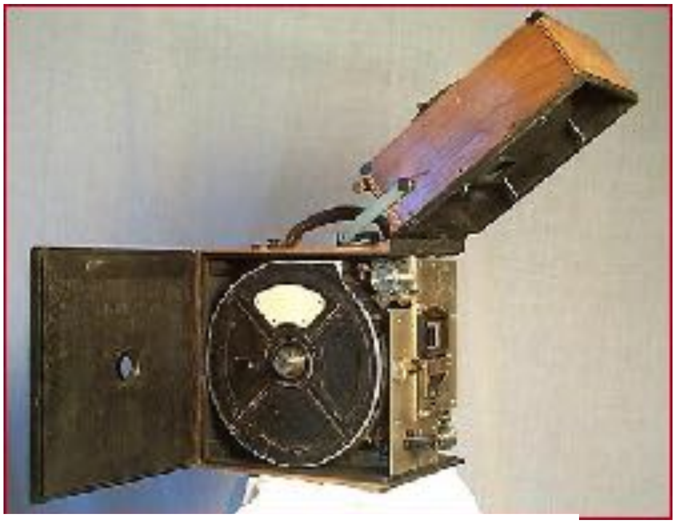
FIG. 5 Opened Le Parvo (“Wood…”).

“The camera’s eyepiece… has a red filter… The film was black and white [with no emulsion] so the operator could actually look through the camera while filming and not flash the film with light entering from the eyepiece” (“Wood…”) (Fig. 7). Antique *Le Parvo’s* are reported to still shoot film that “seems to have a life of its own” (“Wood…”).

The function of the Zinematograph as a projector would be similar to the original Lumière Cinématographe. In place of the Le Parvo’s internal viewfinder would be a hollow channel. Opening a hatch at the rear of the camera and shining an elliptical light source, such as a

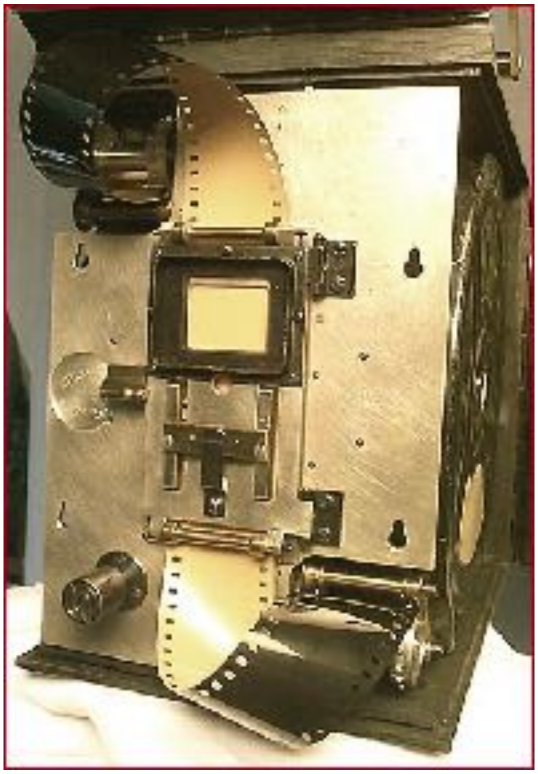

FIG. 6 Film gate (“Wood…”).

FIG. 7 Le Parvo rear with eyepiece (“Wood…”).

Source4—commonly used in theater—a narrowly focused Fresnel, or even a Mini Maglite, would enable projection. The light path would be from light source, through channel, through film gate and negative, through the lens and to the screen. Depending on the radiant heat of the light source, a glass globe could be positioned between the light source and the camera like with the Cinématograph.

The Zinematograph’s body would be constructed of wenge, a native African hardwood known for its dark color—similar to ebony but at half the price—its strength and water-resistance. Initial estimates to enclose the Zinematograph’s working components with wenge were around $60. The front portion of the Zinematograph, that which houses the lens mount and viewfinder, would differ from that of the Le Parvo. In place of the hinges that allowed this portion to swing up on the Le Parvo, the Zinematograph would have a grooved channel that would allow the front portion to slide into the rear of the camera. This would help retain strength and alignment.

Secondary research makes it clear that in order for the chemical film format to compete with the emerging High-def format, in terms of resolution and the other image qualities, that the larger the image captured on the negative, "the more silver halide real estate," the better. The Zinematograph would employ the 35mm format. The cameras design accommodated Kodak Standard, short pitch, film stock. Pitch is the "distance from the center of one perforation of film to the next" (Motion…112). Therefore, the Kodak Standard short pitch length of .1866 presented th most crucial dimension in the design of the camera. This pitch length would directly affect the spacing of the sprocket teeth—and thereby ultimate size of the film sprockets—as well as the dimensions of the intermittent mechanism and film frame mask within the film gate. The choice to use the Kodak Standard short pitch resulted because of it being the most commonly employed negative stock for originating contact prints (Motion… 25) and the standard for Kodak's 35mm still photography film. The latter of which would enable the use of 100-foot bulk rolls like E100VS or TMax 100 if they could be obtained for less than the cost of Kodak's cinematographic film stock.

The camera design, as film development accounts for the largest portion of budget expenditure on a film production, aimed at reducing the total amount of film necessary to capture the motion image. To capitalize on the 25% gain in shooting time and nearly 33% gain in budget cost offered by shooting 3-perf over 4-perf at 24 fps, the camera would incorporate the 3-perf, Super35 picture format. To get the most out of the negative space in between the perforations, the captured image within the film gate will be masked to a 16:9 aspect ratio—the difference between this and 1.85:1 likely unnoticeable to a theater audience watching a live projection of the camera's images. The Super 35 variant would also have the benefit of affecting lighting cost by using higher-speed film stocks with less lighting equipment. Furthermore, this aspect ratio excels at transfer to a digital media asset and playback in the High-Def format. The camera would operate at 15 frames per second as a means of reducing the total amount of film stock used during production. By shooting at fifteen instead of 24 fps results in nearly 40% less film stock used for an equal shooting time. Fifteen frames per second remains greater than the 10-14 frames per second necessary to provide the illusion of motion to the human eye. Most silent film footage succeeded at a rate of 16 frames per second—24 fps being the result of the addition of sound to film—only one frame greater than 15 frames per second. As the camera also doubles as projector, it will be possible to recreate the frame rate for playback before an audience. Finally, if the developed film footage was transferred into a digital media asset via TeleCine at the current NTSC standard of 29.9 fps, reducing the speed by half in post production would almost exactly reproduce the 15 fps capture rate.

Filming 3-perf at 15 fps would allow a 400-foot magazine to last for approximately 10 minutes. compared to shooting 4-perf at 24 fps, when a 400-foot magazine gives 4.5 minutes of shooting time ("3 perf…"), this is a 55% savings.

Use of reversal film increases savings on film stock. Reversal film allows use of the same stock for shooting and then for projection, without the need for a contact print. This does pose the risk of frequent scratching of the film through increased contact, although this might be worth the gamble if you treat the purchase of film like the purchase of ingredients for one last meal, not knowing if you would ever have enough money to eat again.

The literature review specifies ten common elements that all motion camera mechanisms have in common—the Ten Commandments of motion film camera design.

One, they must possess a surface finish that does not scratch the film. All elements of the Zinematograph that require machining, mainly the chassis and gearing, would be constructed from cheap and durable aluminum and rounded and polished at points that would contact the film surface. The only paint used for the interior of the camera would be a flat black for the shutters, which will not contact the film path.

Two, the film take-up should be such that there is no stress on the film via the aid of a friction clutch driving mechanism. This resulted in the design of a wrap-spring clutch system attached to the hand crank's main shaft and engaging the film core.

Three, all film should be housed in a light tight container, such as a film magazine. The magazines would accommodate a 400-foot role of core-loaded film in the fashion of a simple 35mm film canister. Designed from simple sheet metal, two sides would fit together over the core and film in a manner that would block all light from entering the magazine.

Four, continuous motion sprockets facilitate film movement between the feed magazine, intermittent, and take-up magazine that engage the film only at points that will not compromise the integrity of the areas of the film that record image. The desired 15 fps speed and 3-perf operating characteristics and the use of Kodak Standard film influenced film sprocket design. "In

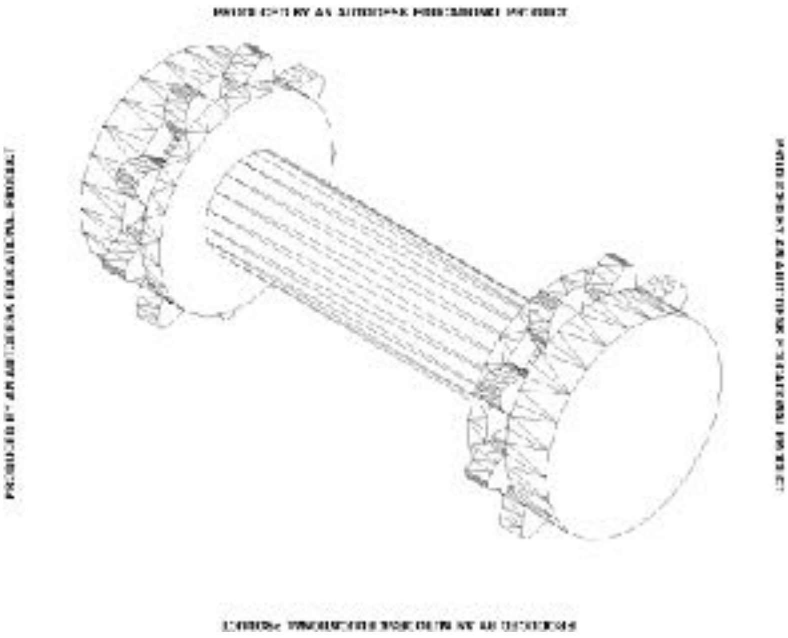

FIG. 8 Three-picture film sprocket.

practice sprocket wheels are described by the length of the film equal to the number of pictures which could be wrapped round the circumference" (Wheeler 286). To keep the size of the sprocket small and yet still practical, with a fair amount of surface space in contact with the film, The Zinematograph would incorparate a three-picture film sprocket (Fig. 8). Each sprocket would have nine teeth. To accommodate the .1866-inch film pitch, the pitch diameter of the sprocket wheel, or portion of the wheel that the film would wrap around, excluding the height of the sprocket teeth, must be 0.5346 inches. The profile of the sprocket teeth would be of the involute form. "An involute is a curve that is traced by a taut cord unwinding from a circle" (Gears…). The involute form allows the teeth to engage the perforations without binding the film. The determined size of the sprockets' teeth would allow free movement within the dimensions of the film perforation.

Five, ther intermittent mechanism can move the film forward an amount equal to the height of one picture, bring it to rest, then return to a point ready to repeat the cycle. The heart of the Zinematograph, the intermittent mechanism, mimicked the sprocket system employed by film projectors. Since the Zinematograph would be used as both camera and projector, and the intermittent would be advancing film both before and after processing, the durability, accuracy and function of the sprocket system deemed a virtue. One function would allow the Zinematograph to be operated, while filming or projecting, in both directions—possibly an interesting avenue for experimentation. The same three-picture sprocket used to advance film from the feed magazine to the take-up magazine incorporates into the design of the intermittent. To affect the movement and rest periods of the film motion, the sprocket geared itself to a

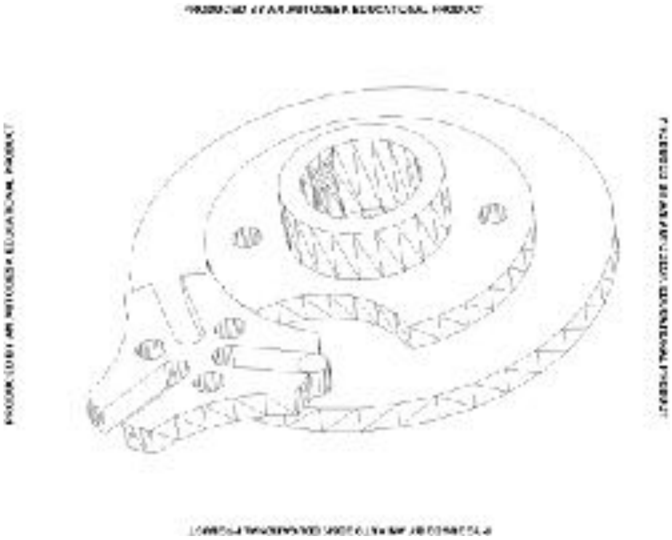

FIG. 9 Geneva mechanism.

Geneva mechanism (Fig. 9). The Geneva, or star wheel, designed considering the diameter of 0.500 inches, less than that of the film sprocket, yet large enough to be durable and easily mounted within the drive train. It had three stations, or slots, so that every one complete revolution of the star wheel would equal one complete revolution of the intermittent film sprocket—thus, one movement of the star wheel would advance the film one frame. The continuosly moving star wheel would remain idle through 300° of its rotation, and rotate for 60° of its rotation. Thus, while operating at 15 fps, the star wheel would be idle for approximately 5/100th of a second and rotate for approximately 1/100th of a second.

Six, the continuously revolving shutter geared itself to the intermittent mechanism. A variable speed shutter would be beyond the scope of cost and complexity of this project. Instead, the Zinematograph relies on four unique, interchangeable shutters—three of which for shooting and one for projection. To increase shutter 'cut-off' efficiency, or "the time taken either to completely open or completely close the camera aperture" necessitated the design of the four shutters with "the greatest acceptable diameter which could be accommodated in the camera body [while being] mounted with its centre of rotation as far as possible from the gate aperture" (Wheeler 69). The three shutter angles used for filming: 93.75°, 131.25° and 253.12°. Knowing that the camera would most often be operated at 15 fps and used in conjunction with a Sekonic L-508 Cine model light meter, whose frames per second selection jumps from 12 to 16, the shutter angles could proportionately emulate 100°, 140°, and 270° shutters operating at 16 fps. The fourth shutter, designed to increase flicker rate during projection, had a 90°/90° split shutter. (Fig. 10).

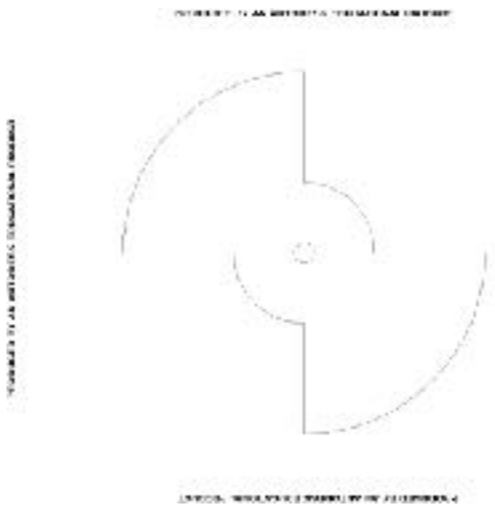

FIG. 10 Projection shutter.

FIG. 11 XG7 lens mount.

Seven, the camera will possess a lens mount that will accept a range of objective lenses without the need for further adjustment or calibration. To fulfill this requirement, a free Minolta XG7 35mm still camera, with a broken film advance lever, acts as the lens mount (Fig. 11). The lens mount would therefore accept the full line of lenses compatible with the original still camera. The lens mount would be positioned at a point within the camera a distance of 0.966 inches from the film plane, a distance equal to that of the lens mount within the body of the XG7.

Eight, the camera should be fixed with a viewfinder enabling sight of the field of view captured by the objective lens. The XG7 incorporated a reflex mirror and ground glass component. The Zinematograph incorporates a sight panel leading from the ground glass to the side of the camera. A lever included into the design would enable manual operation of the reflex mirror, opening and closing the path of light from the lens to the ground glass or lens to the film plane. The ground glass would be marked to the same aspect ration as the aperture mask within the film gate. This operation, allows the camera to be sighted and focused prior to image acquisition on film—during image capture, however, the reflex assisted viewfinder would be closed. Thus, necessitating the need for a side range finder similar to the Le Parvo.

Nine, there should be an indicator noting frames-per-second. The Zinematograph would not include a visual indicator of fps. The operation of the hand crank would rely on the rhythmic function of a musician, employing the beat of a battery operated metronome, also obtained for free, plus the cost of a 9-volt battery. This allow one to calculate fps. By setting the metronome to 120 beats per minute allows the operator to sync their hand motion to a beat at the top and bottom of the crank handle's rotation. Knowing that each complete revolution of the hand crank will advance the camera 15 frames, every two beats of the metronome signals 15 fps. Adjusting the beats per minute of the metronome alters the Zinematograph's fps.

Ten, the camera should possess a footage counter. Although timing the length of shooting time and calculating the length of film footage consumed would have been the cheapest method, Thit was decided to save some headache on set by including an actual footage counter into the Zinematograph's design. A stock, three-digit mechanical rotary counter (Fig. 12) geared to the camera's drive train would calculate footage from 1 to 999 feet, purchasable online at a sale price of $4.99.

FIG. 12 3-digit mechanical rotary counter (www.fargocontrols.com).

Beyond the Ten Commandments, a few other components must be incorporated into the Zinematograph's design. The Zinematograph's crank handle (Fig. 13) used a stock part—a counter-balanced, solid aluminum, finished in a grey enamel finish, and able to mount to the 0.25-inch main drive shafts cost $23.18.

The sprocket teeth controlled motion of the film through the film gate (Fig. 14), both advancing and stopping, and would be integrated with the film perforation.

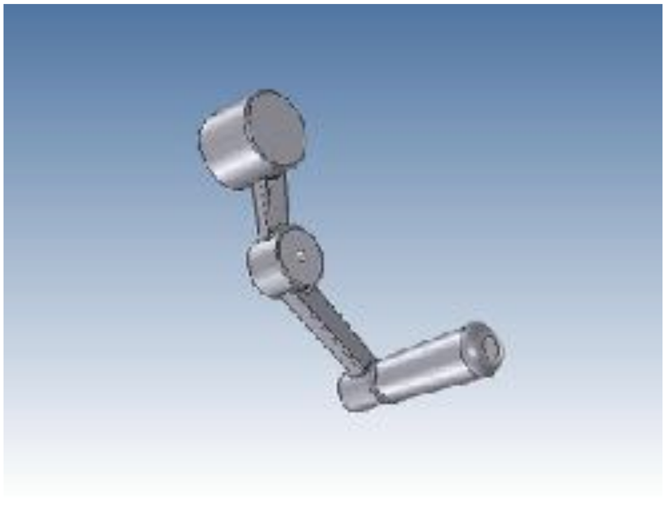

FIG. 13 Crank Handle (www.jergensinc.com)

The use of pilot pins to hold the film in place seemed superfluous. The design uses a spring tensioned film gate (Fig. 14) to help steady the film during exposure. The design uses pressure rollers to tension the film against the film sprockets. ARRI 16mm film cameras possess a mounting plate on the bottom with two holes tapped to accept

1/4 or 3/8-inch machine screws, thus enabling secure fixture to a tripod head. The Zinematograph also incorporates this into the camera design. Finally, an inexpensive aluminum handle, purchased at Lowes for less than $3, would be fastened to the top of the camera.

The Zinematograph's drive train (Fig. 15), or system of mechanical components that facilitate the motion of the film, underwent two designs.

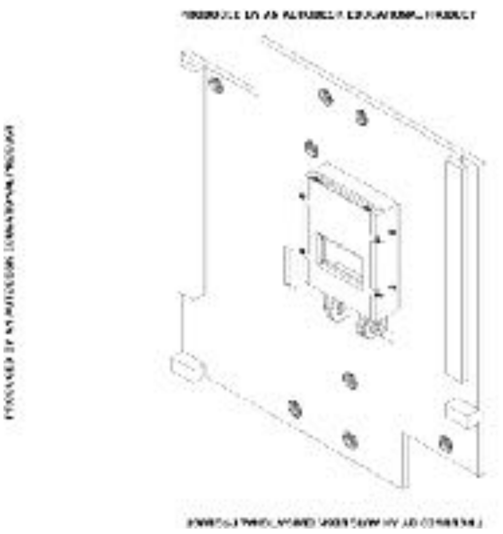

FIG. 14 Film Gate

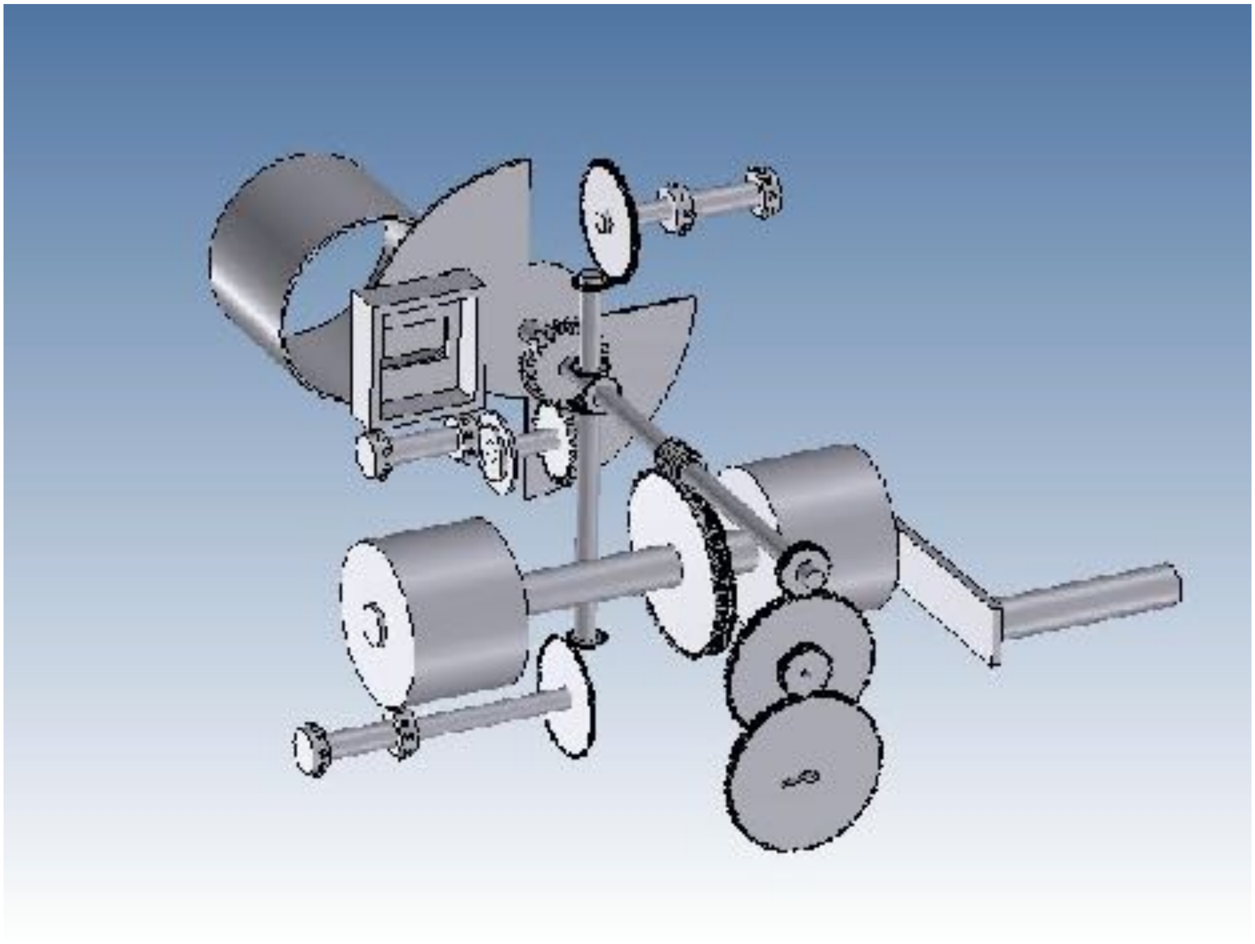

FIG. 15 First drive-train concept.

The first design resulted by trying to create the simplest and most efficient design—with few parts, no timing belts that would wear and need replacing and gearing that would operate as smoothly and quietly as possible. Completely shaft driven, the first drive train incorporated a worm step-up drive, spiral bevel gears to transmit motion to the film advance and take-up sprockets and helical gearing to transmit motion to the drive wheel of the intermittent mechanism. This gearing allows smooth and quiet operation, and a long life when properly mounted and lubricated

"Worm gears are used for the transmission of motion and/or power between non-intersecting shafts at right angles," and "are considered the smoothest and quietest form of gearing when properly maintained" (Gears… 149). They are also allow high ratios of speed change in a minimal amount of space. Therefore, the camera's initial drive train had a worm drive as the primary gearing to transmit motion from the crank handle to the shutter, intermittent, film feed and take-up sprockets. Since the greatest speed change takes place from the one revolution per second motion of the hand crank to the 15 revolutions per second of the shutter and intermittent mechanism the worm gearing configure had a step-up drive with a ratio of 1:15. Worm drives most commonly reduce speed rather than increase speed as in a step-up drive. Therefore, specific considerations must be taken in their design. The worm most importantly must possess a lead angle of 45° and a thread angle of 30° (Buckingham 148). A stock worm gear to facilitate these necessary considerations couldn't be found, since the common lead and thread angles of worm gears used in reduction drives are between 3° and 15°, and 14.5° and 25°, respectively. A proper step-up drive would need to be custom made and therefore costly and time consuming. As a result, this design was abandoned.

The second drive train design specifically incorporated gears and other parts available as stock drive components. As such, the key gearing was composed of helical gears. Helical gears are stronger, can carry a greater load, and operate more smoothly than simple spur gears of comparable size (Gears… 143). ARRI has employed helical gearing in its intermittent mechanisms to drive the camera shutter (Wheeler 61). Unfortunately, the second design also required the use of pulleys and timing belts. The pulleys would significantly raise the cost of

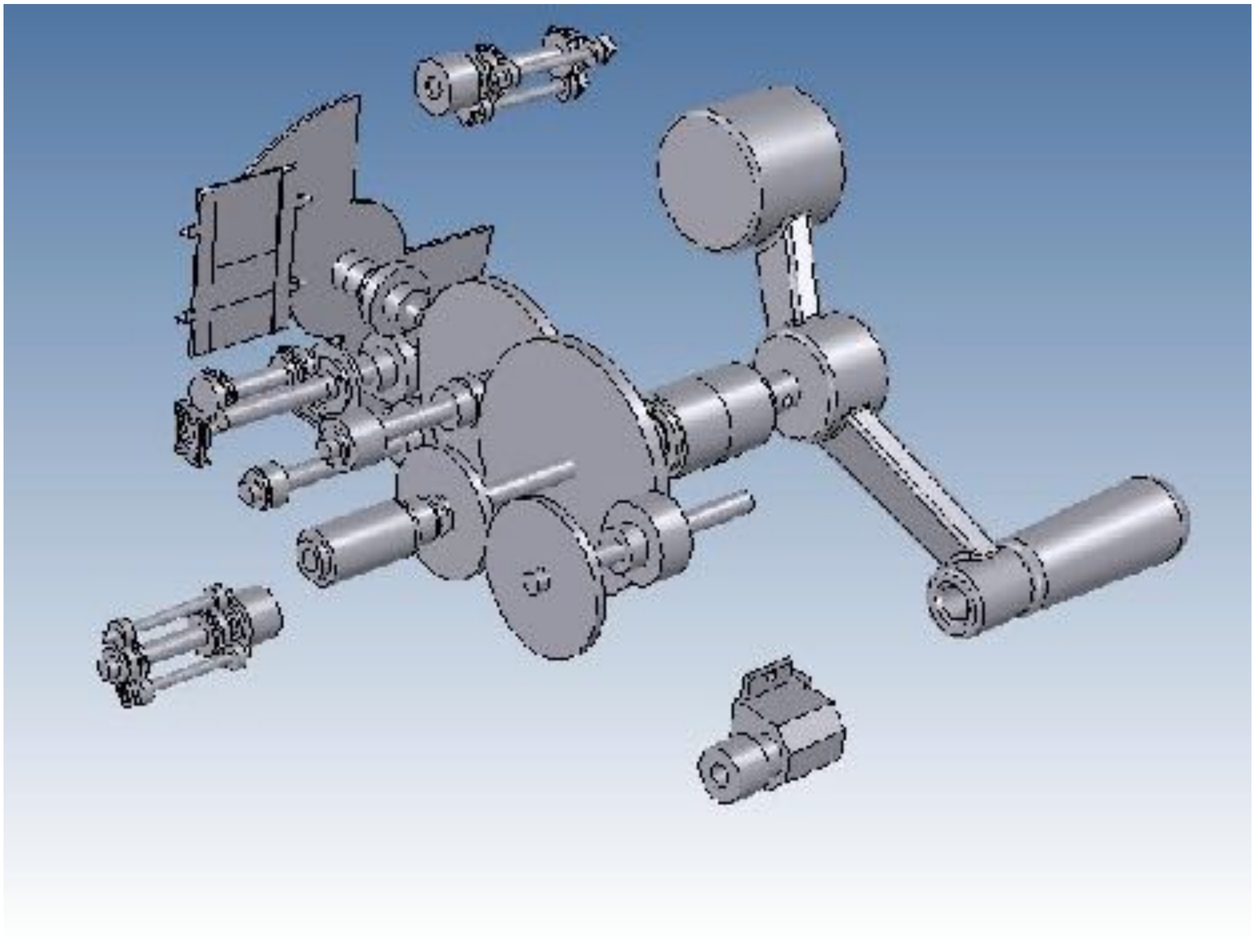

FIG. 16 Second Drive train. The large disks near the center are helical gears drawn simply with their pitch circles.

total gear components and the belts have the potential to wear more quickly than simple shafts and easily slip out of position. However, since the price of a timing belt can be mere pocket change, replacing them would be mostly a matter of inconvenience.

The final cost to birth the Zinematograph—a film camera and projector whose cost could be likened to a diet of rice and a nice Zinfandel when compared to the $60,000 plus ARRI porterhouse steak and Romanée Conti—estimated at $920.16. This resuled in two parts. First, the cost of stock drive components and raw materials needed to construct the Zinematograph. Second, the cost to machine the Zinematograph's custom components, such as the intermittent, film gate, film sprockets, shutters and chassis. Table 1 outlines the cost and source for key components and raw materials.

TABLE 1 Components and materials price list.

Parts ordered from SDP

Description	Tech Specs	Order Part #	Quantity	Cost(Each)	Total
Full Shaft	O.D.=.2497, L=3.25	A 7X 1-08032	2	$2.33	$4.66
Int/Counter Shafts	O.D.=.2497, L=3.125	A 7X 1-08031	2	2.33	4.66
Helical Gear	48DP, .25Bore, 30Teeth, Left Hand	S1L86Z-P048A030	2	16.43	32.86
Helical Gear	48DP, .25Bore, 30Teeth, Right Hand	S1R86Z-P048A030	1	16.43	16.43
Helical Gear	48DP, .25Bore, 90Teeth, Left Hand	S1L86Z-P048A090	1	23.66	23.66
Helical Gear	48DP, .25Bore, 20Teeth, Right Hand	S1R86Z-P048A020	1	15.08	15.08
Helical Gear	48DP, .25Bore, 100Teeth, Left Hand	S1L86Z-P048A100	1	28.82	28.82
Metal Take-Up Pulleys	.080(MXL) Pitch, 18 Grooves	A 6N16-018DF1208	4	13.02	52.08
Take-Up Timing Belts	.080(MXL) Pitch, 106 Grooves	A 6G16-106012	2	2.74	5.48
Spur Gear	48DP, .25Bore, 72Teeth	A 1T 2-Y48072	1	5.95	5.95
Spur Gear	48DP, .25Bore, 84Teeth	A 1T 2-Y48084	1	6.49	6.49
Counter Pulley	Pitch.080, .25Bore, 30Grooves	A 6T16-030DF2508	1	4.84	4.84
Counter	Pitch.080, .25Bore, 18Grooves	A 6T16-018DF2508	1	4.52	4.52
Counter Belt	Pitch.080, .25width, 18Grooves	A 6G16-090025	1	3.15	3.15
Counter PulleyBore Reducer	.25 to 3mm,	A 7A30-250309	1	5.86	5.86
Main Shaft	O.D.=.2497, L=6.625	A 7X 1-08066	1	3.1	3.1
Handle:Coupling / Shutter Shafts	O.D.=.2497, L=1.5	A 7X 1-08015	2	2.01	4.02
Take-Up Shafts	O.D.=.2497, L=2.25	A 7X 1-08022	2	2.19	4.38
IntSprocket Shaft	O.D.=.2497, L=1.375	A 7X 1-08013	1	2.01	2.01
Shaft Coupling for Handle	.25:.25Bore, O.D.=.438,L=.75	S5925Y-SO22-01	1	11.98	11.98
Collar for Clutch End	O.D.=.438, .1875Bore(bored to .25) L=.25	A 7C 2-11608	1	5.38	5.38
Washer for Clutch	O.D.=.625, .255Bore, W=.0625	A 7B 7-S081002	2	1.08	2.16
Collar	.2498Bore, OD=.5, W=.25	S5000Y-25016	8	4.88	39.04
Thrust Washers	.255Bore, O.D.=.4375, W=.0625	A 7B 7-S080702	20	1.01	20.2
Machine Key	.125 x .125 x 1.25	A 9C39-0440	2	0.56	1.12
Key Stock	.0625 x .0625 x 12.0	A 9C40-0212	1	3.07	3.07
Clutch Springs	O.D.=.360, F.L.=.88, Solid= .346	S78CSY-036042088	4	1.33	5.32
Extension Springs	L=.25, O.D.=.063, E.L.=.46	S78ESY-006008025	6	2.01	12.06
Extension Springs	L=.5, O.D.=.063, E.L.=1.050	S78ESY-006008050	4	2.88	11.52
Shaft(Set Pins, etc.)	O.D.=..0622, L=12	A 7X 1-0212	2	3.54	7.08
			SDP Grand Total:		$346.98

Parts ordered from Bold Depot

Description	Tech Specs	Part #	Quantity	Price Each	Total
Int Lock Set Screw	0-80,1/16	8385	1	0.36	0.36
Machine Screws	Ph, Pan Head, 6-32,1/2	1543	11	0.06	0.66
Machine Screws	Ph, Flat Head, 6-32,1/2	1488	9	0.07	0.63
Handle Screws	Ph, Oval Head, 8-32, 3/4	1299	4	0.11	0.44
Handle Nut	#8-32	2644	4	0.08	0.32
Handle Washer	lock, 8	3021	4	0.06	0.24
Nuts	#6-32	2643	20	0.08	1.6
Lock Washer	#6	3022	20	0.06	1.2
Counter Screws	Ph, Pan Head, 4-40, 7/16	9214	2	0.06	0.12
Counter Nuts		2642	2	0.08	0.16
Counter Washer		5563	4	0.06	0.24
Lens Mount Screws	2mm-.4,10mm	6815	4	0.06	0.24
LM Nut	2mm-.4	7362	4	0.06	0.24
LM Washer	2mm	7362	4	0.06	0.24
Eye Bolt	10-24,1 3/4	12267	1	0.38	0.38
Eye Bolt Nut	10-24,	2645	1	0.08	0.08
Eye Bolt Washer	10-24,	2946	1	0.06	0.06
			Bolt Depot Total		7.21

Camera Body

Description	Tech Specs	Quantity	Price Each	Total
Wenge	Dark, Hardwood by board feet	4	16.5	66
		Bolt Depot Total		66

Material and Hardware Grand Total: $420.19

The rate to machine the parts involves an unstable variable that must be calculated into the full cost to complete the Zinematograph. This could ultimately raise the Zinematograph's price tag above $2,500. To build the Zinematograph for $920.16 requires a machining cost of $500 dollars, as quoted by Chuck Ringering, Chief Machinist for Spacewalker Inc., in Bonne Terre, Missouri. Ringering turned down the project because of the labor time necessary to make the parts. A second quote was obtained from the well equipped, Contemporary Engineering Designs, Inc., in Bloomsdale, Missouri. The response was as follows, "We are looking at a minimum of two months and probably closer to three months for us to get these done… just by glancing at the prints you are looking at a few thousand dollars to complete this" (Bayette 10:42 am). The reason: Contemporary Engineering Designs, Inc, is "a CNC production shop and to shut down production to run prototypes is rather expensive" (Bayette 5:58 pm). An attempt to obtain a third quote from Paul Harris, Owner and General Manager of Farmington Machine Company received Harris's positive response about his abilities to easily make the parts, however it would have taken him more than three weeks to arrive at an accurate quote. Beyond the simple price tag, the time necessary for a machinist to complete the project proved to be the ultimate variable that halted the actual construction of the Zinematograph.

Final Analysis

The primary research can be reduced to a recipe that would enable 35mm film production for one that can only afford to live on a diet of rice and a nice Zinfandel, not the diet of fine steak and Romanée Conti of the professional film industry. By targeting the two major benefactors to the high cost of chemical 35mm film production, the extraneous technology employed into the design of the professional film camera, and that of the film stock and its processing and allowing enough time for manufacturing, revealed the possibility to make a motion film camera for $920.16 that when operating would save over 55% in negative costs. This is a significant revelation to one wishing to shoot in the classic format of superior visual images—35mm chemically processed celluloid—at a cost less than the emerging Hi-Def format. Having personally been romanced by the magic of the celluloid cinema, I consider myself as one such person. The pursuit of this recipe did not lack challenge and struggle. However, I still view this avenue of pursuit as full of merit and worthy of further endeavor. For its pursuit enables the pursuit of creative expression via one of the most significant art forms of the Twentieth Century.

The inspiration for this project came from witnessing the effects the Digital Dark Ages first hand. While viewing footage captured in the MiniDV format with the 3CCD Sony VX1000 5 years prior, the degradation of images and sound had already become apparent through dropped frames, pixilated images, and clipped audio. The affect of watching this footage created an unnerving feeling not present when watching silent film footage with scratches and dirt—which seemed mystical. Furthermore, being able to look over and physically handle a 35mm still negative captured in the same time period as the MiniDV footage, by using the same lenses that would be used with the Zinematograph, increased my respect for the abilities of the chemical medium. The images still looked beautiful without the aid of a video deck and monitor. I began to adopt the “old can be good” theory in my attempt to create a high quality means of capturing the motion image. I looked forward to jettisoning the tedium of hours spent logging and capturing video images to the digital workstation and avoiding the physical and mental stresses that becomes apparent to many who spend prolonged time working with computers. My attempt to recreate the cinématographe follows in this vein.

It could be argued that a steady diet of rice and a nice Zinfandel would not lead to clogged arteries, however this project did possess cholesterol—or challenges. Time proved the biggest challenge. You have one semester to compete your Senior Overview project at Webster University, yet the time factor incorporated into each of the challenges that follow increased the project's length to two semesters and caused the postponement of my graduation. This ultimately resulted in the termination of this project's total completion—achieving a working model of the Zinematograph. The other challenges included acquiring basic engineering fundamentals that would enable the best design choices at the lowest cost, learning the software that would translate these design choices into a format that a machinist would be able to understand and manipulate and working with machinist to manufacture the Zinematograph's custom metal components.

At the outset of this project I possessed little understanding of the engineering fundamentals necessary to ensure that the camera I designed would successfully and efficiently operate. However, I set forth on a self-directed crash course in engineering. This necessitated considerable time and effort scouring the stacks at Saint Louis University's Pius Library, and other Saint Louis Colleges' library collections, in search of books related to engineering. These books facilitated my ability to discern the differences between spur, spiral bevel, miter, helical and worm gears and their specific advantages and disadvantages, the involute form, choosing materials to use for their best strength to price ratio and understand the specific rules regarding ANSI Standards so that everything fit together properly. Also, with the initial idea being to custom make all parts for the camera, specifically its gearing and drive components, considerable time and effort went into trying to mathematically calculate the variables of these different components. For instance, using the Gleason System for calculating the diametrical pitch, spiral angle, pressure angle, shaft angle, pitch diameter, cone distance, circular pitch, addendum, dedendum, etc. of the pinion and gear of a spiral bevel set, or calculating the center distance for specific pulleys and helical gears.

Obtaining and learning the software that would enable me to translate my ideas into a format that a machinist would be able to manipulate posed another challenge. The conceptualization and design phases of this project utilized two modeling software platforms—

IronCAD Inovate Version 9 and AutoCAD 2006. Following my inquiry for engineering advice from the professors at Washington University in Saint Louis' School of Engineering and Applied Science, Professor Jerry W. Craig mailed me a one year trial version of the conceptual solid modeling software, IronCAD Inovate. With this software I rendered a three-dimensional model of the Zinematograph and animated the motion of key components to view how they would work together. The design of a scale model of the working Zinematograph used an educational version of AutoCAD 2006 that I obtained for free from student sources. Desinging the components of the Zinematograph used the three-dimensional modeling capabilities of the AutoCAD software. I knew that designing these parts to scale using AutoCad would enable these components to be transferred to a CNC—or computer numerical control—milling machine by a machinist that would fabricate the actual mechanical components.

Prior to the effort given to establishing the Zinematograph's design I thought I secured a machinist capable of fabricating the parts needed for constructing its parts. A machinist that I knew for many years, currently working for a professional CNC milling company— gave me \ verbal agreement to fabricate the parts. At first I understood that they had the abilities to fabricate, with no charge for labor, the complex gearing that I had in mind for the camera. After spending much effort calculating the parameters for such gears I discovered that, in fact, the CNC facility at his disposal lacked the capability of cutting the spiral or helical dimensions of the gears I required. This resulted in the formulation of the second design—relying on stock products for the more complex gearing and using the machinist for fabrication of the less complicated parts: chassis, shutters, intermittent and 3-picture film sprockets. I couldn't find stock components for the last of these. Thus, I had to alter the design of one solid component into six smaller components that could easily be machined and the fitted together to form the complete sprocket. After having completed the second design, My machinist informed me that they had recently been given extra responsibilities. This resulted in another semester's worth of my time to complete the new design. With time, at this point, an even larger burden than money I turned to several local machine shops for estimates on completing the project. Although the financial cost of completing the parts varied from one shop to the next, the all agreed on the costly amount of time needed for completion—a cost that I couldn't pay. Thus, I abandoned the Zinematograph project without transforming the design into realty.

I say "abandoning the Zinematograph project at this point," because I possess the opinion that this project merits further endeavor. I do not view this as a selfish desire to satiate the curiosity as to whether the Zinematograph design would function and be a viable means to give independent and experimental filmmakers a way to afford the quality of 35mm cinematography. The concept of incorporating classical and modern technologies could further be applied to the developing process of film shot with the Zinematograph. Using the existing design, the main requirement to complete this project would be to secure a machinist willing to fabricate the Zinematograph's aluminum components. From which would follow a timeline and accurate budget estimate for completion of the working Zinematograph. The only other foreseeable requirement would be to find a place, like the Webster University Sculpture Studio, to construct the Zinematograph's body and assemble all the pieces.

The pioneers of cinematography proved it possible to capture emotionally stimulating moving images by combining the early technology of chemical photography with a few basic, handmade mechanical components. The evolution of this technology introduced innovations such as optical sound recording, variable shutters, 3-chip charge coupled devices, and ultimately High Definition digital cinema. All of which skyrocketed production costs to astronomical proportions and into an elite position that the majority of those with the passion for cinema will never be able to obtain. The 35mm chemical film format offers superb image capabilities since the dawn of cinematography. This cineaste, with a desire to visually express themselves, must be weary of technological advances and embrace the medium's simple origins. Wherein lies a wealth of history and the potential for future filmmaking on a budget of rice and a nice Zinfandel.

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