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By Jonathan Erland

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This article outlines a new approach to the production of motion picture traveling matte photography. A solution is demonstrated to overcome the problems encountered when photographing models, i.e., aircraft, space ships, etc., when these incorporate surface finishes such as specular metallic or glossy paint, or when they include thin sections such as struts or antennae. The process requires a sophisticated motion control system capable of multiple passes in registration.

In the course of the production of motion pictures, it is sometimes impractical, uneconomical, or simply impossible to place actors in the environment depicted in the story. To resolve this dilemma, various techniques have been evolved over the years to composite such scenes from separately filmed elements.

In the very early years, animation was used in such films as Georges Melies' *Trip to the Moon.* Later this gave way to processes such as the "held/take" in which a scene was shot, perhaps on location, with some area of the frame blocked out so as to receive no exposure. The unexposed portion of the frame was subsequently exposed to some foreground action, while the background area was blocked off with an opaque matte to protect the latent image already recorded. Essentially the same process is used to incorporate a painting which depicts the distant, dangerous, or totally imaginary scene against which the actors are to appear; this is known as matte painting.

A major drawback to these processes is that they cannot depict the actors or other foreground subjects moving in front of the background. An early attempt to solve this problem produced the famous "carousel," in which actors, on dummy horses or in automobiles, appeared to be traveling through a countryside. In reality, a large cylindrical painted backdrop revolved through the frame immediately behind the actors. This evolved into the more effective processes of rear projection and front projection, in which the background scene (filmed separately) is projected onto a screen and re-photographed, along with the foreground action, to produce a composite image.

This approach, however, necessitates the synchronizing of the shutters of both the projector and the camera. Considerable difficulty is encountered with the evenness of the illumination across the screen and the illumination and color balance of the foreground scene versus the projected image. Added to this is the need to have the background "plate" already filmed, and the increased expensive studio time; in the end, there is usually a discernible loss of image quality in the re-photographed projected image when compared to the original photography of the foreground action.

In order to retain control of the image quality and the flexibility inherent in the optical compositing approach, while acquiring the freedom of subject movement basic to the front projection process, it became necessary to create mattes that would change from frame to frame, or "travel."

The use of "traveling mattes" was probably first introduced to facilitate such effects as "wipes," in which one image is gradually displaced by another over a period of many frames. Many versions of this device were common, such as wiping from right to left or top to bottom, or starting from a minute speck and enlarging to fill the entire screen. The traveling mattes produced for those applications were generally done by hand or mechanically, but not photographically.

The demanding nature of new applications for traveling mattes required that they be produced photographically and in conjunction with the foreground action scene. Two main approaches were taken to achieve this end — "single-film" and "multi-film," each with a number of variations.

Single-Film

The first single-film matte process was probably one that relied on sheer contrast, with the foreground action filmed against a jet-black backing, and the resultant image printed through several generations of high contrast stock until a matte was achieved. Owing to the inevitable distortion introduced by so many generations, the results of this process were generally poor.

The next single-film approach, which arrived with the advent of monopak color film, relied upon the dedication of one-third of the visible spectrum to the matte. All three emulsion layers of color negative stock have been tried at one time or another, but the clear favorite has always been blue. As a result, the dominant traveling matte process in the industry today is the "bluescreen" process.

There are probably as many variations on the bluescreen process as there are visual optical-effects specialists. In general, the procedure is as follows. The foreground action scene is staged in front of a blue backing and photographed on color negative stock. (The blue backing may be produced as a painted backing and front-lit, as a front projection screen illuminated from the camera position by a blue light, or as a translucent seamless blue transmission screen illuminated from behind.) The color negative image is then used, according to the particular method employed, to produce a set of black and white separations as well as a set of mattes. If both the foreground element and the background element have been broken down into separations, a high degree of control is possible in compositing the final shot.

However, a number of difficulties still remain. Rapidly moving objects which cause the image to streak, as

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well as items such as hair or glass, become difficult to reproduce without "fringing," the result of the partially exposed edge of the moving subject either "dropping in" or "dropping out" of the matte. The effect is to produce either a truncation of the subject or a black border or "matte line" adjacent to it. Obviously, nothing in the foreground scene can be pure blue in color, as it would disappear along with the bluescreen, leaving the background scene to show through the "hole." Petro Vlahos' excellent version of the bluescreen process, known as the "color difference" process, went a long way toward solving these problems but is expensive in terms of time and materials.

"...Not only did the model (a gleaming black aircraft) promise to be difficult to matte, but the backgrounds against which it would appear are the most extreme test of any matting system — arctic snow and ice and stunning cloudscapes..."

Multi-film

The several multi-film techniques all employ the three-strip Technicolor camera, which is now rarely used for its original purpose. For the multi-film traveling matte, only two strips of film are used, a color negative (Eastman 5247) and a film sensitive to some narrow portion of the spectrum. A beam splitter is installed directly before the film gates to pass the image in the visible spectrum to the color negative while diverting to the other film the image carried in the narrow band selected to produce the matte. The narrow bands normally employed for this purpose are ultraviolet (360–420 nm), otherwise known as diazo blue; infrared (700–900 nm); and sodium vapor yellow (589 nm).

Of the three types, Petro Vlahos' sodium vapor system is felt to be the best. It results in a matte image of the same size as the foreground subject image, whereas the ultraviolet and infrared mattes are distorted in size by virtue of their respective positions at opposite ends of the visible spectrum. Because the matte image is formed on a separate piece of film, there is no need to break the color negative down into separations, nor to lose any portion of the spectrum in order to gain a matte. There is also no problem of fringing, and glass objects as well as fine details like hair can be faithfully matted.

Motion Control Animation

One facet of the motion picture business spared the complexities of traveling mattes altogether is, of course, animation. Here the images (cells) are naturally self-matting. In the case of stop-motion animation, it is necessary to hand-draw the mattes on an enlarged projected image of each consecutive frame, as was done in the landmark film, *King Kong*. Neither technique, however, is capable of recording the subtle but distinctive image "streak" that occurs when a subject moves during the exposure of an image. In Kubrick's *2001: A Space Odyssey*, Douglas Trumbull filmed exquisite miniatures representing huge objects by a process of held/takes and in-camera composites. This successfully preserved the sense of real movement, but prohibited allowing various objects in a frame to touch or cross each other, since there were no mattes to protect them from double exposure.

In creating the special visual effects for *Star Wars*, John Dykstra had to devise a way to produce many overlapping images and to record "streak," that blurring of a moving object when photographed that allows the human eye to perceive and interpret the movement as "real." It was necessary to composite not just two, but many separate elements for a single frame.

The largest possible film format was needed in order to reduce the image degradation that would result from the numerous steps required to create the final scene. Yet the cameras that would photograph the miniatures had to be miniature themselves, in order to maneuver about the nodal point of the lens in extremely close proximity to the models. They also had to be able to do this repeatedly and in perfect registration in order to incorporate assorted lighting effects in and on the subjects. Therefore, the highly desirable multi-film matting approach had to be rejected, dependent as it was on the relatively huge size and complexity of the camera and the relatively small size of the film format. Similarly, the desirable large film format of 65 mm foundered on its limited lens selection, paucity of available film stock, and the sheer bulk of the camera itelf.

Out of this dilemma, Dykstra produced an exceptional solution, namely, to combine bluescreen matting with the almost defunct Vistavision 8-perforation, 35-mm movement. To support this concept, a new generation of photographic equipment was created, incorporating sophisticated electromechanical systems to control the motions and functions not only of the camera and subject, but also of other pertinent apparatus. These systems fulfilled the requirement that the camera be able to make numerous passes in perfect registration, at exposure rates of many seconds per frame.

Equipped with a sophisticated motion-control system, it is possible to achieve much the same result as the multi-film process by the simple expedient of filming consecutive passes in which the "matte" pass and the "subject" pass are photographed separately and sequentially on the same film load. This is the front/back lit process, although a blue transmission screen may be used as the source rather than a white one. For this screen, the author has designed specially phosphored fluorescent tubes, together with a specific dye/pigment formula, which limit the output to a band width of 20 nm. The process is further refined by the utilization of a blue separation filter on the camera lens. The result is a very pure monochromatic blue matte.

A major problem with any system that depends upon an illuminated screen beyond a subject to produce a matte, however, is that the radiation it generates whether it is infrared, ultraviolet, or within the visible spectrum will be reflected from any glossy or specular metallic surface on the foreground subject. A possible exception to this would be a system based on polarized light (Burnell, Brewster, et al.); but even this would be ineffectual with specular metallic surfaces, due to poor polarization of light reflected from such a surface.

In bluescreen work, the problem of reflected light (known as blue spill) is exacerbated whenever a wide-angle lens is in use, as the subject is then required to be relatively close to the bluescreen in order to provide suffi-

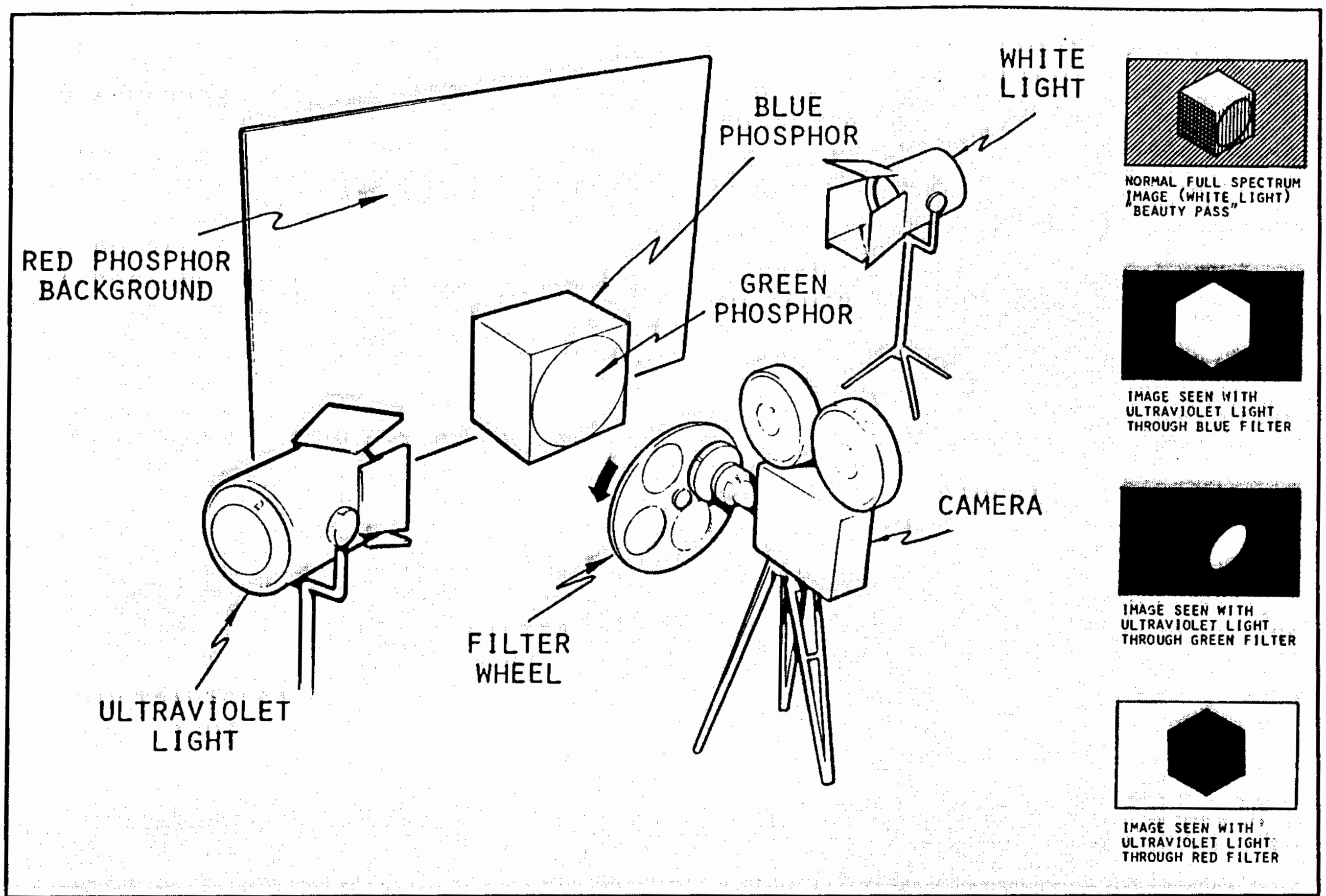


Figure 1. Diagrammatic representation of layout for reverse bluescreen.

cient coverage around it. Roger Dorney of Apogee, Inc., in conjunction with Doug Smith and camera personnel, has devised ingenious methods to overcome the more extreme cases of blue spill. These include shooting backup passes of assorted combinations (using red filters and additional lighting set-ups, as well as black velvet backings) to assure that some combination will yield a valid matte.

Even then, it is usually necessary to add yet another element, known as "the garbage matte," to remove the light stands and assorted other paraphernalia that gave this element its name. Furthermore, very thin sections such as wires, wing edges, struts, etc., are apt to be "wrapped" by the light or other radiation and to drop out of the matte. The result is that either a hole or a separation will occur in the matte of the subject.

These problems, among others too numerous to mention, were all brought into harsh focus when Clint Eastwood approached Apogee, Inc., to produce the special effects for the motion picture *Firefox.* Not only did the model (a gleaming black aircraft) promise to be difficult to matte, but the backgrounds against which it would appear presented the most extreme test of any matting system — arctic snow and ice and stunning cloudscapes.

Reverse Bluescreen

To counter the above problems, the author and Roger Dorney sought to turn the bluescreen process "inside out" (Fig. 1). Instead of trying to photograph an opaque subject against an illuminated screen, we attempted to photograph an illuminating source against a black background. The phrase "illuminating source" is used deliberately, because this process differs from the familiar front/back lit process in that the subject itself is made to become a source of radiation rather than merely a reflector of radiation.

This is accomplished in the following manner. A subject model is prepared for photography, except that some of the usual constraints can now be eliminated. This method permits incorporating highly reflective surfaces, such as glossy paint or specular metallic materials or the use of any color, including blue. In addition, fine elements, such as mesh, thin wires, struts, and very narrow wing-edges, can now be successfully included.

When the model is complete in all its detail, it is coated with a transparent medium, such as lacquer, containing a phosphor which is invisible in the absence of ultraviolet radiation. The subject can now be photographed, illuminated by normal stage lighting; this can be augmented by ultraviolet blocking filters, such as Wratten 2B, if the lamps emit more than a minimal amount of ultraviolet radiation.

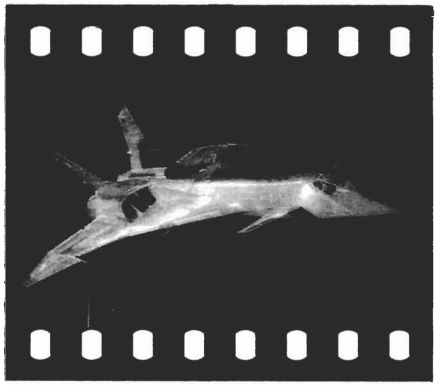
A second pass is now filmed, on the same film load, but consecutive to it. This time the stage lights are extinguished and the subject is exposed to ultraviolet radiation of a wavelength of approximately 360 nm. The ultraviolet radiation striking the subject is converted by the phosphor in the coating on the surface of the subject from 360 nm to about 430 nm and thus re-emitted as visible blue light.

The subject is now functioning as an illuminating source rather than as a reflector of the light falling upon it, and it is this source which is photographed. An ultraviolet blocking filter, such as a Wratten 2E, is used at the lens to exclude from the camera the substantial amounts of ultraviolet radiation which would otherwise effec-

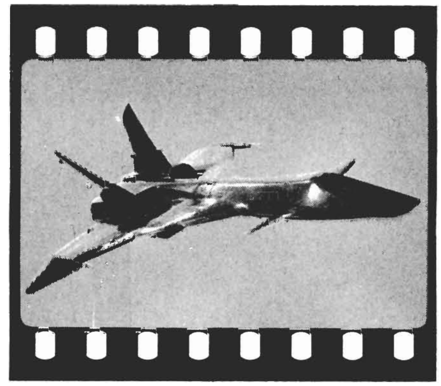
CONVENTIONAL BLUESCREEN PROCESS*

A demonstration of limitations inherent in this technique.

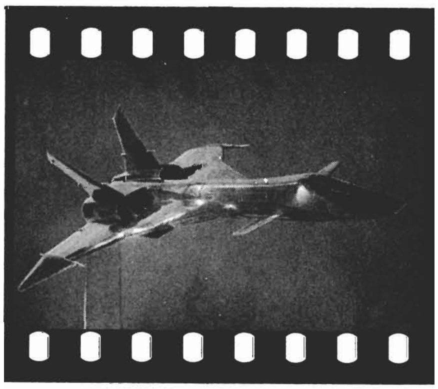
1. Original shot. Note blue reflected on wing surfaces from bluescreen, undesirable but unavoidable on such surfaces.



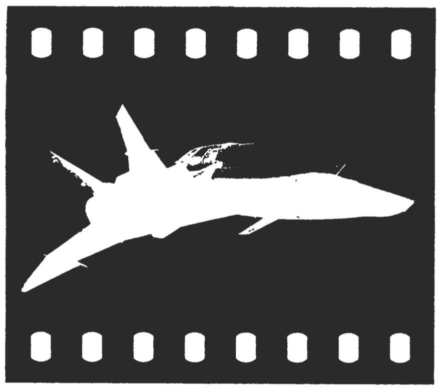
2. Blue separation. Used with original negative (#1) to provide burn in, or "window matte" (#5).



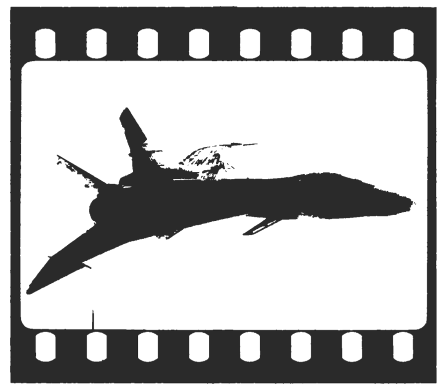
3. Red separation. Used in conjunction with green separation to print final composite (#4).



4. Green separation. Used to print both blue and green in final composite.



5. Burn-in matte produced by bi-packing negative of #1 with blue separation #2 using red filter. Note the break-up of the left wing.



6. Hold-out matte generated from #5 — clearly breaking up in the wing.

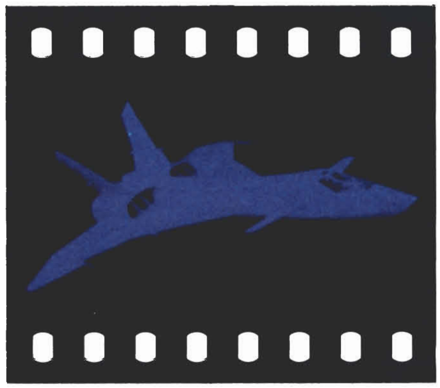
7. Background with hold-out matte, showing holes in wing.

8. Final print — unacceptable.

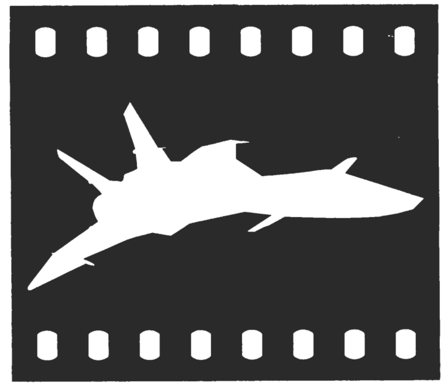
*See *J. SMPTE*, 74, No. 3, pp. 217-236.

REVERSE BLUESCREEN — SINGLE PHOSPHOR VERSION

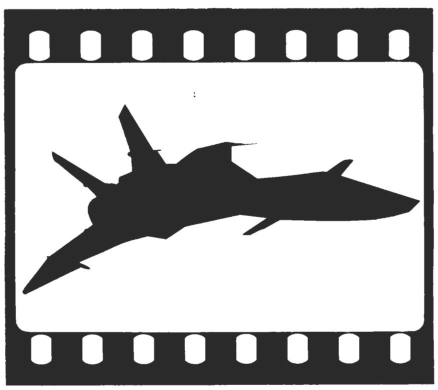
1. Beauty pass — model illuminated by incandescent light. Note reflections.



2. Matte pass. (Phosphored Firefox irradiated with ultraviolet light.) Reflections nonexistent in this pass.



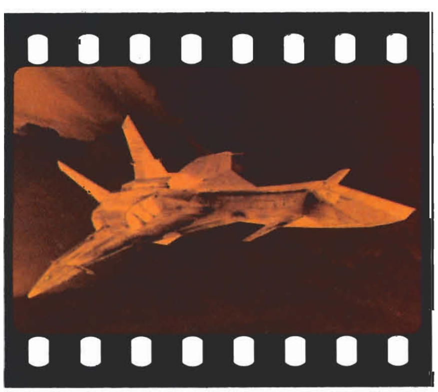
3. Burn-in matte generated from #2. No holes in wings.



4. Hold-out matte generated from #3.

5. Background plate.

6. Background plate bi-packed with hold-out matte (#4).

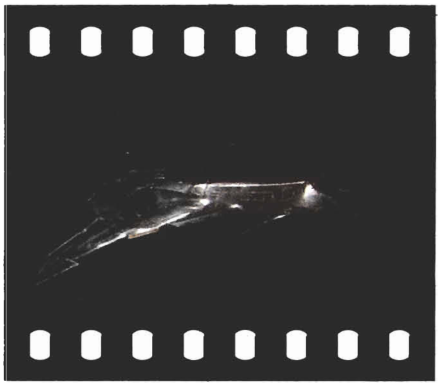


7. Color dupe negative of final frame.

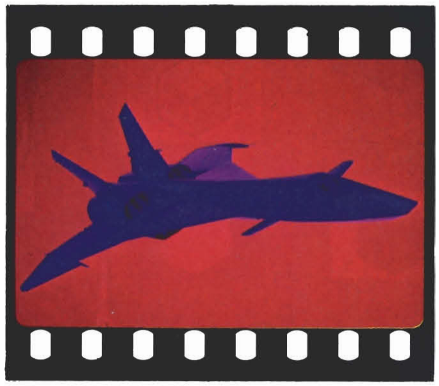
8. Composite scene.

REVERSE BLUESCREEN — MULTI-PHOSPHOR VERSION

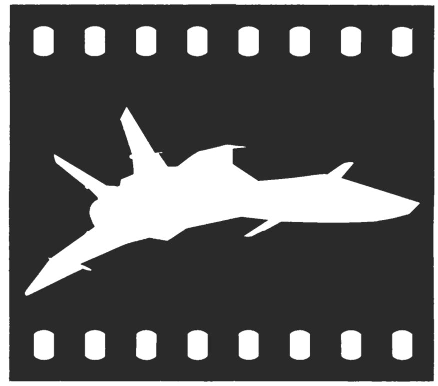
Method for including additional lighting effects.



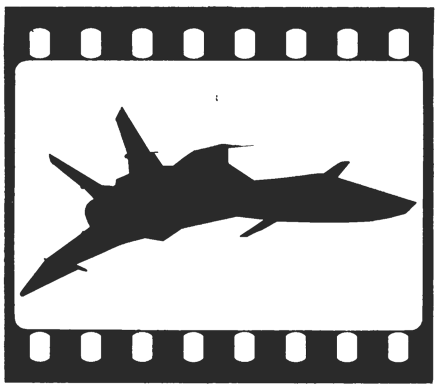
1. Beauty pass — model illuminated by incandescent light.



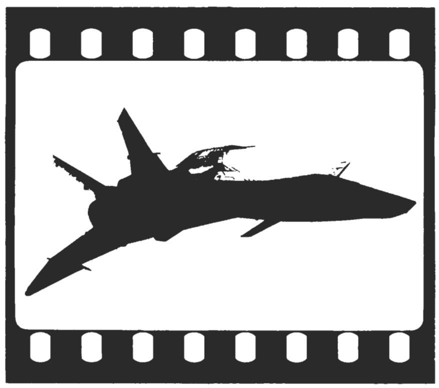
2. Red/blue matte pass — phosphored Firefox. Blue set in front of red phosphored backing, both irradiated with ultraviolet light.



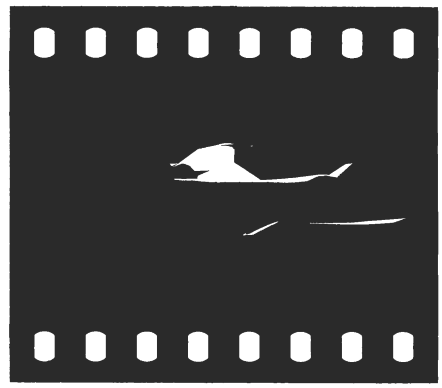
3. Burn-in matte generated from blue record of #2 — similar to burn-in of single-phospor version.



4. Hold-out matte generated from burn-in matte #3.



5. Second hold-out matte generated from red record of #2, with deliberately induced spill from backing similar to conventional bluescreen hold-out matte.



6. Matte-difference matte. The difference between #3 and #5 used to print sunlight effect on left wing.

7. Background plate bi-packed with hold-out matte #4.

8. Final print showing additional sunlight effect on left wing.

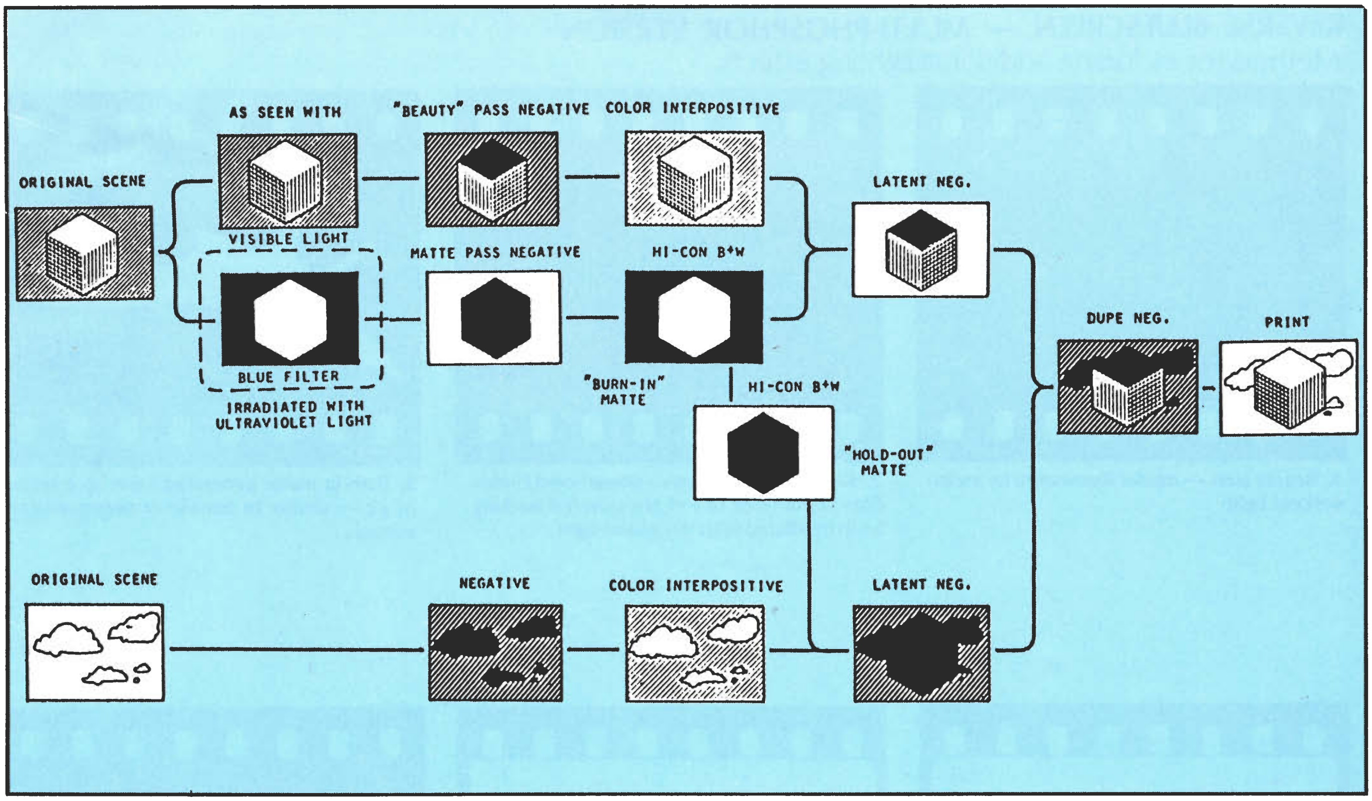


Figure 2. Reverse bluescreen — flow chart of optical steps (single phosphor version).

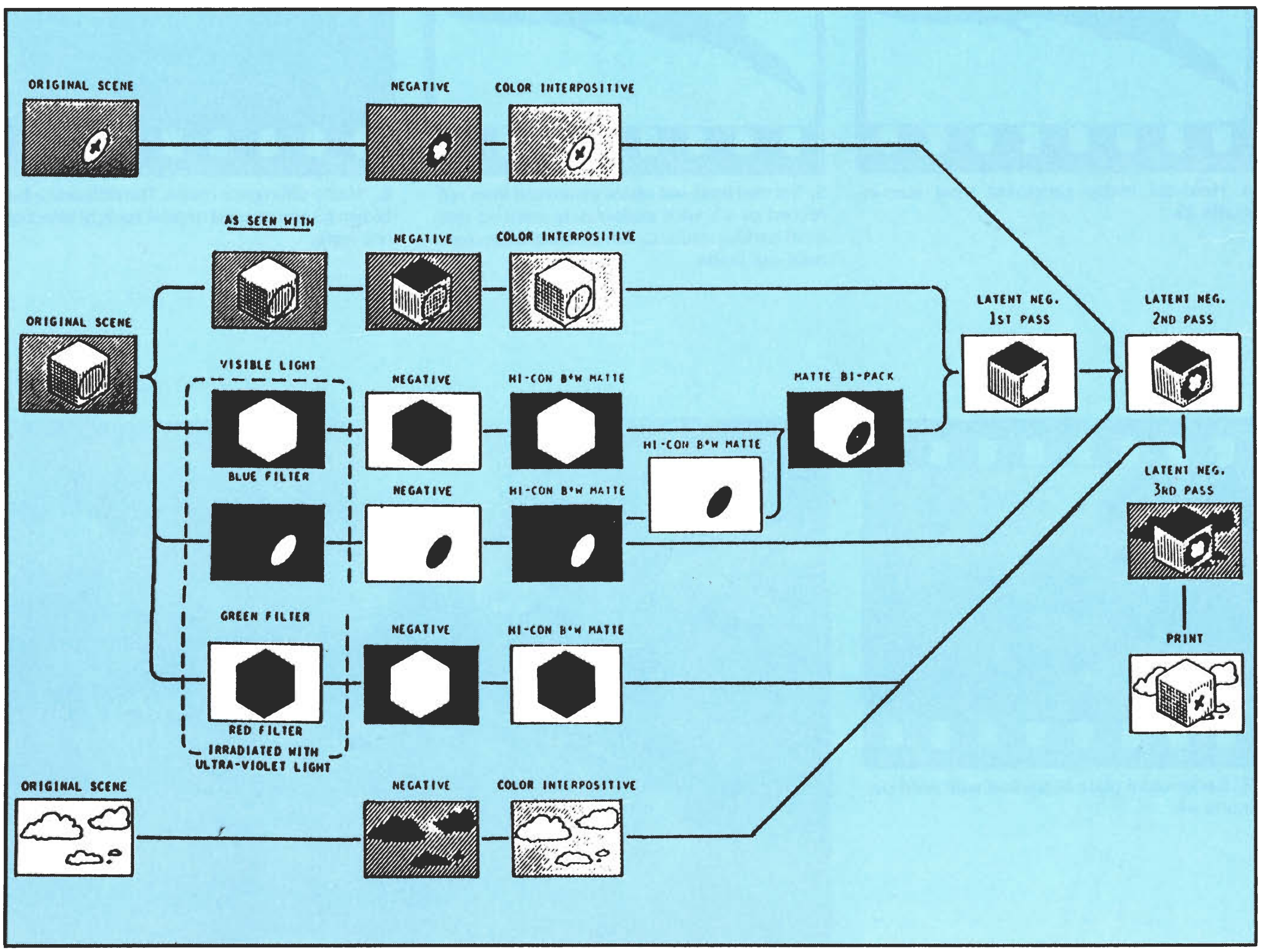


Figure 3. Reverse bluescreen — flow chart of optical steps (three-phosphor version).

tively fog a color film emulsion. This image is further refined by the use of a color-separating dichroic filter at the camera lens. The image thus rendered is formed almost exclusively by the phosphor coating on the surface of the model, with relatively little vestigial imaging from the model itself.

In this way, variations on the model, brought about by paint color, texture changes, etc., are minimized, as the object is to produce a monochromatic image with as uniform a density as possible. The image can, of course, be formed as readily by a green or red phosphor; and where a black and white stock is used for the matte pass, a white phosphor will serve the purpose. The use of a monochrome phosphor (such as blue) on a color stock will become apparent later in this article.

The resultant matte image has some substantial advantages over mattes arrived at by other means. Some of these advantages stem from the fact that fewer steps and fewer pieces of film are required in the optical composition sequence of the "reverse bluescreen" process. Even under extreme conditions, such as a subject receding into the distance and becoming quite small, the image still retains its integrity and refuses to disintegrate, as happens when the same shot is attempted via conventional bluescreen. Still another advantage is the improved ability to record "streak."

The procedure in the optical department is straightforward, fast, and economical. The original negative matte image is printed on a high contrast stock using a blue filter (Fig. 2). The exposure having the best contrast between the clear subject area and the opaque background area (usually a density of approximately 2.6 to 2.7) is printed. The selected density tends to "pinch" the subject image slightly, thus affording a tight fit. The reverse is then printed from this matte, completing the set. The first matte, or burn-in, is then simply bi-packed with a positive of the original negative, printed, and followed by a bi-pack of the background scene with the "hold-out" matte. A subtle, but significant advantage is the fact that the reverse bluescreen matte image and the interpositive subject image are of the same generation, and both are one generation from the original negative. The result is a virtually automatic and precise fit in the compositing process.

A variation of this process consists of the addition of a red phosphor backing and model mount, which is recorded via a red filter onto the previously recorded blue phosphor image. The result is the creation of an image capable of providing both male and female mattes in one generation. These mattes can each contain different information. This concept can be extended to include the green record, obtaining a total of three original mattes plus any number of permutational derivatives (Fig. 3).

One application of this advantage can be found in an aircraft model shot in which the cockpit area is to be clearly seen, and it is desirable to see the background through the cockpit windows. In conventional bluescreen, several problems could arise: the light transmission through the several layers of glass could drop off in intensity; and "fall out" of the matte or the transmission could form a matte on which reflections in the glass area would be obliterated and replaced by the background.

In reverse bluescreen, the cockpit windows are covered with a phosphored friskette paper for the blue pass, creating a complete matte. If used alone, this yields an image of the cockpit and the glass with its reflections, but with a black void beyond. With the addition of the red phosphor pass (in which the blue phosphor covers are removed from the cockpit), the area beyond the glass records on the hold-out matte. Thus, the background is printed, in addition to the glass and its reflections, as a double exposure.

An example of a situation requiring the use of all three mattes is the previously mentioned cockpit shot, in which a console screen is visible on the instrument panel. The third matte allows the composition of an image which includes a screen display on an instrument panel seen through a window on which there are also reflections.

Another application concerns reflections on polished surfaces. In this instance, the "spill" naturally occurring in the red screen pass permits the print-through of the background onto the previously printed "whole" image of the subject, instead of replacing the subject by the background as in conventional bluescreen or front/back lit methods.

In other situations, a "matte difference matte" may be produced. This is done in a manner not unlike Petro Vlahos' "color difference matte," from which the name is obviously derived. The burn-in matte from the blue phosphor pass is double-exposed with the hold-out matte from the red phosphor pass (which for this purpose has had spill actually induced to some desirable level). The resultant matte image consequently represents the difference between its two predecessors. This permits printing into the spill area only, for example, showing the light of a sunset reflected onto an aircraft. Or, it may be used to add more substance to figures such as the chess pieces in the chess scene in *Star Wars*, since all or part of the process can be applied to stop-motion animation photography by changing from sequential passes to sequential frames.

There are, to be fair, disadvantages to this system. For example, it is necessary to provide removable coverings for any holes, cracks, or heavy texture on the model, as any area that cannot be adequately irradiated with ultraviolet will not be able to generate sufficient visible light. These coverings then have to be coated with phosphor to complete the image and avoid holes in the matte. Unfortunately, the technique does not lend itself to live-action photography.

The process, for which a patent has been applied, will be further refined and made available to the industry under license from Apogee, Inc.

Conclusion

In summary, then, the following results have been accomplished:

1. Reduction or elimination of many of the restrictions on the configuration of models, particularly with regard to surface finish, reflectance, color, and detail.
2. Elimination of the requirement for illuminated backings and complex model-mount pylon illumination systems, making possible greater freedom in lighting the model as well as in camera movement around it.
3. Elimination of the need for garbage mattes.
4. Improvement in the ability to record "streak" without "fringing."
5. Substantial reduction of the number and complexity of both stage and optical steps required to composite the final image.
6. Improvement of the final image with broadening of the range and scope of effects possible.
7. Reduction by about one-third of the total time and materials required, and a system made accessible to different film formats, such as 65-mm.