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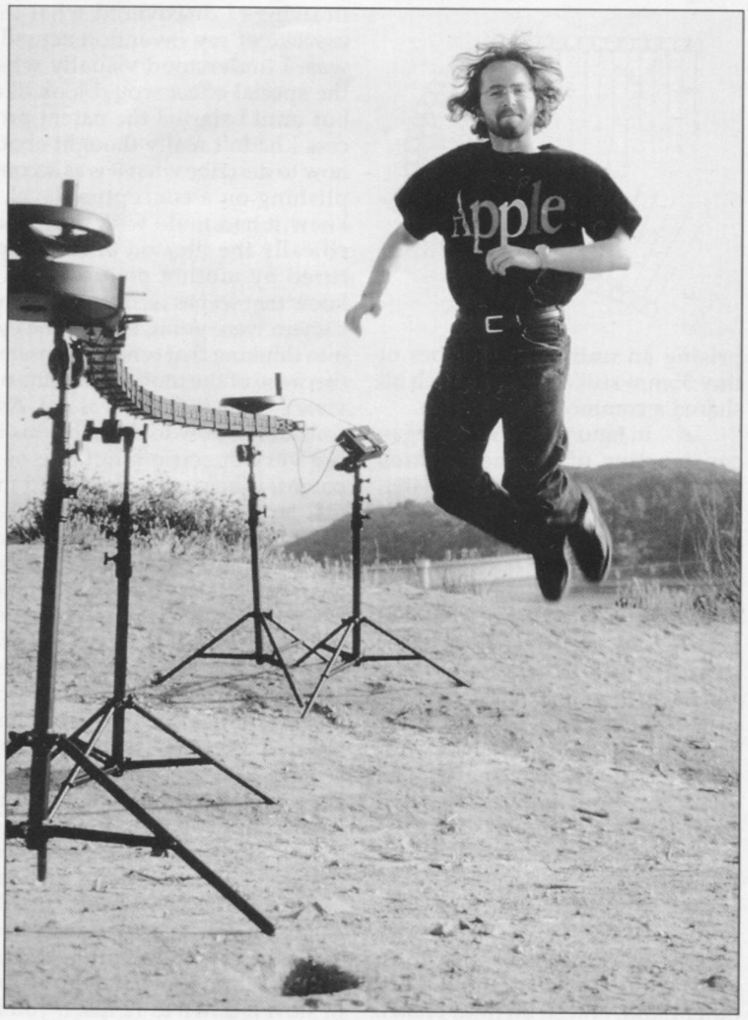
Virtual Camera Movement: The Way of the Future?

A new patent-pending camera system may soon enhance special effects, and even help change the way we interact with visual images.

by Dayton Taylor



Virtual Camera Movement is a patent-pending cinematographic process which separates the time-base of a virtual, moving point-of-view from the time-base of a subject. One application of the process is a system of recording moving motion picture scenes which appear frozen in time, a feat accomplished by an integrated, multi-lensed camera system which records still frames both en masse and simultaneously. The process also has ramifications in producing interactive virtual camera movement for digital image delivery systems, such as the Internet and interactive television.

In the following pages, the system's inventor, Dayton Taylor, offers an overview of this unique system and its potential uses.

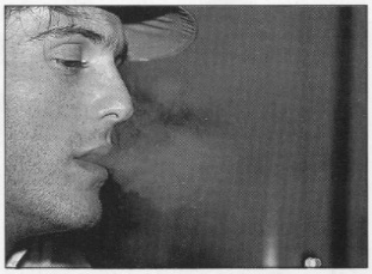
History

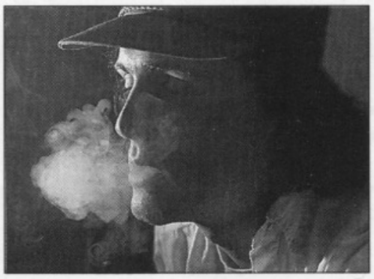
In 1985, during my undergraduate studies at the University of Colorado, I became interested in film theory — in both a technical and aesthetic sense — and its relationship to still photography. I had been exposed to the work of Chris Marker (*La Jetee*) in my classes, and had read in *American Cinematographer* about the special effects work that Industrial Light & Magic had provided for Steven Spielberg's *Indiana Jones and the Temple of Doom.*

Influenced by Marker, who had made *La Jetee* with a still camera, I took still pictures and imagined the flow of time before and after the pictures were taken. Taking further cues from ILM's work on *Temple of Doom*, for which the special effects company used still cameras to record miniatures frame-by-frame, I used my still camera to animate motion picture scenes. I turned my motor-driven Nikon F3 into a movie camera, shot scenes with it, and then turned it into a film projector so I could play the scenes back on my wall.

The more I worked with this hybrid motion picture-still photography system, the more I began imagining scenes and editing in my head. I started playing with the concept of the match cut in

Dayton Taylor in action with a prototype of his camera at Lake Hollywood.





Right: ***Taylor's initial experiments with time-based photography in 1985 include these simultaneous still photos shot with a pair of electronically synchronized cameras.*** **Below:** ***His work led to the idea of a camera array system, as seen in a curved position.***

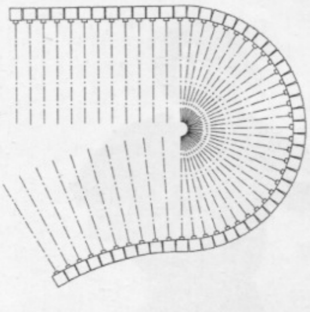
narrative film, where a motion picture scene cuts from one shot to another (usually on an action within the shot) for the purpose of making a smooth transition from shot to shot without an interruption in the flow of time. I rigged two still cameras to capture this instantaneous change in point of view by slaving the shutter of one still camera to the other with a remote-control circuit. When the "master" camera fired, so did the "slave."

In still photographs, this instant was a point in time from two different perspectives — two completely different photographs with two things in common, *subject* and *time*. These factors, of course, are the same things an editor looks for when assembling a match cut in film.

I found the pairs of pictures my cameras took to be fascinating because the uncanny simultaneity was so evident in them. I shot hundreds of pictures with this pair of cameras, choosing subjects that I felt would emphasize the uniqueness of the simultaneity of the images: objects in the air, people in motion, etc.

After working with these tools and images for some time, I began imagining the points-of-view between the two simultaneous pictures, just as I had done when I first saw *La Jetee* and when I watched my own still-camera "movies." At first, my fascination with the idea was based on the impossibility of what I was imagining, until I realized that it was not impossible; a "path" of many other potential camera positions and images existed, and if these individual elements were recorded simultaneously and then sequenced like a motion picture, they would appear to create a moving point-of-view of a moment frozen in time. I fell in love with the idea and wanted to record such images.

Over the next few years, while working in the film industry, I continued to think about the idea and discuss it with other people. I began considering how to build a special camera that would record the effect efficiently and with the largest possible degree of flexibility and versatility. I came up with a design: a modular system comprising an unlimited number of tiny 35mm still cameras which all shared a common strip of film.



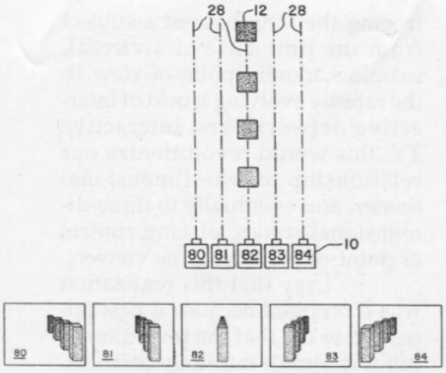
In January of 1994, I began construction of a camera which was completed three months later.

I started by cutting an old Mitchell 35mm magazine in half, to provide the feed and take-up of the film; I based my camera module design on the simplest box camera I could find: the Kodak Funsaver. I carved and glued together a single camera "module," a 35mm still camera basically consisting of a lens, a box, and a film plane, with a light-tight passage that would allow the film to enter and exit from module to module. I then made a rubber mold of the original. I used the rubber mold to make copies, hooked them together, tested them, found out they needed work, reworked the plastic-and-glue original, made another mold, and so on until I had a good design. After testing 10 modules, I made an additional 50 copies while a local engineering and design firm (Electrokinetics) modified my bisected Mitchell magazine, outfitting it with the necessary hardware to provide shutter timing, strobe sync, and film transport.

My decision to patent the camera and the process of recording the effect forced me to focus on exactly what the invention was, and what it was not. The complex nature of the patent process requires the creation of text and drawings following very strict rules, with systems of redundancy which are intended to ensure that the words and drawings in the patent all describe the same invention in a variety of different ways.

Through the process of putting my ideas into words and drawings I discovered what the essence of my invention actually was. I understood visually what the special effect would look like, but until I started the patent process I hadn't really thought about how to describe what it was accomplishing on a conceptual level. I knew it had to do with time, specifically the illusion of time captured by motion pictures, and I knew that scenes recorded with my camera were going to trick the eye into thinking that time was passing (because of the motion of point-of-view), when in fact it was not. As I considered how to describe this in the very specific language of a patent, it became apparent to me that heretofore in motion pictures the time-bases of the subject and of the moving camera had always been treated as if they were one. This was for good reason: in motion picture cameras, which record frames sequentially, they are one, and in projectors, which replay frames sequentially, they are one. The time-bases are (and always have been) linked in the sequential systems we use to record and replay motion pictures.

In normal motion pictures the time-base is 24 fps (as dictated by the projection system). By changing the speed of the camera, you can play tricks with the time-base: you can speed it up to 60 fps, or slow it down to 12 fps. If you're a stop-motion animator, you may



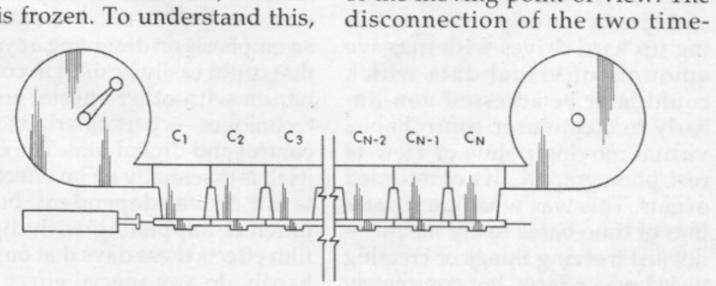
Above: *Diagram of a linear array camera in relation to a subject and the resulting array of perspectives of the subject.* Below: *Schematic of a linear camera array with magazines at each end.*

even slow it down to 1 frame per minute or slower, but it's still essentially one time-base which will eventually be locked in the 24 fps time-base of the projector.

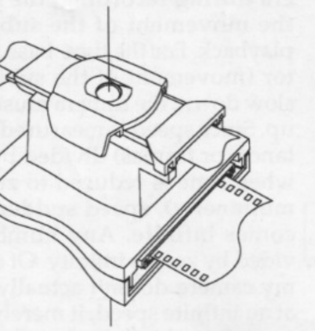
As I pondered my patent application, I realized that I had to address the issue of there actually being two separate time-bases, or at least two different time-base indicators: the time-base indicator of the subject and this "other" time-base indicator of the "moving" camera as it travels through space. It appeared to me that this distinction had never really been addressed before, because these two time-bases had always been married together in the systems we use to record and replay motion pictures. The schism that the "impossibility" of their separation represented in normal motion picture scenes is what made the idea so interesting, and the effect so seemingly impossible, but it also made the invention difficult to describe.

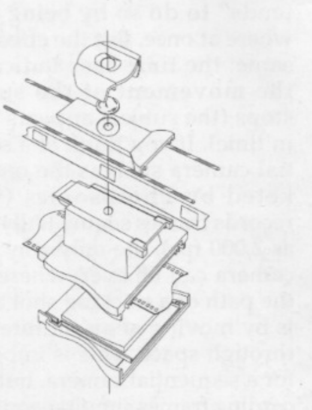
The camera's ability to record an infinite number of frames per second (simultaneity) results in zero speed in the time-base indicator of the subject during playback. In other words, the subject is frozen. To understand this, one need only think about how slow-motion works: the higher the frame rate of a motion picture camera during recording, the slower the movement of the subject in playback. For the time-base indicator (movement of the subject) to slow down, the camera must speed up. Since speed is measured in distance (or frames) divided by time, when time is reduced to zero (simultaneity), speed suddenly becomes infinite. Any number divided by zero is infinity. Of course, my camera doesn't actually move at an infinite speed, it merely "pretends" to do so by being everywhere at once. But the effect is the same: the time-base indicator of the movement of the subjects stops (the subject appears frozen in time). If you think of a sequential camera such as the one marketed by Photosonics (which records frames sequentially as fast as 2,000 fps), the only way such a camera can be everywhere along the path of a tracking shot at once is by moving at an infinite speed through space. This is impossible for a sequential camera, but by recording frames simultaneously, the speed of my camera is essentially infinite. This is the source of the power of the "impossible" illusion it creates.

Since the speed of the moving point-of-view of my camera can be varied by adding more points-of-view (real or simulated), or by skipping points-of-view (dropping frames), the time-base of the point-of-view is independent of the time-base of the subject. And since the speed of the subject can be adjusted by varying the speed of the sequential triggering of the shutters of the cameras (up to an infinite speed — i.e., simultaneity), the time-base of the subject is similarly independent of the time-base of the moving point-of-view. The disconnection of the two time-



Below: ***Perspective patent drawing of one 35mm camera module. Bottom: Exploded view of module shows relationship of film, shutter and lens.***





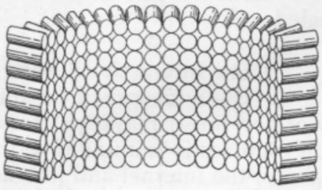
bases, therefore, is complete. Either time-base can be varied independently from the other, through a range of speeds from zero to infinity. The original idea of the time-stopping special effect is really just an extreme example (infinite camera speed) of what the invention actually is, which is a process of completely separating these two previously linked time-bases.

The new problem, in terms of my patent application, was that my mind began racing ahead to all of the other ramifications of the separation of these two time-bases. I began imagining rings of video cameras, walls of video cameras, all recording simultaneously, but also continuously and synchronously at 30 fps, filling up hard drives with massive amounts of visual data which could later be accessed non-linearly to create user-controllable, virtual moving points of view of real, photographic, live or recorded events. This was what the separation of time-bases really meant — not just freezing things or creating weird new effects, but completely freeing the time-base of a subject from the time-base of a virtual, seamless, moving point-of-view. In the rapidly evolving world of interactive networks and interactive TV, this would revolutionize our relationship to two-dimensional scenes, and eventually to three-dimensional scenes, placing control of point-of-view with the viewer.

I say that this realization was a problem because it first appeared to me that the invention itself was almost infinitely complex. How could I possibly describe the future of interactive TV in my patent application? Most of the technology which would someday drive the interactive networks didn't even exist yet. But I kept coming back to the notion of what the invention really was; it wasn't a camera, and it wasn't a machine which would someday serve up interactive TV. It was, in fact, a method of producing the point-of-view of a "virtual camera" by selectively sequencing images captured by a plurality of synchronous, simultaneous cameras, thereby disassociating the time-base of the subject from the time-base of this virtual point-of-view. My patent application (which I called "A System for Producing Time-Independent Virtual Camera Movement in Motion Pictures and Other Media") describes this essential nature of the invention, and is now pending.

As I began a new design for the special effect camera with Electrokinetics last year, I began to consider how to optimize it for maximum versatility. I realized that while stopping everything in the frame may be an attention-grabbing effect, some subtler aspects of the effect might be equally in demand one day and provide additional long-term markets for the camera system. It seemed obvious that I should put an emphasis on designing a system that could easily be used in combination with other special effects techniques — particularly motion control and digital film. The effect itself is essentially a film effect and is not digital-dependent, but so much is happening with digital film effects these days that one can hardly do any special effect any-more without part of the process being digital.

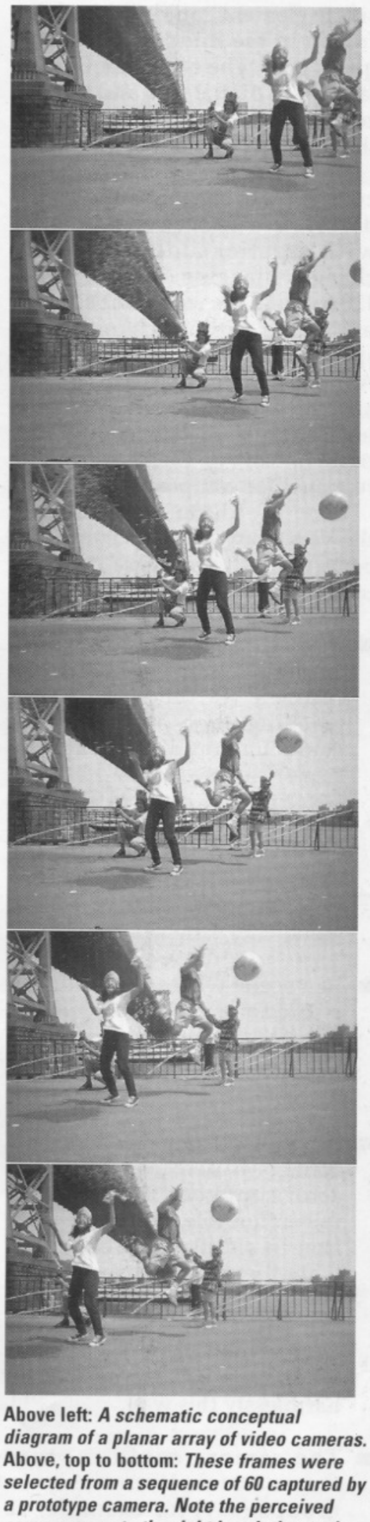
The single most important tool in digital effects is layering (matting with multiple layers of mattes), and its counterpart, image tracking and image stabilization (the latter of which greatly enhances the effectiveness of matting techniques). One option I wanted to incorporate into the new design was the ability to isolate various parts of the shot for "freezing" via layering in post. Another was the ability to start and stop time within the shot (and within the camera).



To ensure that my new camera would be able to do both of these things, I designed it with the capability of shooting frames sequentially or simultaneously, with the ability to switch modes in the middle of a shot, and with perfect registration of images from shot-to-shot for compositing, while also making it as flexible (bendable and twistable) as possible on-the-fly (from take-to-take).

To help conceptualize what the camera is capable of, one must first forget the idea of how a normal motion picture camera works (motion picture film passing through the camera with each frame being exposed sequentially in the camera's gate). Instead, think of the film itself as "being" the camera (it also helps to visualize the film stretched out not vertically, but lengthwise, as it sits in the camera.) If you consider the idea of being able to expose each frame of the shot whenever you want, not just simultaneously, you can begin to imagine the many uses of the camera.

Because the camera can record frames sequentially, it can "pretend" to be a normal motion picture camera. The most important implication of this ability is in layering. By shooting takes in which nothing is frozen in the shot, one could create a background plate which contains normal motion, and then freeze a single element in a subsequent take. Or that



Above left: ***A schematic conceptual diagram of a planar array of video cameras.*** **Above, top to bottom:** ***These frames were selected from a sequence of 60 captured by a prototype camera. Note the perceived camera move to the right in relation to the static subjects.***

single element could suddenly be frozen in the middle of a subsequent take. The takes can then be layered in digital film and the frozen parts blended seamlessly with the moving parts of the image.

Additional effects can be created by firing the cameras randomly, in simultaneous sets, or with drastic, sudden "speed" changes (imagine changing from 120 fps to 12 fps within the space of one frame without changing the speed of the camera's movement). Although the camera is long, like any camera it can be moved during a shot. If it is moved by a motion-control rig, the move can be repeated for compositing.

In order to better elucidate the versatility of the camera, I've come up with a series of potential usage scenarios:

- A very complicated scene full of extras and animals could be "frozen" in the middle of a tracking shot, after which a character could walk into the frozen scene, passing behind foreground objects (frozen people, etc.) and in front of background objects, while the camera would be free to move around with respect to the scene.
- In a scene where the "camera" tracked along the beach looking out at the ocean, the ocean could be "frozen" while the camera kept tracking.
- A single element in the frame could be frozen: for example, an actor could be "frozen" in an uncomfortable, gruesome position to simulate a dead body while the camera moved around freely. Similarly, by applying the effect mid-shot, an actor could "die" on camera. Dead animals could also be created harmlessly this way.
- The camera could capture frames simultaneously in groups (say, for example, 12 frames each), and in intervals (for example, half-second intervals). The effect of doing this repeatedly would be a smooth point-of-view of a subject which is leaping a half-second forward in time every half-second, then freezing for a half-second, then leaping forward again, and so on. If layered with conventional motion, this type of motion could give a moving object or character within a scene a very unique (and conceptually disturbing) look.

Of course, the system can be used purely for aesthetic reasons as well. Like any technological innovation, only through application of the technology will all of the system's capabilities be revealed.

The Interactive Future

The widespread capability of non-linear playback of motion pictures is imminent in the realm of the Internet and interactive TV. Virtual camera movement is essentially a system of nonlinear recording. It is the production-end counterpart to interactive television.

Digital interactivity is destined to bring about major changes in how we record and view events.

Virtual camera movement will be produced with digital video cameras shooting hundreds or thousands of images simultaneously in arrays at 30 frames per point-of-view per second. The huge databases of images that these camera arrays will record will then be interactively played back and sequenced by computer, allowing viewers to simultaneously control individualized virtual moving points of view of subjects as time flows forward or backward, or is stopped.

Imagine using such a camera system to record the finish line of the hundred-yard dash at the Olympic Games in Sydney, Australia in the year 2000, or imagine recording a boxing match with a dome of cameras over the ring. Digital interactivity is destined to bring about major changes in how we record and view events.

In the coming years, interactive TV systems will be implemented on a wide scale, the speed of the common Internet connection will increase, and the capacity and speed of CD-ROMs or their equivalents will increase. As these things happen, there will be an ever-increasing incentive to record scenes which embody fully interactive virtual camera movement — from virtual reality to games to televised sporting events to interactive digital multimedia presentations.

Even without interactive playback systems, a hybrid of the special effect and interactive camera systems can be created today to record instant "frozen" replay scenes in sports. A series of digital still cameras controlled by a computer can capture simultaneous digital still images instantaneously. The computer can then instruct the cameras to download their images into the computer, assemble them in a series, and almost immediately output "frozen" moving shots to conventional playback systems such as conventional TV.

Eventually, when you view certain images on your TV or your computer, you will have the option of adjusting the position of your personal point of view, as if you had control of the camera that shot it, while the scene moves forward in time. And because the system that will produce this type of interactivity will have many points-of-view, if your viewing system permits, you will have the option of watching the scene stereographically (in 3-D). All the system will have to do is provide you with two different images — one for each eye, recorded by two side-by-side cameras.

Technical Notes

The following are some of the functional capabilities (and limitations) of the newest design of my film camera system:

- The system has the ability to seamlessly integrate the time-stopping effect and regular photography through compositing and the internal option of shooting frames simultaneously — or sequentially at 24 fps. Plates (sets of stills) can be recorded sequentially and/or simultaneously in layers (separate shots which are layered in the post process), starting and stopping time in-camera at any point in a shot and on any layer. The camera system operates silently in simultaneous mode and at 24 fps (for sync-sound recording).
- The system has perfect registration (for composite shots) if it is used in a stationary position, or it can be moved by a motion-control rig with motion-control options equivalent to conventional techniques (although the camera is "long").
- The system does not require strobe lighting for synchronicity and can therefore shoot exterior scenes. (It is strobe-sync-ready and has a strobe-sync output if this is preferred.) Regardless of whether it is used indoors or out, by not requiring strobes, the system allows lighting that will integrate better with the conventionally shot parts of the scene.
- The system has the ability to record time passing from a stationary camera's point of view. Of course, a normal motion picture camera is a much better way to do this, but for seamless integration of the effect it might be nice to do it within the special effect camera. The way this is done is by moving the entire camera in the opposite direction of the sequential firing of cameras. By moving faster or slower than the sequential firing of cameras, it can appear to sit perfectly still then gradually begin to track at any speed in any direction, or can change speed or direction during a shot, suddenly freezing a subject at the end of a shot, etc.
- The system is designed to be rigid yet compact, meaning it can be hidden or removed in post more easily than conventional still cameras. It is not a cumbersome rig loaded up with carefully aligned still cameras. It is sturdy yet flexible, as well as compact and lightweight. →

- The system is very efficient to use — the film is continuous, making it easy to deal with in post and allowing unlimited takes on set simply by reloading the magazine. A roll-out can only occur between takes, not during a take as with a conventional camera. A footage counter indicates when it is time to reload.

- The system can be flexed and twisted between setups without reloading the film and without any need to realign the lenses. The lenses automatically align themselves to the overall curve. It's like a giant flexible snake that can be locked in any position within the limitations of the piece of film inside: it can be straight, curved, inverse curved, tilted up, tilted down, etc.

- The system can appear to pan left or right during a shot or can appear to track in a semi-forward direction. Although the lenses are always "pointed" straight forward, by selectively "printing" the left or right side of the frame (the 35mm frame is horizontal and 8 perfs wide) it can achieve these pan and "direction" effects. By correcting the perspective of the selected portion of the frame in digital film, the wide-angle lens distortion which results from selective use of the frame can be corrected ("printing" is in parenthesis above because all post-production is done in digital film).

- The system can track straight forward when it is shooting sequential frames, but runs the risk of bumping into objects on set since it is so "wide" (or long, depending on how you look at it).

- The system is modular and can be configured to any length. If the shot is only going to last four seconds, it can be configured to only be 96 cameras long, etc.

- The system has a minimal need for morphing to create intermediate frames. The lenses are so close together (1.5 inches) that only if the point of view is to move very slowly would you need to introduce artificial points-of-view. Frames can be skipped in post if the apparent movement of the perspective is too slow.

- The system is so close to being perfectly registered (optical alignment of lens axes) that there is a minimal need for stabilization in post, yielding the sharpest possible image. Because the optical alignment of lenses is so good, the lens characteristics (particularly wide-angle lens distortion) are uniform from frame-to-frame, producing full-frame image stability and sharpness. For variations in optical axis alignment, a digital film image stabilization tool can be used. ◆