PART SEVEN: HOLOGRAPHIC CINEMA: A NEW WORLD

"Someday you'll be able to go to a party and be the only one there."

ANDY WARHOL

In April, 1969, overlooking the Pacific from the crest of Malibu Canyon in Southern California, I became one of the few persons to view the world's first successful holographic motion picture. There at Hughes Research Laboratories one can look across the canyon to see a Catholic monastery, Sierra Retreat, perched majestically atop its own mountain, commanding the same spectacular view of the earth, the sea, and the sky. This contrast impressed me perhaps even more than the technological wonder I had just witnessed: the temples of science and religion separated by a canyon as old as time, each in its own way dedicated to the same quest for God.

The art of holographic cinema *circa* 1970 is comparable to that of conventional cinema *circa* 1900. The few scientists who have made the first crude holographic films are the Edisons and Lumières of our time. Through the hologram window we peer into a future world that defies the imagination, a world in which the real and the illusory are one, a world at once beautiful and terrifying. It is certain that holographic cinema and television will be common by the year 2000; but more probably this will take place within fifteen years from now. Meanwhile, holographic cinema is still in its infancy; in the following pages I hope to dispel many of the misconceptions that surround it, and to provide some understanding of the possibilities inherent in this totally new way of making images.

Wave-Front Reconstruction: Lensless Photography

The first enigma we encounter in holography is that no optical image is formed. Instead, the wave front or diffraction pattern of light waves bouncing off the subject is captured directly on a photosensitive surface without passing through lenses that would form it into an image. Each point on the surface of an object reflects light waves in constantly expanding concentric circles in much the same way that rings are formed when a pebble is dropped into a pool of still water. A collection of these circles and the interference pattern resulting from their intersecting trajectories constitute the wave front of light from the object. If one is able to "freeze" or store this wave front, one then has the potential of reconstructing a three-dimensional image exhibiting all the properties that a viewer would see if he were looking at the real object through a window the size of the photograph.

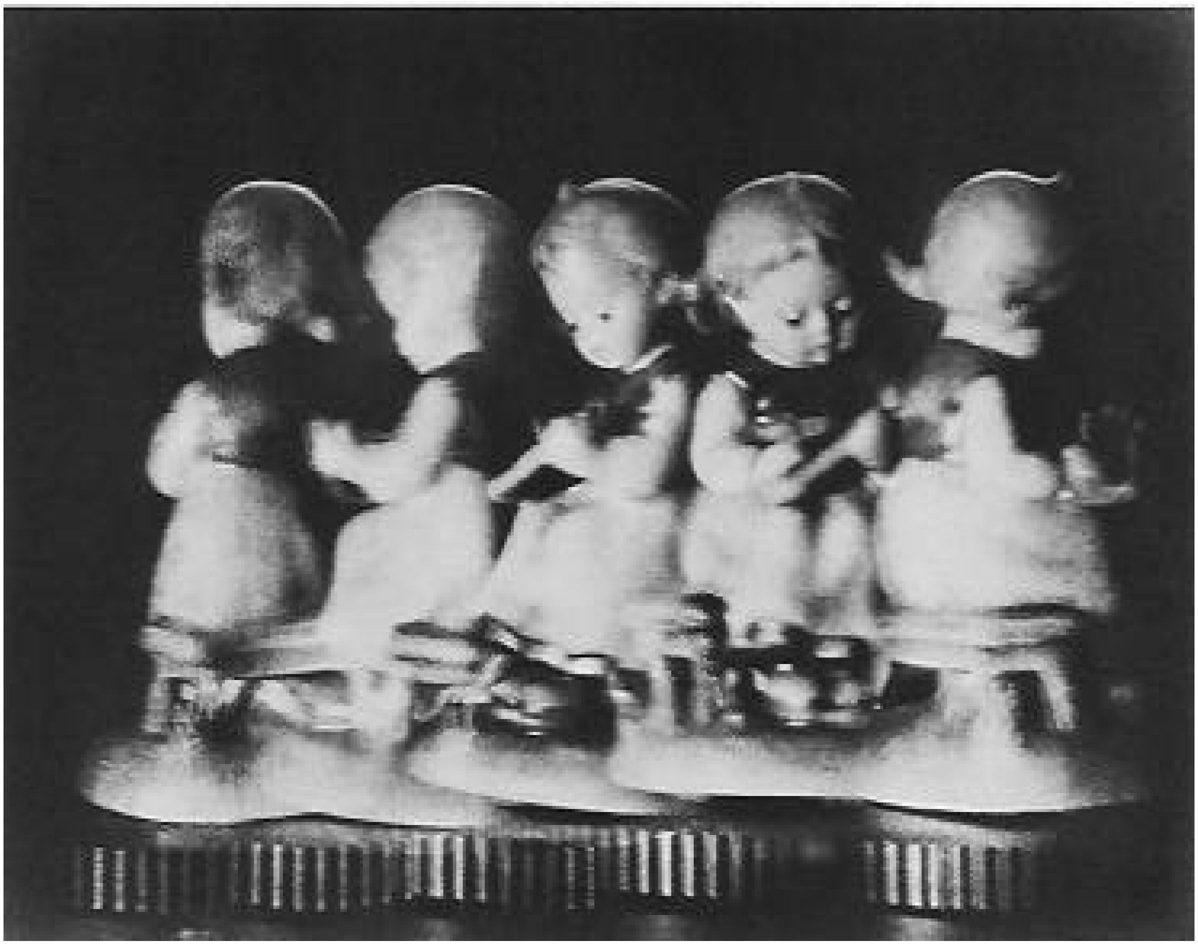
The secret of capturing and reconstructing wave fronts of light was discovered in 1947 by Dr. Dennis Gabor of the Imperial College of Science and Technology in London. Light waves are described by their intensity and frequency; ordinary optical photography records only the intensity of the waves, not the frequency; yet the frequency is the information necessary to reconstruct a three-dimensional image. Dr. Gabor found that it was possible to record both intensity and frequency of wave fronts by imprinting interference patterns of light on a photosensitive surface.

Just as rings in a pool of water tend to dissipate the farther they travel, so light waves similarly tend to lose their cohesiveness. Light is described as "cohesive" in direct proportion to the distance over which its waves remain "in phase," or in step with one another: ordinary "white light" (sunlight) has a very short cohesive length. Dr. Gabor recognized that in order to reconstruct a faithful three-dimensional image of an object, one would need very cohesive light. The ideal would be light whose waves all traveled at one frequency. Since no such light existed in 1947, he approximated it with a filtered mercury arc lamp. The images he obtained from the process, though extremely poor in quality, were called *holograms* from the Greek root

Diffusion of a laser beam as part of *Nine Evenings* intermedia presentations by Experiments in Art and Technology (EAT), New York, 1967. Photo: Peter Moore.

holos meaning whole, since they recorded a whole picture—both intensity and frequency.

In 1960 Dr. Theodore Maiman of the Hughes Aircraft Company in California invented an instrument called the *laser,* named from the initials of Light Amplification by Stimulated Emission of Radiation. As the name implies, the laser generates a beam of light that is totally coherent since it is all one wavelength. Then in 1965 Emmett N. Leith and Juris Upatnieks of the University of Michigan used the laser in a modification of Dr. Gabor's original holographic technique to produce the first completely successful three-dimensional image. Instead of using one beam like Dr. Gabor, Leith and Upatnieks used a prism to derive two beams from one laser. The subject beam was used to illuminate the object, while the reference beam was used to



Multiple-exposure photo approximates what a viewer would see in animated hologram made at Bell Telephone Laboratories. Either the plate is moved across a laser beam, or it remains stationary and the viewer moves his head from left to right. The figure appears to rotate in full three dimensions. Photo: Bell Telephone Laboratories.

interfere with it, creating a pattern that was recorded on a photographic plate, forming the hologram.[1]

To reconstruct the image, another laser is directed at the hologram from the same position occupied originally by the reference beam. This beam emerges from the film shaped exactly in the form of the wave fronts reflected from the original object. A picture is formed that is identical with the object itself, in true three-dimensionality, requiring no lenses or polarizing glasses as in the stereoptic process used for so-called 3-D movies. The phenomenon that distinguishes true 3-D from stereoptic illusion is called *parallax,* or the apparent displacement of perspectives when one object is viewed from different angles. In holography, different areas of the picture become visible depending on one's angle of approach; if the photographic plate were large enough, one could actually move to the periphery and look behind objects, discovering areas not visible from a frontal view.

However, the ability to do this is restricted by the frame size of the photographic surface, either plate or film strip. Although images up to thirty-five feet in depth are considered possible through the technique of "panoramic holography," the largest holographic plates are only one- or two-feet square; the largest motion-picture film practical for any purpose is only 70mm. wide; thus the viewing effect is always one of peering through a small window into a larger three-dimensional space. This obviously restricts the size of an audience that can simultaneously observe one holographic display: no more than two persons can view a holographic plate with comfort, and film-viewing systems are restricted to the peep-show level of one person at a time.

[1] Emmett N. Leith and Juris Upatnieks, "Photography by Laser," *Scientific American* (June, 1965), pp. 24-35.

Dr. Alex Jacobson: Holography in Motion

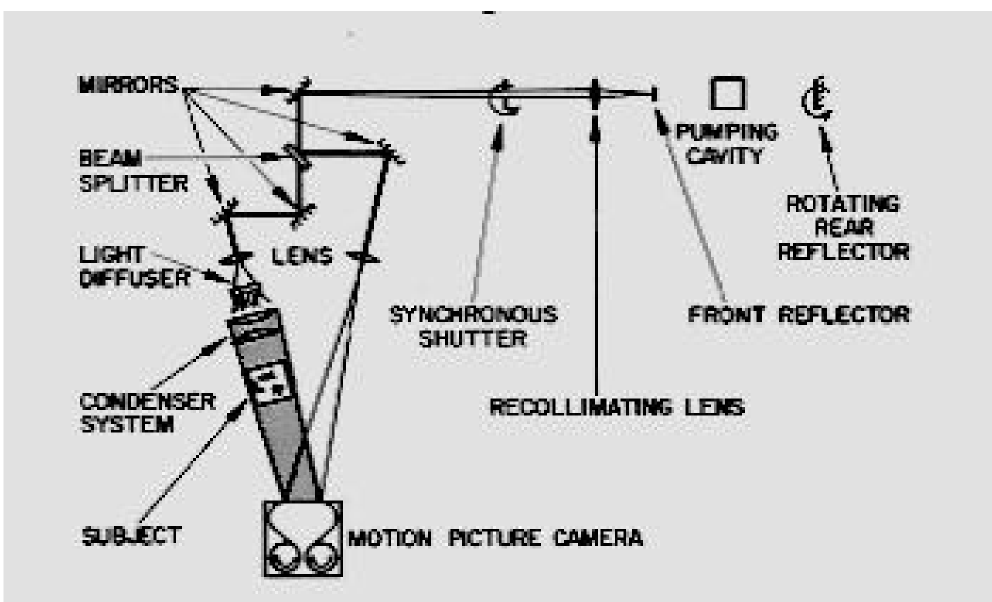
Until Dr. Alex Jacobson and his colleague Victor Evtuhov made their holographic movie of tropical fish in an aquarium at Hughes Research Laboratories, the only motion in holography had been artificially animated. Matt Lehman of Stanford University, Charles Ernst of the TRW Systems Group, and scientists at Bell Telephone Laboratories had created photographic plates on which many separate holograms of the same object were recorded in tiny vertical strips. To obtain the illusion of motion one either moved one's head from side to side or remained stationary and moved the plate horizontally across a laser beam. In each case, however, the motion was not recorded in real time: separate holograms were made for each stationary position of the image.

Jacobson's aquarium movie was the world's first real-time holographic film. He used a pulsed ruby laser, which emits light in bursts 35-billionths of a second in duration, each with 25,000 to 50,000 watts of peak power.[2] Such brief exposures are necessary in motion holography since any movement of the object more than one-thousandth of an inch during exposure will blur the image. Jacobson and his associates designed and built the camera apparatus, which exposed 100 feet of film at 20 fps, using a Hulcher Model 100 sequential-still camera with lens and shutter removed.

The film stock was AGFA-Gevaert 10E75 emulsion on a common acetate base in 70mm. format. The stock is designed especially for holography though its photochemical constituents are quite common. The only unusual requirement holography makes on film is very high resolution capabilities. Ideally, a holographic emulsion should be able to resolve two lines 25-millionths of an inch apart, or 1,500 readable lines per millimeter. (The price paid for this resolving power is speed: the first film used to make holograms, Kodak 649-F

[2] This amounts to approximately one millijoule of light, or one-thousandth of a joule (Joule is the amount of energy required to heat one gram of water one degree Centigrade). One billionth of a second is known as a *nanosecond, so*-called Q-switched laser emit pulses of light one-trillionth, or a *picosecond,* in duration.

Two photos from a holographic movie of tropical fish made by Alex Jacobson and Victor Evtuhov at Hughes Research Laboratories, Malibu, California. 1969. Laser light was shined through the aquarium at camera. Dark area at right of photos does not appear in the actual movie. Photos: Hughes Research Laboratories.



Schematic diagram of Hughes holographic movie system. Laser is indicated as "pumping cavity."

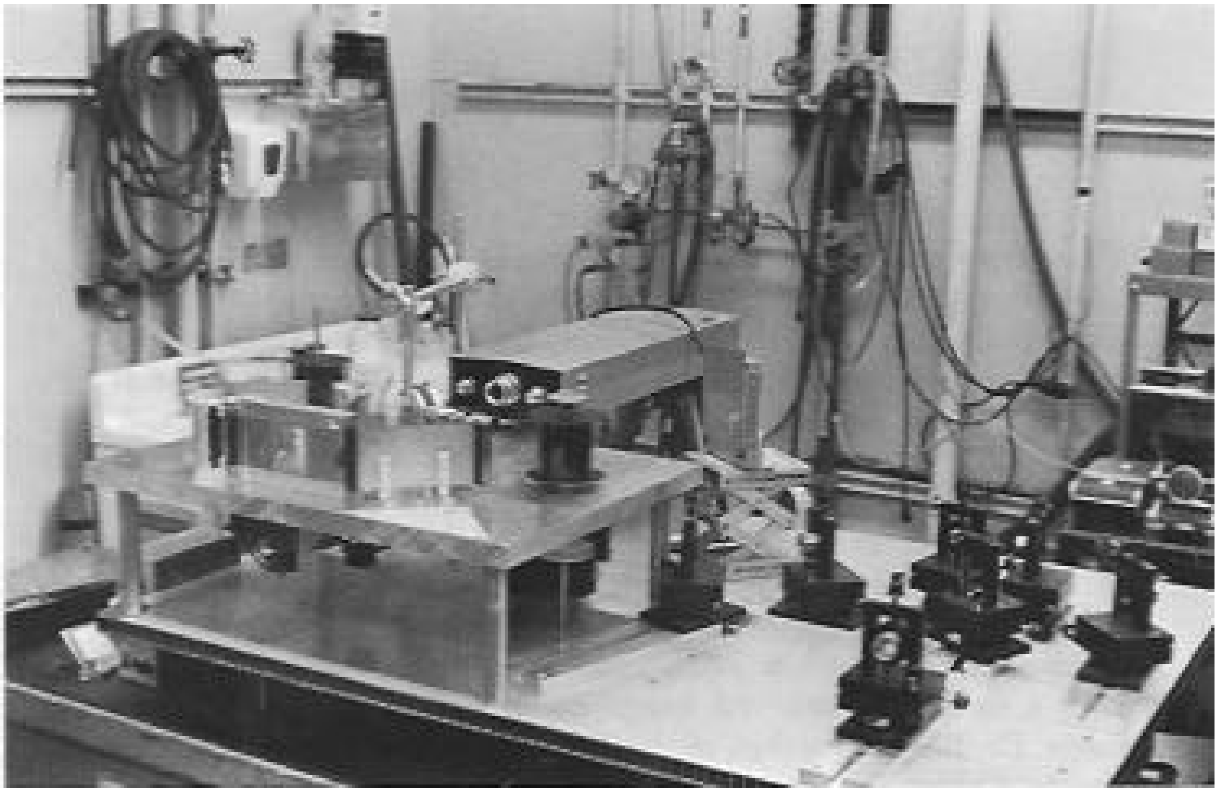
spectrographic plate had an ASA rating of .02.) Thus, after eight months and many thousands of dollars in equipment, Jacobson produced 30 seconds of film in which one peeked through a 70mm. aperture to find tropical fish swimming leisurely in three-dimensional space.

Limitations of Holographic Cinema

Three types of lasers are used in holography, identified by the active element whose atoms are electronically charged to generate light: the helium-neon laser, the argon laser, the ruby laser. Since human images are essential to commercial holography, a pulsed laser must be used; this excludes the helium-neon laser, which is strictly CW (continuous wave) and cannot be pulsed. The argon laser does not approach the 35 to 50 nanoseconds required to make action holograms. This leaves the ruby laser, which produces a fiery red image of extreme graininess, and whose light is not so cohesive as the helium-neon laser.

Since black-and-white holography is not possible, one is stuck with a monochromatic red image unless full-color holograms are made. Dr. Ralph Wuerker, of the TRW Systems Group in Redondo Beach, California, admits that full-color holographic cinema is a possibility "if the government is ready to support that kind of research with all the money they have in Fort Knox." Wuerker, who has developed a special "holocamera" for recording holograms with low-coherence lasers, suggests that full-color holographic movies might eventually be made using two lasers instead of one, optically mixing their colors as in television: red from a ruby laser, and blue and green from a doubled neodymium glass laser.

Dr. Jacobson, however, does not consider this to be a major problem in the development of holographic cinema. "In the hierarchy of difficulties color might be considered a second-level problem," he said, "and granularity would be only a minor snag. People already have devised means of clearing up the graininess. But a first-level problem is illumination. I back-lit my fish because if I were to illuminate from the front I wouldn't have enough light to make a hologram. We barely had enough light as it was, and that's why I selected the small subject. If you want to make a commercial holographic movie, you at least have to be able to illuminate a room-sized scene. We estimate that in order to shoot a room-sized scene at twenty frames per second you'd need an input to the laser of something in excess of five million watts. Now I don't know how



Hughes holographic projection system. Viewer must peer through 70mm. aperture of film transport table. Photo: Gene Youngblood

powerful Grand Coulee Dam is, but that's a large portion of its output."

Seeking a solution to this problem, for the last few years several firms have been working on white-light holography, in which ordinary illumination sources are used both to make and view the hologram. Optical systems are used to overcome the incoherence of white light. Another proposal is the technique called *integral photography* in which many ordinary photographs from different perspectives are combined in holographic form. The resulting image, although synthetic, gives all the properties of a true hologram of the same scene. And since the image is formed by conventional photography, any type of illumination can be used. The process is extremely complex and tedious, however, and it is practically inconceivable that a movie could be made in this manner.

Both Dr. Jacobson and Dr. Wuerker insist that holography depends on the use of laser light in recording as well as viewing the image.

Holographic movie viewing system developed by North American Philips Corporation. Laser inside the box shines through 70mm. film as it passes viewing aperture. Photo: North American Philips Corp.

"Using white light to reconstruct a hologram is like playing a stereo record through a Vitaphone," Dr. Wuerker said. "People accept it now because the field is young enough, just as they accepted inferior sound recordings in the early days of that field. But in holography, fidelity depends on laser light." Dr. Jacobson suggests that we will "just have to wait until a big laser comes along—big in terms of the amount of energy it puts out. You need two combinations: enough energy to illuminate the scene and expose the film, and you also need it in a very short time to avoid motion blur. Instead of using one illuminator you could use ten or fifteen lasers. That's a possibility. But the cost and volume of equipment would still be prohibitive."

Projecting Holographic Movies

The popular misconception of a holographic image as something with which the viewer can interact—moving around and through it in three-dimensional space while viewing it—may become a reality in holographic cinema of the future. Since a hologram is not made with lenses it always creates what is known as a *virtual image* on the opposite side of the film from the viewer, as though one were looking through a window, because the image always appears exactly where it was when the hologram was recorded.

However, associated optically with the virtual image is what's known as the *real image,* which comes to focus on the side of the film nearest to the viewer. All that would be required to see the real image is a special optical system to reverse the holographic process. This system does not yet exist; but it seems that a technique known to the ancient Egyptians and practiced by magicians for centuries may provide the means for a future system of large-scale, real-image holographic movie theatres.

Known generally as "The Illusion of the Rose in the Vase," this simple process involves the use of a lens, concave mirror, and pin-hole light source to transpose illusionistically an object into three-dimensional space in full color. In addition to floating an image in space, it can be used to magnify or miniaturize the image. As in the archetypal example, it can cause a natural-sized object like a rose to appear suddenly in an otherwise empty vase. Through a system of lenses and mirrors an object at another location can be suspended in space wherever desired.

In Japan this process is used to project tiny three-dimensional human beings onto the miniature stage of a puppet theatre: the actual persons are beneath the stage floor, dancing in front of a large mirror. Before we had holography an actual object was needed to create this effect, but now that we have three-dimensional images without three-dimensional objects it is possible to develop a system of holographic cinema based on this ancient concept. The object is simply replaced by a strip of holographic film. Even then, however, the scene would be visible only to an audience of two hundred persons.

"If you get into an area much larger than that," explains Dr. Wuerker, "you confront the problem of what is and what isn't 3-D. You don't see much 3-D beyond twenty or thirty feet, so the effect would be lost if you had to sit very far away from the image. Either you'll have a projected image that's like a person on a stage where about a hundred people can observe him, or you'll have a personalized box like a TV set, or a hood over your head."

Wuerker also conceives of a holographic cylinder that would either revolve slowly or remain stationary while the audience rotated around it. "But now comes the reality," he warns. "And the reality obviously is a cylinder, so you're limited in your stage area. It wouldn't be much more than just one man. But you could have an interview with that man." Holographic movies may be severely limited by their total dependence on reality, Dr. Wuerker suggests. "When you make a movie, the cameraman focuses the camera. He forces you to look at this actor or this scene or whatever. In a holographic movie you don't have that. Your own eyes are the lens, just as in reality.

"For example, if you had two actors, one upstage, the other downstage, you'd focus on whichever one you wanted to. When the focusing is up to the viewer you're simulating reality even more closely; in fact as far as the viewer's concerned it *is* reality. But holograms can't be doctored once the image is on the film. You can't touch it up or edit. You can synthesize, and you can superimpose and you can multiplex, but you can't play with focusing as you can in photography. And you might find that in holographic movies things like jump cuts are not likely."

Dr. Wuerker also envisions cube holograms instead of plates or film strips. "You can use a thick medium rather than a thin medium. Someone will develop a glass block that is photosensitive, about a quarter of an inch thick. You coat this glass box holographically, putting a hundred images on it. You hold it up to a laser and as you rotate it your separate images will come out. You couldn't pack information any tighter than you could this way. This is definitely in the future and definitely in the viewing of movies. Holographic recording itself is at this point already. But if you compound that by using depth in your plate as a third dimension—you have a thousand lines per millimeter so every cubic millimeter will have 10^9 bits of information. And there you go. But still you won't be able to pull the tricks that are in movies or on TV because holography is too dependent on actuality."

The Kinoform: Computer-Generated Holographic Movies

However, means have been devised through which even the hologram may no longer need "reality" to exist. Dr. Lou Lesem and his associates at IBM in Houston have developed methods of generating three-dimensional holographic images digitally through computers. Using an IBM Model 360-44, Dr. Lesem calculated the pattern in which a laser's light waves would be scattered if they actually struck the simulated object. A computer-controlled laser interference system is then used to create this pattern on plates or film. The resulting image is called a *kinoform.*

"When they learn to perfect this system," said Dr. Jacobson, "you'll be able to make holograms as abstract as you can with conventional cinema. You could have a three-dimensional computer-generated holographic movie of the Stargate Corridor in *2001.* I don't think that's any further off than any of these other things. In fact it's probably closer. We might even be able to do it now."

Moreover, the ability of holography to record natural phenomena that exist beyond the range of human perception—shockwaves, electrical vibrations, ultraslow-motion events—could contribute to an experience of nonordinary realities totally beyond the reach of conventional cinema or television. And the most likely mode of viewing will be the individualized frame or enclosure. "The difference between the window frame and the movie frame," observes Dr. Wuerker, "is that you can get your face up so close that the frame disappears and all you're seeing is the illusionistic world on the other side. You're in it."

Technoanarchy: The Open Empire

"In another moment Alice was through the glass and had jumped lightly down into the looking-glass room. The very first thing she did was to look whether there was a fire in the fireplace, and she was quite pleased to find that there was a real one, blazing away as brightly as the one she had left behind. 'So I shall be as warm here as I was in the old room,' thought Alice, 'warmer in fact, because there'll be no one to scold me away from the fire.'"

LEWIS CARROLL

John Cage tells the story of an international conference of philosophers in Hawaii on the subject of Reality. For three days Daisetz Suzuki said nothing. Finally the chairman turned to him and asked, "Dr. Suzuki, would you say this table around which we are sitting is real?" Suzuki raised his head and said yes. The chairman asked in what sense Suzuki thought the table was real. Suzuki said, "In every sense."[3] The wise thinker is a true realist; he might well have been talking about the future of cinema.

I've attempted to bring the past, present, and future of the movies together in one image so that a vast metamorphosis might be revealed. One can no longer speak of art without speaking of science and technology. It is no longer possible to discuss physical phenomena without also embracing metaphysical realities. The communications of humanity obviously are trending toward that future point at which virtually all information will be spontaneously available and copyable at the individual level; beyond that a vast transformation must occur. Today when one speaks of cinema one implies a metamorphosis in human perception.

This transformation is being realized on the personal level as well as on the global front of the industrial equation itself, where it can be realized only through the synergetic efforts of all men applying all

[3] Cage, *op. cit.*, p. 35.

disciplines. While personal films, videotapes, and light shows will continue to expand human communication on one level, organizations such as PULSA at Yale University, and the various national chapters of Experiments in Art and Technology (E.A.T.) are suffusing art, science, and the eco-system of earth itself at that point where all converge within the purview of modern technology.

Not only do computer, video, and laser technologies promise to transform our notion of reality on a conceptual level, they also reveal paradoxes in the physical world that transcend and remake our perception of that phenomenon as well. A glimpse of the future of expanded cinema might be found in such recent phenomena as the spherical mirror developed by the Los Angeles chapter of E.A.T. for the Pepsi-Cola Pavilion at Expo '70 in Osaka. Although it developed from the synergetic technologies of computer science and poly-vinyl-chloride (PVC) plastics, it is triumphantly nontechnical as an experience. It's just a mirror—a mirror that is nearly two-thirds of a sphere made of 13,000 square feet of air-inflated mirrorized mylar one-thousandth of an inch thick. It is ninety feet in diameter and fifty-five feet high, and weighs approximately 250 pounds.

There have been other mirrorized mylar (or PVC) spherical tensile structures, notably the Pageos and Echo satellites. But they weren't constructed as mirrors per se and, of course, one could not enter them. Thus once again, as in the case of *City-Scape,* we see that humanity's most ambitious venture into the frontiers of reality—the space program—contributes to the expansion of the world of art: both are efforts to comprehend larger spectra of experience.

Essentially a full-scale model of the pavilion mirror that later was constructed in Japan, E.A.T.'s sensuous, transcendentally surrealistic mirror-womb was revealed to the world in September, 1969, in a cavernous blimp hangar in Santa Ana, California. There, sustained in 210-degrees of space and anchored by 60,000 pounds of water in two circular tubes at its base, was a gateway to an open empire of experiential design information available to the artist. An astonishing phenomenon occurs inside this boundless space that is but one of many revelations to come in the Cybernetic Age: one is able to view actual holographic images of oneself floating in three-dimensional space in real time as one moves about the environment.

Hemispherical mirror developed by the Los Angeles Chapter of Experiments in Art and Technology for the Pepsi-Cola Pavilion at Expo '70 in Osaka, Japan. Shown in a blimp hangar at the Marine Corps Air Station, Santa Ana, California. Specifications: 13,000 square feet of mirrorized mylar 1/1000th of an inch thick, air-inflated to a 210-degree hemisphere, ninety feet in diameter and fifty-five feet high. Photo: David MacDermott.

Because the mirror is spherical no lenses or pinhole light sources are necessary: the omni-directionally-reflecting light waves intersect at an equidistant focal point, creating real images without laser light or hardware of any kind. Interfaced with perpetual fog banks and krypton laser rainbow light showers at the World Exposition, the mirror indeed "exposed" a world of expanded cinema in its widest and most profound significance.

The accelerating transformations of radical evolution often generate illusions of impending disaster: hence the overriding sense of paranoia that seems to cloud the new consciousness as we thrust toward the future. Yet surely some revelation is at hand. In 1920 W. B. Yeats (in his poem "The Second Coming") saw that things were falling apart: "The falcon cannot hear the falconer; /... the centre cannot hold; / Mere anarchy is loosed upon the world,... / And what rough beast, its hour come round at last / Slouches towards Bethlehem to be born?"

Yeats didn't know what was coming, and thus like all of us he feared it. But in assigning Bethlehem as its birthplace he suggested that we were to be visited by a savior, however fearsome. That savior is technoanarchy and he is born out of the industry of man's ignorance, in spite of our petty copulations, in contradistinction to our minor misbehaviors. The term anarchy is defined as "a political theory... advocating a society based on voluntary cooperation and free association of individuals and groups... a utopian society having no government and made up of individuals who enjoy complete freedom." The biologist John Bleibtreu is an anarchist, then, when he speaks of "… a new sustaining myth which corre-sponds to reality... this new mythology which is being derived from the most painstaking research into other animals, their sensations and behavior, is an attempt to reestablish our losses—to place ourselves anew within an order of things, because faith in an order is a requirement of life."[4] Yesterday, man needed officialdom in order to survive. But technology has reversed the process: survival today depends on the emergence of a natural order. Thus we see that anarchy and order are one, because history is demonstrating that officialdom is no order at all.

Technology is the only thing that keeps man human. We are free in direct relation to the effective deployment of our technology. We are slaves in direct relation to the effectiveness of our political leadership. (Herbert Read: "Effective leadership is fascism.") The world is populated by three-and-a-half-billion human slaves, forced by the masters of politics continually to prove our right to live. The old consciousness perpetuates myths in order to preserve the union; it reforms man to suit the system. The new consciousness reforms the system to suit man. Water takes the shape of its container. We have no basis for postulating a "human nature" until there's no difference between the individual and the system. We cannot ask man to respect his environment until this difference is erased. This is anarchy: seeking a natural order. It is technoanarchy because it will be realized only through the instrumented and documented intellect that we call technology.

[4] Bleibtreu, *op. cit*., p. 8.

"As they are extended into mythologies, metaphysical systems allow mankind the means to abide with mystery. Without a mythology we must deny mystery, and with this denial we can live only at great cost to ourselves. It seems that we are in the process of creating a mythology out of the raw materials of science in much the same way that the Greeks and Jews created their mythologies out of the raw materials of history."[5]

The limits of our language mean the limits of our world. A new meaning is equivalent to a new word. A new word is the beginning of a new language. A new language is the seed of a new world. We are making a new world by making new language. We make new language to express our inarticulate conscious. Our intuitions have flown beyond the limits of our language. The poet purifies the language in order to merge sense and symbol. We are a generation of poets. We've abandoned the official world for the real world. Technology has liberated us from the need of officialdom. Unlike our fathers we trust our senses as a standard for knowing how to act. There is only one real world: that of the individual. There are as many different worlds as there are men. Only through technology is the individual free enough to know himself and thus to know his own reality. The process of art is the process of learning how to think. When man is free from the needs of marginal survival, he will remember what he was thinking before he had to prove his right to live. Ramakrishna said that given a choice between going to heaven or hearing a lecture on heaven, people would choose the lecture. That is no longer true. Through the art and technology of expanded cinema we shall create heaven right here on earth.

[5] *Ibid*., p. xi.

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