PART FOUR:
CYBERNETIC CINEMA AND COMPUTER FILMS

"The computer is the LSD of the business world. It absolutely guarantees the elimination of all the business it is now being brought to serve."

MARSHALL MCLUHAN

The Technosphere: Man/Machine Symbiosis

If one were to propose a Bill of Rights for the year 2000 it would defend human liberty, not civil liberty. Guaranteed rights would include health, truth, reality, sexual fulfillment, study, travel, peace, intimacy, leisure, the right to be unique. Man is not "civilized" until he is whole. He is not whole until he's assured these rights. But I would add another: the right of every man to be protected from the consequences of his own ignorance. The computer provides this protection.

The computer does not make man obsolete. It makes him fail-safe. The computer does not replace man. It liberates him from specialization. The transition from a culture that considers leisure a "problem" to a culture that demands leisure as a prerequisite of civilized behavior is a metamorphosis of the first magnitude. And it has begun. The computer is the arbiter of radical evolution: it changes the meaning of life. It makes us children. We must learn how to live all over again.

"Recently, as in his natural symbiotic relations with plants and animals, man's relation to cybernetic systems has been subtly changing toward a more closely-woven interdependency resembling his other ecological ties. This trend often is depicted as 'intelligent' machines dominating man; but the possibility is more clearly that of organic partnership…"[1]

In laboratories all over the world, biochemists are drawing ever closer to the secrets of the genetic code. Younger readers of this book may within their lifetimes, rub shoulders with pre-programmed humans. I do not say "synthetic" or "artificial." Fuller: "We speak erroneously of 'artificial' materials, 'synthetics' and so on. The basis for this erroneous terminology is the notion that nature has certain things which we call natural, and everything else is 'manmade,' *ergo* artificial. But what one learns in chemistry is that nature wrote all the rules of structuring; man does not invent chemical structuring rules; he only discovers the rules. All the chemist can do is to find out what

[1] John McHale, "New Symbiosis," *Architectural Design* (February, 1967), p. 89.

nature permits, and any substances that are thus developed or discovered are inherently *natural."*[2]

John McHale: "We refuse to accept the reality of potentially limitless wealth inherent in our new symbiotic relation to automated technological processes. Scientific and technical development destroys all previous intrinsic value in physical resources or properties. From this point on, broadly speaking, all materials are inter-convertible. The only unique resource-input is human knowledge—the organized information which programs machine performance. The products are non-unique and expendable, as are the machines and materials. The only part of the whole process which is non-expendable and uniquely irreplaceable is man. Those social orientations which have had great survival value in the past now endanger survival in the present and cripple our approach to the future."[3]

In 1963 two Soviet scientists amplified the bio-electrical muscle currents of a human body to operate exoskeletal servomechanisms attached to the limbs.[4] For the first time, organic partnership was achieved to the direct physical advantage of man. The director of cardiovascular surgery at Maimonides Hospital asserted, also in 1963: "Surgery is essentially an engineering discipline… the integration of electronic circuits into the human body as functioning and permanent parts… is going to become very important within the next ten years."[5] Since that remark we have witnessed a steady increase in the number of cyborgs walking among us. Scientists now speak of "moral spectrums for machines" based on the extent to which the machine "...helps or hinders human beings to realize their potentialities and thus to lead satisfactory lives."[6]

The computer amplifies man's intelligence in about the same ratio that the telescope extends his vision. The man/computer symbiosis

[2] Fuller, *Ideas and Integrities* (Englewood Cliffs, NJ.: Prentice-Hall, 1963), pp. 75, 76.
[3]McHale, "People Future," *Architectural Design* (February, 1967), p. 94.
[4] A. E. Kobvinsky and V. S. Gurfinkel, *Time* (December, 1963).
[5]A. Kantrowitz, *Electronic Physiologic Aids* (New York: Maimonides Hospital, 1963).
[6] M. W. Thring, "The Place of the Technologist in Modern Society," *Journal of the RSA* (London, April, 1966).

is developed to the point where the machine instructs its user and indicates possibilities for closer interaction. One needn't read the manual but may consult the machine directly with the order, "I want to do something, instruct me." It is not even necessary to be in the presence of the computer to do this. One can carry out one's work thousands of miles away, linked to the computer through remote viewing and operating consoles.

The Human Bio-Computer and His Electronic Brainchild

The verb "to compute" in general usage means to calculate. A computer, then, is any system capable of accepting data, applying prescribed processes to them, and supplying results of these processes. The first computer, used thousands of years ago, was the abacus.

There are two types of computer systems: those that measure and those that count. A measuring machine is called an *analogue* computer because it establishes analogous connections between the measured quantities and the numerical quantities supposed to represent them. These measured quantities may be physical distances, volumes, or amounts of energy. Thermostats, rheostats, speedometers, and slide rules are examples of simple analogue computers.

A counting machine is called a *digital* computer because it consists entirely of two-way switches that perform direct, not analogous, functions. These switches operate with quantities expressed directly as digits or discrete units of a numerical system known as the *binary* system.[7] This system has 2 as its base. (The base of the decimal system is 10, the base of the octal system is 8, the base of the hexadecimal system is 16, and so on.) The binary code used in digital computers is expressed in terms of one and zero (1-0), representing on or off, yes or no. In electronic terms its equivalent is voltage or no voltage. Voltages are relayed through a sequence of binary switches in which the opening of a later switch depends on the action of precise combinations of earlier switches leading to it. The term *binary digit* usually is abbreviated as *bit,* which is used also as a unit of measurement of information. A computer is said to have a "million-bit capacity," or a laser hologram is described as requiring 10^9 bits of information to create a three-dimensional image.

The largest high-velocity digital computers have a storage capacity from four thousand to four million bits consisting of twelve to forty-

[7] Wiener, *op. cit.,* pp. 88-90.

eight digits each. The computer adds together two forty-eight digit numbers simultaneously, whereas a man must add each pair of digits successively. The units in which this information is stored are called ferrite memory cores. As the basic component of the electronic brain, the ferrite memory core is equivalent to the neuron, the fundamental element of the human brain, which is also a digital computer. The point at which a nerve impulse passes from one neuron to another is called a synapse, which measures about 0.5 micron in diameter. Through microelectronic techniques of Discretionary Wiring and Large Scale Integration (LSI), circuit elements of five microns are now possible. That is, the size of the computer memory core is approaching the size of the neuron. A complete computer function with an eight-hundred-bit memory has been constructed only nineteen millimeters squared.[8]

The time required to insert or retrieve one bit of information is known as memory cycle time. Whereas neurons take approximately ten milliseconds (10^{-2} second) to transmit information from one to another, a binary element of a ferrite memory core can be reset in one hundred nanoseconds, or one hundred billionths of a second (10^{-7} second). This means that computers are about one-hundred-thousand times faster than the human brain. This is largely offset, however, by the fact that computer processing is serial whereas the brain performs parallel processing. Although the brain conducts millions of operations simultaneously, most digital computers conduct only one computation at any one instant in time.[9] Brain elements are much more richly connected than the elements in a computer. Whereas an element in a computer rarely receives simultaneous inputs from two other units, a brain cell may be simultaneously influenced by several hundred other nerve cells.[10] Moreover, while the brain must sort out and select information from the nonfocused total field of the outside world, data input to a computer is carefully pre-processed.

[8] A. T. Lawton and G. E. Abrook, "Large Scale Integration," *Science Journal* (London, August, 1968).
[9] N. S. Sutherland, "Machines Like Men," *Science Journal* (London, October, 1968).
[10] *Ibid.*

Hardware and Software

It is often said that computers are "extraordinarily fast and extraordinarily accurate, but they also are exceedingly stupid and therefore have to be told everything." This process of telling the computer everything is called computer programming. The hardware of the human bio-computer is the physical cerebral cortex, its neurons and synapses. The software of our brain is its logic or intelligence, that which animates the physical equipment. That is to say, hardware is technology whereas software is information. The software of the computer is the stored set of instructions that controls the manipulation of binary numbers. It usually is stored in the form of punched cards or tapes, or on magnetic tape. The process by which information is passed from the human to the machine is called computer language. Two of the most common computer languages are Algol derived from "*Algo*rithmic *La*nguage," and Fortran, derived from *"For*mula *Tran*slation."

The basis of any program is an algorithm—a prescribed set of rules that define the parameters, or discrete characteristics, of the solution to a given problem. The algorithm *is* the solution, as opposed to the *heuristics* or methods of finding a solution. In the case of computer-generated graphic images, the problem is how to create a desired image or succession of images. The solution usually is in the form of polar equations with parametric controls for straight lines, curves, and dot patterns.

Computers can be programmed to simulate "conceptual cameras" and the effects of other conceptual filmmaking procedures. Under a grant from the National Science Foundation in 1968, electrical engineers at the University of Pennsylvania produced a forty-minute instructional computer film using a program that described a "conceptual camera," its focal plane and lens angle, panning and zoom actions, fade-outs, double-exposures, etc. A program of "scenario description language" was written which, in effect, stored fifty years of moviemaking techniques and concepts into an IBM 360-65 computer.[11]

[11] Ron Schneiderman, "Researchers Using IBM 360 to Produce Animated Films," *Electronic News* (June 17, 1968), p. 42.

In the last decade seventy percent of all computer business was in the area of central processing hardware, that is, digital computers themselves. Authorities estimate that the trend will be completely reversed in the coming decade, with seventy percent of profits being made in software and the necessary input-output terminals. At present, software equals hardware in annual sales of approximately $6.5 billion, and is expected to double by 1975.[12]

Today machines read printed forms and may even decipher handwriting. Machines "speak" answers to questions and are voice-actuated. Computers play chess at tournament level. In fact, one of the first instances of a computer asking itself an original question occurred in the case of a machine programmed to play checkers and backgammon simultaneously. A situation developed in which it had to make both moves in one reset cycle and thus had to choose between the two, asking itself: "Which is more important, checkers or backgammon?" It selected backgammon on the grounds that more affluent persons play that game, and since the global trend is toward more wealth per each world person, backgammon must take priority.[13]

Machine tools in modern factories are controlled by other machines, which themselves have to be sequenced by higher-order machines Computer models can now be built that exhibit many of the characteristics of human personality, including love, fear, and anger. They can hold beliefs, develop attitudes, and interact with other machines and human personalities. Machines are being developed that can manipulate objects and move around autonomously in a laboratory environment. They explore and learn, plan strategies, and can carry out tasks that are incompletely specified.[14]

So-called learning machines such as the analogue UCLM II from England, and the digital Minos II developed at Stanford University, gradually are phasing out the prototype digital computer. A learning machine has been constructed at the National Physical Laboratory that learns to recognize and to associate differently shapedshadows which the same object casts in different positions.[15] These new elec-

[12] Robert A. Rosenblatt, "Software: The Tail Now Wags the Dog," *Los Angeles Times Outlook* (June 29, 1969), sec. 1, p. 1.
[13]Fuller, "Prospect for Humanity," *Good News.*
[14] *Science Journal* (October, 1968).
[15] Bronowski, *op. cit., p. 47.*

tronic brains are approaching speeds approximately one million times faster than the fastest digital computers. It is estimated that the next few generations of learning machines will be able to perform in five minutes what would take a digital computer ten years. The significance of this becomes more apparent when we realize that a digital computer can process in twenty minutes information equivalent to a human lifetime of seventy years at peak performance.[16]

N. S. Sutherland: "There is a real possibility that we may one day be able to design a machine that is more intelligent than ourselves. There are all sorts of biological limitations on our own intellectual capacity ranging from the limited number of computing elements we have available in our craniums to the limited span of human life and the slow rate at which incoming data can be accepted. There is no reason to suppose that such stringent limitations will apply to computers of the future... it will be much easier for computers to bootstrap themselves on the experience of previous computers than it is for man to benefit from the knowledge acquired by his predecessors. Moreover, if we can design a machine more intelligent than ourselves, then *a fortiori* that machine will be able to design one more intelligent than itself."[17]

The number of computers in the world doubles each year, while computer capabilities increase by a factor of ten every two or three years. Herman Kahn: "If these factors were to continue until the end of the century, all current concepts about computer limitations will have to be reconsidered. Even if the trend continues for only the next decade or so, the improvements over current computers would be factors of thousands to millions... By the year 2000 computers are likely to match, simulate or surpass some of man's most 'human-like' intellectual abilities, including perhaps some of his aesthetic and creative capacities, in addition to having new kinds of capabilities that human beings do not have... If it turns out that they cannot duplicate or exceed certain characteristically human capabilities, that will be one of the most important discoveries of the twentieth century."[18]

[16] W. K. Taylor, "Machines That Learn," *Science Journal* (October, 1968).
[17] Sutherland, *Science Journal.*
[18] Herman Kahn, Anthony Wiener, *Year 2000* (New York: Macmillan, 1967), p. 89.

Dr. Marvin Minsky of M.I.T. has predicted: "As the machine improves... we shall begin to see all the phenomena associated with the terms 'consciousness,' 'intuition' and 'intelligence.' It is hard to say how close we are to this threshold, but once it is crossed the world will not be the same... it is unreasonable to think that machines could become *nearly* as intelligent as we are and then stop, or to suppose that we will always be able to compete with them in wit and wisdom. Whether or not we could retain some sort of control of the machines—assuming that we would want to—the nature of our activities and aspirations would be changed utterly by the presence on earth of intellectually superior entities."[19] But perhaps the most portentous implication in the evolving symbiosis of the human biocomputer and his electronic brainchild was voiced by Dr. Irving John Good of Trinity College, Oxford, in his prophetic statement: "The first ultra-intelligent machine is the last invention that man need make."[20]

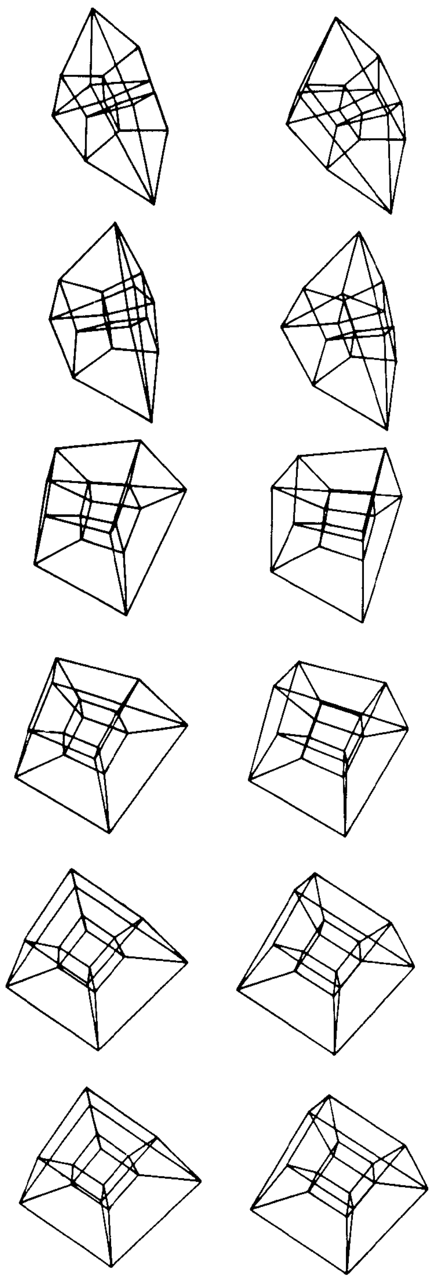
[19] Arthur C. Clarke, "The Mind of the Machine," *Playboy (December*, 1968), p. 118.
[20] *Ibid.*

The Aesthetic Machine

As the culmination of the Constructivist tradition, the digital computer opens vast new realms of possible aesthetic investigation. The poet Wallace Stevens has spoken of "the exquisite environment of face." Conventional painting and photography have explored as much of that environment as is humanly possible. But, as with other hidden realities, is there not more to be found there? Do we not intuit something in the image of man that we never have been able to express visually? It is the belief of those who work in cybernetic art that the computer is the tool that someday will erase the division between what we feel and what we see.

Aesthesic application of technology is the only means of achieving new consciousness to match our new environment. We certainly are not going to love computers that guide SAC missiles. We surely do not feel warmth toward machines that analyze marketing trends. But perhaps we can learn to understand the beauty of a machine that produces the kind of visions we see in expanded cinema.

It is quite clear in what direction man's symbiotic relation to the computer is headed: if the first computer was the abacus, the ultimate computer will be the sublime aesthetic device: a parapsychological instrument for the direct projection of thoughts and emotions. A. M. Noll, a pioneer in three-dimensional computer films at Bell Telephone Laboratories, has some interesting thoughts on the subject: "...the artist's emotional state might conceivably be determined by computer processing of physical and electrical signals from the artist (for example, pulse rate and electrical activity of the brain). Then, by changing the artist's environment through such external stimuli as sound, color and visual patterns, the computer would seek to optimize the aesthetic effect of all these stimuli upon the artist according to some specified criterion... the emotional reaction of the artist would continually change, and the computer would react accordingly either to stabilize the artist's emotional state or to steer it through some pre-programmed course. One is strongly tempted to describe these ideas as a consciousness-expanding experience in association with a psychedelic computer... current



Visualizing the invisible: Six successive stereo pairs from a film by A. Michael Noll of Bell Telephone Laboratories, demonstrating the rotation, on four mutually perpendicular axes, of a four-dimensional hypercube projected onto dual two-dimensional picture planes in simulated three-dimensional space. The viewer wears special polarized glasses such as those common in 3-D movies of the early 1950's. It was an attempt to communicate an intuitive understanding of four-dimensional objects, which in physics are called *hyperobjects*. A computer can easily construct, in mathematical terms, a fourth spatial dimension perpendicular to our three spatial dimensions. Only a fourth digit is required for the machine to locate a point in four-dimensional space. Photo: Bell Telephone Laboratories.

technological and psychological investigations would seem to aim in such a direction."[21]

This chapter on computer films might be seen as an introduction to the first tentative, crude experiments with the medium. No matter how impressive, they are dwarfed by the knowledge of what computers someday will be able to do. The curious nature of the technological revolution is that, with each new step forward, so much new territory is exposed that we seem to be moving backwards. No one is more aware of current limitations than the artists themselves.

As he has done in other disciplines without a higher ordering principle, man so far has used the computer as a modified version of older, more traditional media. Thus we find it compared to the brush, chisel, or pencil and used to facilitate the efficiency of conventional methods of animating, sculpting, painting, and drawing. But the chisel, brush, and canvas are *passive* media whereas the computer is an *active* participant in the creative process. Robert Mallary, a computer scientist involved in computer sculpture, has delineated six levels of computer participation in the creative act. In the first stage the machine presents proposals and variants for the artist's consideration without any qualitative judgments, yet the man/machine symbiosis is synergetic. At the second stage, the computer becomes an *indispensable* component in the production of an art that would be impossible without it, such as constructing holographic interference patterns. In the third stage, the machine makes autonomous decisions on alternative possibilities that ultimately govern the outcome of the artwork. These decisions, however, are made within parameters defined in the program. At the fourth stage the computer makes decisions not anticipated by the artist because they have not been defined in the program. This ability does not yet exist for machines. At the fifth stage, in Mallary's words, the artist "is no longer needed" and "like a child, can only get in the way." He would still, however, be able to "pull out the plug," a capability he will not possess when and if the computer ever reaches the sixth stage of "pure disembodied energy."[22]

[21] A. M. Noll, "The Digital Computer as a Creative Medium," *IEEE Spectrum* (October, 1967), p. 94.
[22] Robert Mallary, "Computer Sculpture: Six Levels of Cybernetics," Artforum (May, 1969), pp. 34, 35.

Returning to more immediate realities, A. M. Noll has explained the computer's active role in the creative process as it exists today: "Most certainly the computer is an electronic device capable of performing only those operations that it has been explicitly instructed to perform. This usually leads to the portrayal of the computer as a powerful tool but one incapable of any true creativity. However, if 'creativity' is restricted to mean the production of the unconventional or the unpredicted, then the computer should instead be portrayed as a creative medium—an active and creative collaborator with the artist... because of the computer's great speed, freedom from error, and vast abilities for assessment and subsequent modification of programs, it appears to us to act unpredictably and to produce the unexpected. In this sense the computer actively takes over some of the artist's creative search. It suggests to him syntheses that he may or may not accept. It possesses at least some of the external attributes of creativity."[23]

Traditionally, artists have looked upon science as being more important to mankind than art, whereas scientists have believed the reverse. Thus in the confluence of art and science the art world is understandably delighted to find itself suddenly in the company of science. For the first time, the artist is in a position to deal directly with fundamental scientific concepts of the twentieth century. He can now enter the world of the scientist and examine those laws that describe a physical reality. However, there is a tendency to regard any computer-generated art as highly significant—even the most simplistic line drawing, which would be meaningless if rendered by hand. Conversely, the scientific community could not be more pleased with its new artistic image, interpreting it as an occasion to relax customary scientific disciplines and accept anything random as art. A solution to the dilemma lies somewhere between the polarities and surely will evolve through closer interaction of the two disciplines.

When that occurs we will find that a new kind of art has resulted from the interface. Just as a new language is evolving from the binary elements of computers rather than the subject-predicate relation of the Indo-European system, so will a new aesthetic discipline that bears little resemblance to previous notions of art and the creative process. Already the image of the artist has changed

[23] Noll, "The Digital Computer as a Creative Medium," p. 91.

radically. In the new conceptual art, it is the artist's *idea* and not his technical ability in manipulating media that is important. Though much emphasis currently is placed on collaboration between artists and technologists, the real trend is more toward one man who is both artistically and technologically conversant. The Whitney family, Stan VanDerBeek, Nam June Paik, and others discussed in this book are among the first of this new breed. A. M. Noll is one of them, and he has said: "A lot has been made of the desirability of collaborative efforts between artists and technologists. I, however, disagree with many of the assumptions upon which this desirability supposedly is founded. First of all, artists in general find it extremely difficult to verbalize the images and ideas they have in their minds. Hence the communication of the artist's ideas to the technologist is very poor indeed. What I do envision is a new breed of artist... a man who is extremely competent in both technology and the arts."

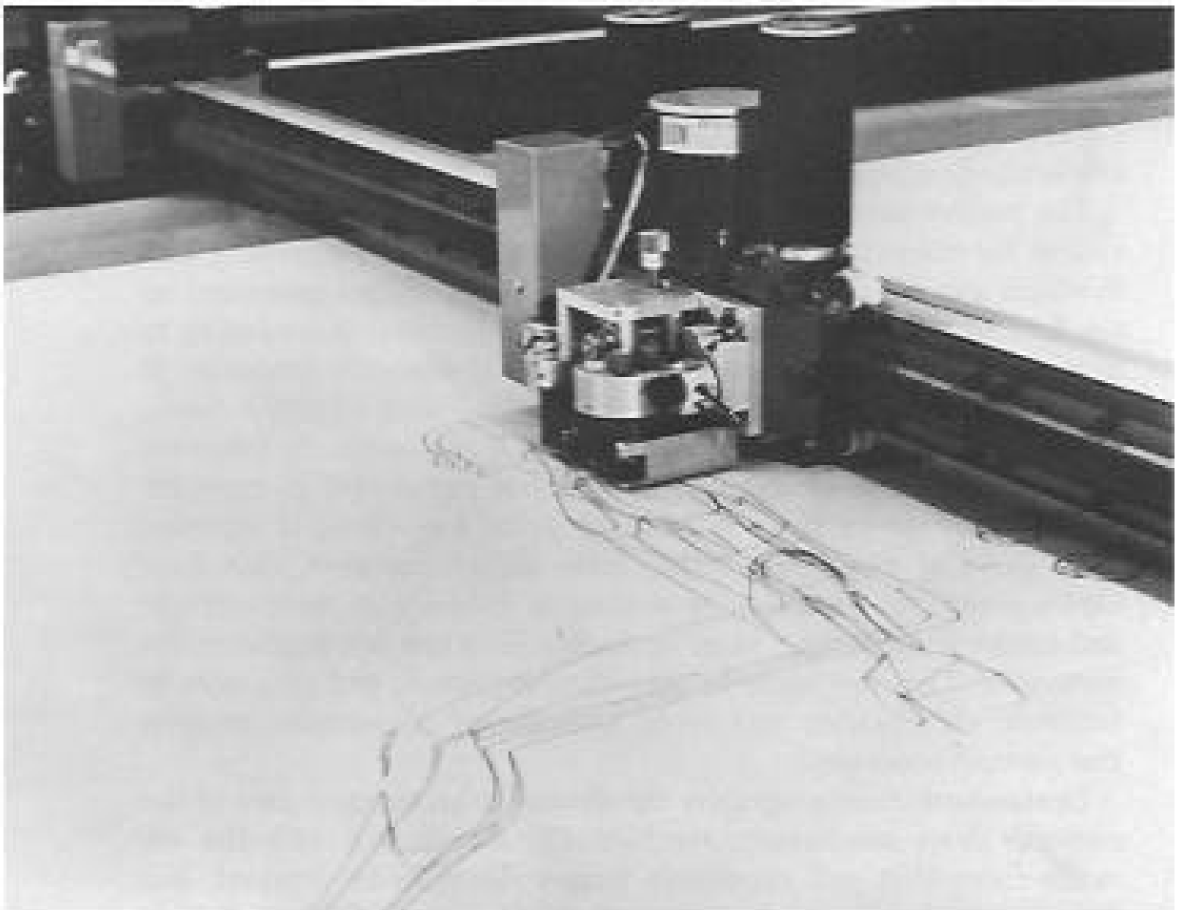
Thus Robert Mallary speaks of an evolving "science of art... because programming requires logic, precision and powers of analysis as well as a thorough knowledge of the subject matter and a clear idea of the goals of the program... technical developments in programming and hardware will proceed hand in glove with a steady increase in the theoretical knowledge of art, as distinct from the intuitive and pragmatic procedures which have characterized the creative process up to now."

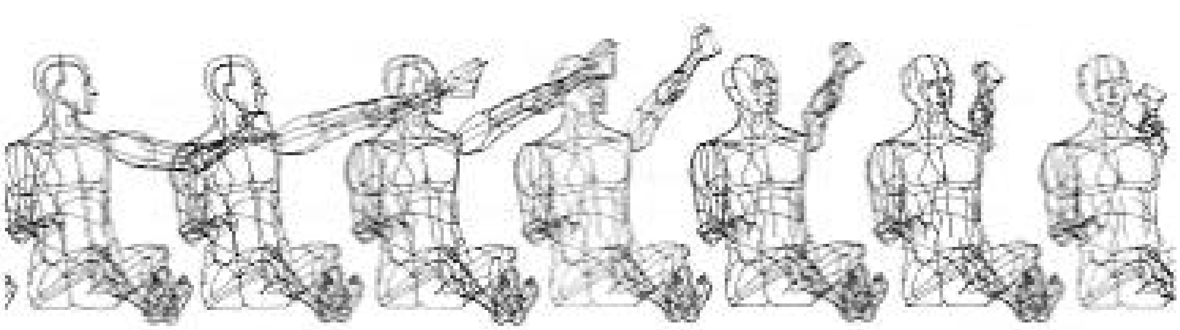
Cybernetic Cinema

Three types of computer output hardware can be used to produce movies: the mechanical analogue plotter, the "passive" microfilm plotter and the "active" cathode-ray tube (CRT) display console. Though the analogue plotter is quite useful in industrial and scientific engineering, architectural design, systems analysis, and so forth, it is rather obsolete in the production of aesthetically-motivated computer films. It can and is used to make animated films but is best suited for still drawings.

Through what is known as digital-to-analogue conversion, coded signals from a computer drive an armlike servomechanism that literally draws pen or pencil lines on flatbed or drum carriages. The resulting flow charts, graphs, isometric renderings, or realist images are incrementally precise but are too expensive and time-consuming for nonscientific movie purposes. William Fetter of the Boeing Company in Seattle has used mechanical analogue plotting systems to make animated films for visualizing pilot and cockpit configurations in aircraft design. Professor Charles Csuri of Ohio State University has created "random wars" and other random and semi-random drawings using mechanical plotters for realist images. However, practically all computer films are made with cathode-ray tube digital plotting output systems.

The cathode-ray tube, like the oscilloscope, is a special kind of television tube. It's a vacuum tube in which a grid between cathode and anode poles emits a narrow beam of electrons that are accelerated at high velocity toward a phosphor-coated screen, which fluoresces at the point where the electrons strike. The resulting luminescent glow is called a "trace-point." An electromagnetic field deflects the electron beam along predetermined patterns by electronic impulses that can be broadcast, cabled, or recorded on tape. This deflection capability follows vertical and horizontal increments expressed as xy plotting coordinates. Modern three-inch CRTs are capable of responding to a computer's "plot-point" and "draw-line" commands at a rate of 100,000 per second within a field of 16,000 possible xy coordinates—that is, approximately a million times faster and more accurate than a human draftsman. When





Above: Mechanical analogue plotter draws pilot for computer-animated film by William Fetter of the Boeing Company in Seattle, Washington. *Below:* Animated sequence from the film. Photo: Boeing Company.

interfaced with a digital computer, the CRT provides a visual display of electronic signal information generated by the computer program.

The passive microfilm plotter is the most commonly used output system for computer movies. It's a self-contained film-recording unit in which a movie camera automatically records images generated on the face of a three-inch CRT. The term "microfilm" is confusing to filmmakers not conversant with industrial or scientific language. It simply indicates conventional emulsion film in traditional 8mm., 16mm., or 35mm. formats, used in a device not originally intended for the production of *motion* pictures, but rather *still* pictures for compact storage of large amounts of printed or pictorial information. Users of microfilm plotters have found, however, that their movie-producing capability is at least as valuable as their storage-and-retrieval capability. Most computer films are not aesthetically-motivated. They are made by scientists, engineers, and educators to facilitate visualization and rapid assimilation of complex analytic and abstract concepts.

In standard cinematography the shutter is an integral part of the camera's drive mechanism, mechanically interlocked with the advance-claws that pull successive frames down to be exposed. But cameras in microfilm plotters such as the Stromberg-Carlson 4020 or the CalComp 840 are specially designed so that the shutter mechanism is separate from the film pull-down. Both are operated automatically, along with the CRT display, under computer program control.

Some computer films, particularly those of John Whitney, are made with active twenty-one-inch CRTs such as the IBM 2250 Display Console with its light pen, keyboard inputs, and functional keys, whose use will be described in more detail later on. This arrangement is not a self-contained filmmaking unit; rather, a specially modified camera is set up in front of the CRT under automatic synchronous control of a computer program. This system is called "active" as opposed to the "passive" nature of the microfilm plotter because the artist can feed commands to the computer through the CRT by selecting variables with the light pen and the function keyboard, thus "composing" the picture in time as sequences develop (during filming, however, the light pen is not used and the

Cybernetic movie studio: The IBM 2250 Display Console with CRT, light pen, and function keyboard. Photo: IBM.

CRT becomes a passive display of the algorithm). Also, until recently the display console was the only technique that allowed the artist to see the display as it was being recorded; recent microfilm plotters, however, are equipped with viewing monitors.

Since most standard microfilm plotters were not originally intended for the production of motion pictures, they are deficient in at least two areas that can be avoided by using the active CRT. First, film registration in microfilm plotters does not meet quality standards of the motion-picture industry since frame-to-frame steadiness is not a primary consideration in conventional microfilm usage. Second, most microfilm plotters are not equipped to accept standard thousand-foot core-wound rolls of 35mm, film, which of course is possible with magazines of standard, though control-modified, cameras used to photograph active CRTs.

Recently, however, computer manufacturing firms such as Stromberg-Carlson have designed cameras and microfilm plotters that meet all qualifications of the motion-picture industry as the use of computer graphics becomes increasingly popular in television commercials and large animation firms. Passive CRT systems are preferred over active consoles for various reasons. First, the input capabilities of the active scope are rarely used in computer animation. Second, passive CRTs come equipped with built-in film recorders. Third, a synchronization problem can arise when filming from an active CRT scope caused by the periodic "refreshing" of the image. This is similar to the "rolling" phenomenon that often occurs in the filming of a televised program. The problem is avoided in passive systems since each frame is drawn only once and the camera shutter remains open while the frame is drawn.

The terms "on-line," "off-line," and "real time" are used in describing computer output systems. Most digital plotting systems are designed to operate either on-line or off-line with the computer. In an on-line system, plot commands are fed directly from the computer to the CRT. In an off-line system, plot commands are recorded on magnetic tape that can instruct the plotter at a later time. The term "real time" refers specifically to temporal relationships between the CRT, the computer, and the final film or the human operator's interaction with the computing system. For example, a real-time interaction between the artist and the computer is possible by drawing on the face of the CRT with the light pen. Similarly, if a movie projected at the standard 24 fps has recorded the CRT display exactly as it was drawn by the computer, this film is said to be a real-time representation of the display. A live-action shot is a real-time document of the photographed subject, whereas single-frame animation is not a real-time image, since more time was required in recording than in projecting.

Very few computer films of significant complexity are recorded in real-time operation. Only one such film, Peter Kamnitzer's *City-Scape,* is discussed in this book. This is primarily because the hardware necessary to do real-time computer filmmaking is rare and prohibitively expensive, and because real-time photography is not of crucial importance in the production of aesthetically-motivated films. In the case of John Whitney's work, for example, although the imagery is preconceived for movie projection at 24 fps, it is filmed at about 8 fps. Three to six seconds are usually required to produce one image, and a twenty-second sequence projected at 24 fps may require thirty minutes of computer time to generate.

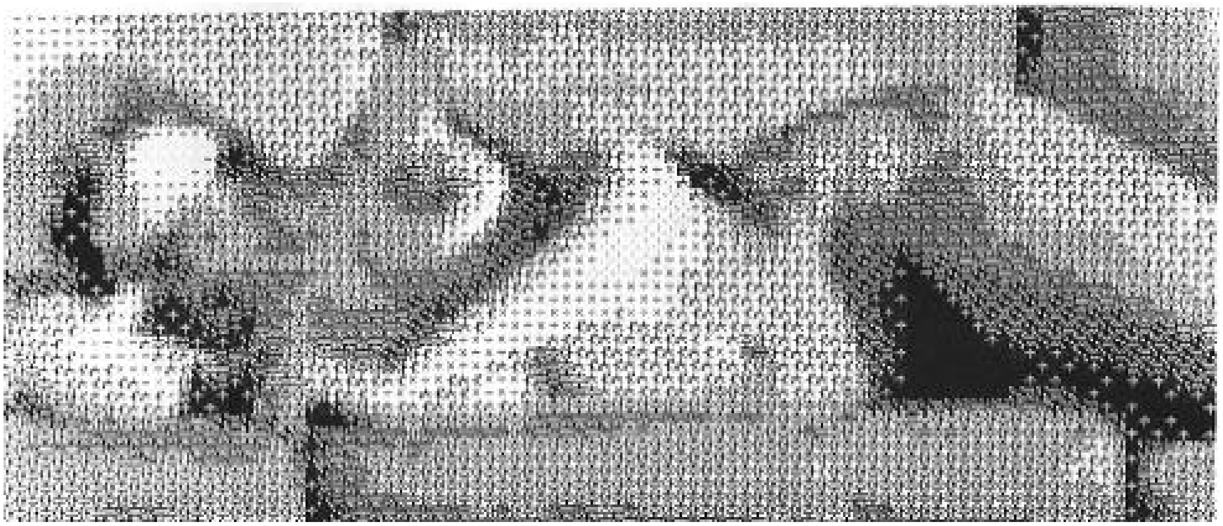
Most CRT displays are black-and-white. Although the Sandia Corporation and the Lawrence Radiation Laboratory have achieved dramatic results with full-color CRTs, the color of most computer films is added in optical printing of original black-and-white footage, or else colored filters can be superposed over the face of the CRT during photography. Full color and partial color displays are available. As in the case of *City-Scape,* however, a great deal of color quality is lost in photographing the CRT screen. Movies of color CRT displays invariably are washed-out, pale, and lack definition. Since black-and-white film stocks yield much higher definition than color film stocks, most computer films are recorded in black-and-white with color added later through optical printing.

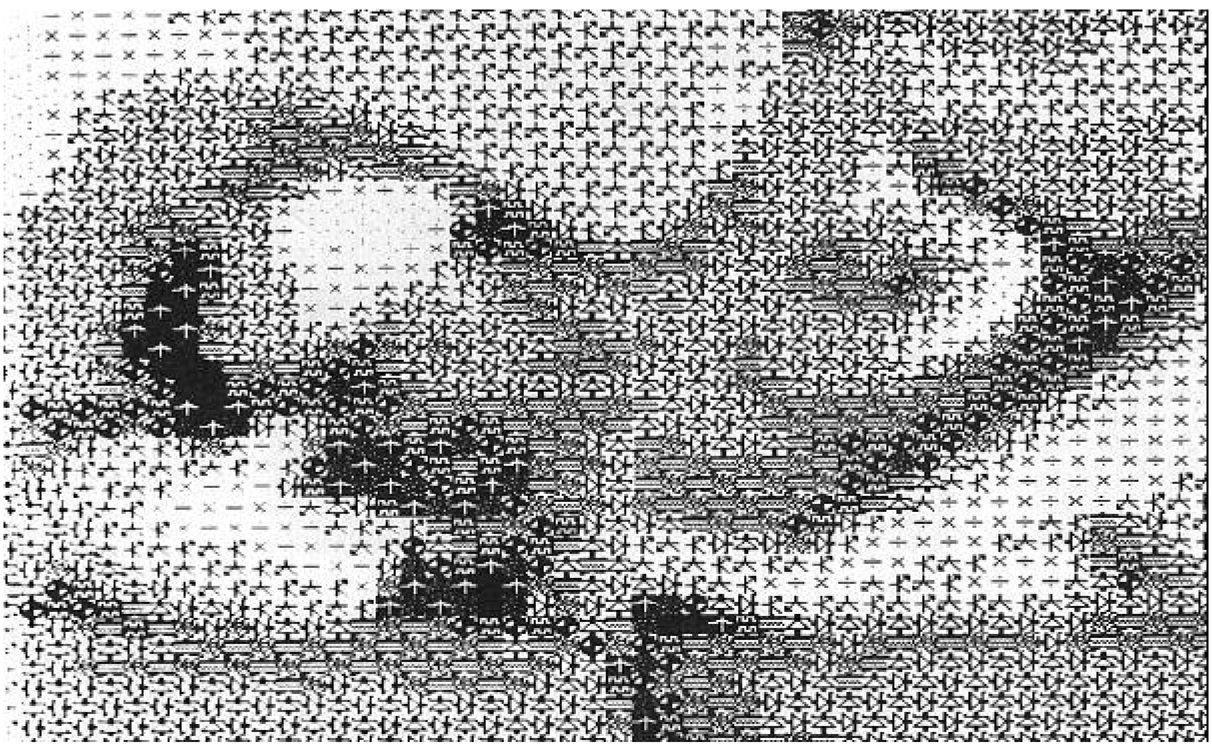
A similar problem exists in computer-generated realistic imagery in motion. It will be noted that most films discussed here are non-figurative, non-representational, i.e., concrete. Those films which do contain representational images—*City-Scape, Hummingbird*—are rather crude and cartoon-like in comparison with conventional animation techniques. Although computer films open a new world of language in concrete motion graphics, the computer's potential for manipulation of the realistic image is of far greater relevance for both artist and scientist. Until recently the bit capacity of computers far outstripped the potentials of existing visual subsystems, which did not have the television capability of establishing a continuous scan on the screen so that each point could be controlled in terms of shading and color. Now, however, such capabilities do exist and the tables are turned; the bit capacity necessary to generate television-quality motion images with tonal or chromatic scaling is enormously beyond present computer capacity.

Existing methods of producing realistic imagery still require some form of realistic input. The computer does not "understand" a command to make this portion of the picture dark gray or to give that line more "character." But it does understand algorithms that describe the same effects. For example, L. D. Harmon and Kenneth Knowlton at Bell Telephone have produced realistic pictures by scanning photographs with equipment similar to television cameras. The resulting signals are converted into binary numbers representing brightness levels at each point. These bits are transferred to magnetic tape, providing a digitized version of the photograph for computer processing. Brightness is quantized into eight levels of density represented by one of eight kinds of dots or symbols. They appear on the CRT in the form of a mosaic representation of the original photograph. The process is both costly and time consuming, with far less "realistic" results than conventional procedures.

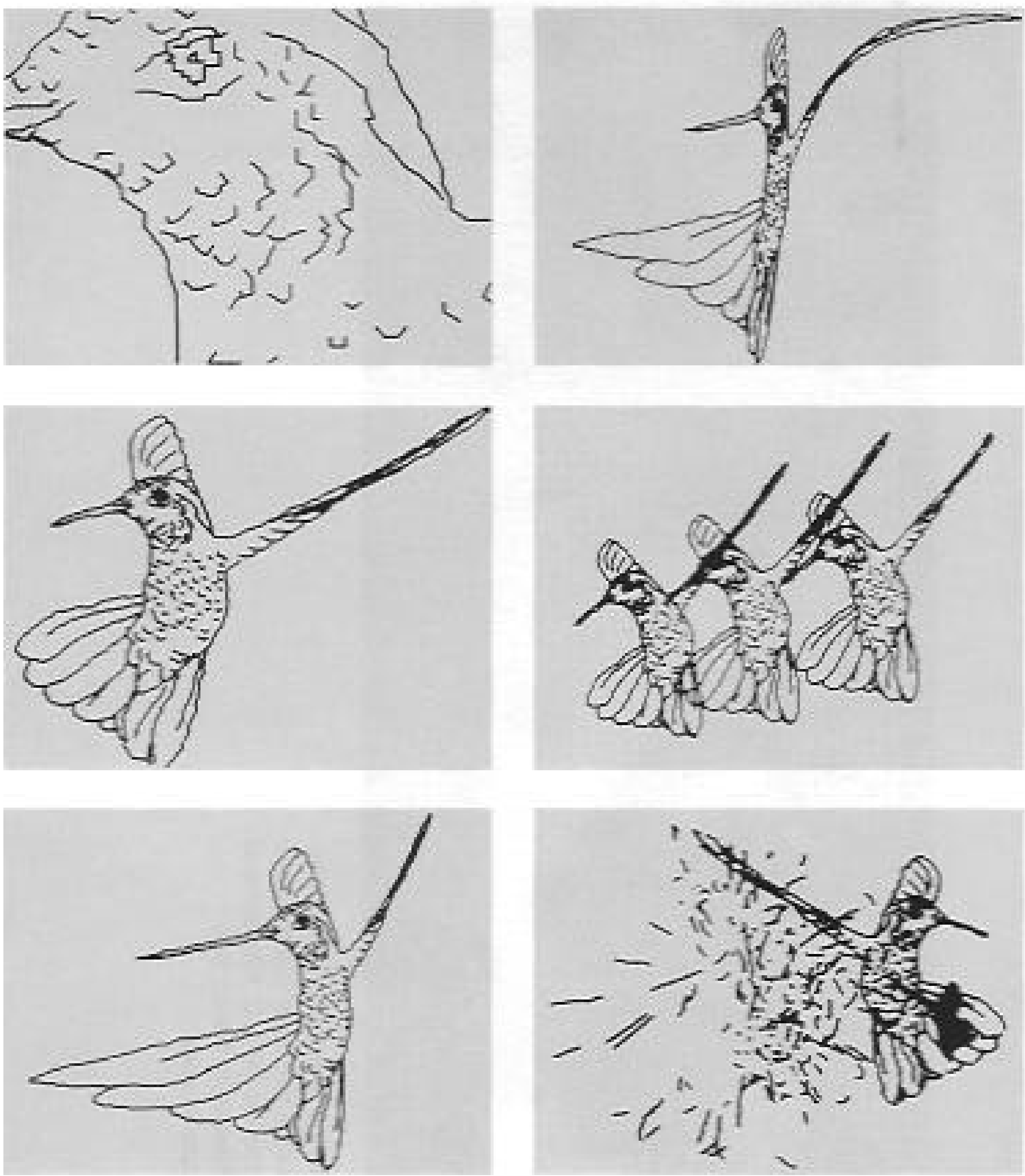
The Computer Image Company of Denver, Colorado, has devised two unique methods of producing cartoon-like representational computer graphics in real-time, on-line operation. Using special hybrid systems with the advantages of both digital and analogue computers, they generate images through optical scanning or acoustical and anthropometric controls. In the scanning process, called *Scanimate,* a television camera scans black-and-white or color transparencies; this signal is input to the Scanimate computer where it is segmented into as many as five different parts, each capable of independent movement in synchronization with any audio track, either music or commentary. The output is recorded directly onto film or videotape as an integral function of the Scanimate process.

The second computer image process, *Animac,* does not involve optical scanning. It generates its own images in conjunction with acoustical or anthropometric analogue systems. In the first instance the artist speaks into a microphone that converts the electrical signals into a form that modulates the cartoon image on the CRT. The acoustical input animates the cartoon mouth while other facial characteristics are controlled simultaneously by another operator. In the second method an anthropometric harness is attached to a person—a dancer, for example—with sensors at each of the skeletal joints. If the person moves his arm the image moves its arm; when the person dances the cartoon character dances in real-time synchronization, with six degrees of freedom in simulated three-dimensional space. It should be stressed that these cartoon images are only "representational" and not "realistic." The systems were designed specifically to reduce the cost of commercial filmmaking and not to explore serious aesthetic potentials. It's obvious, however, that such techniques could be applied to artistic investigation and to nonobjective graphic compositions.





Reclining nude scanned from photo and reconstructed by computer using bright-ness-level symbols. By L. D. Harmon and Kenneth C. Knowlton. Photo: Bell Telephone Laboratories.



Charles Csuri: *Hummingbird.* 1967, 16mm. Black and white. 10 min. Computer-manipulations of hand-drawn figure using *xy* plotting coordinates.

Professor Charles Csuri's computer film, *Hummingbird,* was produced by digital scanning of an original hand-drawing of the bird. The computer translated the drawing into *xy* plotting coordinates and processed variations on the drawing, assembling, disassembling, and distorting its perspectives. Thus the images were not computer-generated so much as computer-manipulated. There's no actual animation in the sense of separately-moving parts. Instead a static image of the bird is seen in various perspectives and at times is distorted by reversals of the polar coordinates. Software requirements were minimal and the film has little value as art other than its demonstration of one possibility in computer graphics.

Limitations of computer-generated realistic imagery exist both in the central processing hardware as well as visual output subsystems. Advancements are being made in output subsystems that go beyond the present bit-capacity of most computers. Chief among these is the "plasma crystal" panel, which makes possible billboard or wallsize TV receivers as well as pocket-size TV sets that could be viewed in bright sunlight. The Japanese firms of Mitsubishi and Matsushita (Panasonic) seem to be leaders in the field, each having produced workable models. Meanwhile virtually every major producer of video technology has developed its own version. One of the pioneers of this process in the United States was Dr. George Heilmeier of RCA's David Sarnoff Research Center in Princeton, New Jersey. He describes plasma crystals (sometimes called liquid crystals) as organic compounds whose appearance and mechanical properties are those of a liquid, but whose molecules tend to form into large orderly arrays akin to the crystals of mica, quartz, or diamonds. Unlike luminescent or fluorescing substances, plasma crystals do not emit their own light: they're read by reflected light, growing brighter as their surroundings grow brighter.

It was discovered that certain liquid crystals can be made opalescent, and hence reflecting, by the application of electric current. Therefore in manufacturing such display systems a sandwich is formed of two clear glass plates, separated by a thin layer of clear liquid crystal material only one-thousandth of an inch thick. A reflective mirror-like conductive coating is deposited on the inside face of one plate, in contact with the liquid. On the inside of the other is deposited a transparent electrically-conductive coating of tin oxide. When an electric charge from a battery or wall outlet is

Prototype for flat, wall-size TV screens and computer visualization subsystems of the future: Dr. George Heilmeier demonstrates RCA's liquid crystal display. Photo: RCA.

applied between the two coatings, the liquid crystal molecules are disrupted and the sandwich takes on the appearance of frosted glass. The frostiness disappears, however, as soon as the charge is removed.

In order to display stationary patterns such as letters, symbols, or still images, the coatings are shaped in accordance with the desired pattern. To display motion the conductive coatings are laid down in the form of a fine mosaic whose individual elements can be charged independently, in accordance with a scanning signal such as is presently used for facsimile, television, and other electronic displays. To make the images visible in a dark room or outdoors at night, both coatings are made transparent and a light source is installed at the edge of the screen. In addition it is possible to reflect a strong light from the liquid crystal display to project its images, enlarged many times, onto a wall or screen.

The implications of the plasma crystal display system are vast. Since it is, in essence, a digital system composed of hundreds of thousands of discrete picture elements (PIXELS), it obviously is suitable as a computer graphics subsystem virtually without limitation if only sufficient computing capabilities existed. The bit requirements necessary for computer generation of real-time realistic images in motion are as yet far beyond the present state of the art.

This is demonstrated in a sophisticated video-computer system developed by Jet Propulsion Laboratories in Pasadena, California, for translation of television pictures from Mars in the various Mariner projects. This fantastic system transforms the real-time TV signal into digital picture elements that are stored on special data-discs. The picture itself is not stored; only its digital translation. The JPL video system consists of 480 lines of resolution, each line composed of 512 individual points. One single image, or "cycle," is thus defined by 245,760 points. In black-and-white, each of these points, individually selectable, can be set to display at any of 64 desired intensities on the gray scale between total black and total white. Possible variations for one single image thus amount to 64 times 245,760. For color displays, the total image can be thought of as three in-dependent images (one for each color constituent, red, blue, and green) or can be taken as a triplet specification for each of the 480 times 512 points. With each constituent being capable of 64 different irradiating levels in the color spectrum, a theoretical total of 262,144 different color shadings are possible for any given point in the image. (The average human eye can perceive only 100 to 200 different color shadings.)

These capabilities are possible only for single motionless images. Six bits of information are required to produce each of the 245,760 points that constitute one image or cycle, and several seconds are necessary to complete the cycle. Yet JPL scientists estimate that a computing capability of at least two megacycles (two million cycles) *per second* would be required to generate motion with the same image-transforming capabilities.

It is quite clear that human communication is trending toward these possibilities. If the visual subsystems exist today, it's folly to assume that the computing hardware won't exist tomorrow. The notion of "reality" will be utterly and finally obscured when we reach that point. There'll be no need for "movies" to be made on location since any conceivable scene will be generated in totally convincing reality within the information processing system. By that time, of course, movies as we know them will not exist. We're entering a mythic age of electronic realities that exist only on a metaphysical plane. Meanwhile some significant work is being done in the development of new language through computer-generated, nonrepresentational graphics in motion. I've selected several of the most prominent artists in the field and certain films, which, though not aesthetically-motivated, reveal possibilities for artistic exploration. We'll begin with the Whitney family: John, Sr., and his brother James inaugurated a tradition; the sons John, Jr., Michael, and Mark are the first second-generation computer-filmmakers in history.

John Whitney: Composing an Image of Time

"My computer program is like a piano. I could continue to use it creatively all my life."

The foremost computer-filmmaker in the world today, John Whitney has for more than thirty years sought new language through technological resources beyond human capacity. He has, however, remained resolutely "humanist" in his approach, constantly striving to reach deep emotional awarenesses through a medium essentially austere and clinical. He has realized his goal to a remarkable degree, yet he would be the first to admit that there is a long way to go. "Computer graphic systems," he has said, "present an opportunity to realize an art of graphics in motion with potentials that are only now conceivable and have never been explored."

In his essay "Systems Esthetics," Jack Burnham observed: "Scientists and technicians are not converted into artists, rather the artist becomes a symptom of the schism between art and technics. Progressively, the need to make ultrasensitive judgments as to the uses of technology and scientific information becomes 'art' in the most literal sense."[24] Whitney is making those judgments with a powerful extension of his brain.

Following studies at Pomona College in California, Whitney spent a year in Europe where he studied photography and musical composition. In 1940 he began specializing in concrete designs in motion, working with his brother James on animated films which won first prize at the first Experimental Film Festival in Belgium in 1949.

Early in the 1950's he experimented with the production of 16mm. films for television and in 1952 wrote, produced, and directed engineering films on guided missile projects for Douglas Aircraft. He was a director of animated films at UPA in Hollywood for one year. The title sequence for Alfred Hitchcock's *Vertigo* was among the

[24]Jack Burnham, "Systems Esthetics," *Artforum* (September, 1968), pp. 30-35.

work he produced in association with Saul Bass during this period. Following that he directed several short musical films for CBS television, and in 1957 worked with Charles Eames assembling a seven-screen presentation for the Fuller Dome in Moscow. Each screen was the size of a drive-in movie screen.

In 1960 Whitney founded Motion Graphics Inc., producing motion-picture and television title sequences and commercials. Much of this work was done with his own invention, a mechanical analogue computer for specialized animation with typography and concrete design. In 1962 he was named Fellow of the Graham Foundation for Advanced Study in the Fine Arts. Finally, after approximately a decade, he found himself free once again to begin experimenting with less commercial, more aesthetic, problems of motion graphics.

The analogue computer work gained Whitney a worldwide reputation, and in the spring of 1966 International Business Machines became the first major corporation to take an "artist in residence" to explore the aesthetic potentials of computer graphics. IBM awarded Whitney a continuing grant that has resulted in several significant developments in the area of cybernetic art. Whether working with hand-drawn animation cards or highly abstract mathematical concepts, Whitney has always displayed an artist's intuition and a technologist's discipline. He is a man of tomorrow in the world of today.

The history of cybernetics reached a milestone during World War II with the development of guidance and control mechanisms for antiaircraft artillery. Two men riding a telescope table sighted enemy aircraft and followed their penetration into the battery range. Selsyn motors in the gun-director mechanism automatically aimed an entire battery of guns while analogue computers set fuse times on explosive shells and specified true-intercept trajectories from data fed into the ballistics equation from movements of the operators.

An M-5 Antiaircraft Gun Director provided the basic machinery for Whitney's first mechanical analogue computer in the late 1950's. This complex instrument of death now became a tool for producing benevolent and beautiful graphic designs. Later Whitney augmented the M-5 with the more sophisticated M-7, hybridizing the machines into a mammoth twelve-foot-high device of formidable complexity

John Whitney working with his mechanical analogue computer. Photo: Charles Eames.

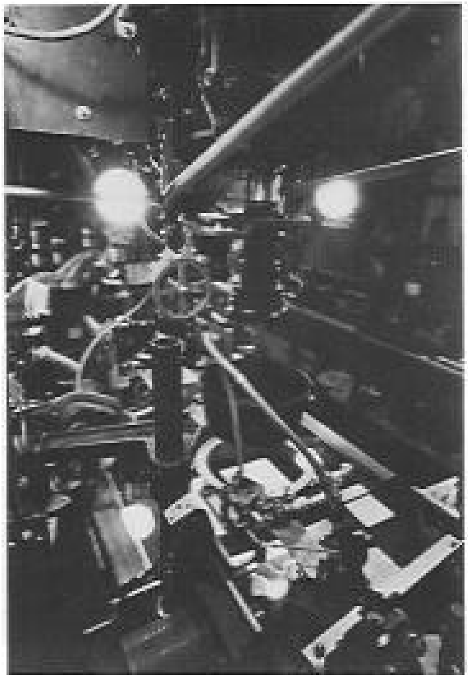
upon which most of the business of Motion Graphics was conducted for many years.

Similar to the analogue device built by Whitney's brother James for the production of *Lapis,* but far more complex, the machine consists of primary, secondary, and tertiary rotating tables, cam systems, and other surfaces for pre-programming of image and motion sequences in a multiple-axis environment. Whitney's son John, Jr., an electronics genius who improved his father's device as a teen-ager by rewiring and implementing its circuitry, explains the basic functions of the machine:

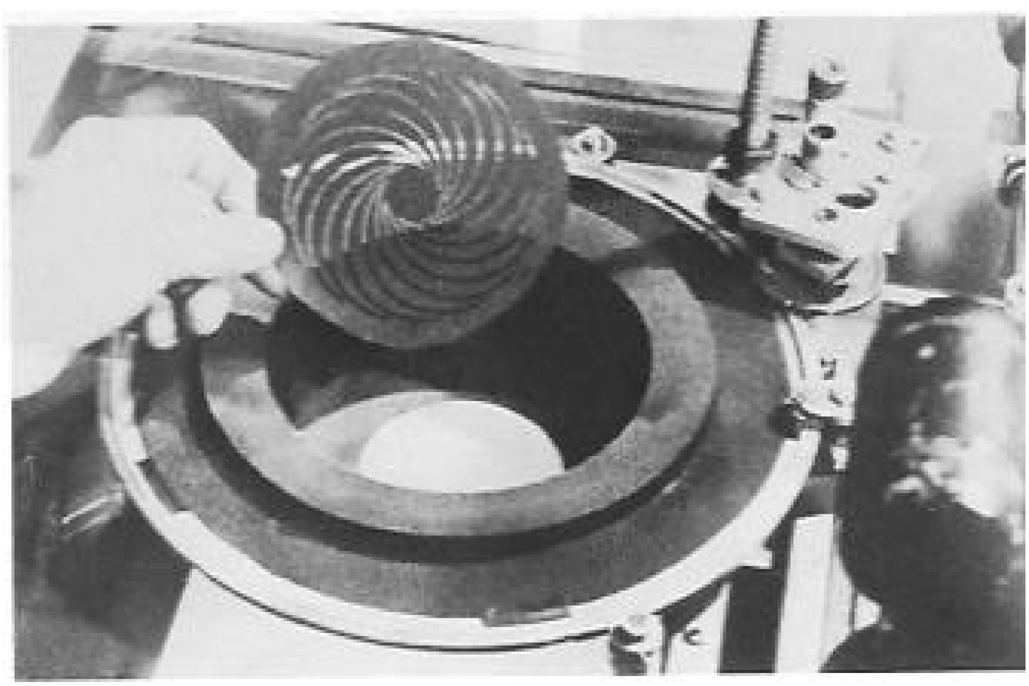
> There's not one function that isn't variable. The whole master table rotates and so does every part in it, as well as moving laterally, horizontally, and in some cases vertically. The camera moves in the same way completely independent of the rest of the machine, or in synchronization with it. I don't know how many simultaneous motions can be happening at once. There must be at least five ways just to operate the shutter. The input shaft on the camera rotates at 180 rpm, which results in a photographing speed of about 8 fps. That cycle time is constant, not variable, but we never shoot that fast. It takes about nine seconds to shoot one frame because the secondary rotating tables require nine seconds to make one revolution. During this nine-second cycle the tables are spinning on their own axes while simultaneously revolving around another axis while moving horizontally across the range of the camera, which itself may be turning or zooming up and down. During this operation we can have the shutter open all the time, or just at the end for a second or two, or at the beginning, or for half of the time if we want to do slit-scanning.

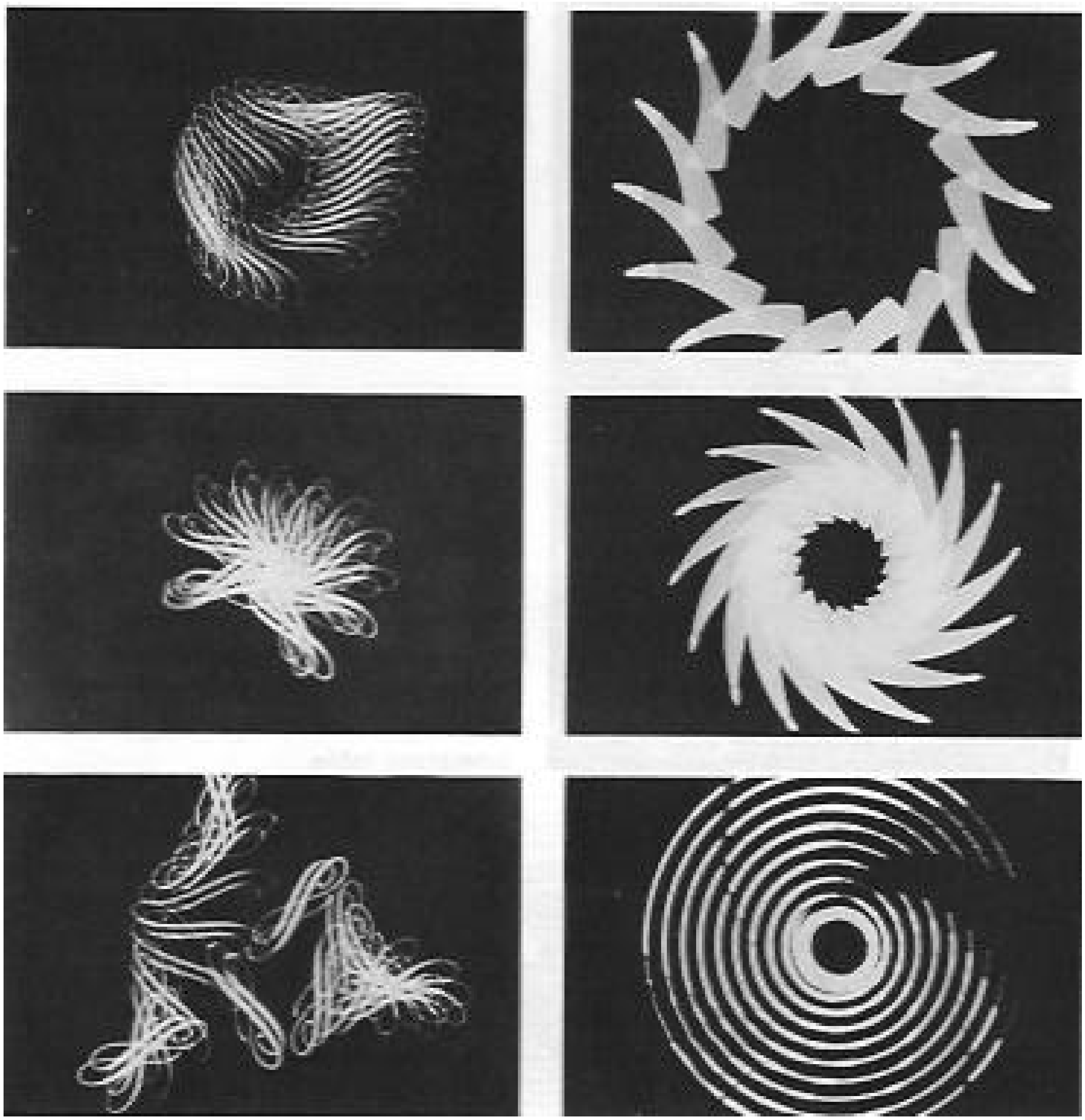
The elder Whitney actually never produced a complete, coherent movie on the analogue computer because he was continually developing and refining the machine while using it for commercial work. It remained for his sons John and Michael to make full creative use of this device that had dominated their childhood from earliest recollection. However, Whitney did assemble a visual catalogue of the effects he had perfected over the years. This film, simply titled *Catalogue,* was completed in 1961 and proved to be of such overwhelming beauty that many persons still prefer Whitney's analogue work over his digital computer films.

The machine, like the digital computer, not only facilitated the quick and effortless rendering of complex geometrical shapes and



Left: Camera zoom lens *(center)* focusing into primary rotating table of Whitney mechanical analogue computer. (Photo: Charles Eames)
Below:
Whitney places design template into computer table.





John Whitney: Catalogue. 1961.16mm. Color. 7 min. "Floral patterns curl as though they were actually organic growths..."

motions, but also actually helped realize certain graphics possibilities that otherwise might not be conceivable to the artist untrained in mathematical concepts. *Catalogue* is a brilliant display of floral patterns that seem to bloom and curl as though they were actually organic growths photographed in time-lapse. Also they have a natural quality quite unlike traditional single-frame animation and are far more convincing. Elsewhere in the film, neon-like coils expand and contract, throwing out bursts of pastel color. Dish-shaped curvilinear disks wobble and strobe, stretch and contract in a variety of unexpected ways. Syncretistic dot-pattern fields collect together as in *Lapis.* Strings of green light perform seemingly impossible transformations into endless intertwined configurations of baffling optical complexity. Words assemble and disintegrate, defying logic. Floral ringlets pop like neon confetti, showering the screen with flak bursts of color.

Unlike the digital computer, which requires only a mathematical code as its input, the mechanical analogue computer as used by the Whitneys requires some form of input that directly corresponds to the desired output. That is, at least a basic element of the final image we see on the screen must first be drawn, photographed, pasted together, or otherwise assembled *before* it is fed into the analogue equipment for processing. This means that a great deal of handicraft still is involved, though its relation to the final output is minimal. The original input may be as simple as a moiré pattern or as complex as a syncretistic field of hand-painted dots—but *some* form of handmade or physically demonstrable information is required as input in the absence of conventional computer software.

GENE: You're among the few people in the world working to bring the public into a closer understanding of technology on a basis we can relate to—a movie, pretty colors, things that move. It's very important.

JOHN: Just after World War II my brother and I were constantly excited by a future world. We sort of expected it to happen before the 1940's were past. We thought nothing of taking on the formal and creative problems of a totally technological medium such as the cinema. It's taken twenty or thirty years to realize that the technology we looked upon as being the technology of the future was far from it. Instead of being the camera, the most important piece of instrumentation is the computer itself. Still ahead is considerable disciplined study to gain understanding or control of this kind of formal dynamic material so that it can be human. That's the whole problem. The light show people are doing a lot of wonderful sensory things, but I feel there must come insight into what is riot seen now—an understanding of a whole new area of conceptual form. The light show people are doing something like an infant pounding on the keys of a piano. Sometimes it can be very creative and terribly exciting. But in the long run, looking at it as an adult, it's just banging away at the piano without training. We know that someone who plays a Beethoven sonata maybe has been sharpening his sensibilities and manual dexterity with that one piece for seven or eight years. That's the way I see the relationship between computer aesthetics and contemporary light shows.

GENE: Where would you place yourself today concerning what you've done and what you'd like to do?

JOHN: In one sense I'm just beginning. In another sense my work with the digital computer is a culmination of all my interests since the 1940's because I found myself forced into the techniques and mechanisms of cinema. I got to work with the digital computer thanks to the fact that I developed my analogue equipment to the point that I had. As I continued to develop the machine I realized it was really a mechanical model of the electronic computer. Anyone experimenting with the medium of cinema as opposed to working in the industry is forced into a direct confrontation with his technology. People tried all different techniques of abstract cinema, and it's strange that no one has really invented anything that another experimental filmmaker can take up and use himself. It's starting afresh every time. Jim and I were trying to make something and there wasn't a machine available for making it. So my work has come to fruition because the past thirty years of search for instrumentation has culminated in the present availability of the computer. On the other hand I'm only beginning to use it. We all are. It's the same with those who are beginning to use the computer to compose music—they're at a very primitive stage today.

Permutations (see color plates), the first cohesive film to come out of Whitney's work with the digital computer, is a dazzling display of serial imagery that seems to express specific ideas or chains of ideas through hypersensitive manipulation of kinetic empathy. The patterns, colors, and motions dancing before us seem to be addressing the inarticulate conscious with a new kind of language. In fact, Whitney thinks of his work precisely as the development of a new communicative mode. Speaking of *Permutations,* he explains:

> The film contains various types of dot patterns which might be compared to the alphabet. The patterns are constructed into "words," each having basically a two-hundred-frame or eight-second time duration. These words in turn can be fitted contextually into "sentence" structures. My use of the parallel to language is only partially descriptive; I am moved to draw parallels with music. The very next term I wish to use is "counterpoint." These patterns are graphically superimposed over themselves forward and backward in many ways, and the parallel now is more with counterpoint, or at least polyphonic musical phenomena. Should it be called "polygraphic phenomena"?

Whatever they're called, Whitney's films are impossible to describe with the archaic language of the phonetic alphabet. Circles, crescents, quadrants, and multiplex forms of infinite variety and endless motion interact serially, and cosmically, until one is transported into a realm of expanded consciousness that intuitively understands this new language. It's as though the very essence of the idea of permutation is expressed in this film, as though the "word" no longer were separate from the fact. And that's exactly what Whitney has done: he's merged language with what it is intended to express. "Beautiful" seems such an inadequate term in this respect.

Before discussing the film itself, it will be helpful to understand in some detail how it was made, beginning with the program and going on through the final stages of photography and optical printing. This will be helpful to readers interested in making computer films, since Whitney's methods and working conditions are those most likely to be available to the average person—with the exception of his own specialized film processing equipment.

Dr. Jack Citron of IBM became interested in Whitney's work and began collaborating with him before there was any formal IBM support. Dr. Citron later was given formal responsibility for further work with Whitney under the IBM program, exploring the creative possibilities inherent in the IBM Model 360 computer and the IBM 2250 Graphic Display Console. It was Citron who wrote the original program called GRAF (Graphic Additions to Fortran), which Whitney has been using since the spring of 1966.

Citron: One of the things I was interested in doing was to set up a kind of instrument which would buffer the computer user from the technical details. I think this can only be done by someone who understands both areas. The line of attack in my program was to start with what's in the artist's mind, and somehow have him use a kind of mathematics which he learns by rote with a "teaching program," to learn to express what's in his head visually. Once such a program is written, the fact that the programmer who wrote the algorithms knew what the artist needed enables the artist to sit down and say the kind of things John says without all that other training. I'm very happy it worked that way. Certainly in the future one will need more of a mathematical-logical background than artists have today. But you won't need ten years of schooling in nuclear physics. The thing that should be done is to develop a scientific curriculum for the artist. I don't know of anyone seriously considering that, but it should be done.

WHITNEY: Dr. Citron and I talked for some time before I actually began working. When I first began to realize from correspondence with IBM that I would be given the grant, the first thing that came to my mind was the question: would I be able to draw a free-hand line and somehow get that into the computer as digital information so I could manipulate it? I was presenting these ideas in preliminary talks and I was told that anything you can define mathematically you can do with a computer very easily. At first, having flunked mathematics consistently all through school, I was a bit horrified. And yet I began to realize the great breadth of elegance in simple geometrical graphics, and the historic respect geometry has enjoyed as a graphic form. Slowly these misgivings about having to define things in mathematical form died off... Some people in computer work criticize me for not being able to program myself instead of relying on someone else. Yet I've used this one program for more than three years and I know that it is still only fragmentarily explored. In terms of software the program Dr. Citron developed for me is like a piano. I could continue to use it creatively all my life. But one program is like one area of a total palette. Let's assume that other people are going to develop other programs that will have another area of significance. Some of the ultimate orchestrations to come in fifteen or twenty years will perhaps involve many combined programs.

The GRAF program is based on a single polar-coordinate equation having about sixty parameters. In preparation for a display of images in what is called the "learning" stage of the program, the light pen is used to select numerical variables, displayed on the CRT, which can be assigned to any of the parameters of the program to determine a particular graphic pattern. After values have been selected for all parameters and the camera is brought into play to record the images, control of the computer program is by punch cards, not the light pen. The shutter of the computer camera specially modified by Whitney and his son John is operated electrically, under control of the computer. The functions of opening and closing the shutter and advancing the film are controlled by a separate program in addition to GRAF.

Three types of punch cards are used during filming for control of images, and are signified as Identification Statements (for specifying particular curves), Parameter Statements (for assigning values to the curve), and Frame Statements (for control of successive displays). During this time the artist interacts with the computer through the Program Function Keyboard (PFKB), part of the 2250's hardware. The PFKB is equipped with thirty-six sets of keyswitches and lights. The program turns on light 1 as a signal to open the camera shutter. Interface connections between camera and computer include feedback circuits that allow the camera, in effect, to respond to computer commands: thus key 1 is depressed, entering 20 volts back into the computer and pulsing the camera with 5.3 volts, which operates one single frame exposure. This is followed by an exposure timing loop in the program, and subsequently light 2 is illuminated ordering the shutter to close. Programmed logic decides whether or not more information is to be displayed for this same frame of film.

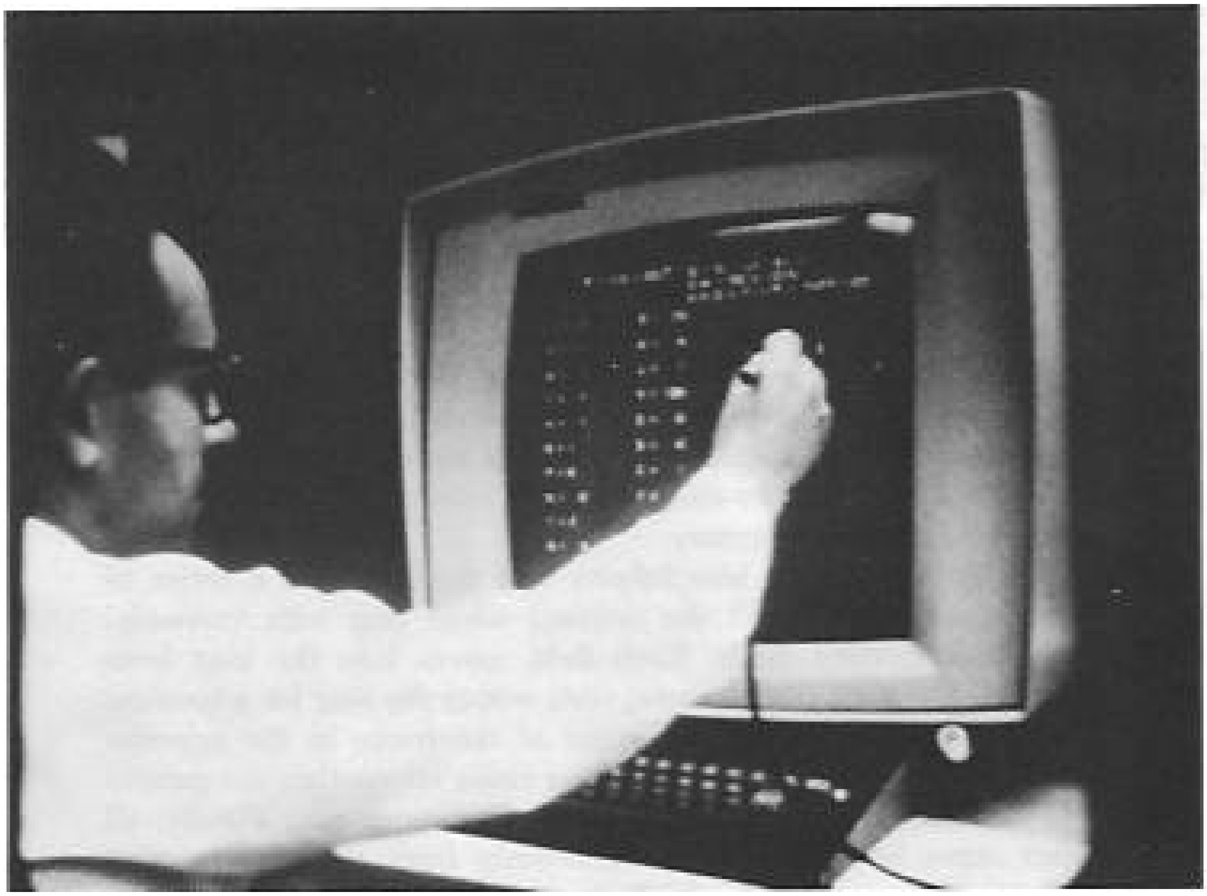
When the film frame is to be advanced, light 3 goes on and the next curve is computed and displayed, the camera is activated, and so on.

The 35mm. black-and-white negative from the camera is processed normally on high-contrast stock yielding an image that consists of clear lines on a dense black field. This film is threaded into the projector side of Whitney's optical printer, which has several special features: the optical axis of the system is vertical with the camera looking down into the projector. The projector itself is mounted on a compound mill table. Thus additional translations and rotations of a mechanical nature may be superimposed, and the camera may be moved along the axis so as to provide for an additional scaling factor of from .1 to 10. A stepping switch circuit and preset frame counter allow a wide range of skip-frame ratios to expand editing capabilities temporally. For *Permutations* Whitney used little skip-framing, but quite a bit of superimposition, slowing and speeding, and forward and backward printing.

Set to a *tabla* solo by Balachander, *Permutations* begins with a ring of white dots in a black void, with individual white dots circumscribing the inner circumference of the ring. This becomes an oval floral pattern of blue, green, and pink dots moving simultaneously clockwise and counterclockwise.

Two factors quickly become apparent: first, the neon-like cold scintillation of the image, a result of electrons deflecting traces in the cathode phosphor at a rate of 30 cycles per second. In our fluorescent world of neon suns and video eyes this scintillating glimmer more closely approximates daily experience than, say, the artificial arc lamp lighting of conventional movies.

Second, is the quite noticeable seriality of the composition, the unified wholeness of the statement, although it is composed of discrete elements. In defining "serial" in this context I should like to quote from art critic John Coplans: "To paint in *series* is not necessarily to be *serial.* Neither the number of works nor the similarity of theme in a given group determines whether a [work] is serial. Rather, seriality is identified by a particular interrelationship, rigorously consistent, of structure and syntax: serial structures are produced by a single indivisible process that links the internal structure of a work to that of other works within a differentiated whole. While a series may have any number of works, it must



Dr. Jack Citron, IBM Los Angeles, selects numerical values for a typical image, using the light pen at the 2250 Display Console.

must as a precondition of seriality have at least two... there are no boundaries implicit to serial imagery; its structures can be likened to continuums or constellations... all contemporary usage of serial imagery is without either first or last members. Obviously at one point there had to be a beginning, but its identity becomes subsumed within the whole, within the macrostructure. The same principle applies to the last member. At any given point in time one work in a series stands last in order of execution, but its sequential identity is irrelevant and in fact is lost immediately on the work's completion."[25]

[25] John Coplans, "Serial Imagery," *Artforum* (October, 1968), pp. 34-43.

It is this seriality, then, that identifies *Permutations* both as "words" and "sentence structures" as well as a complete overall statement, which is the meaning of the title. Whitney speaks of "graphic integrity" in this respect, referring to the mathematically precise interrelationships between forms, colors, and movements.

At one point in the film there is an exploration of centrifugal and centripetal ring movement in alternating colors and dot-pattern fields. This becomes an extremely dramatic statement in which bright emerald-green linear figures sweep the inner circumference of a white ring in a black void. The action is asymmetrical, not center-oriented, a fluid kind of motion not restricted to one point, a multiplex motion with no static elements, moving on a path in space that approximates a trajectory.

This figure vanishes into infinity and there follows a series of superimpositions that fill the original white ring with variously-colored dot-pattern fields. Each field moves into the ring from different directions in the frame, rests within the ring for a moment scintillating gently, then moves out of the frame in the opposite direction from which it came, making room for another dot-pattern field of another color which moves in simultaneously. Finally, all colors move into the ring simultaneously from all sides, forming circles within circles all scintillating smoothly in a floral configuration.

GENE: You seem hesitant or apologetic using the parallel with musical forms.

JOHN: I'm wary of it. I've been making that analogy all along, but I'm aware of the pitfalls of a lot of people in history. Da Vinci talked about an art of color which would be dealt with as musical tones. Wilfred and Remmington in England at the turn of the century were building color organs. They were so hung up with parallels with music that they missed the essence of their medium. People talk about abstraction in graphics as being cold or inhuman. I just don't see that at all. What is a musical note? It's totally abstract. That's the essential point and that's why I use the musical analogy. The essential problem with my kind of graphics must resemble the creative problem of melody writing. It is perhaps the most highly sensitive task of art, involving as it does balance, contrast, tension, and resolution all brought into play with minimum expenditure.

Music really is the art that moves in time. The many statements about architecture being frozen music notwithstanding, here we are truly looking at another art that moves in time. Someone once said about musical compositions: "Time and tone completely fill each other... what the hearer perceives in the tones and rests of a musical work is not simply time but shaped and organized time... so the conventional formula receives its final interpretation: music is a temporal art because, shaping the stuff of time, it creates an image of time." I like that idea very much, so I ask myself, what can be essentially the image of time for the eye to perceive?

One such image in *Permutations* involves bright blue, green, and red ellipses that move in perspectival space from static positions at each side of the frame, growing larger as they move alternately to the center and back again, exchanging positions. The feeling is precisely one of counterpoint and of temporal experiences.

This sentence structure becomes a white ring spinning rapidly on a vertical axis until it appears to be a group of white rings in a cagelike configuration, still spinning on a polar vertical axis. Inside this cage appears a similar ring of elliptical spheres, emerald green, revolving on a horizontal axis. Finally, the whole assemblage becomes an incredibly beautiful constellation of all colors and quickly runs through all configurations and movements seen during the film. These are seen moving around, within, and through a total field of scintillating colors as the film ends.

GENE: Which comes first, sound or image?

JOHN: Image. In *Permutations* the sequences and colors were all done before I selected a piece of music, yet there are all these astonishing relations with the music. That's where accident is working in my favor. In many areas of art and music it has been commonplace for the artist to tell you there's nothing in his work that doesn't have some sort of valid relationship or meaningful reason for being there. They've constantly sought to avoid arbitrariness—not accident: you can often make an accident turn into a very wonderful twist to new meaning. But the worst kind of arbitrariness is when a person thinks his own casual decisions are great simply because he's done it, because he decided to be arbitrary. I expect to make a lot more progress in the direction of having more and more levels of formal organization—therefore it should be more and more human and multistructured.

GENE: In one sense you're in the forefront of avant-garde art today, concerned as it is with systems aesthetics, scientific discipline, and so on. In another respect, however, you do seem to be running against the grain of a trend toward the stochastic element, especially in music, films, and theatre.

JOHN: It's a universal misunderstanding. At the Aspen Design Conference in 1967, a scientist was describing a problem scientifically, saying it could be done this way and that, and then he said if it couldn't be done in such a rigorous way let's do it anyway and that'll be art. Scientists very frequently get excited about becoming involved in art. And the very first thing that comes to their minds is just to chuck out the whole discipline that their entire career is based on. They think if it's art, it's free. Anything that goes with random numbers is art; and anything that has to be worked out carefully so that this goes here and this has got to go there, that's not art, that's science. But for my money it's more important and difficult to get this here and that there in the area of art, because it involves much more than just counting numbers and making it mathematically sound: it's got to be intensely and intuitively sound. That's what I'm searching for. That's what I mean by structure.

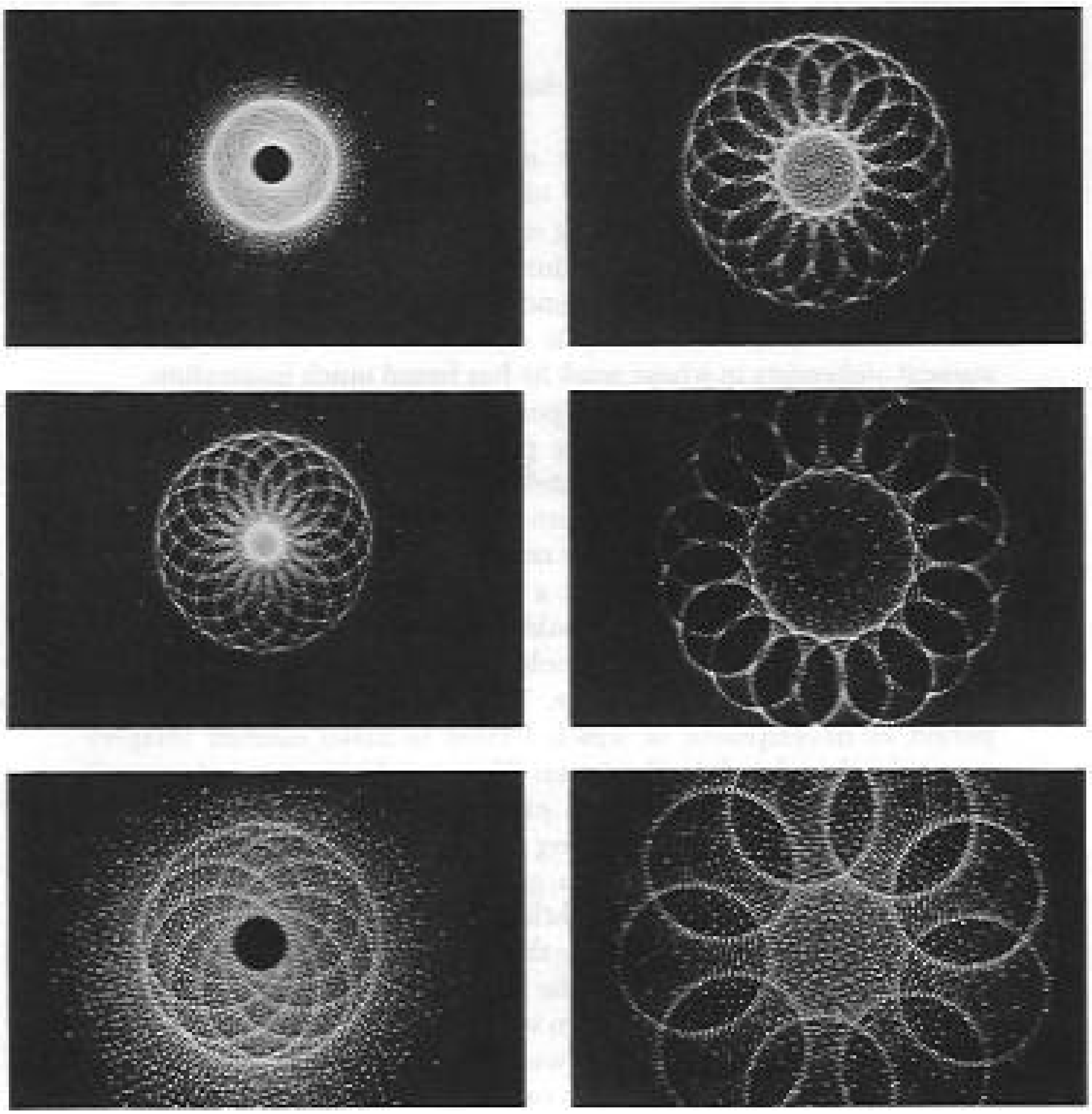
James Whitney's *Lapis:* Cybernetic Philosopher's Stone

James Whitney's cybernetic art seems totally removed from the idyllic scene in the serene Southern California garden where he has developed ceramic handicraft to a fine art in days of quiet meditation. Yet his *Lapis is* perhaps the most beautiful, and one of the most famous, of all computer films. Like the work of his long-time friend, Jordan Belson, it represent expanded cinema in its widest meaning: an attempt to approximate mind forms. That Whitney claims to have failed in his quest does not subtract from the archetypical eloquence of his works. They are glowing testimony of the truth of Herbert Read’s assertion that greatness lies “in the power to realize and even to forecast the imaginative needs of mankind."

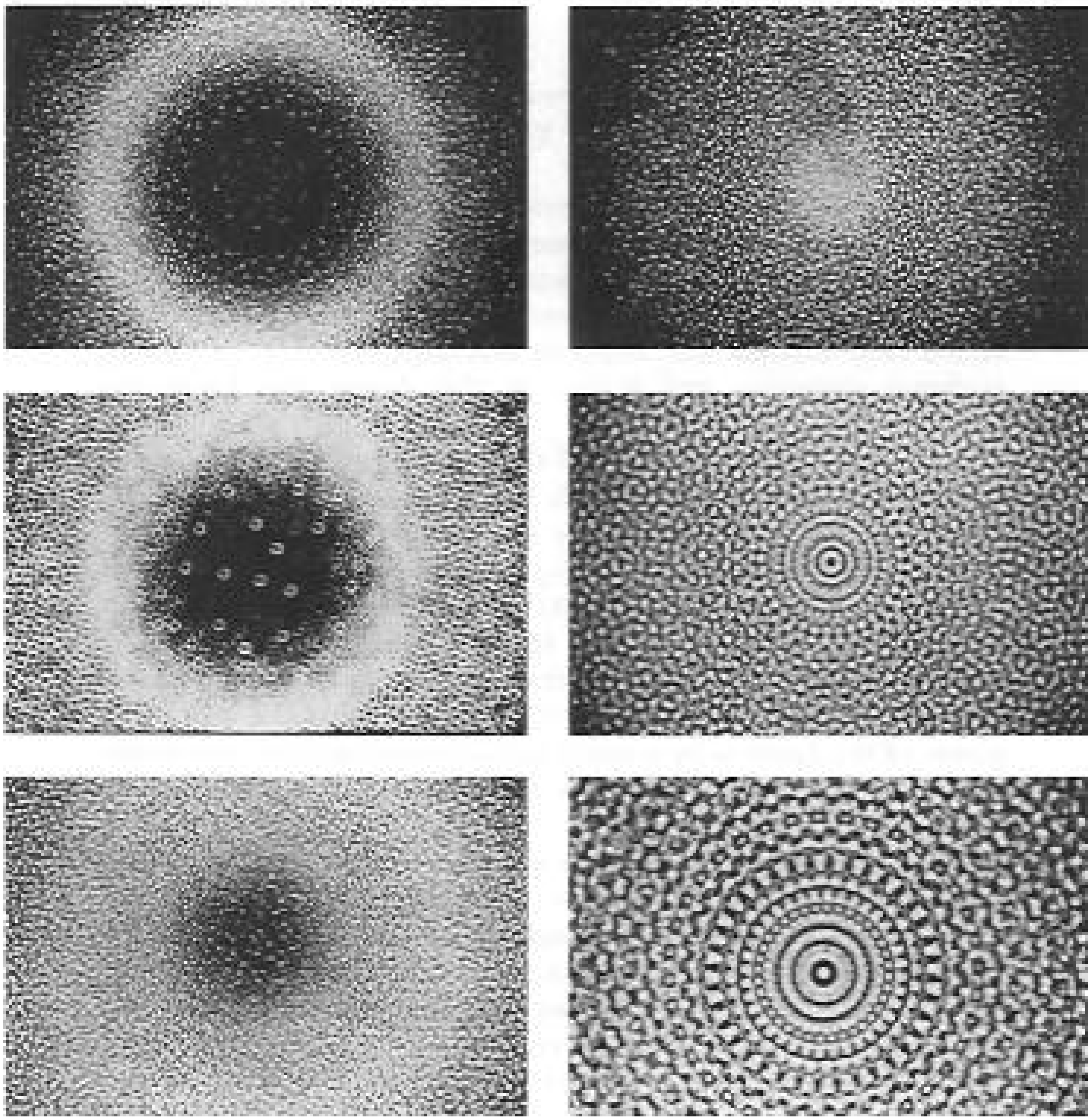
The fundamental imaginative need of mankind today is, as it always has been, the bridging of the chasm between spirit and matter. Atomic science is moving us closer to that realization. But in the words of Louis Pauwels, "just as science without conscience spells ruin for the soul, conscience without science means defeat also." In this respect Whitney is a "scientist of the soul" like the ancient alchemists in whose work he has found much inspiration.

Internationally known as experimental filmmakers because of their five *Film Exercises* of the period 1941-44, James and John Whitney began working separately around 1945. "After the exercises," James recalls, "the structure of my work was external, following pretty close to serial imagery concepts. The intent was a unity of structure which would result in a whole experience. The structure was whole, and naturally it would relate to your own attempts at wholeness: as you were more whole the structures you were dealing with would become more whole. Then after that there was a long period of development in which I tried to make exterior imagery more closely related to the inner. Those early images just weren't relating thoroughly to my own experiences in meditation, for example, where forms are breaking up. So I reduced the structural mode to the dot-pattern, which gives a quality which in India is called the *Akasha,* or ether, a subtle element before creation like the *Breath of Brahma,* the substance that permeates the universe before it begins to break down into the more finite world. That idea as expressed through the dot-pattern was very appealing to me."

Thus in 1950 Whitney began work on his first truly personal film, *Yantra,* an inspired and arduous project, which was to consume ten years before its completion. Drawn entirely by hand on small filing cards, it was an attempt to relate images to Yoga experiences. ". . . A *Yantra is* an instrument designed to curb the psychic forces by concentrating them on a pattern, and in such a way that this pattern becomes reproduced by the worshiper's visualizing power. It is a machine to stimulate inner visualizations, meditations, and experiencees... when utilized in connection with the practice of Yoga the contents of the *Yantra* diagram represent those stages of consciousness that lead inward from the everyday state of naive



James Whitney: *Lapis.* 1963-66. 16mm. Color. 10 min. "A mandala that revolves eternally like the heavens."



Lapis: ". . . they manifest as though out of the air itself, gathering and converging around a central sphere ... revolving with implacable grace against the eerie drone of the tamboura."

ignorance through the degrees of Yoga experience to the realization of the Universal Self."[26]

During most of the ten-year period in which James Whitney was laboriously producing the intricate images of *Yantra* by hand, his brother had developed the analogue computer, which could produce images of far greater complexity in a fraction of the time. After *Yantra* was finished the brothers assembled another mechanical analogue computer, and it was on this device that *Lapis* was created.

In general, the term *Lapis* held the same meaning for the ancient alchemists that the mandala holds for the Lamaist, Tantrist, Taoist, Hindu: a kind of "philosopher's stone" or aid to meditation. In alchemical times, and later during the period of the Rosicrucians, the *Lapis* was felt to contain a vital force or mystic power, a center of knowledge. Hermes asserted that the *Lapis* was composed of body, soul, and spirit, "…that thing midway between perfect and imperfect bodies." Gnostic philosophy suggests that the way to the power of the *Lapis* is by a spiral or circumambulation, specifically, according to Jung, "a mandala that revolves eternally like the heavens."

Whitney began work on *Lapis* in 1963 and completed it in 1966. Much of this time was consumed, however, in the construction of the analogue computer that programmed the extremely intricate mandala-like structure of the film. Thus cybernetics assisted Whitney to return through the centuries to the ancient practice of syncretism in his search for a more total vision.

The opening sequence of *Lapis is* startlingly beautiful: a pure white frame into which, very slowly, moves a ring of thousands of tiny particles. They manifest as though out of the air itself, gathering and converging around a central sphere of light, gradually tightening, growing more complex, until they become a vast syncretistic mandala of intricate geometrical patterns. These configurations defy definition as they revolve with implacable grace against the eerie drone of a tamboura.

[26] Heinrich Zimmer, *Myths and Symbols in Indian Art and Civilization* (Harper Torchbook; New York: Harper & Row, 1946), pp. 141-142.

To achieve this effect, Whitney hand-painted glass plates with fields of dot-patterns that began sparsely and collected into high concentration toward the center. These were placed on rotating tables beneath a vertically-mounted camera. The tables spun on their own axes while simultaneously revolving around another axis, and at the same time moving horizontally across camera range.

At first the huge mandala is a monotone beige against a white field, then it becomes a glowing red-orange and crystallizes into thousands of intricate modules, each containing a green floral pattern inside a diamond configuration. Forms take shape and vanish as the whole revolves majestically, its movement accentuated by the sonorous drone of the tamboura. Suddenly the image disintegrates into a loose cloud of red, yellow, and orange particles that solidify into the word *Lapis.* This bursts apart slowly as the first beats of the tabla are heard and a raga begins.

The mandala draws away from the camera until its individual sections are no longer distinguishable from the whole. It dissolves into a blue multispoked mandala in the center of a black void, revolving and spewing out showers of fine sparklike particles that fade and vanish. One seems to detect snowflake crystals, diamonds, molecular clusters—but they're transformed before the mind's eye can grasp their trajectory. Later we see starbursts throwing off showers of light, spinning around dark centers. A repeat of the opening sequence is done in blue and black—thousands of tiny blue particles slowly collecting around a central vortex. For a split second the particles freeze into diamond-like crystals and then melt back into the syncretistic field. A vibrant orange sun shimmers in blackness, surrounded by a corona of concentric rings, each enclosing a peacock floral pattern.

Finally the original beige mandala reappears and spins rapidly through the various configurations we've seen throughout the film. Two translucent globes within a blinding white center begin to stretch apart diagonally across the frame, creating a sense of enormous tension and stress, shimmering, pulsating, until the final blackout. This was Whitney's way of suggesting what he calls "the last breaking or snapping, unable to reach *Samadhi.* That was because *Lapis* was near the end of what I could do. The machine restricted me; my fantasies couldn't flow. Of course we're in the most primitive stages of cybernetic art, but my inner imagery gave way at the same time that my outer ability to control the instrument broke down."

Whitney finds more than a casual resemblance between Eastern philosophy and modern science, and suggests that this confluence may have a profound effect on conventional notions of art. "Only to a person who has expanded his consciousness," he says, "is ordinary experience expanded. So it's exciting where art is going in this respect. Art and science are getting much closer to Eastern thought. But you'll always find those who seek to go beyond any language. Those are the people whose eyes and ears are really open. But they will come back, and they will be totally open and very sympathetic to what the artist is doing, but they won't have the energy to remain within that confine of art. Artists must in order to create. The other man will see art as the great play and fun that it is, but he won't be able to put that same sort of intensity into it as the artist does. The artist, in a sense, must keep a lot of ignorance. To stay in the world you have to preserve a certain amount of ignorance.

"I certainly do not feel that art is dead. But when you're really involved with the thing you want to experience, you stop conceiving it. Art finally becomes a barrier to accepting what *is.* Art stays within its closed circle and reality never does. Art is all symbols of reality. Symbols are never going to free you. But it would be foolish to say 'Stop making art.' That's not what I'm saying. One should be aware of its limitations, that's all. This must be what they had in mind when they said: 'Thou shalt not create graven images."

The Younger Whitneys: Children of the New Age

"An inadvertent spin-off from technology will transform man into a transcendental being. Nothing we can conceive now will give us a clue to what that spin-off will be. But I suspect that vision will play an important role. The eye will have a lot to do with it."

JOHN WHITNEY, JR.

If the Starchild Embryo of 2001 were to grow up as a human he'd probably feel quite at home with the Whitney brothers. From earliest childhood the future has been their way of life. John, Jr., Michael, and Mark all were born well after World War II. They were raised in an environment of science, technology, the arts, Eastern philosophy. John Cage, Buckminster Fuller, and Jordan Belson have been their houseguests. Their eyes and ears have been nourished by higher orders of sight and sound than most of us are able to conceive. At eighteen John was filming slit-scan sequences, several years before Stanley Kubrick discovered the technique. "I surpassed Dad when I was about eleven," says John, who built his father's computer camera and wired an analogue computer at an age when most boys find model airplanes challenging.

In 1965 the Whitney living room was transformed into a multiple-projection environment with seven screens and ten projectors mounted on two levels. At that time John was eighteen, Michael was seventeen, and Mark was fourteen. And what were they thinking?

MICHAEL: We were anxious to get away from the limitations of a single screen. Obviously the answer was multiple screens. As very young children we were exposed to the films our father and Jim had made. All of our lives we've been exposed to that kind of non-realist material. We didn't try to interpret them. We just accepted them as films without any other hangups. People call our films "abstract" but they're not. They're concrete films. "Abstract" means to make an abstraction from something concrete, but our films *are* concrete. I can remember when all the other kids in the neighborhood would go to the movies every Saturday afternoon and our parents wouldn't let us go. There was an obvious reason of course: those movies were absolute trash. John and I were thinking in terms of "performance" films: not just one strictly-composed film but multi-images whose relationships could be improvised in real time. You would "play" as you felt. We began to envision encompassing other art forms. We had ideas about cartridge loops and spontaneously interchangeable films. Some system that would make possible a real-time film image composition, being able to change a cartridge so you could compose spontaneously.

Also during this period, while Michael was studying calculus and physics, John was completing his first computer film *Byjina Flores,* a pidgin-Spanish satirical translation of "vagina flowers." Though he has since disowned this film, it remains a beautiful optical experience, one of the few movies that might stand comparison (in concept if not in fact) to the Op Art of Vasarely or Bridget Riley. John's father had devised a method of scanning an image through a slit, which would guide the phasing relationship between the image and the camera. This was essentially the method used by Doug Trumbull several years later for the Stargate Corridor of *2001.*

In *Byjina Flores,* filamented, fluted panels of neon-bright red, orange, and yellow shift rhythmically across the range of vision to produce weird perspectival illusions and kinetic trajectories. Objects, which seem to be giant walls of lightbulbs, warp, wobble, and dance, alternating colors stroboscopically. The effect approximates a kind of sculpture in time, a kinetic molding of the temporal as well as the optical experience.

JOHN: It was an overall pattern of moiré dots moving with a scan-line which guided the phasing between the moiré and the lens. The artwork was trucking horizontally while the zoom was moving in and out to achieve the illusion of curvature, warps, and perspectives. My idea was to work with illusions of color and retinal persistence of images. There's one point where it only slightly works as I intended, so the film becomes a total failure for me. We've hardly begun to scratch the surface of possibilities with the slit-scan. The computerized optical printer I've built will scan consecutive frames of a whole motion-picture sequence. I could've had the whole *2001* setup reduced down to a small panel and scanned it on our computer and come up with the same effect. In the making of *Byjina Flores* and all our analogue films there are parallels with the way one programs a digital system, that is, determining variable values in a system by setting cam rates and directions which are linked differentially to related functions and amplitudes.

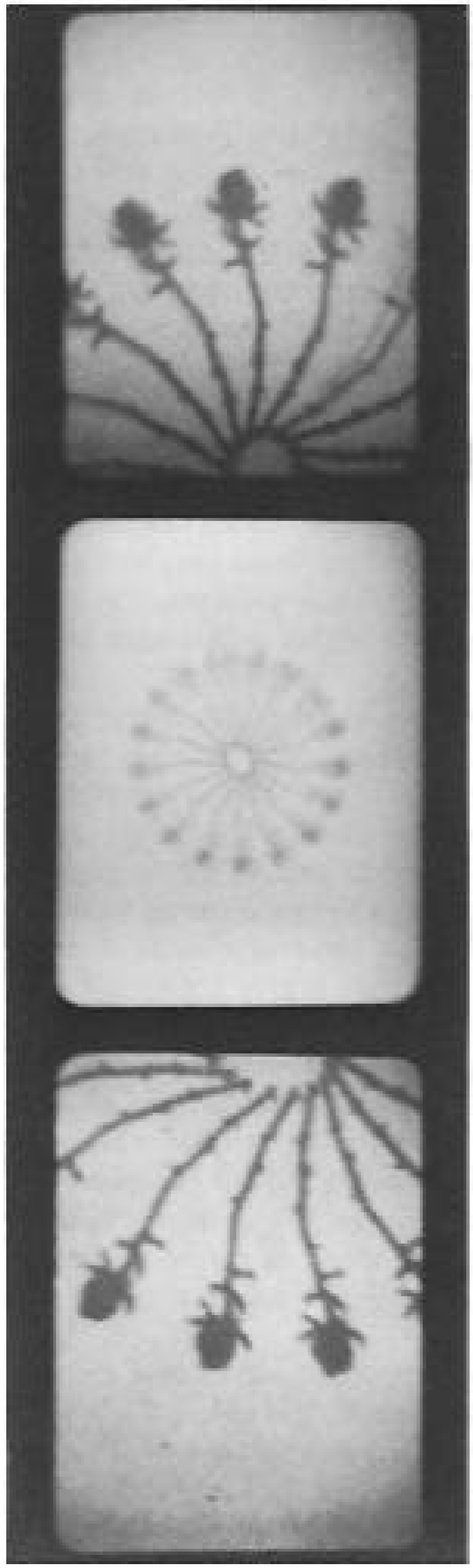
From September 1966, to September 1967, the brothers staged several multi-screen environmental shows across the country. For a Grateful Dead concert in San Francisco they worked with Tom DeWitt and Scott Bartlett, using eight or nine screens at angles to each other. At the Center for the Study of Democratic Institutions in Santa Barbara, they staged an environmental presentation using a truckload of equipment including speakers, ten projectors, and dozens of film loops for projection on five screens that they constructed at the site. In 1967 they were given a building on the grounds of the Monterey Pop Festival and trained nine projectors on three screens. A day after the festival closed they were in Aspen, Colorado, showing their work at an international design conference.

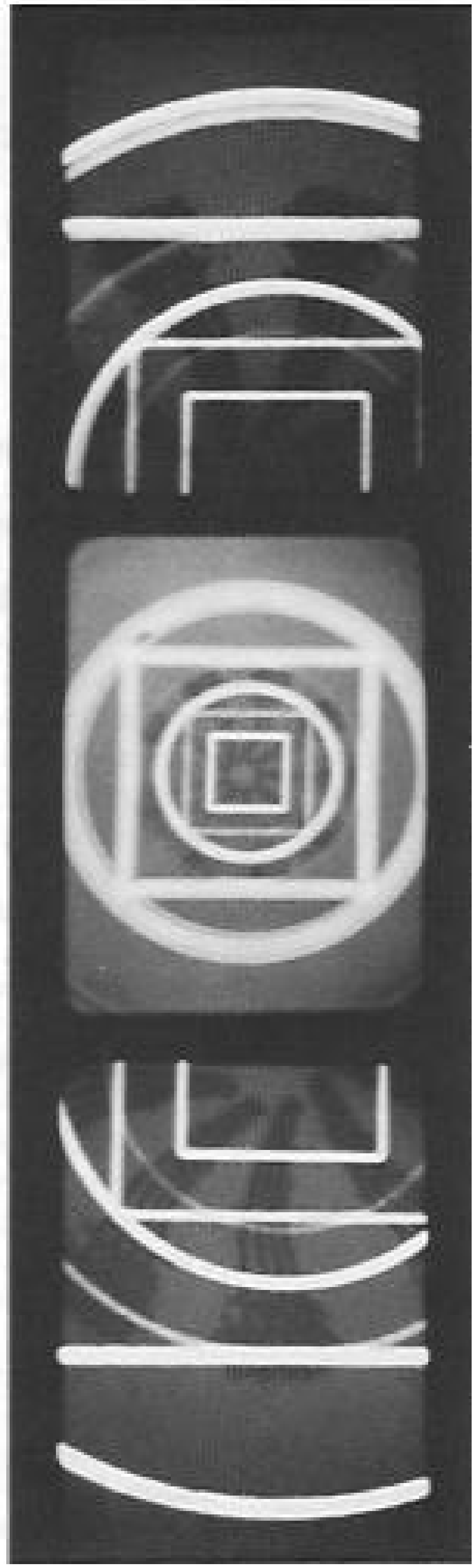
By this time John, Jr., had made more than 5,000 feet of computer film out of which came the extraordinarily beautiful, and now famous, triple-screen film that remains untitled (see color plates). It was premiered at Expo '67 in Montreal and later that year was shown at the Museum of Modern Art in New York. The film is a sequential triptych: it develops in time and space, exploring the relationships of both form and color, visual tensions, rhythmic modes, and optical illusions in a way that relates each screen to the other two with flawless exactitude.

It is among the few independently-produced multiple-projection films to justify its own multiplicity. Whereas most multiple projection is gratuitous and arbitrary, the Whitney film is a cohesive whole, each element accentuating and complementing the other two in ways that make the experience incomplete without all three parts. The flanking images are identical, though reversed, so as to frame the center screen symmetrically, and the close synchronization of form and color among the screens demands highly controlled projection conditions.

Like most Whitney films the triple-screen film is set to an East Indian sound track. It begins with circular arrangements of rose stems, the halves of one circle split between the two end screens in burnt sienna, the center screen yellow ochre with a complete but smaller circle of stems revolving at a faster rate than its counterparts. What we are seeing is actually two views of one configuration divided into a triad. As the stems revolve, the colors change from warm yellows to cool violets.

This becomes a vortex display of concentric circles and squares endlessly moving into the frames and diminishing into infinity only to be succeeded by other layers of circles and squares of different colors moving in unison. In this sequence the image split between the two end screens is different from the central image in color, but identical in design. Once again, the flanking images are larger than





the center image and, moving in precise synchronization, create an optical tension that induces a strong kinetic empathy in the viewer. The colors alternate between cerulean blue, Mars red, rose madder, and black. A sense of tension and vertigo is established through manipulation of form and motion from screen to screen, while simultaneous color changes create their own "narrative" in still another nonverbal dimension.

GENE: What particular aesthetic, if any, did you follow in making this film?

JOHN: When I was eighteen I was drawn deeply into Eastern thought, Jungian psychology, the subconscious. When I think about the time when I made that footage—trying to understand what happened—I became merely an instrumentality in tune with a force, a creative energy force which expressed itself. I was able to make the films without thinking too much about what I was doing. There was just this continuous flow of energy between me, the machine, and the images. But the machine became transparent. I don't think I was conscious of any systematic manipulation or exploration of a geometrical theme, though it is undeniably in the film. I was able to be sort of comprehensive when I was making the images, whereas when I made the machine I had to be a mechanical engineer, an electronics engineer, and an optical engineer.

The relatively rectangular imagery of the previous sequence now becomes a series of ornate, almost baroque, circular forms, floral patterns, and interconnected rings, all moving inward at various rates to vanish as other rings appear, and so on. The colors at this point are extraordinarily florid, ranging the entire spectrum in kaleidoscopic brilliance and mosaic complexity. The images at times

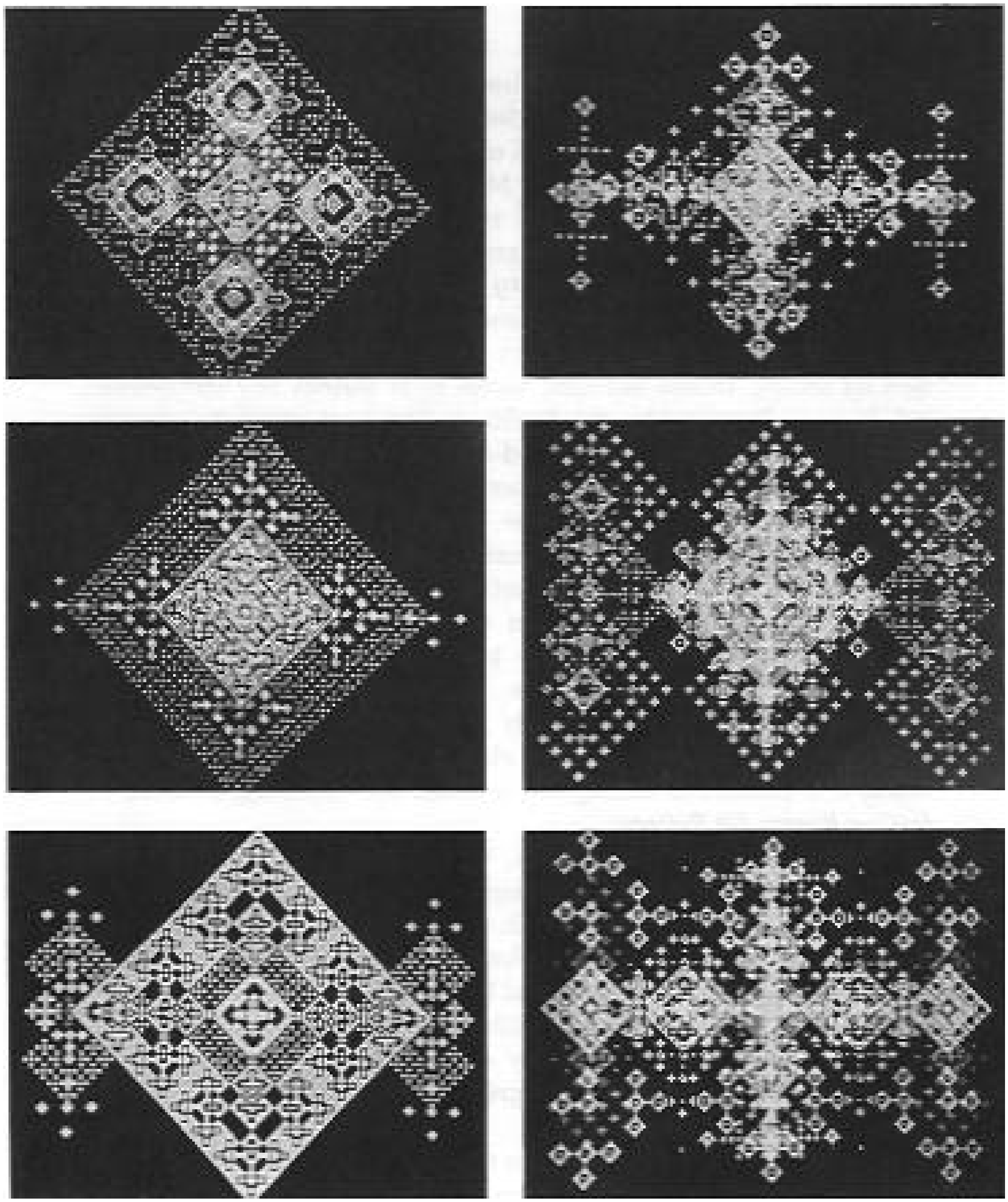
John Whitney, Jr.: Untitled. 1967.16mm. Triple-projection. Color. 17 min. "A sense of vertigo is established... the images at times resemble gears, flowers, cosmic configurations..." Shown are two three-screen "frames" from the film.

resemble gears, flowers, cosmic configurations, and dancing optical ellipses.

There is a brief pause and the second portion, or "movement," of the film begins. Throughout this section the center screen explores variations on the square, the circle, and the triangle while the flanking screens run through a dazzling repertoire of optical effects. These include mandala-like configurations around which sweep bright fingers of light in mauve and violet, bouncing curvilinear dish-shapes, starburst clusters, and clocklike metronomes in flawless synchronization with the music. The archetypal mandala symbolism of "squaring the circle" assumes dominance in the final moments of the film as all three screens accelerate in a symphony of color, design, and motion.

Today John and Michael Whitney have become computer programmers, working with digital computers in addition to the computerized, hybridized optical printer and the analogue computer. Like John Stehura, whose work we shall discuss later, Michael Whitney is involved in formulating new computer-language systems specifically for graphics problems. He speaks of "graphic integrity," and of a visual language that would approach the purity and abstraction of music. Like his father and brother, he maintains that such a quantum leap in the manipulation of visual graphics is only now possible because of the digital computer and its unprecedented powers.

One of the first efforts toward this goal *is Binary Bit Patterns,* a dazzling exploration of archetypal geometrical configurations that approaches *déjá vu.* The film was made on a PFR-3 programmable film recorder manufactured by Information International, Inc., in Santa Monica, California. The PFR-3 is a specialized visual sub-system driven by the Digital Company's small PDP-9 computer. It is a hybridized microfilm plotting system built specifically for reading film into the computer or recording information on motion-picture film. There are 16,000 possible *xy* coordinate points on the three-inch face of the PFR-3's cathode-ray tube. Produced with a program developed by one of the firm's employees, Michael Whitney's *Binary Bit Patterns* provides a deep emotional experience despite the fact that it has less kinetic activity and less image variation than the films of his brother or father.



Michael Whitney: *Binary Bit Patterns.* 1969. 16mm. Color. 3 min. "Squadrons of polyhedral modules come pulsating out of a black void..."

Perhaps metamorphosis best describes the effect of this film, in which quiltlike tapestries of polyhedral and crystalline figures pulsate and multiply with some kind of universal logic. In effect, if not style, it is reminiscent of Norman McLaren's *Mosaic* and Brakhage's *The horseman, the woman, and the moth.* In the McLaren film, geometrical clusters of dot-patterns collect and multiply with mathematical precision. In *Binary Bit Patterns* there is the same sense of mathematical play although it is not as discrete as the McLaren film; shapes are always permutating into other shapes, and an ornate, almost baroque, visual style softens any mathematical dryness. It resembles the Brakhage film because of its approximation to what Stan calls "closed-eye vision," the patterns we see when our eyes are shut. These ornate snowflake crystals flash and multiply before us with the same kind of ghostlike evasiveness as the colors that flicker across the retina of our mind's eye. Squadrons of polyhedral modules come pulsating out of a black void, growing and multiplying until the screen is a tapestry of intricate, ever-changing image-color fields. The impact is enhanced considerably by an extraordinary guitar-tape composition by Whitney and Charles Villiers. Michael not only talks about music, he composes and plays it on acoustical and electric guitars. As with Belson's work, it is difficult to distinguish whether one is seeing, hearing, or feeling *Binary Bit Patterns.*

Even without sound, however, the film is extraordinarily hypnotic. The boys speak of such imagery as possibly developing into a kind of "kinetic wallpaper," which could be rear-projected onto the translucent walls of a room at close range in ultra-high resolution using large format film and special lenses. One would live in a home whose very walls were alive with silent kinetic activity—not the shallow flickering of present-day color organs but rather "visual music" of the highest graphic integrity and psychic relevance.

GENE: Do you think of the future in connection with computers?

JOHN: Well let's divorce the future from technology and talk about human values. I see the nature of things today in the world and there seems to be a strong force of discontent and evil. And I wonder how can there not be some counterbalancing force, something that can apply itself to the spirit of man? And I begin

The Whitney brothers. *Left to right:* John, Jr., Mark, Michael. Photo: Gene Youngblood.

to think about what is the meaning of the film work I'm doing? I believe it's possible that an inadvertent spin-off from technology will transform man into a transcendental being. There isn't much we can conceive now that can give us a clue to how it will come about. But I suspect that vision will play an important role. The eye will have a lot to do with it. It could conceivably be some external thing, which metaphysically will affect the mind and cause some transcendental experience. So with that in mind I've been thinking of ways to integrate the realist image into the nonobjective image so that a synthesis will evolve, a cinematic experience which might contribute to an evolutionary transformation of man's thought processes.

MICHAEL: It's very effective to use a realist image for its nonobjective values. You're using it for its form, and if the form happens to be human it's evocative and easily digested. The whole idea is to work with the imagery and to develop total and complete control through structuring, once you have the ability to control the problems with the equipment. Man has not yet learned to master tools that will express as much eloquence and latitude as his imagination.

JOHN: I'm not suggesting that the films as we know them today will be the releasing force. We don't know how to integrate realist and nonobjective images effectively yet. But I think our computerized optical printer will help show the way. The use of the realist image is just a basis, a starting point. Working with optical scanning you transform the images, and this seems to be a key to bringing nonobjective and realist imagery together. And why bring them together? Because it may lead to new insights and new experience.

GENE: What sort of new experience?

JOHN: Well of course I don't know. But I've been thinking about dreams. Why is it difficult for a person to understand his own dreams? Why don't people know what their dreams are telling them? Why does a person have to go to someone else—an analyst—to know about his own personal dreams, which someone else can't possibly understand? Why don't dreams reveal themselves to us naturally as part of daily experience? Now maybe this "new experience" I'm wondering about will be the point in evolution when man reaches that level of sophistication as a sentient being. I believe the analyst is serving a function now which won't be needed in the future. Everything we know now in the "rational" world will be subsumed in the new knowledge or wisdom of the future. I think parapsychology, extrasensory perception, and related phenomena certainly cannot be ignored as possibilities. So in terms of our film work, the only way it may have some relevance to future consciousness is through problems of formal design. Not the technical things we're doing, just the design problems. In other words, sparking an inner revolution through exterior manipulation. The high state we achieve through LSD or marijuana today is insightful to the extent that it may be similar to what man will feel on a daily basis in the future without exterior manipulation. This state has already happened in the East—not in the Occident because it's not part of our heritage— but it has happened with the Yogis and so on, and it's coming to the West through technology.

GENE: Perhaps this simultaneous awareness of inner and outer space is the beginning of that new experience you're talking about, John. A new attitude toward experience.

JOHN: And space. And time. And motion. And the speed of light.

GENE: The Uncertainty Principle becoming a certainty.

JOHN: So I've built this machine, which will be the cohesive force in our future work. We're amassing film. The machine will bring it all together and also will generate its own imagery. It's the beginning of an application of technology to an area where it's never been applied. Bringing together a whole number of disciplines. So, as sources of imagery we have the printer itself, we have the analogue computer, we have live-action films—which is where our brother Mark is proving very effective, as a person able to go out into the world and get something meaningful on film. And then Michael who, from his studies in physics and calculus, has some exciting ideas of ways to use a digital computer with images.

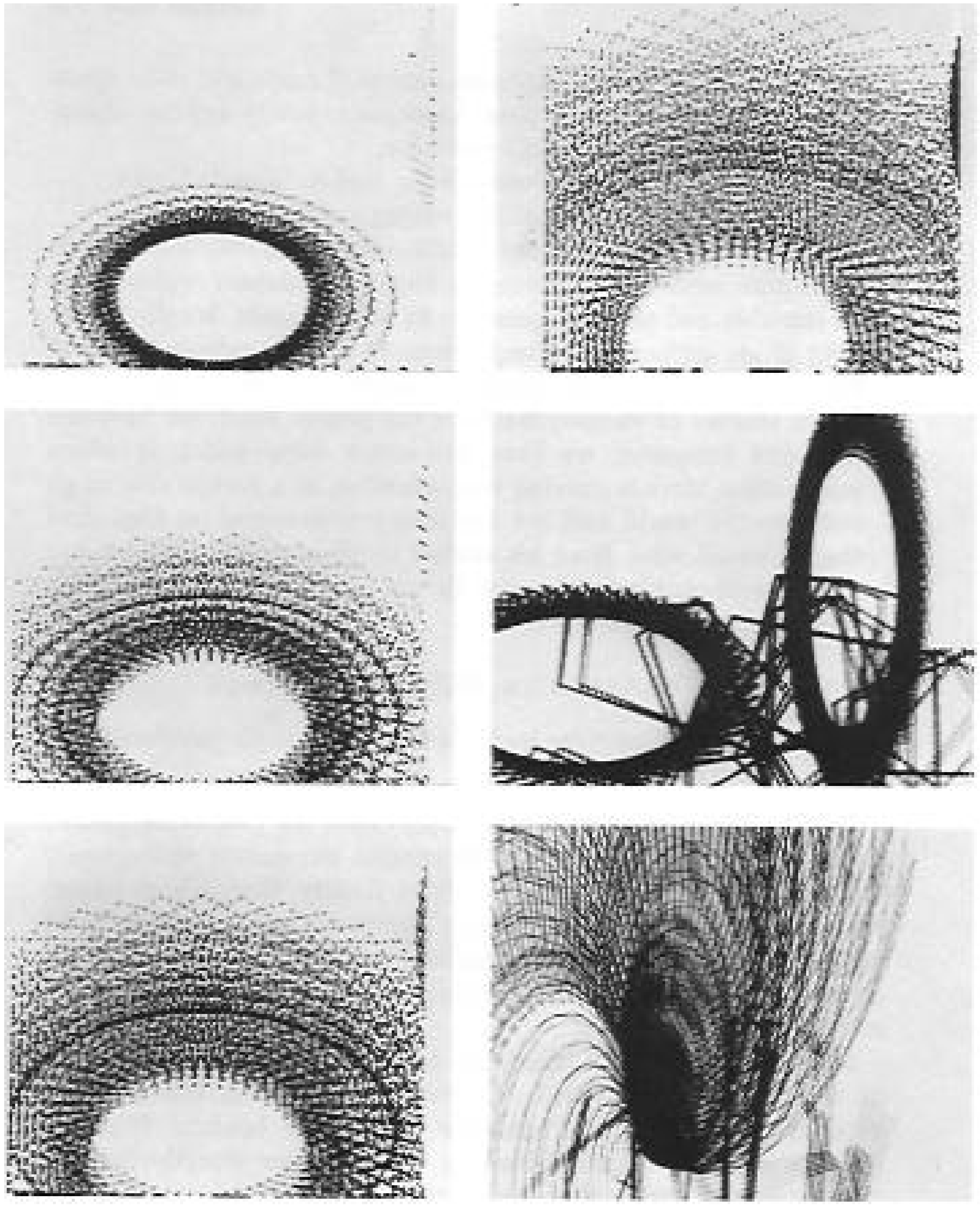
John Stehura: The Aesthetics of Machine Language

"Studying computer language leads the artist back to the paintbrush—but a computerized paintbrush."

John Stehura's spectacular film *Cybernetik 5.3* (see color plates) combines computer graphics with organic live-action photography to create a new reality, a Third World Reality, that is both haunting and extraordinarily beautiful. *Cybernetik* makes use of realist imagery for its nonobjective qualities and thus impinges directly upon the emotions more successfully than any computer film discussed in this book.

However, Stehura considers the film only an "incidental test" in an ongoing experiment with computer graphics that has occupied most of his time for the last nine years. Like Michael Whitney, Stehura is interested in addressing the computer directly through graphic images rather than using mathematics to achieve graphics and thus becoming enmeshed in a "number game."

Cybernetik is unique also in that it was constructed from semi-random image-generation techniques similar to Michael Noll's *Gaussian-Quadratic* figures. Whereas most of the computer films



John Stehura: *Cybernetik* 5.3.1965-69. 16mm. Color. 8 min. A series of basic image forms before the addition of color, showing random character of permutations.

discussed so far are characterized by mathematical precision, *Cybernetik* exudes a strong feeling for the uncontrolled, the uncontrollable, the inconceivable.

Stehura began studying computer programming at UCLA in 1961 when he was eighteen years old. He became quite conversant with computer languages and in 1965 programmed the first images that were to become the film *Cybernetik 5.3* in its completed version some four years later. It is the only computer film Stehura has produced so far, having spent most of his time developing a special "metalanguage," which he calls "Model Eight," designed specifically for modeling computer music and graphics systems.

Cybernetik originally was to have a computer sound track generated by the same program, but Stehura found the directly corresponding track inappropriate and later set the film to Tod Dockstader's *Quatermass,* a chilling otherworldly suite of organized electronic sound by one of America's least-known but most unusual artists. The result is a film strongly reminiscent of *2001* in the sense that it creates an overwhelming atmosphere of some mysterious, transcendental intelligence at work in the universe.

Throughout the film, complex clusters of geometrical forms and lines whirl, spin, and fly in three-dimensional space. Showers of parallel lines come streaking out of infinity. Crescents and semicircles develop dangling appendages and then expand until they no longer exist. Whirling isometric skeletal structures permutate into quadrant figures, polygons, rotating multiple-axis tetrahedrons, expanding fanlike disks, and endless coils.

These images are neon-bright in alternating blue, red, orange, and green. They vibrate rapidly as they take shape and disintegrate. The staccato, spiraling, buzzing rumble of Dockstader's sound complements the kinetic activity with its own sense of acoustical space. This storm of geometrical fantasy is superimposed over a star-spangled image of the solar system in emerald green.

STEHURA: I programmed *Cybernetik* in Fortran, and specified about twenty fields so that images would metamorphose into other orders of design. In writing the program I defined a "field" as a point in space having a certain effect on anything entering its area. For example, the sun is a field. That was the basic idea. I made them very specific. I said when the image gets near this mathematical point it will either get brighter, or darker, or be altered in such and such a way, like enlarge, or burst into points, or diminish into infinity. So that's the reason for the randomness. When the images go into the metamorphosing fields, their mathematical order, while specified, becomes too complex and appears to be random. Once all the rules in the program were specified, I simply turned it on to see what would happen. If I liked the results, I'd leave it. At one point I tried to trace back how the computer generated certain forms but it was becoming too complex and pointless.

GENE: How were the color separations and superimpositions programmed?

JOHN: The basic imagery was computed on an IBM 7094 digital computer at UCLA before we had any type of on-line graphic display equipment. So I ran the computer for seven or eight hours and took the digital tapes to General Dynamics in San Diego where they had a Stromberg-Carlson 4020 Microfilm Plotter. Initially I specified how many movies I wanted and how long I wanted each one to be. The program indirectly specified color based on the form or position of a figure. The output went onto three plot tapes which were converted into three pieces of black-and-white film. These pieces were used to mask primary colors in a contact printer. There was a piece of black-and-white film to represent the color red, a piece to represent the color green, and one for blue. Then I processed that footage with the contact printer for the colors specified.

A fascinating aspect of this film is that it traps the viewer into expecting mathematically logical transformations by developing in that manner for several minutes, and suddenly the forms explode or behave quite unpredictably. Once this effect has been fully explored, the solar system fades into a fish-eye image of people's faces and other representational imagery distorted, however, almost to the point of nonobjectivity. This sequence is printed in high-contrast, bas-relief positive-negative color reversals, in the manner of Pat O'Neill's *7362*. In addition, the images are speeded so that a frenetic, visually distorted atmosphere is generated, suggesting extra-terrestrial creatures or anthropomorphic entities. The whirling multicolored geometrical images move across this bizarre background as though one were peering into a new dimension of existence. Dockstader's organized sound reaches a crescendo of chaotic dissonance as the final images of the film fade and disintegrate into nothingness. The sense of dynamic kinetic activity has been so powerful that this abrupt halt leaves the viewer suspended and breathless.

STEHURA: In writing programs in computer languages such as Fortran I've worked with about five parameterized models with which you can specify designs numerically. One is the "mosaic" scheme, which is the style developed for the Beflix language. You're building things with squares. Your basic figure is the square and you're building patterns and shading things with squares. The result is a mosaic pattern with chains of alternatives. The second scheme is the field model which I used for *Cybernetik,* in which you set objects or points in space and by controlling the strength of fields you produce image forms. A third scheme is a mathematical model of your arm as it would be used to draw figures. You define angles, specify arcs and curves, and work within those parameters. The fourth scheme I worked with is based on the deflection principle. Your mathematical model is patterned after a room or enclosure into which a ball is fired at high speed, bouncing from wall to wall. You plot paths of the trajectories, angles of deflection, distances traveled, the shape of the environment in which the projectile is moving. All this is simulated mathematically and was interesting because it presented form as the space between objects or containers. Finally there's the scheme I call "masking," which is similar to the idea of mattes in conventional filmmaking. The basic idea here is that you don't have a positive figure you're drawing, but you have masks or shapes which hold back light. You define a form and its motion, and you use that form to contain or exclude another image. It's like a cutout or translucency. You can treat computer graphics in that way.

GENE: Where has all this experimentation led you in terms of using the computer as an artistic tool?

JOHN: I discovered that working with program languages to produce graphics is rather hopeless. They're really designed for playing with numbers. A general problem with computer languages is that you get into simulating reality. That's the trip physicists and meteorologists are into. It's close to their way of thinking and their problems, but I think it's a waste of time in computer graphics or music. My explorations in computer language led me back to conventional animation, back to the paintbrush—a computerized paintbrush. So the next level, after playing with these language or parameter systems, was to establish another level of control over the computer. The idea of building a metasystem or a control system to control control systems appeared very interesting to me. So over the last four years I've developed a metalanguage which I call "Model Eight" since it's the eighth approach to these systems. It consists of a set of operators to work on one-, two-, or three-dimensional patterns: sensory patterns, music, drawings, motion, and so on. It's not a computer language which is operated one point at a time, but rather functions nonsequentially on large blocks of data. My idea was to develop a language which would synthesize all the schemes I mentioned earlier so that, for instance, in terms of work involved, whereas it took a couple of years to devise "Model 5.3" to make *Cybernetik,* my feeling was that it could be done in a couple of hours.

GENE: What sort of input-output situations are involved?

JOHN: Well, the two input systems I've found most advantageous are the optical-scanner and the light pen, drawing directly on the CRT. I have three modes of operation with the scanner: first, a point-by-point scan like a television scan starting at one corner and moving across, and you get a list of intensities which describe a picture, or just certain areas or colors. You can label it and manipulate the whole thing or just that part. Second is an *isoline* type of scan, which is what you see in weather maps: circles within circles which indicate certain degrees of intensity and so on. Then, third, there's the situation in which you start out with an isoline approach but produce lines which fill certain areas, and that output can appear on the CRT or be further modified.

GENE: What about drawing with the light pen? I understand that some artists, like Norman McLaren, have found this rather unsatisfactory.

JOHN: Well, the light pen is a crude drawing instrument, it's true. You can't do many subtle things, the resolution is low, and the way you operate you're always stopping, waiting for "INTERRUPT," for the computer to accept your line, or the accuracy always seems to be off, but it does have certain advantages related to large-volume image production. One of them is that you can input information that's more specific to the way the computer's operating. You put in a point or a line at a time, and by remembering what you're doing you can control a lot of image transformations. Representational forms are almost impossible to program with computer languages, and are extremely difficult for a computer to process. But by taking the alternate route, by drawing representational forms with the light pen you've given the computer graphic information which can be simply transformed according to simple motion and shading procedures. If you want to draw a dragon, for example, and have it transformed into a person, you simply draw the head and type in "HEAD" and then you draw the head of the man and label it "HEAD" and the computer operates on it to do the transformation. You can label portions as you draw to control the flow of the transformation. You can transform anything you can draw into anything else. And in this way you bypass much of computer language specification.

GENE: What relationship does "Model Eight" have to all this? What is the control situation?

JOHN: Drawing is a specific operation just as scanning or projections. With the language aspect you can specify a fish-eye projection or a projection on a certain plane and you supply the parameters. Now, after I've passed an image through a simulated fish-eye projection, what I want to do is start shading the forms in a different style. So you could call on a surfacing operator which will fill in your image with colors or mosaics. Now, my language isn't fixed. One "word" doesn't mean one fixed thing in one fixed context. For example, you have a mathematical model of an arm movement and you tell the computer to swing the arm in a 360-degree arc to define a circle. The basis of this operation is a sine wave to produce the smooth circular form. The fact that you have a sine wave is specified, even if by default. The output of this operation is a circle, a set of points. And as far as I'm concerned it's a wave form just as legitimate as the sine wave. So you could run this form back into the same particular operator and tell the computer to use this form—not the sine or cosine, but this form it has just described. The same recursive form applies to the other operations. For instance, you could take projections of projections, use an object as an element to shade a surface and so on.

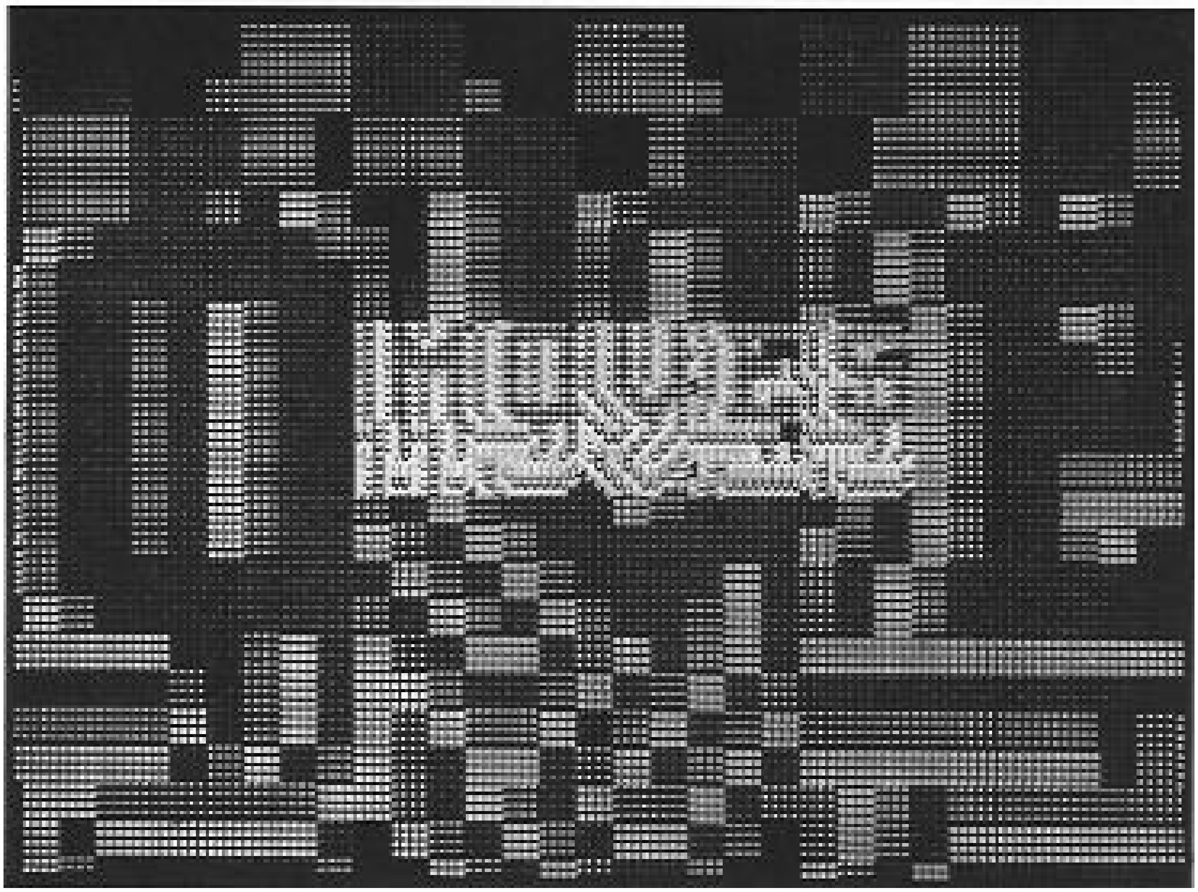
Stan VanDerBeek: Mosaics of the Mind

"We're just fooling around on the outer edges of our own sensibilities. The new technologies will open higher levels of psychic communication and neurological referencing."

For the last five years Stan VanDerBeek has been working simultaneously with live-action and animated films, single and multiple-projection formats, intermedia events, video experiments, and computer graphics. Clearly a Renaissance Man, VanDerBeek has been a vital force in the convergence of art and technology, displaying a visionary's insight into the cultural and psychological implications of the Paleocybernetic Age.

VanDerBeek has produced approximately ten computer films in collaboration with Kenneth Knowlton of Bell Telephone Laboratories in New Jersey. They are descriptively titled *Poem Fields, One* through *Eight,* plus *Collisdeoscope* and a tenth film unfinished as of this writing. The term *Poem Field* indicates the visual effect of the mosaic picture system called Beflix (derived from "Bell Flicks") written by Knowlton. A high-level set of macro-instructions was first written in Fortran. The particular translation or definition of this language for each film is then determined by the subroutine system of mosaic composition called Beflix. A new set of Beflix punch cards is fed into the Fortran-primed computer (an IBM 7094 interfaced with an SC-4020 microfilm plotter) for each new movie desired.

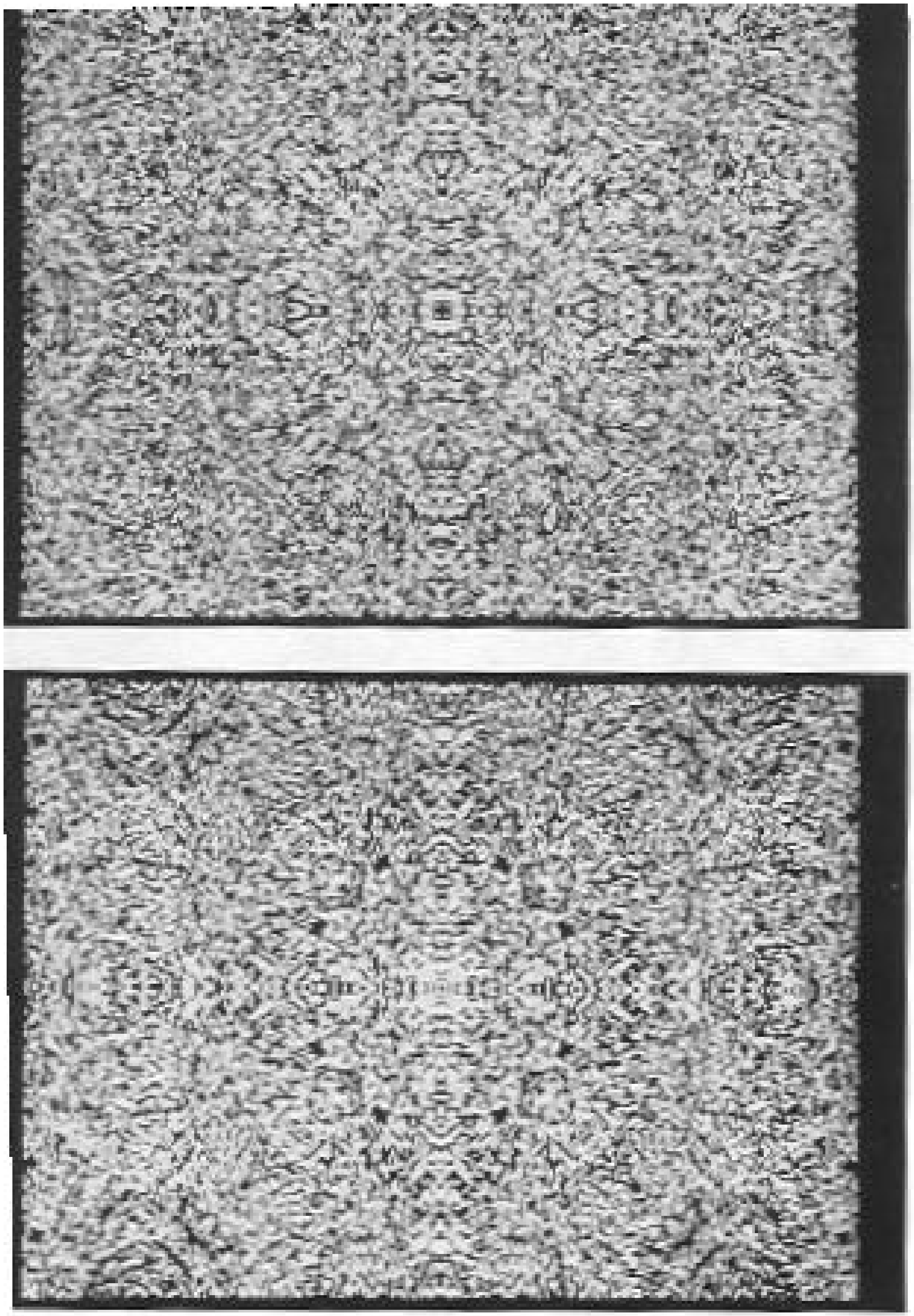
Whereas most other digital computer films are characterized by linear trajectile figures moving dynamically in simulated three-dimensional space, the VanDerBeek-Knowlton *Poem Fields* are complex, syncretistic two-dimensional tapestries of geometrical configurations in mosaic patterns. "The mind is a computer," says



Computer interpretation of the word "movies," from a film by Stan VanDerBeek and Kenneth C. Knowlton.

VanDerBeek, "not railroad tracks. Human intelligence functions on the order of a hundred-thousand decisions per second." It appears this brain capacity was a prime motive in the production of the *Poem Fields,* whose micro-patterns seem to permutate in a constant process of metamorphosis which could very likely include a hundred-thousand minuscule changes each second.

"The present state of design of graphics display systems," VanDerBeek explains, "is to integrate small points of light turned on or off at high speeds. A picture is 'resolved' from the mosaic points of light." The artist seems to feel that this process bears some physiognomic similarities to human perception. "The eye," he notes, "is a mosaic of rods and cones."



Variations of the Beflix technique of mosaic image-making, from computer films by Stan VanDerBeek and Kenneth C. Knowlton.

The early *Poem Fields* were investigations of calligraphic relationships between dogs and alphabetic characters integrated into fields of geometrical patterns constantly evolving into new forms. The most famous of these is *Man and His World* (1967), a title piece for an exhibit at Expo '67.

Variations on the mosaic field became more complex with successive experiments, until simulated three-dimensional depth was achieved in the form of infinitely-repeated modular units in perspective. It is immediately obvious that these films would be prohibitively tedious and time-consuming to do through conventional animation techniques. "Because of their high speeds of calculation and display," writes Knowlton, "the computer and automatic film recorder make feasible the production of some kinds of films that previously would have been far too expensive or difficult. In addition, the speed, ease, and economy of computer animation permit the moviemaker to take several tries at a scene—producing a whole family of film clips—from which he chooses the most appealing result, a luxury never before possible."[27]

The more recent Beflix films have abandoned the original calligraphic patterns for highly complex Rorschach constellations of stunning beauty. They actually began with a film produced by two other scientists at Bell Telephone, B. Julesz and C. Bosche, for use in experiments with human vision and perception. This involved semirandom generation of graphic "noise," whose patterns were reflected several times to produce intricate mandala grids resembling Persian carpets and snowflake crystals.

"We're now working with variations on the Beflix system that involves secondary systems," VanDerBeek explained. "It goes through two levels: first Beflix, then computerizing and quantizing that level. It's something similar to what Ken Knowlton and Leon Harmon did with pictures-within-pictures. We're trying to do that cinematically."

The *Poem Fields* are filmed in black-and-white, with color added later through a special optical process that permits color gradations and increments almost as complex as the forms themselves.

[27] Kenneth C. Knowlton, "Computer Animated Movies," *Cybernetic Serendipity,* a special issue of *Studio International,* ed. Jasia Reichardt (London, September, 1968), pp. 67-68.

Peter Kamnitzer: Pre-Experiencing Alternative Futures

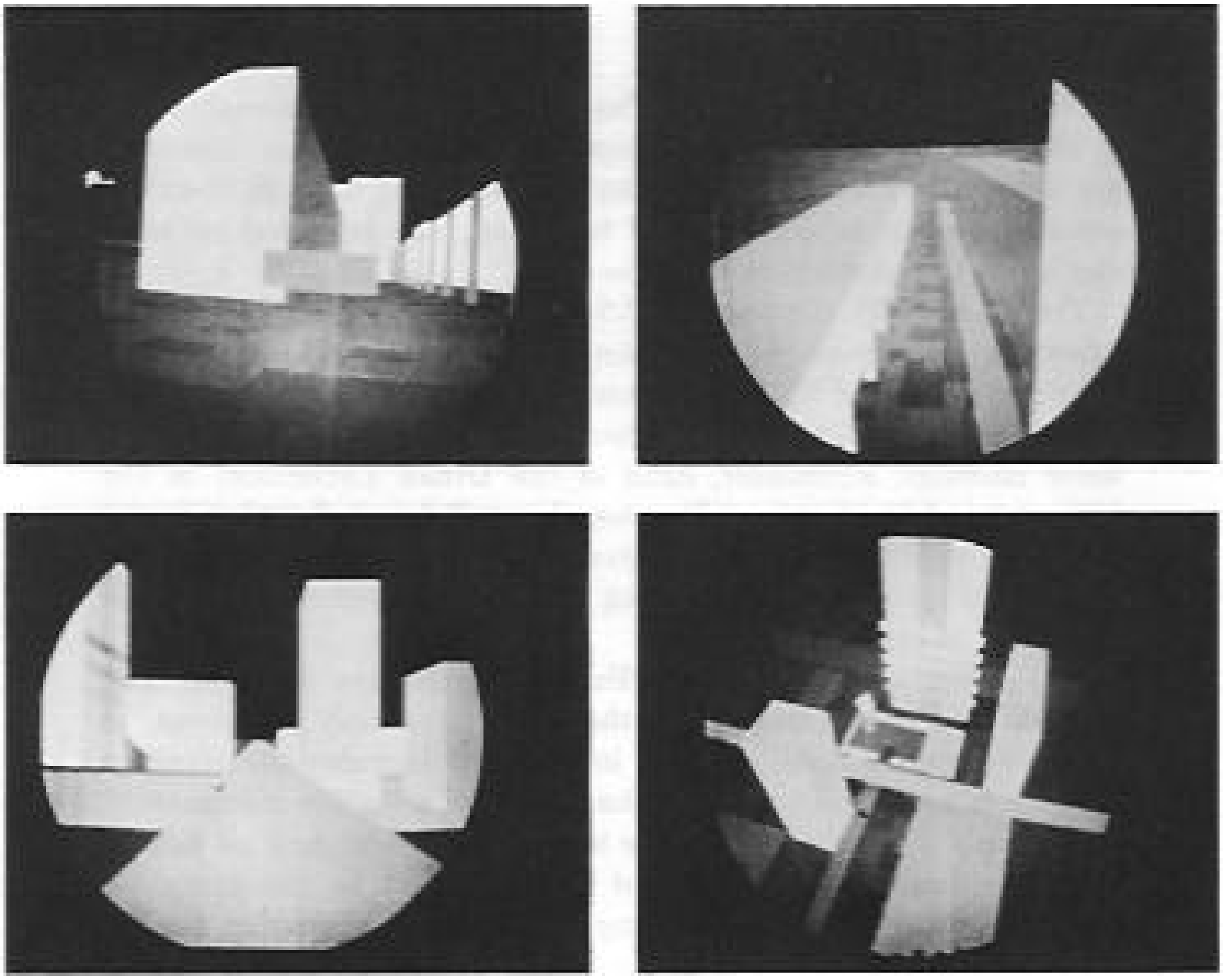
"We would like to put the researcher, designer, decision-maker or the public at large in an environment where they could be exposed to what various futures may look like. We will do this with computer simulation, which I believe will trigger the next creative leap in the human brain."

So far we have restricted our discussion to the computers and computer output subsystems most likely to be accessible to the filmmaker with luck. Furthermore we have been concerned primarily with purely aesthetic applications of these techniques, or what I like to call "computer art for the computer's sake." The limitations of these systems should be obvious by now.

We have seen that in order to obtain computerized representational imagery it is necessary in most cases to begin with some sort of representational input (physical scale models or photographs, etc.), which are then scanned or translated by the computer through optical-pickup devices, servo-driven television cameras or film-storage systems. In fact the most spectacular films discussed so far—*Lapis, Cybernetik 5.3, Permutations,* and the Whitney triple-screen film—were heavily augmented through conventional film-processing techniques.

Furthermore, the impact of these films is wholly visual or experiential, with conceptual appreciation of the computer's role reduced to a minimum. If we can say that a conventional film is "cinematic" only to the extent that it does not rely on elements of literature or theatre, we must therefore say that a computer film is not fully "computerized" until it is relatively free from conventional film-making techniques.

With this in mind we might better appreciate Peter Kamnitzer's *City-Scape,* a film in which no representational imagery existed before it was produced by the computer. The computer drew the city strictly from coded mathematical input in the same way that the Whitneys' geometrical forms are generated from polar equations. The software and hardware requirements to achieve this, however, are extremely sophisticated and expensive. Viewed merely as an animated film, *City-Scape* leaves much to be desired. Compared to *Yellow Submarine,* for example, it is like the earliest tintype



Peter Kamnitzer: *City-Scape.* 1968. 16mm. Color. 10 min. Made at the Guidance and Control Division of NASA's Manned Spacecraft Center, Houston, Texas. Four views of the imaginary city.

compared to laser holography—on a purely visual level, that is. But *City-Scape is* deceptive. First of all, it is not an animated film in the sense that most of the computer films we've been discussing are animated. The color CRT display, produced through electron-scanning similar to conventional television, was recorded on color movie film in real-time, on-line operation.

The $2,000,000 computer, NASA II, and its visual simulation subsystem was developed by General Electric for the Guidance and Control Division of NASA's Manned Spacecraft Center in Houston. It has been used for more than ten years to simulate conditions of lunar landings. Kamnitzer, head of the Urban Laboratory at the University of California at Los Angeles, collaborated with GE and NASA for nearly two years to convert the equipment into a tool that also would allow pre-experiencing of possible environmental situations here on earth.

It is rather unlikely that any filmmaker will have access to such sophisticated equipment for aesthetic purposes only. However, as we have seen, the notion of "art" increasingly includes ultrasensitive judgments as to the uses of technology and scientific information. Consciously or unconsciously, we invent the future. And all futures are conditional on a present that is conditioned by the past. One way to be free of past conditioning is to simulate alternative futures through the fail-safe power of the digital computer. This is "art" at the highest level ever known to man, quite literally the creation of a new world imperceptibly gaining on reality—but not so imperceptibly as before.

A film like *City-Scape* adds still another dimension to the obsolescence of fiction. Whereas Stan Brakhage transcends fiction through mythopoeic manipulation of unstylized reality, Kamnitzer creates not myths but facts—obscuring the boundaries between life and art with a scientific finality unequaled in subjective art. Optimum-probability computerized visual simulation of future environments is not limited to economic, social, or political motivations. The possibilities for purely aesthetic exploration are revolutionary and have yet to be attempted. *City-Scape is* the first step toward that future time in which artists not only will be the acknowledged legislators of mankind but literally will determine the meaning of the word "man."

In programming *City-Scape* Kamnitzer was limited to two hundred and forty edges, or points where tangential planes intersect. Since an architectural edifice normally has only twelve edges, the city could have only twenty edifices. However, rather than having only square boxes, Kamnitzer programmed vertical pilasters and horizontal lines to generate a sense of scale per floor. The necessity of at least two freeways and one tunnel reduced the city to approximately five or six buildings. This information was input to the computer not as a drawing to be scanned, but as mathematical equations of perspectives describing the transformation of a numerical model of a three-dimensional environment onto a two-dimensional display or image plane.

The real-time solution of these equations produced a color CRT display with six degrees of freedom, unlimited dynamic range, true perspective, controlled color and brightness, and infinite depth of focus. With three simple control mechanisms Kamnitzer, seated before the twenty-one-inch screen, was able to: (1) stop and start the forward motion of the "vehicle" moving through the city; (2) control the direction of movement over and under bridges, through tunnels, around corners, etc.; and (3) control visual direction so that, while the vehicle may be moving north the "driver" may look northeast, south, or in any direction without affecting his forward motion.

Because the environment is stored digitally in the computer's memory a true "environmental" sense is created. That is, the operator-driver may move into the city and, after passing one or two structures, may decide to turn around and view what in effect has been "behind" him or otherwise out of range of the CRT display. This is done instantly, with the operator manipulating a lever as the CRT draws a new perspective in color every twentieth of a second. In addition, the operator-driver may enter closed spaces, fly into the air, and pass or "crash" through environment surfaces—without damage, of course, because the crash is only simulated.

Although *City-Scape is* a color film we have not used color illustrations for two reasons. First, the color is not intended as an experience in itself, an exploration of color effects as in *Cybernetik* or the Whitney films, but rather as a means of distinguishing the structures within the city—i.e., the yellow freeway, the blue freeway, the green mall, the gray building, etc. Second, as we already have noted, a great deal of image quality is lost when color television displays are recorded on color film; the result is a pale washed-out image neither so brilliant as the original phosphor, nor so intense as optically-printed color.

As the film begins we are rushing toward the city's skyline against the horizon surrounded by a vast green plain. Once into the city, various types of movement and positions are simulated: circling around the central mall area, driving up freeway ramps and along freeways, riding up and down in an outdoor glass elevator, walking down corridors of buildings, looking out windows, flying above the city in a helicopter that takes off and lands from a skyscraper heliport, the simulation of a drunk driver and his crash into a swimming pool, and finally moving through a solid mass, which the computer translates as a tunnel-like experience.

Only a few minutes have passed before a strong sense of location and environment is created, and the viewer begins to remember positions of structures not on the screen. One actually begins to feel "surrounded" by this city, though viewing it as if through a porthole. The true three-point perspective invests the image with a sense of actuality even stronger than in some conventional live-action films. Kamnitzer relates: "The on-line experience, the sense of power of sitting at the controls, is something very hard to describe. You are turned on. You are involved." It is an extremely close interaction between man and machine. The drunk-driving sequence—in which the "vehicle" swerves and careens through streets before plunging into an empty swimming pool—was done specifically to illustrate the immediacy and plasticity of the computer's reaction to the instructions of the operator.

Kamnitzer considers *City-Scape* a documentary of the possibilities that now exist for an Urban Simulation Laboratory. The concept is, in the absence of an ability to experiment with real people in real cities, to create a simulated environment in which people can pre-experience alternative futures. Kamnitzer's method incorporates the use of conventional mathematical models, man-gaming or operational gaming to simulate the decision environment, and the computed visual simulation subsystem to formulate what Kamnitzer calls "the total question of *if then,* the key to all decision-making."

The metalanguage that Kamnitzer has designed to facilitate this activity is called Intuval, derived from intuition and evaluation. Professor Kamnitzer considers Intuval to be an "answer" to the optimization attitude toward the computer. "What we are doing," he says, "is very different from people who want to use the computer to optimize for them and thereby the computer provides the answers. I am using the visual simulation subsystem to trigger the next creative leap in the human brain, and therefore I consider my approach very different from the usual rush into data banks and optimization. If used in an experientially meaningful manner the computer can provoke the next creative leap, while in my opinion the reading of charts, books, monographs, and statistics does not lead to a creative advancement. Books are being written every day, the libraries are full, the data banks are going to burst, but the decision-maker does not have access to this information when he needs it, in a form that is meaningful to him at this moment.

"I make the outrageous claim that creative innovation can only come from gut knowledge. It cannot come from something that remains purely in the cerebral area. I would even go so far as to say that what we are unable to explain to an intelligent thirteen-year-old, we do not know. So this leads to on-line visual displays and the total question of *if then,* the key to all decision-making. Now I can get information in graphic form of course, but then comes the moment when I want to know *if then.* If I should decide to choose alternate 'B' then these and these and these things will happen. But what if I had chosen alternate 'G'? And so on. So you see the intuitive approach has suffered badly in the past because of its lack of instant evaluation of what is strong and weak in your intuition. The Intuval system I've devised provides the designer or researcher with this instant evaluation. It is not simply a visualizing and pre-experiencing tool.

"It works in the following manner. First we have a hunch or an intuitive idea and we create an environment. Next, through the visual simulation subsystem we experience this environment both from the viewpoint of the designer and the user. And of course we will discover weak points and strong points in the environment so, with the stroke of a light pen, we can change it. We find out where the weakest spots are, we ask the computer to provide the parameters which define this weakest link, we will be shown graphically, then we will change the design and get a second evaluation, which now hopefully will have improved that factor, but we may have lost in another factor. We then again inquire what are the parameters which determine this weakness and so on, evolving into an interactive process.

"There are people who have built fascinating mathematical models, people who do man-gaming and operational gaming, people who experiment with physical-environment simulation in domes and so on, but I do not know of any attempt to bring these disciplines together in an Urban Simulation Laboratory to pre-experience alternative futures and even to pre-experience the inter-action of human beings in a future environment. In this way we can be exposed to what various futures may look like, feel like, and also what they would cost economically, socially, psychologically, and every other way.

"Now for *City-Scape* I was limited to 240 edges. We now realize that with another few million dollars next time we could increase the number of edges from 240 to 1500, and we also could create textures which could, for example, give you the equivalent of a glass wall on a building which would not come out of the 1500 edges. We will also have the ability to collect all 1500 edges in front of the viewer at all times, having no 'invisible' or off-screen edges as in *City-Scape.* This would enhance the realistic detail of the simulation. Finally we will have hemispherical projection inside a globe, with real people interacting with the computed environmental situation. This is a long way off, but I've made it my life's work. We have Intuval, we have *City-Scape,* we have NASA II. It's a beginning."