A COMPUTER ANIMATION PRIMER

by Larry Cuba

jump into this world and doesn't know
where to begin, this book offers no
help.

As the review in Filmmakers Newsletter
concludes, "What is needed now, however,
is a guidebook to these processes that
is more graphic in its explanations---
one that an artist who wishes to employ
the computer as a means of expression
can use with as much ease as one would
use a pencil. An overview book which
covers the whole range of existing
systems by presenting them in a
comprehensible context. A book written
for the beginner, a textbook, if you
will... that introduces and explains
technical concepts as needed to
distinguish the types of systems extant
and the different procedures which
characterize their use. A book which
avoids the technical details like
whether a computer uses the BCD(Binary
Coded Decimal) or EBCIDIC code. Too
much or irrelevent information can be as
harmful as not enough. A book which
will lead the reader through a series of
techniques one step at a time with
examples from existing and accessible
films. There is clearly a need for such
a book. What follows is an outline
which could serve as the basis for it.

0.1 APPROACH

The basic problem is that the term
'computer animation' is being applied to
so many things. And a digital computer
is so general that it can be used at any
stage of film production for a variety
of purposes. To use music as an
analogy, a program can be written to
compose a piece of music by generating a
score which is realized by any number of
conventional acoustic and studio
techniques. Or a computer might control
some sound producing instrument like an
organ (or a loudspeaker). In this case
the program may be used to do nothing

more than read a previously written
score and 'perform' it. The difference
between the function of these two
computer programs is vast, but the
distinction is usually ignored by
calling both 'computer music'.

And so it is with graphics. So the
first step is to distinguish exactly
which functions are being performed by
the computer, which by some other
device, which by a computer programmer
and which by a film artist (if not the
same person).

To begin, we can divide up any system
into two parts: the controlling system
and the drawing system. The contolling
system is the computer itself and comes
in two basic varieties: analog and
digital. The drawing system (or
display) can be either electronic or
mechanical, and the electronic displays
are either raster scan or vector scan.
As distinctions like this continue, the
number of possible systems grows.

The system types can be charted on a
square grid by putting the controlling
systems down the side and the display
systems across the top. Then each box,
the intersection of a controller and a
display, represents a generic type of
system.

The structure of this book is derived
from starting with one system (chapter
1) and then progressing through the
chart adding new concepts and
distinctions in 'a linear fashion. The
discussion of each system type usually
includes thé following:
a) a film or videotape example,
b) a description of the process used to
create the example, including
c) the hardware and software features of
the system type in general and the
particular installation of the example,
d) a brief comparison with other
installations and systems of the same
type possibly with

e) film and videotape examples and
f) variations on the basic approach.

An extra chapter is devoted to
introducing basic concepts of digital
computers (chapter 3). In chapter 9,
systems are discussed which use more
than one of the basic techniques in
combination. This entire outline covers
only computer-aided image synthesis. A
similar approach (as Part II) could
follow on image processing.

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1.0 COMPUTER-MEDIATED DRAWING
    a. the drawing device
    b. the control system

1.1 SYSTEM #1 - COMPUTER: ANALOG; DISPLAY: ELECTRONIC
    a. Around is Around - Norman McLaren
    b. Oscillon - Ben Lapofsky
    c. Who Ho Rays - Stan Vanderbeek
    d.   ?   - Mary Ellen Bute

1.2 A CRT - The oscilliscope
    a. structure: deflection plates et al
    b. response to electronic signal: drawing capability

1.3 AN ANALOG COMPUTER - the music synthesizer
    a. structure: analog modules generate & manipulate electronic
        signals
    b. programming process: the patch (& knobs)
    c. patch examples: basic vocabulary of analog signals
        (sin waves, sawtooths, etc.)
    d. combinations: family of lissajous figures

1.4 RECORDING - Three Ways to Capture Image
    a. time exposure
    b. animation (storage tubes)
    c. direct (continuous: either just the movement of the beam
        or the line created when motion is sped up---persistence
        of vision and phosphor decay)
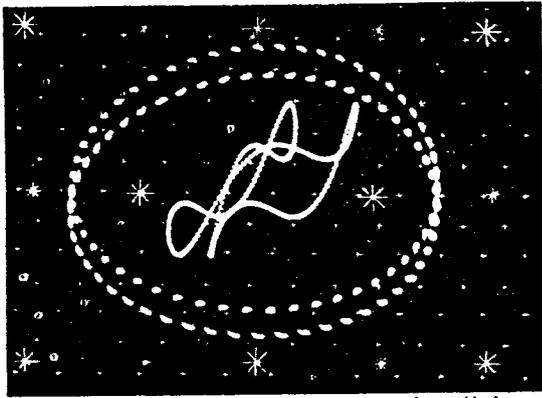
Around is Around

1.1.a. Around is Around - Norman McLaren
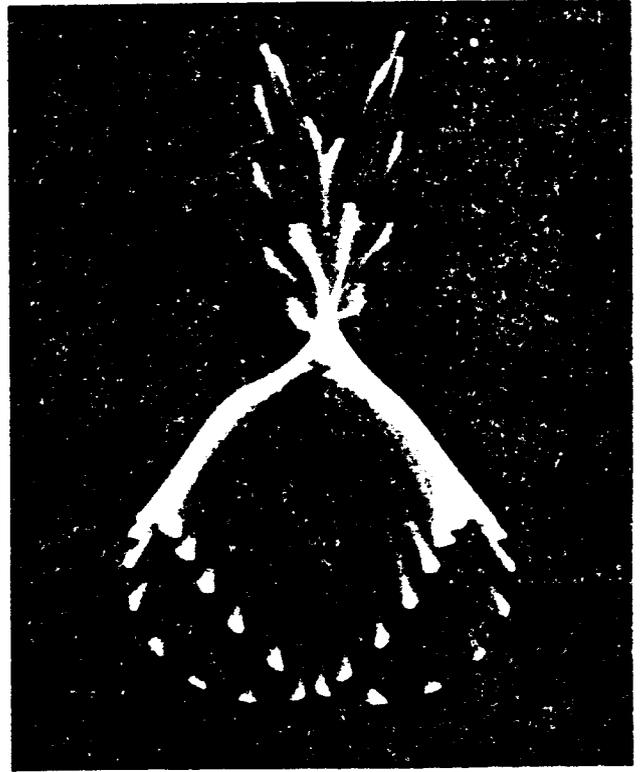
1.1.b. Oscillon - Ben Lapofsky

Mary Ellen Bute, around 1954. (Photo by Ted Nemeth.)

1.1.c. Who Ho Rays - Stan Vanderbeek

1.1.d. Mary Ellen Bute

LIGHTNING IN A BOTTLE:
THE CATHODE-RAY TUBE

A cathode-ray tube is actually a bottle filled with a vacuum and some funny electrical equipment. The equipment in the neck of the bottle shoots a beam of electrons toward the bottom of the bottle.

This beam of electrons is called, more or less for historical reasons, a cathode ray. Think of it as a straw that can be wiggled in the bottle.

Actually the bottle is shaped so as to have a large viewing area at the bottom (the screen), and this screen is coated with something that glows when electrons hit it. Such a chemical is called a phosphor.
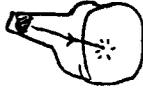
Now, two useful things can be done with this beam.

1) It can be made brighter by increasing the voltage, which increases the number of electrons in the beam.

2) The beam can be moved! That is, it can be made to play around the face of the tube the way you can slosh the stream of a garden hose back and forth on the lawn; or wiggle a straw in a coke bottle. The beam can be moved with either magnetism or static electricity. This is applied in the neck of the bottle-- or even from outside the neck-- by deflection plates, whose electrical pulsations determine the pattern the beam traces on the screen. (Note that the beam can be moved on the screen at great speed.)

The vertical deflection plates can pull the beam up or down on the screen, controlled by a signal to them.
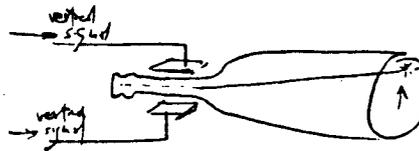
the horizontal deflection plates can pull the beam sideways on the screen, controlled by a signal to them.
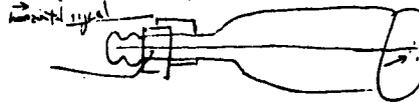
By sending combined signals to both horizontal and vertical deflection plates, we can make the end of the beam-- a bright dot on the screen, sometimes called a flying spot-- jump around in any pattern on the screen. A repeated pattern of the beam on the face of the CRT is called a raster.

From these two capabilities-- brightening and moving the beam-- a number of very special technologies emerge:

TELEVISION uses a zig-zag scanning pattern which repeats over and over. This zigzag pattern is always the same, night and day.

You can usually see the lines clearly on a black-and-white set. The picture consists of the changing pattern of brightness of this beam, which comes in over the airwaves as the television signal.
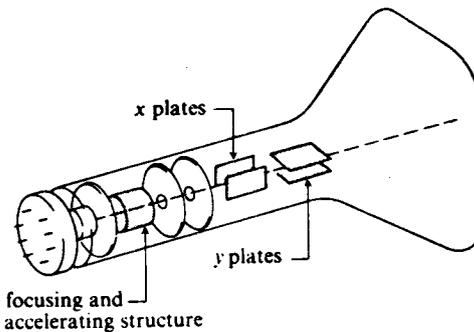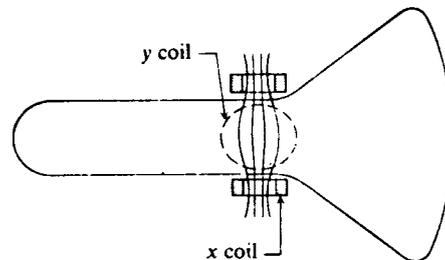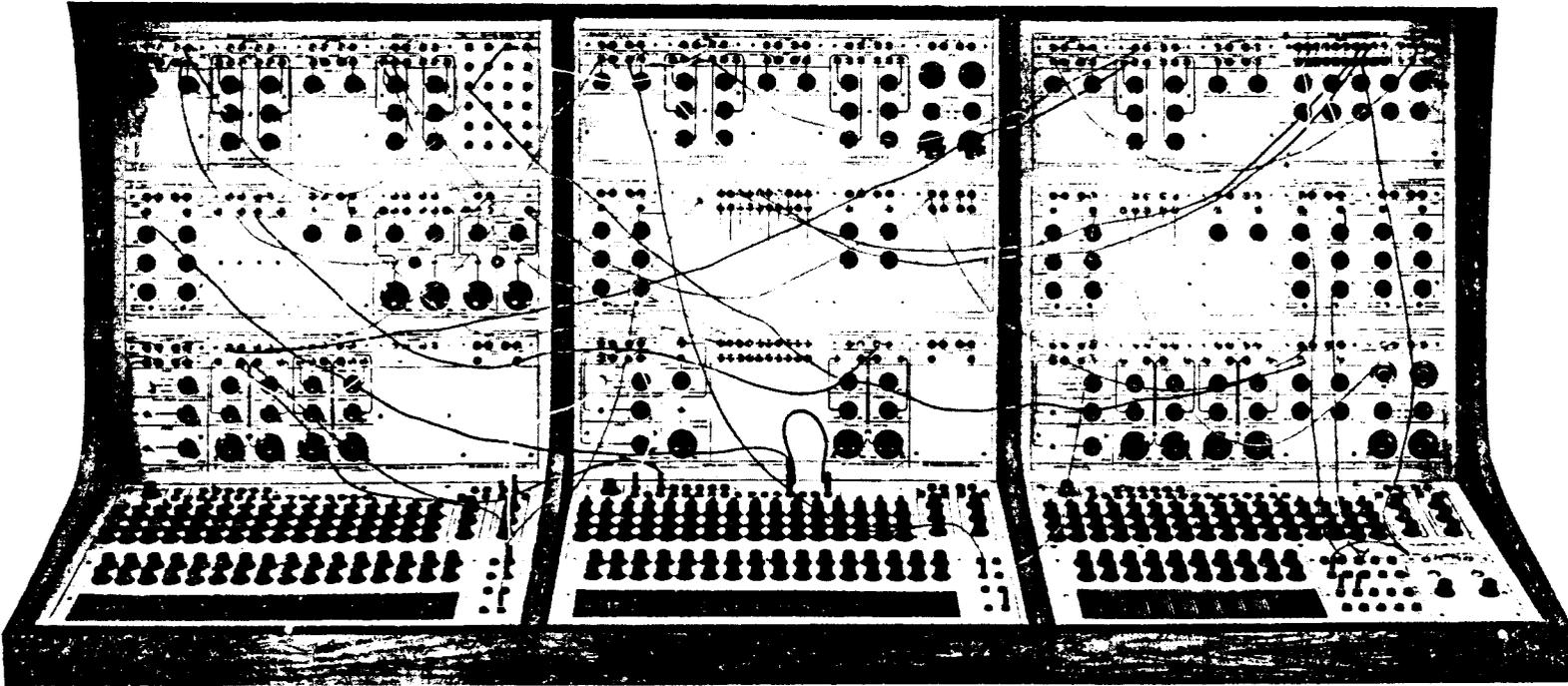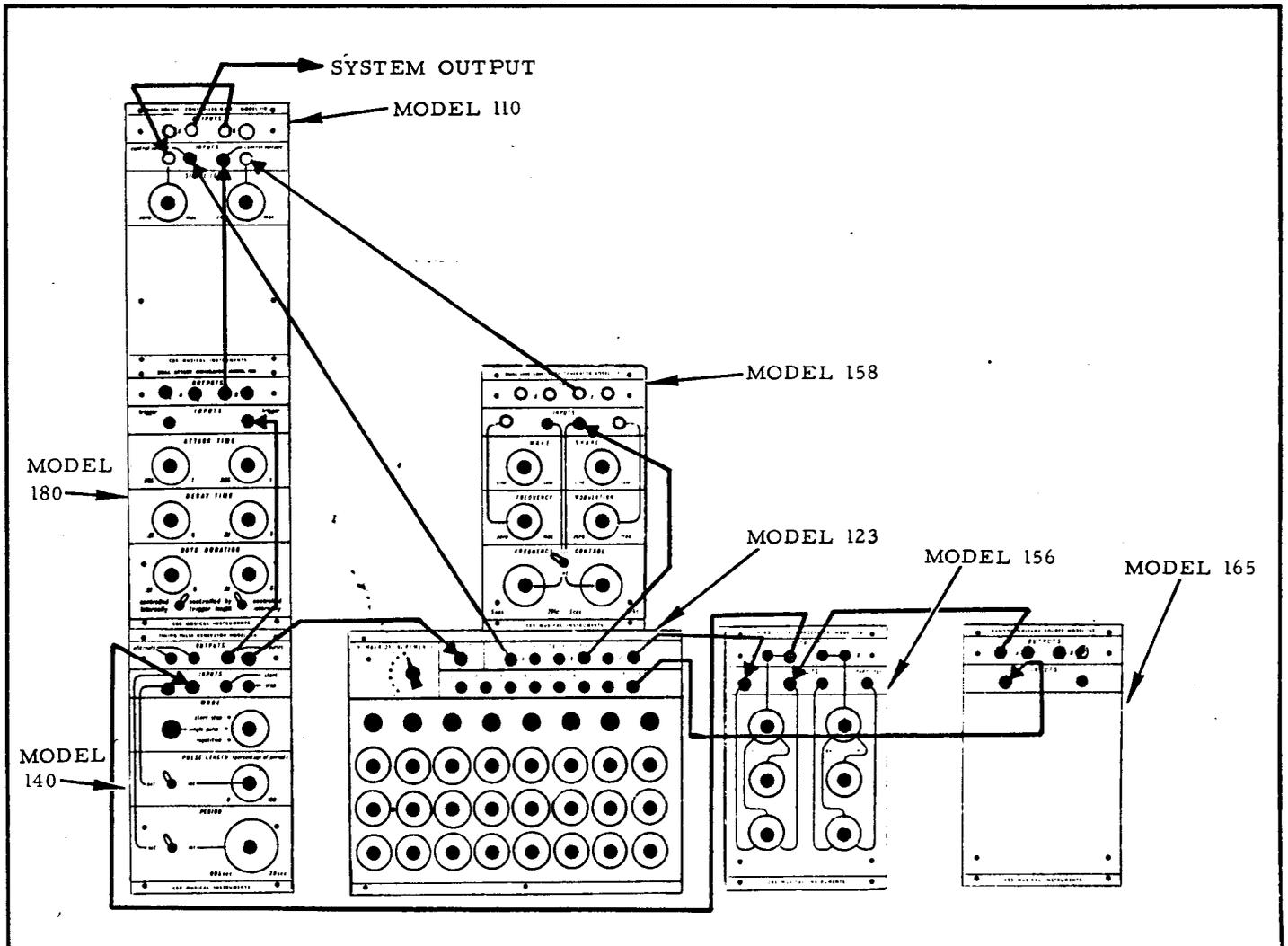
x plates
y plates
focusing and accelerating structure

FIGURE 1-12

y coil
x coil

FIGURE 1-13

1.2 A CRT - The Oscilliscope

1.3 An Analog Computer - The Music Synthesizer

orbital curve of the electron beam on the luminous disk

alternating voltage for Y-axis

time

time

alternating voltage for X-axis
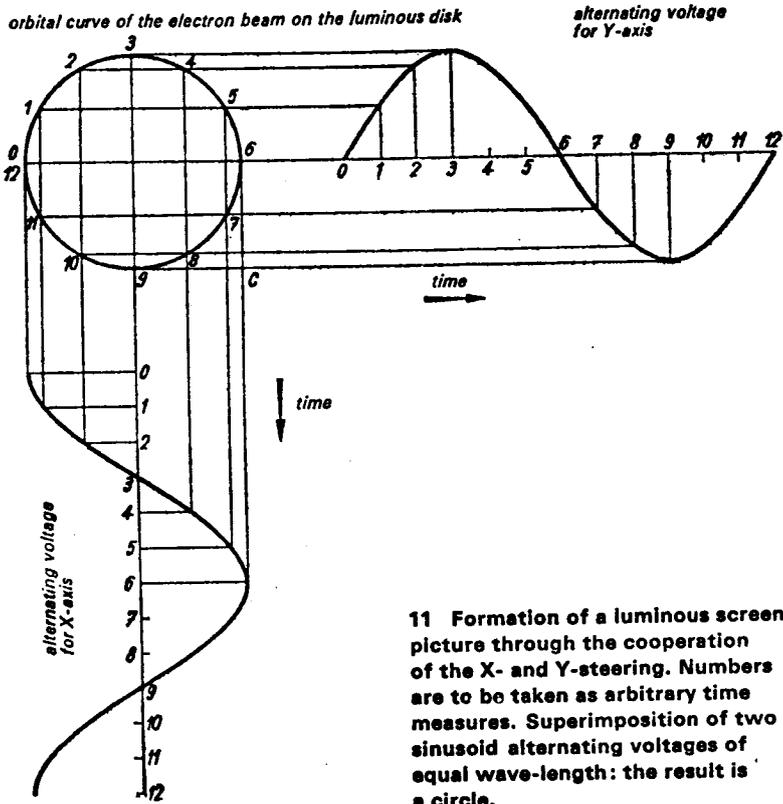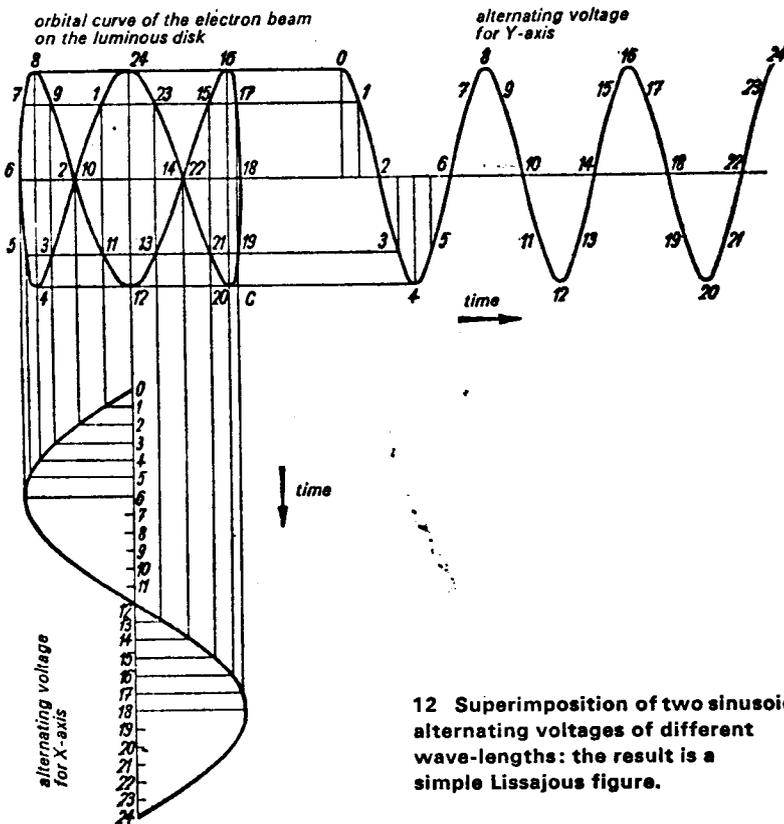
11 Formation of a luminous screen picture through the cooperation of the X- and Y-steering. Numbers are to be taken as arbitrary time measures. Superimposition of two sinusoid alternating voltages of equal wave-length: the result is a circle.

0

III₆

III₃

III₂

1:2   1:3   2:3
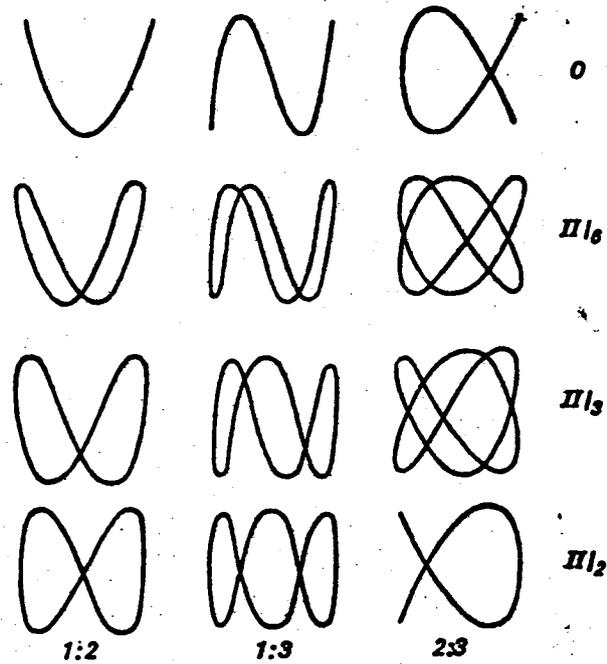
1.3.c. Basic Vocabulary of
        Analog Signals

1.3.d. Family of Lissajous Curves

orbital curve of the electron beam on the luminous disk

alternating voltage for Y-axis

time

time

alternating voltage for X-axis

12 Superimposition of two sinusoid alternating voltages of different wave-lengths: the result is a simple Lissajous figure.

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2.0 SYSTEM #2 - COMPUTER: ANALOG; DISPLAY: MECHANICAL
   a. Terminal Self - John Whitney,Jr.
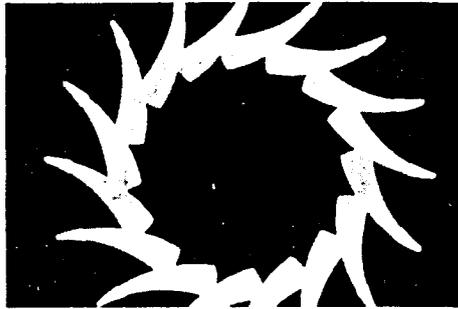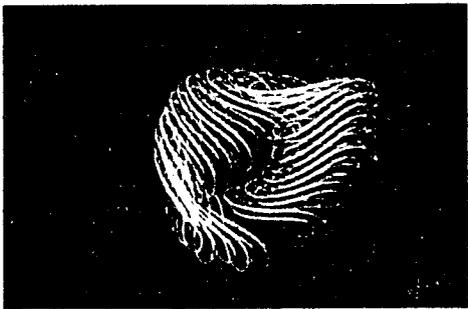   b. Catalog - John Whitney, Sr.

2.1 THE STREAKING PROCESS
   a. Kodalith artwork
   b. structure of Whitney Cam machine
   c. artwork motion and camera control

2.2 MULTIPLE EXPOSURE
   a. film: Lapis - James Whitney
   b. intermittent light source
   c. artwork motion: rotation upon revolution

2.3 THE MOTION-CONTROLLED OPTICAL PRINTER
   a. film: Yin Hsien - Michael Whitney
   b. film: Futureworld (dream effect) - M.W.
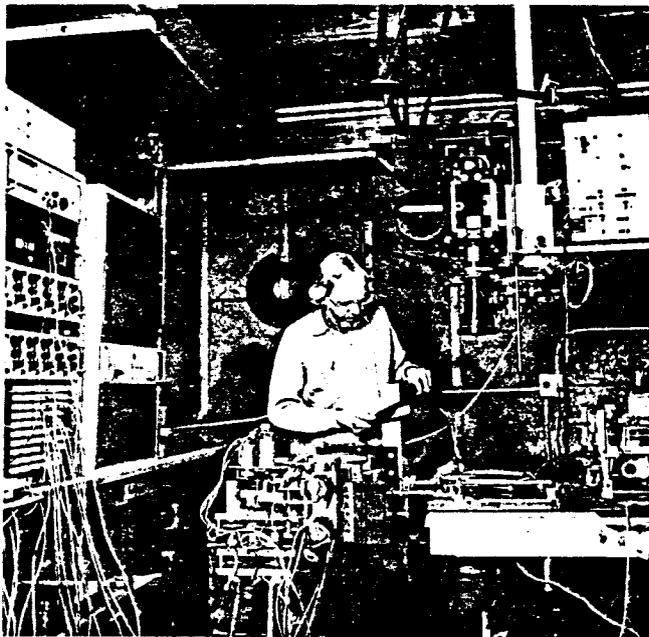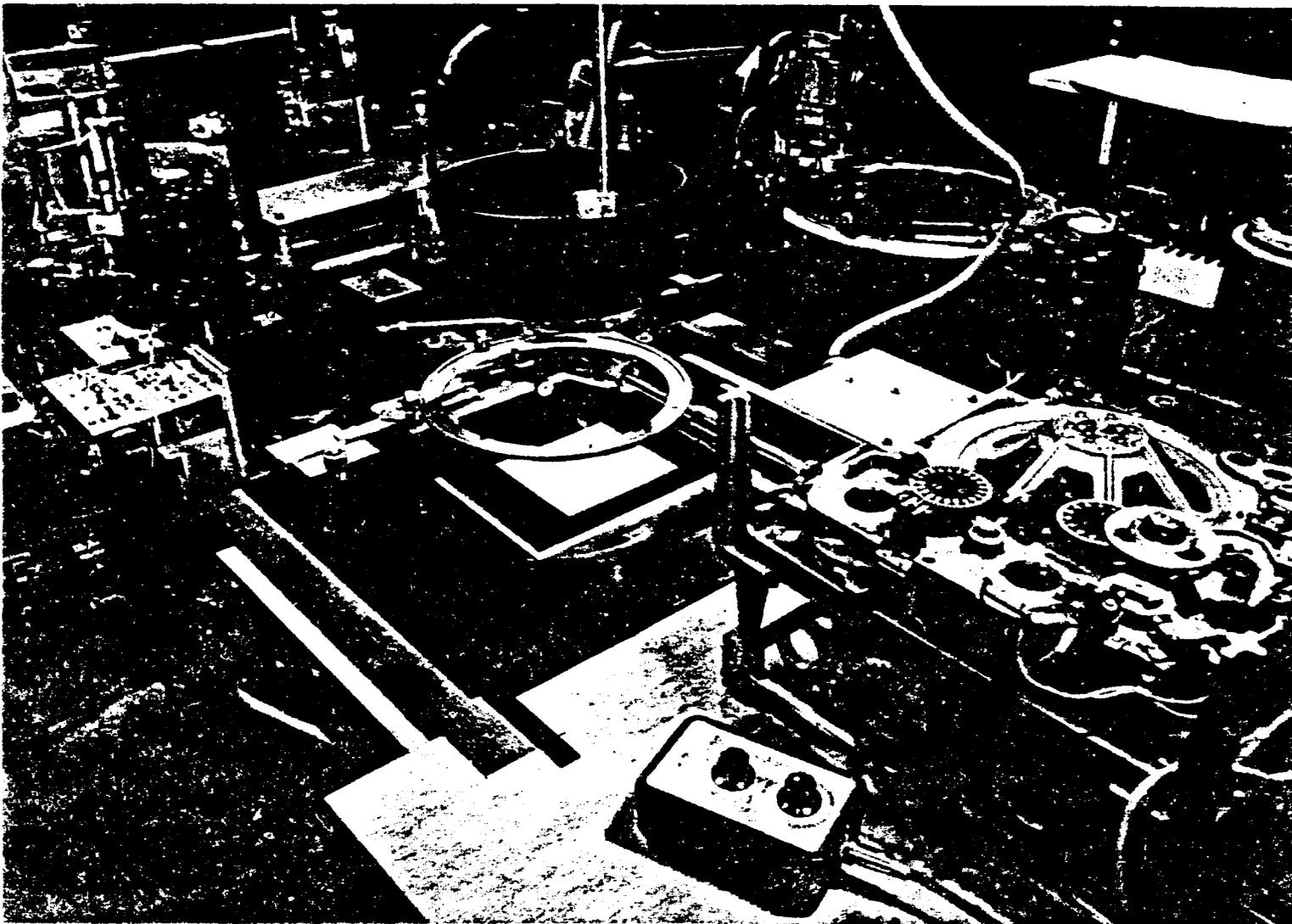   c. modification to produce new machine

2.0.a. Terminal Self - John Whitney,Jr.
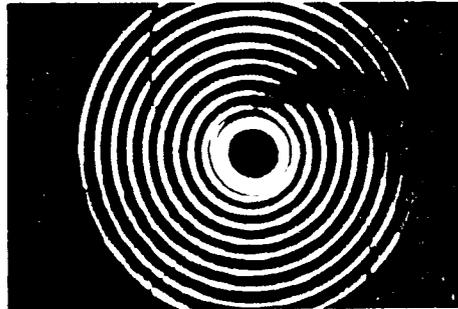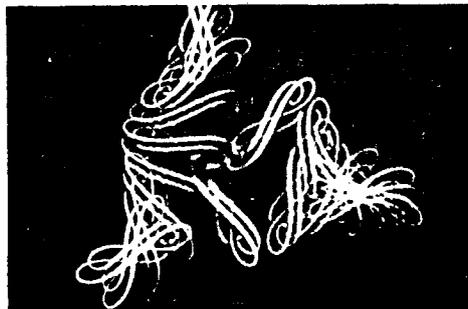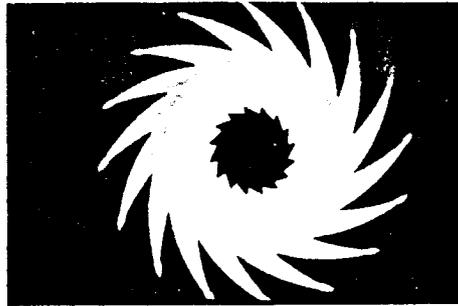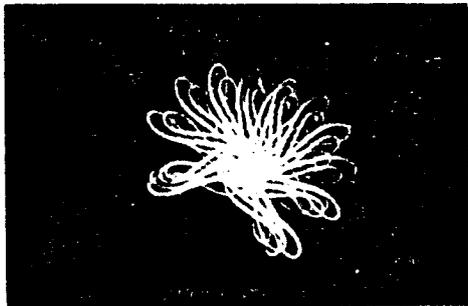
John Whitney: *Catalogue*. 1961. 16mm.
Color. 7 min. "Floral patterns curl as
though they were actually organic
growths . . ."

2.0.b. Catalog - John Whitney,Sr.

The animation equipment used in CATALOG. Two analog computers (one shown in foreground, the other behind controls at left) moves the animation field in a predetermined pattern. A drawing placed on the field is photographed frame by frame; each frame shows it in a different position. Above the animation field can be seen the lens hood, and at the top of the picture, the camera lens.

John Whitney, shown at work with his mechanical analog computer.
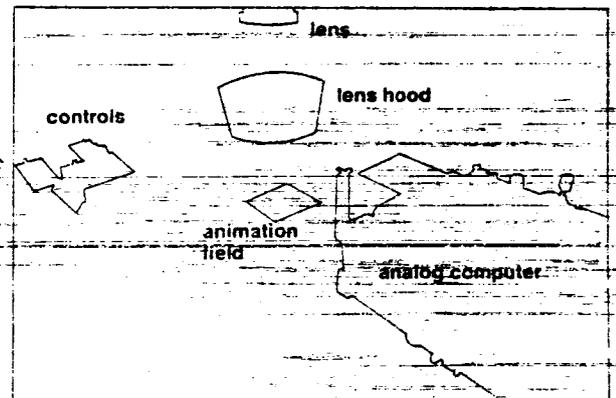
2.1.b. The Whitney Cam Machine
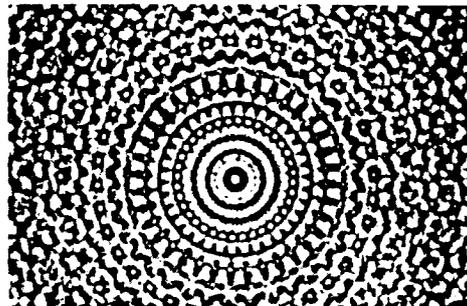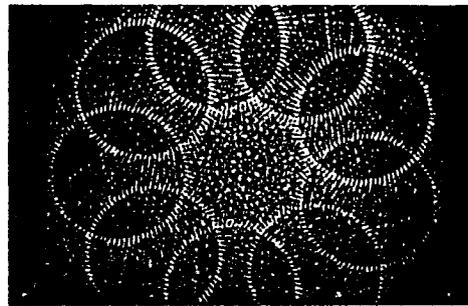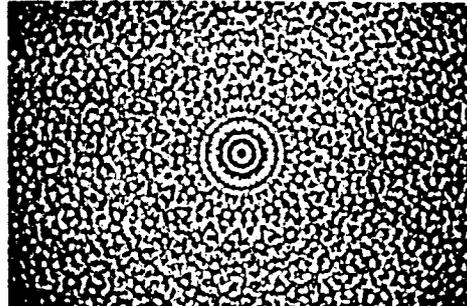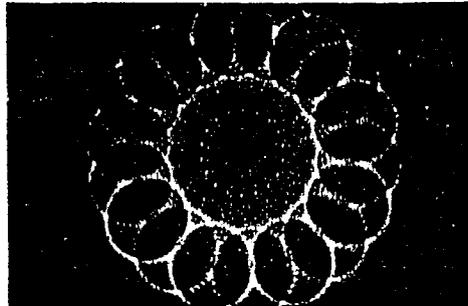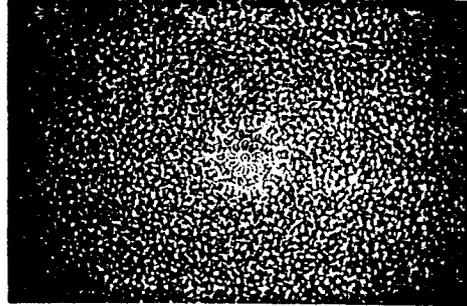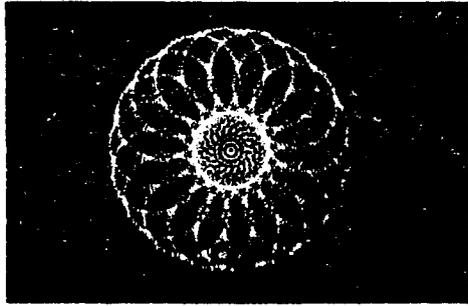
Lapis: ". . . they manifest as though out of the air itself, gathering and converging around a central sphere . . . revolving with implacable grace against the eerie drone of the tamboura."

2.2.a. Lapis - James Whitney

YIN HSIEN   **(1976)**
By Michael Whitney

2.3.a. Yin Hsien - Michael Whitney

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3.0 INTRODUCTION TO DIGITAL COMPUTERS

3.1 THE PAPER PLOTTER
    a. structure (etch-a-sketch analogy)
    b. servo-motors driven by x & y signals (like oscilliscope)
    c. digital computers (& related devices) use display commands
        encoded in signals (which themselves can be ignored
        in favor of command sequence)
    d. X & Y Cartesian Coordinates
   e. command sequence example (vector list programs:2D figures)

3.2 DIGITAL PROGRAMMING
    a. analog vs. digital (signal processing vs. display command
        sequence)[problem now: create vector list vs. signal]
    b. use of system doesn't necessarily imply programming
        many ways to create images w/o programming (later)
    c. physical structure: terminals for I/O; rest invisible
    d. setup example: A/N terminal, computer, plotter
    e. programming lesson:
        1. flow charts and the "program follower"
        2. example: 2D figure, vector list
        3. variables and subroutines
        4. transfer of control: loops, flow charts
        5. 2D transforms: Translation, Scaling;
            algebraic transformation of coordinates=>
   graphic transformation of figure
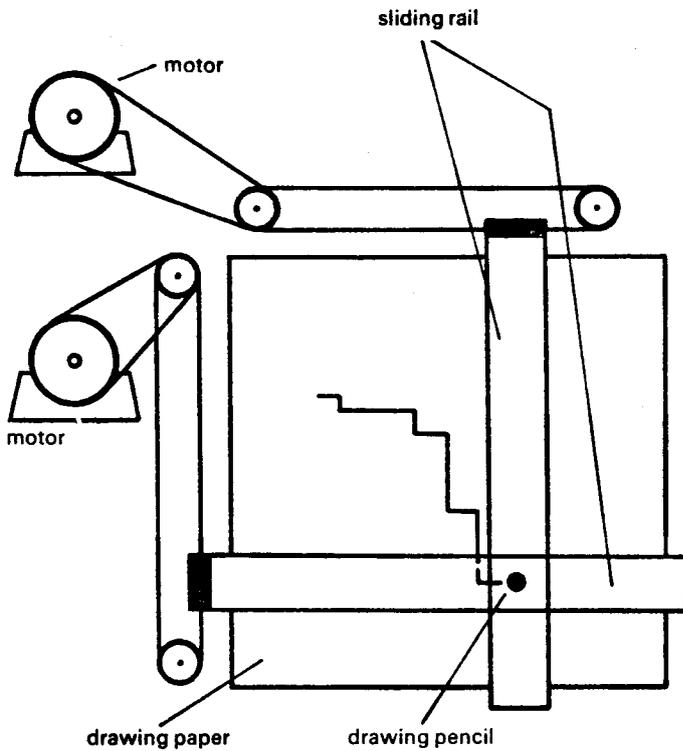
4 Diagram showing the organization of a mechanical plotter. Two servomotors guide the pencil in the direction of the X- and Y-axis across the drawing plate. Any desired configuration can be obtained through the superimposition of the motion components. A mechanism (not shown here) raises the pencil so that single, interrupted lines can also be drawn.

3.1. The Paper Plotter
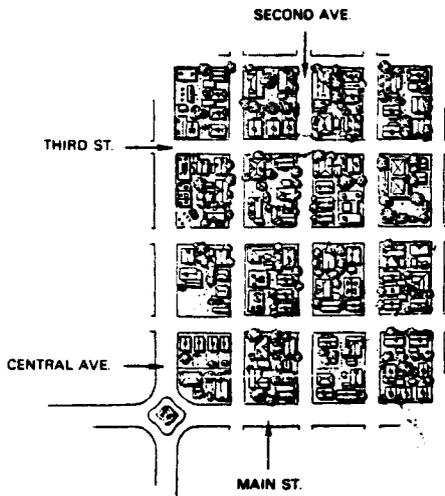
THE HOUSE ON THE CORNER
This map demonstrates how the intersection of two streets can locate a dwelling. Without chance of confusion, the owner could direct visitors to his home by saying simply that he lived at the corner of Second Avenue and Third Street.
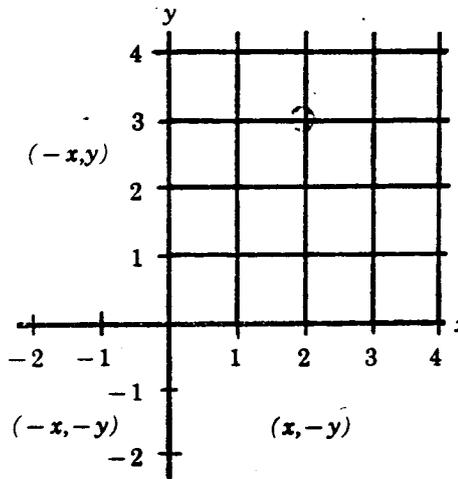
GETTING TO THE POINT
A grid of lines similar to the street arrangement above locates points on a surface. Mathematicians say the point shown here is at 2, 3. The first number is the distance along the horizontal, or x, axis and the second the distance along the vertical, or y, axis.

3.1.d. X & Y Cartesian Coordinates

THE DEEP DARK SECRET

THE MAGIC OF THE COMPUTER PROGRAM

The basic, central magical interior device of the computer we shall call a program follower. A program follower is an electronic device (usually) which reads symbols specifying operations, carries out the step each specifies and goes on to the next.

The program follower reads down the list of instructions in the program, taking each instruction in turn and carrying it out before it goes on to the next.

Now, there are program followers that just do that and nothing more; they have to stop when they get to the end of the list of instructions.

A true computer, however, can do several things more.

PRINCIPLE 1: THE PROGRAM LOOP

It can jump back to an earlier point in the program and go on from there. Repeating the program in this fashion is called a loop.

PRINCIPLE 2: THE PROGRAM BRANCH

It can perform tests on symbols in the memory-- for instance, to see if a loop has been done enough times, or if some other part of the job has been finished-- and jump to some other program depending on these symbols. This is called a branch.

Finally, the computer can change the information stored in memory. For instance, it can place an answer in a specific part of memory.

WHAT, THEN, IS A (Digital) COMPUTER?

A device holding stored symbols
    in a changeable memory,
performing operations on some of those symbols
    in the memory,
in a sequence specified by other symbols
    in the memory,
able to change the sequence
    based on tests of symbols in the memory,
and able to change symbols in the memory.
    (For example, do arithmetic and
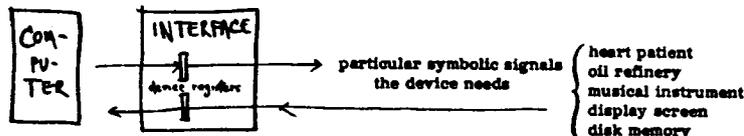   store the result in the memory.)

Rather than try to slip it to you or prove it in some fancy way, let's just state baldly: the power of such a machine to do almost anything surpasses all previous technical tricks in human history.

HOW CAN A COMPUTER CONTROL SO MANY DIFFERENT THINGS?

PRINCIPLE 3: ALL DEVICES LOOK ALIKE.

Answer. Different as they may seem, all devices are controlled in the same way. Every device has an interface, that is, its own special connection setup, and in this interface are the device registers.

These device registers look the same to the computer: the computer program simply moves information patterns into them or moves information patterns from them to see what they contain.


heart patient
oil refinery
musical instrument
display screen
disk memory

The computer, being a machine, doesn't know or care that device register 17 (say) controls a hog feeder, or device register 23 (say) receives information from smog detectors. But what you choose, in your program, to put into device register 17, controls what the hogs eat, and what comes into device register 23 will tell your program, you hope, about smog conditions. Choosing how to handle these things in your program is your business.

COMPUTER
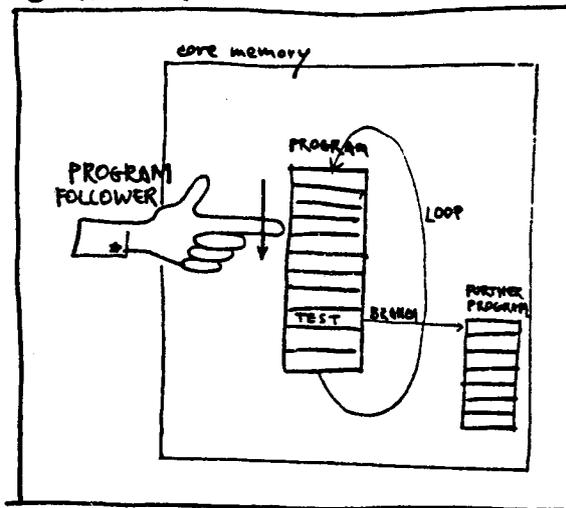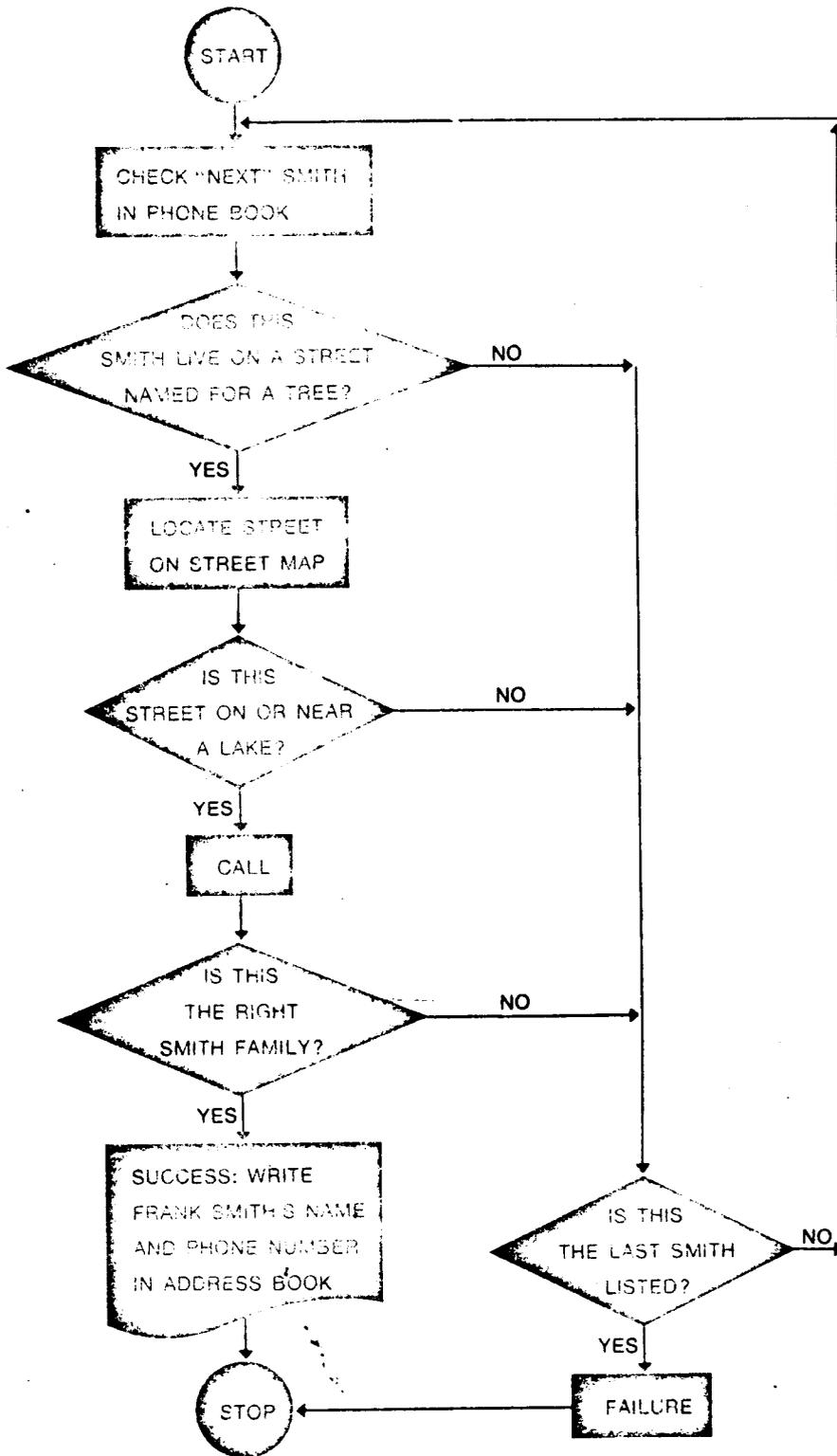
3.2.3.1. Flow Charts

4.0 SYSTEM #3 - COMPUTER: DIGITAL; DISPLAY: MECHANICAL
    a. film: (streaks) Superman titles - ?who
    b. film: (streaks) Hyperdrive Jump, Star Wars - John Dykstra
    c. film: (slitscan) Stargate Corridor, 2001 - Doug Trumbull

4.1 REDESIGNED MECHANICAL DRAWING DEVICE
    a. Whitney Cam Machine designed for analog control
    b. new structure resembles paper plotter for digital control

THE VARIETIES OF THE MOTION-CONTROLLED CAMERA

4.2 ON-LINE MEMORY-DRIVEN (NON-PROGRAMMABLE)
    a. film: Star Wars
    b. process:
        1. Dykstraflex: model shots
        2. streaks: jump to hyperspace
        3. programming: joystick input only
        4. record 1 channel; playback all.
        5. direct view
        6. other similar systems: "Jaws","Ice Box"

4.3 OFF-LINE (PRE-PROCESSED) MEMORY-DRIVEN (PROGRAMMABLE)
    a. film: Bob Abel Commercials
    b. process:
        1. "HAL 9000" -> "Phoebe" tracks: straight streaks
          and slitscans
        2. pre-processed tapes: prepared by hand or
          with digital computer
        3. not previewable
        4. improvement: simulation of mechanics with E&S
          Picture System (see Chap. 9)

4.4 ON-LINE COMPUTER-DRIVEN (PROGRAMMABLE)
    a. film: Star Trek
    b. process:
        1. "Compsy" : for models and graphics
        2. preprocessing (as in 4.3) and on line capabilities
          (as in 4.2)
        3. direct view; immediate playback, programmable
        4. high level software - choice of control modes:
          a. command language programmable
          b. joystick controlled
          c. off-line generated input
          d. any combination of techniques

4.5 COMPUTER-CONTROLLED ANIMATION STAND
     a. film: ?
     b. process:
          1. Oxberry, NFB, Batelle
          2. hardware theoretically as capable as system in
             (4.4) but limited by software
          3. Cinetron: software?

4.6 PROGRAMMING EFFECTS
     a. film: Superman titles
     b. process: building and collapsing streaks
     c. film: 2001 Stargate corridor
     d. process: slitscan

4.7 OTHER TECHNIQUES
     a. multi-planing
     b. curve fitting
     c. interpolation

Illustration showing the Dykstraflex camera, head, boom-arm, track and control electronics, plus the X-wing fighter on pylon. By using the camera frame rate and count as a time base, camera/subject positional changes can be recorded at 24 frames-per-second. The positional change is viewed through the taking lens and is controlled by a joy stick for multi-axis moves, or by an individual potentiometer for single axis moves.
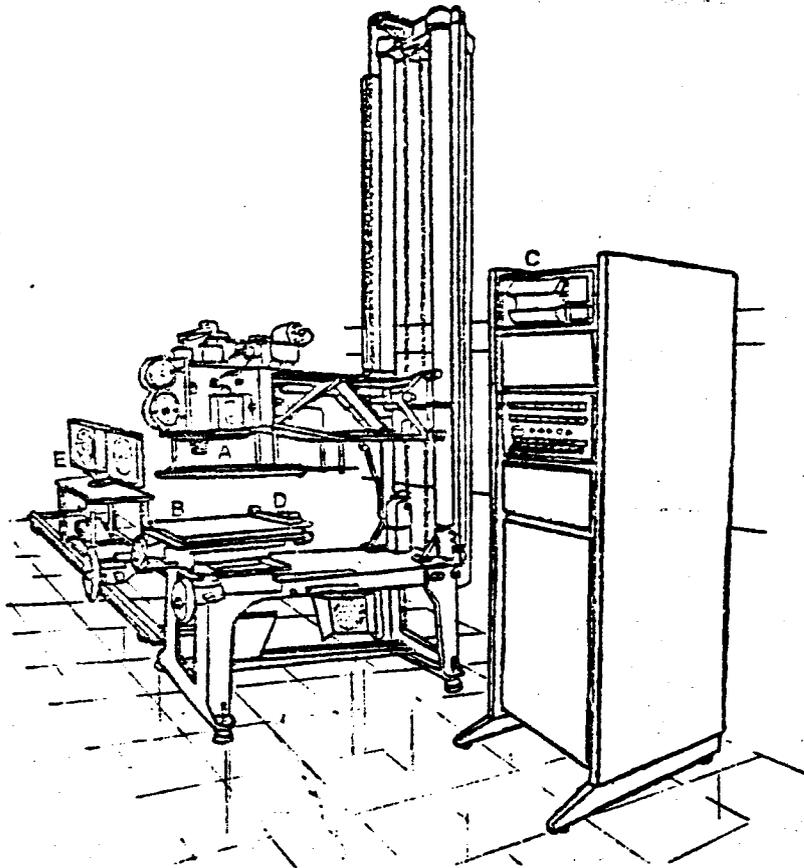

4.2.b.1. 'The Dykstraflex'
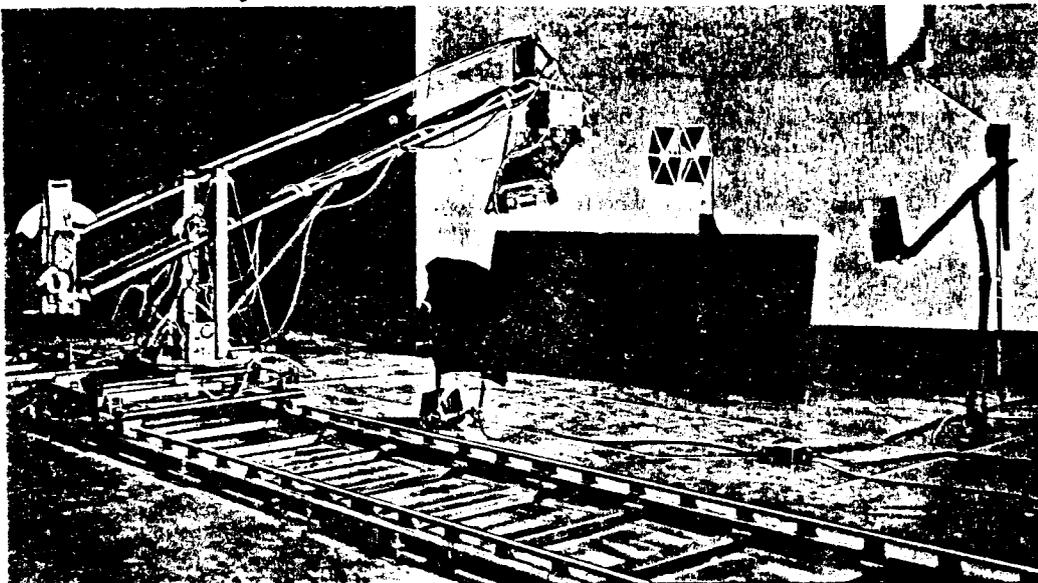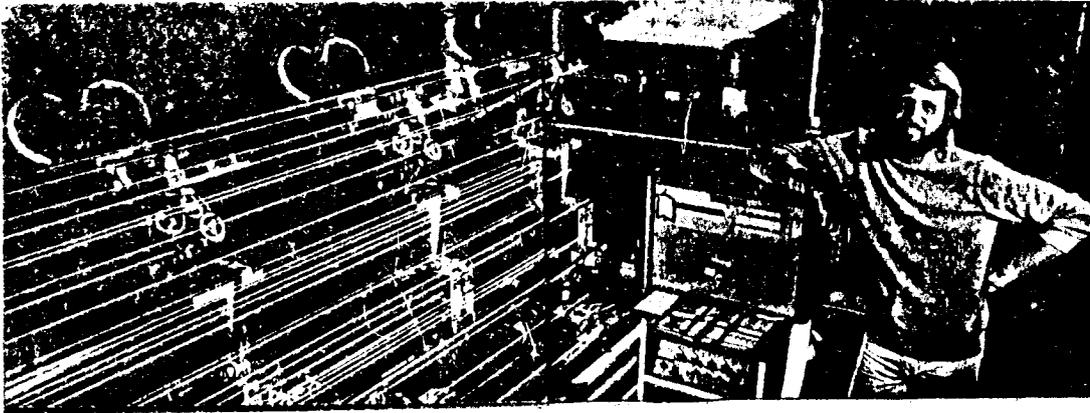
4.3.b.1 Bob Abel's 'HAL 9000'

Figure 3. Battelle's computer-controlled animation equipment.

4.5. The Computer Controlled Animation Stand

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5.0 SYSTEM #4 - COMPUTER: DIGITAL
                 DISPLAY: ELECTRONIC (VECTOR SCAN)
    a. displays come in 3 types corresponding to 3 recording
       methods discussed in chap1:
       1. time exposure   COM's
       2. animation   Storage Tubes
       3. continuous refresh   Real Time Displays

2-D GRAPHICS

5.1 MICROFILM PLOTTER - ON LINE
    a. film: Arabesque - John Whitney,Sr.
    b. process:
       1. hardware: Computer Output Microfilm (COM)
       2. time exposure: vectors plotted directly without
           being stored in list (called: on-line)
       3. sin functions computed - can simulate analog waves
           tradeoff: speed for generality

5.2 MICROFILM PLOTTER: OFF-LINE
    a. film: Two Space - Larry Cuba
    b. process:
       1. hardware: COM + PDP-10 (large mainframe)
       2. vector list written to tape as computed
           (not stored in main memory)
       3. plotter reads tape (called: off-line)

5.3 STORAGE TUBES
    a. film: The Tainted Sky - Kent Wilson (The Senses Bureau)
    b. process:
       1. hardware: Storage Tubes
       2. animation drawing mode or
       3. filming during drawing: the image builds
       4. other examples: green screens in Battlestar
           Galactica

5.4 VECTOR LISTS AND TRANSFORMATIONS
    a. standard: translation, rotation, scaling
    b. distortions: single-axis scaling, etc.
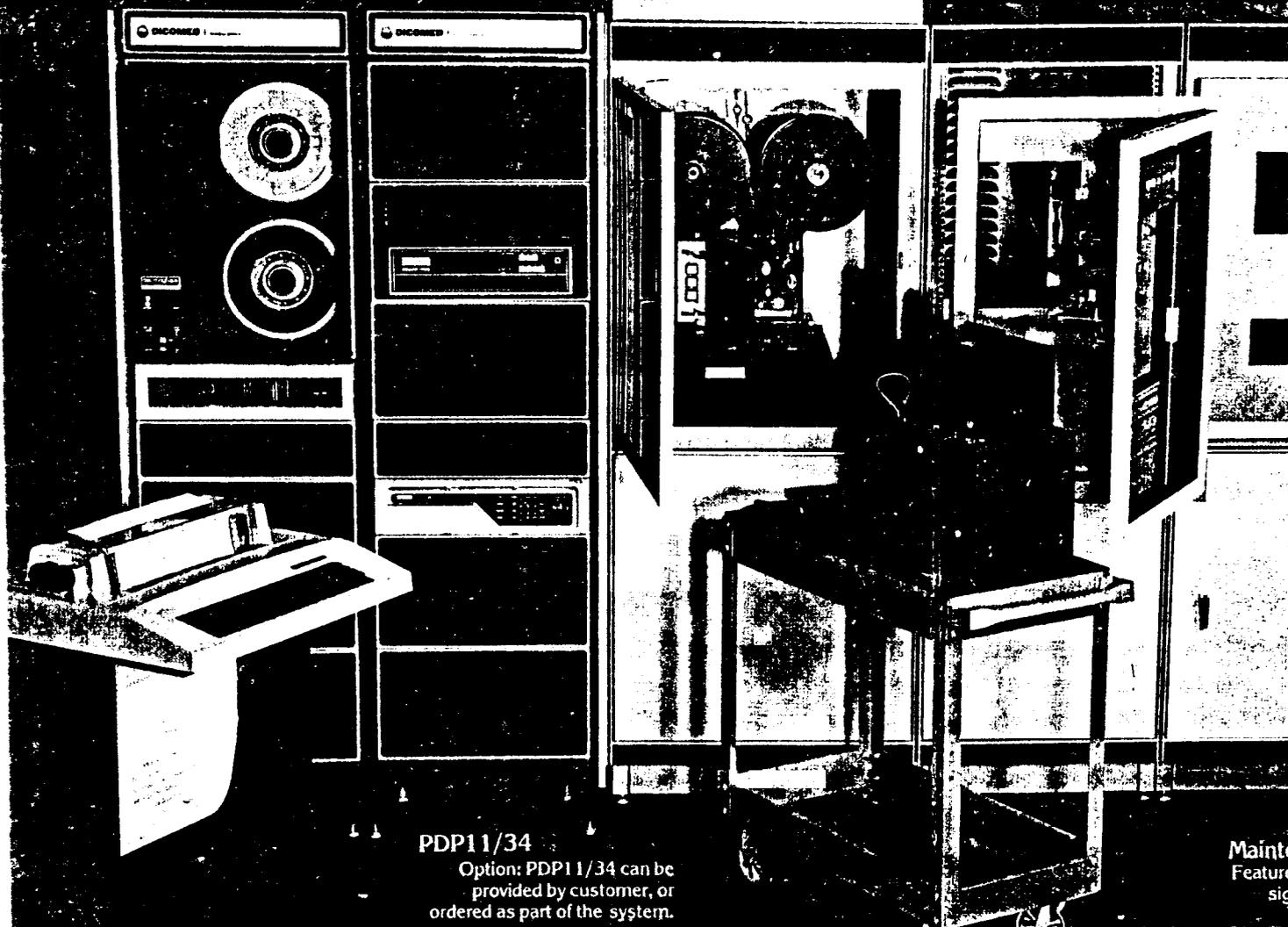
5.5 VECTOR LIST GENERATION (PICTURE AS OBJECT)
    a. type in: 2D figures, square, triangle, etc.
    b. compute by program: circles
    c. drawn in

5.6 DRAWING AND DIGITIZING: THE DATA TABLET
    a. awkward on storage tube
    b. difficult on COM (ask Gary about III)
    c. practical only with Real Time Displays
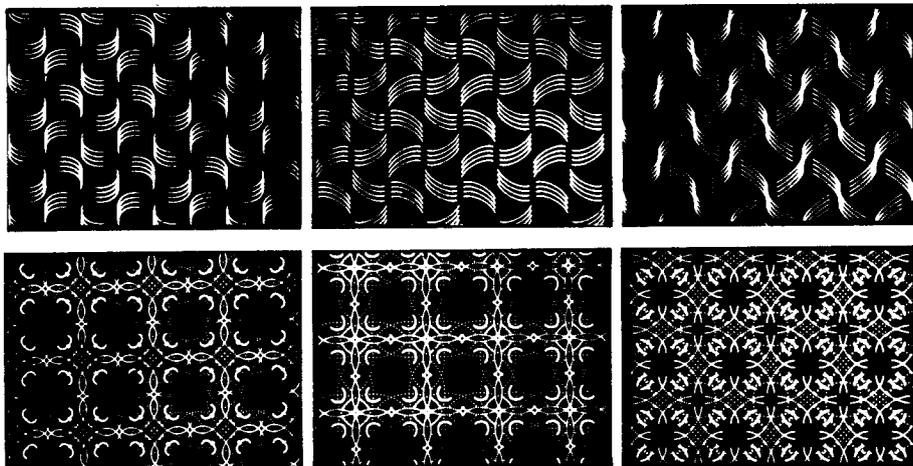
Disk storage: 2.5 megabytes.

Simple operator controls.

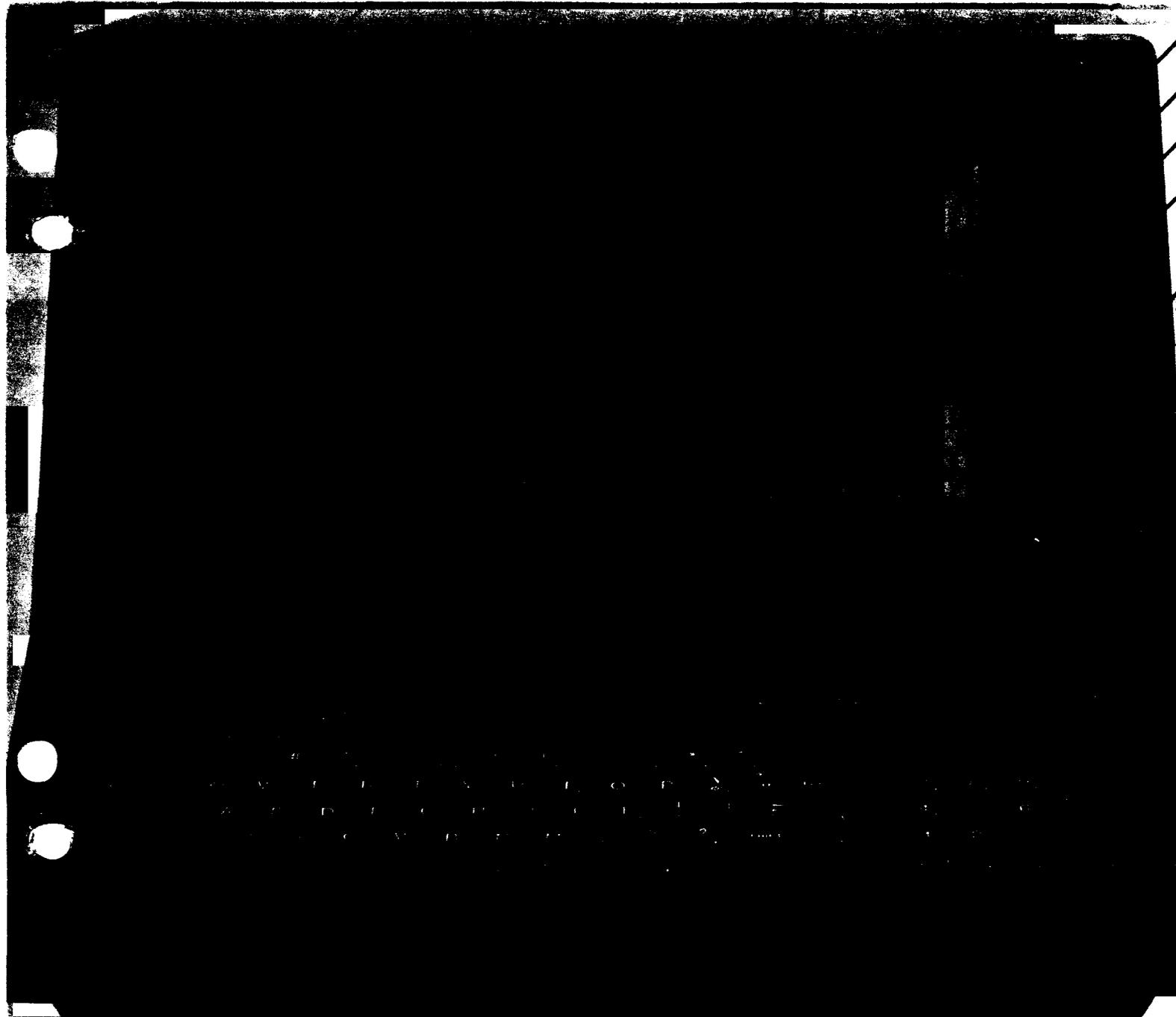PDP11/34
Option: PDP11/34 can be
provided by customer, or
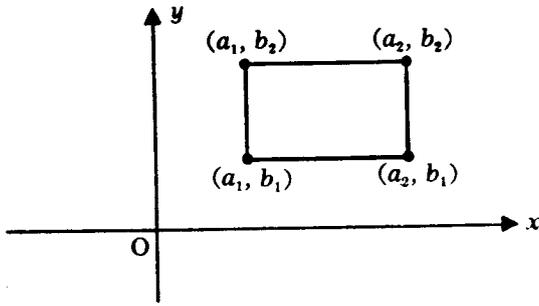ordered as part of the system.

Mainte
Feature
sig

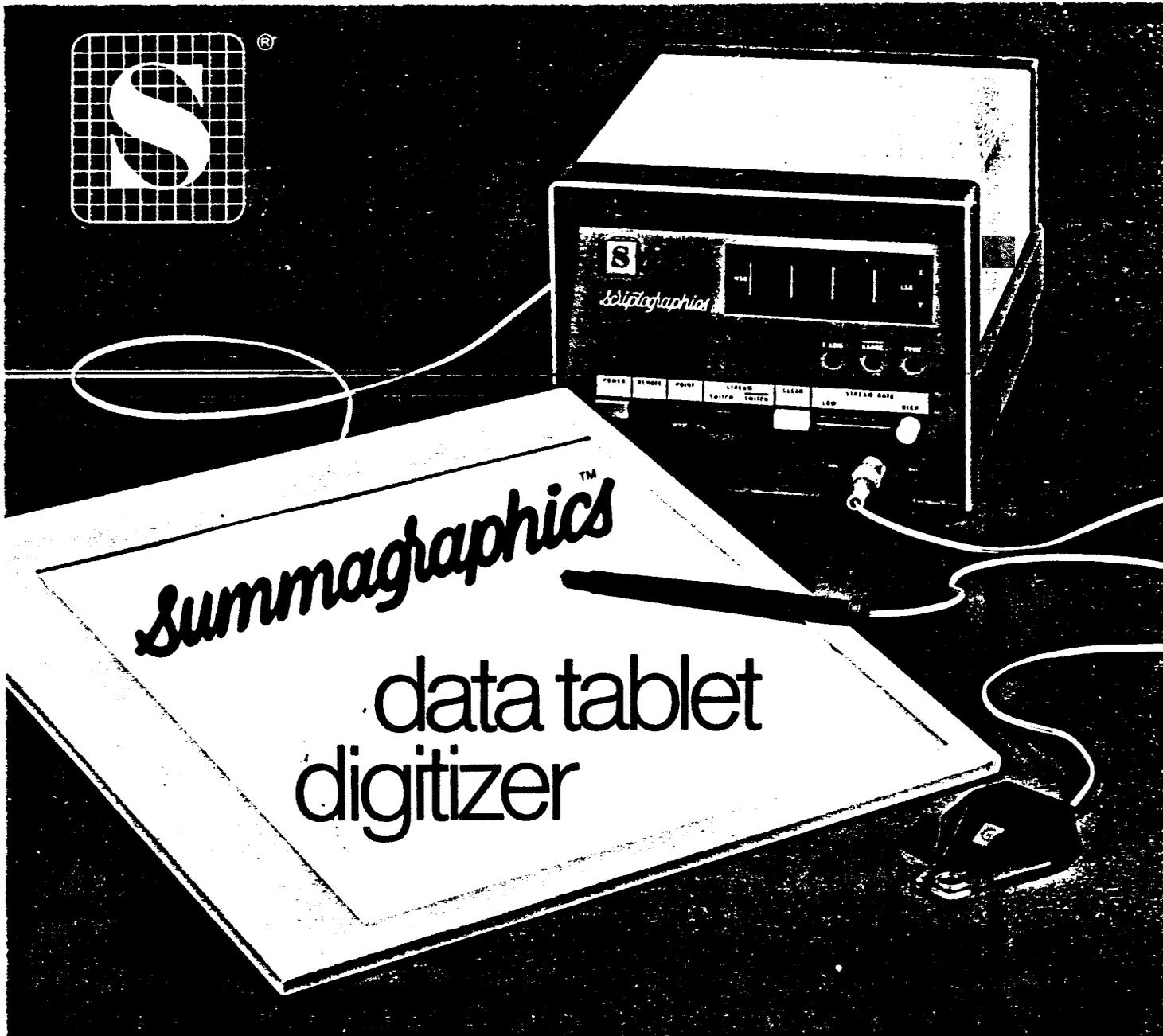5.1.b.1. The Microfilm Plotter (COM)

5.2.a. Two Space - Larry Cuba

5.3.b.1. The Storage Tube

5.5. Vector List Generation

5.6.d. The Data Tablet

A COMPUTER ANIMATION PRIMER

6.0 SYSTEM #5 - COMPUTER: DIGITAL
                DISPLAY: ELECTRONIC (VECTOR SCAN) REAL TIME

6.1 KEY FRAME SYSTEM
    a. film: Hunger - Peter Foldes
    b. process:
        1. artist draws key frames
        2. enters control information
        3. system draws in-betweens (linear interpolation as %)
        4. transformation is from one list to another (order of
            list matters)
        5. skeleton-driven - Marcelli Wein
        6. problems: Ed Catmull's paper

6.2 REAL TIME CONCEPTS
    a. refresh rate: second "program follower"
    b. update rate

                    3D GRAPHICS

6.3 REPRESENTING 3D OBJECTS (CUBE EXAMPLE)
    a. 3D vector lists
    b. parallel projections (3D to 2D)
    c. perspective projection (architectural graphics)
        (use of canned programs to avoid math. transforms
          ---Appendix with detailed math techniques?)
    d. other projections: spherical (fisheye lens)
    e. 3D graphics vs. stereoscopic views

6.4 PARALLEL PROJECTION (REAL TIME ANIMATION)
    a. film: "3/78" - Larry Cuba
    b. process:
        1. hardware: real time structure (2nd "program follower")
        2. interaction (dials,joysticks,buttons,tablet)
        3. vector list becomes display command list (at level which
            can be ignored because of High Level Language:GRASS)
        4. 2D vector list (square & circle) transformed in 3D space
            rotated,scaled,translated & projected to 2D for
            drawing (parallel projection by VG hardware)

6.5 PERSPECTIVE PROJECTION (ANIMATED TIME)
    a. film: Star Wars animation - Larry Cuba
    b. process:
        1. hardware: same as for "3/78"
        2. 3D data input with tablet
        3. GRASS language facilitated list manipulation (building
            new lists by combining many objects transformed)
        4. perspective projection programmed in software
            (example of slow update rate; adequate refresh rate)
        5. filmed in animation time (but no time exposure required)

6.6 PERSPECTIVE PROJECTION (REAL TIME ANIMATION)
    a. film: Black Hole animation - CD Taylor, Bill Kovacs(?)
    b. process:
        1. hardware: E&S Picture System
        2. perspective projection hardware therefore object seen
           rotating,scaling,moving in perspective in Real Time

6.7 PROJECTIONS FROM HIGHER DIMENSIONS (ANIMATED TIME)
    a. film: hypercube in stereo - Michael Noll, Bell Labs
   b. process: software projection

6.8 PROJECTIONS FROM FOURTH DIMENSION (REAL TIME ANIMATION)
    a. film: hypercube film - Tom Banchoff, Charles Strauss, Brown U.
    b. process: hardware array processors

6.9 HIDDEN LINE REMOVAL
    a. film: ?
    b. process: requires more data about objects
        (data structures: point polygon form)
    c. special hardware: watkins box for HLR (hardware from softw.)
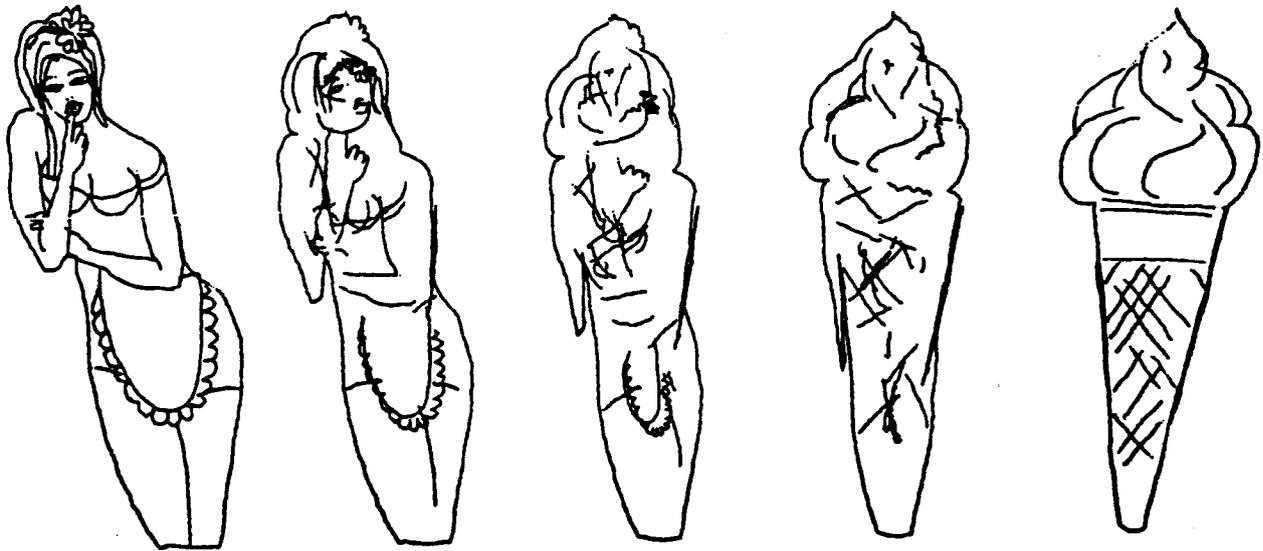
6.1.a. Hunger - Peter Foldes
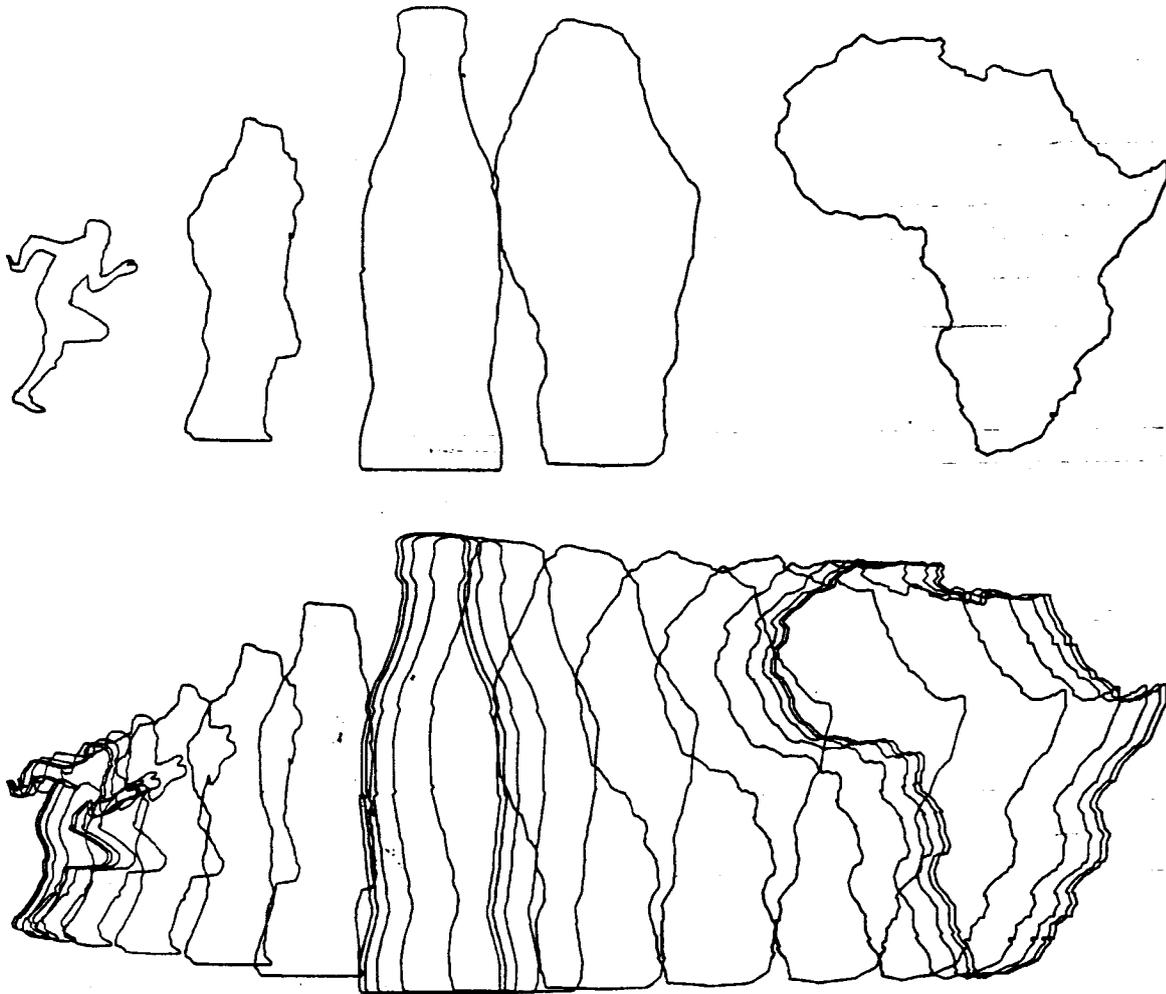
77. Computer Technique Group: *Running Cola is Africa.*
A computer algorithm converts a running man into a bottle
of cola, which in turn is converted into a map of Africa.

6.1.b. The Key Frame Process
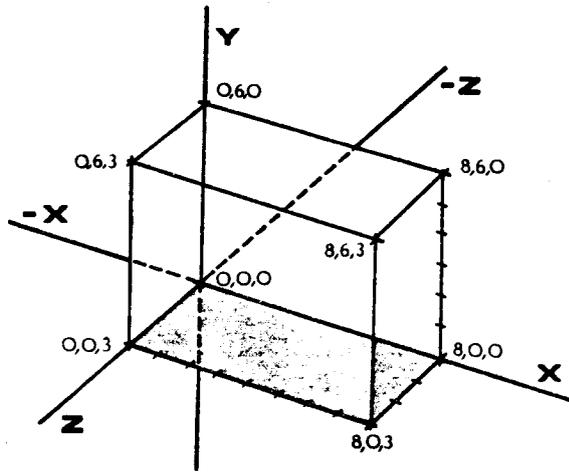
Above: Figure 1 - Basic coordinate system for determining X, Y, and Z coordinates of points that define each geometric shape.

6.3. Representing 3D Objects
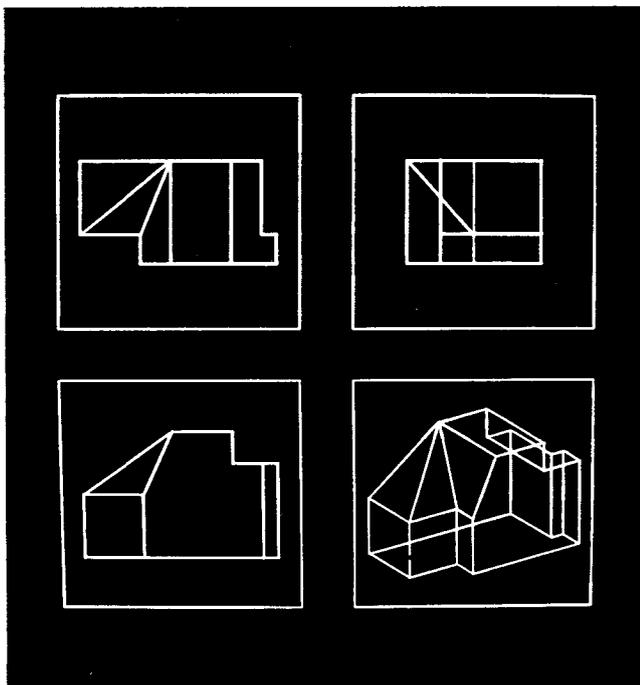
6.3.b. Parallel Projection
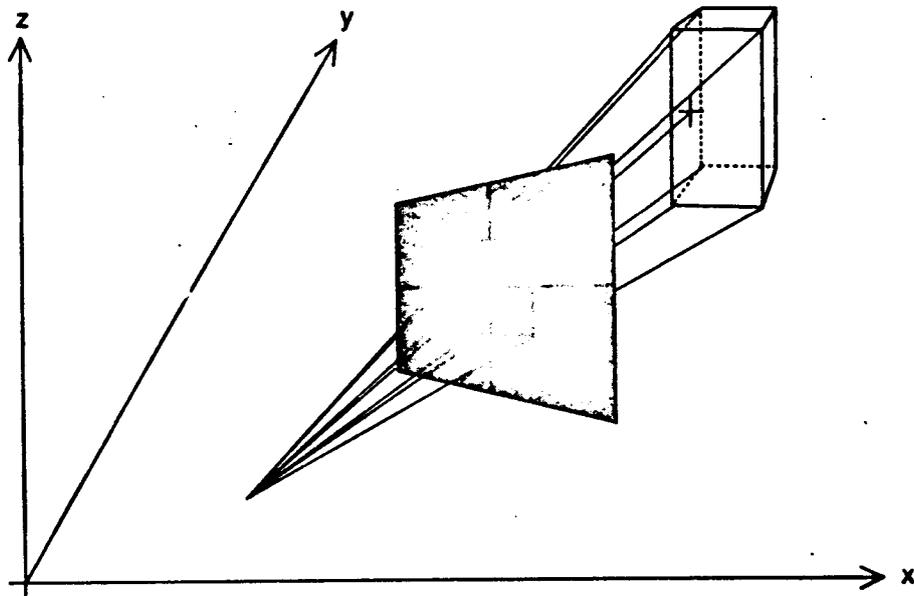
PERSPECTIVE DRAWING is the principle underlying the transformation of a three-dimensional scene into a two-dimensional picture by the computer. View rays (*color*) between an observer and a three-dimensional object intersect an imaginary picture plane. By connecting the appropriate points of intersection one obtains a representation of the three-dimensional object on the plane. The geometric framework whereby the computer locates an object in space is a system of coordinates arising from the orthogonal axes *x*, *y* and *z*.

6.3.c. Perspective Projection
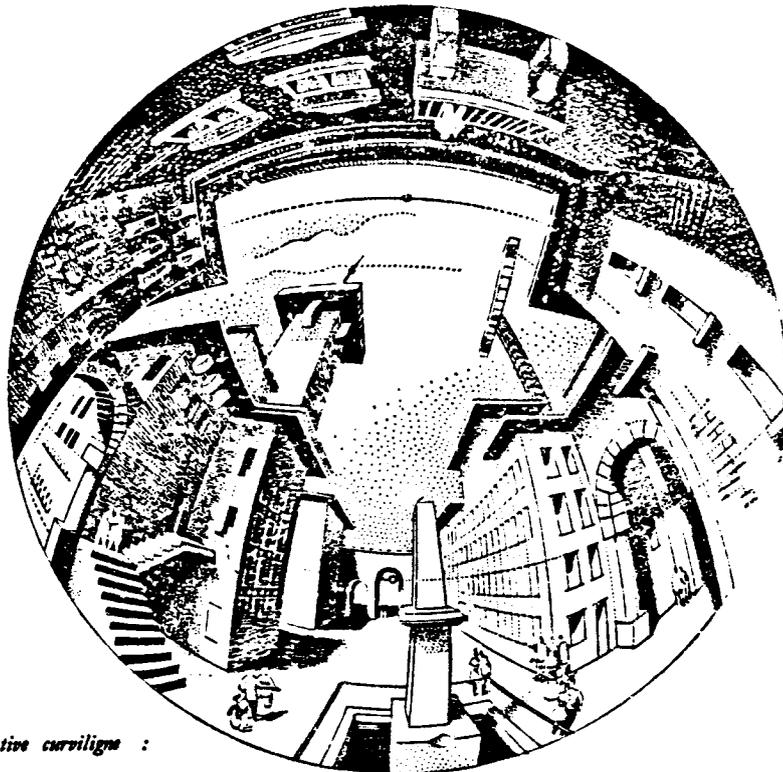
Fig. 6 — Perspective curviligne :
A. Flocon.

6.3.d. Spherical Projection

Figure 8: Gridding on Smooth Surfaces

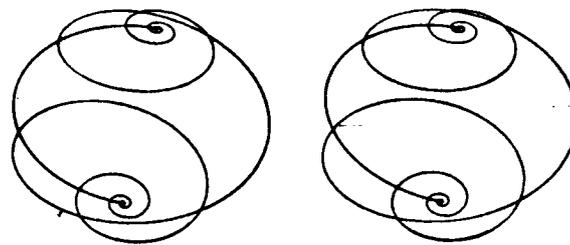**8a: Torus (octagonal cross-section)**
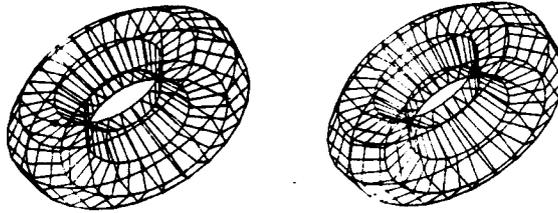
8b: Sphere
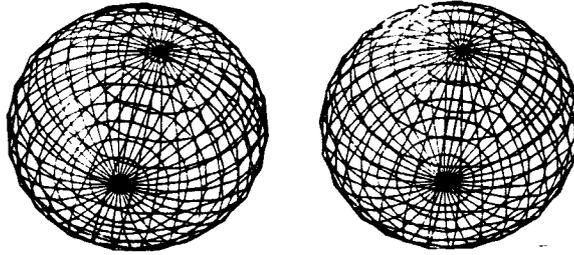
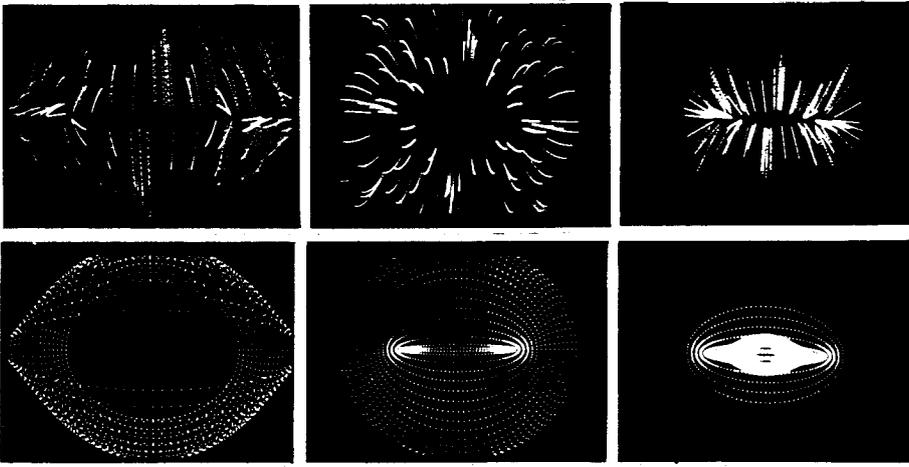**Figure 9: Rulings on Warped Plan Surfaces**

9a: Distortion Out of the Plane
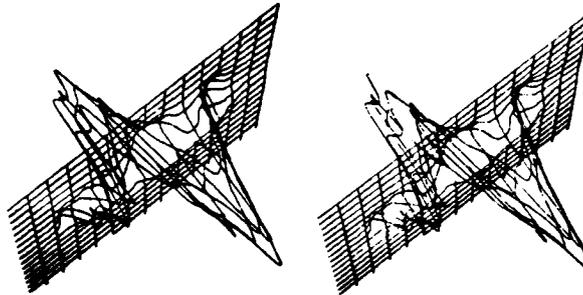
10b: Sphere with a Loxodromic Curve

6.3.e. Stereoscopic Views
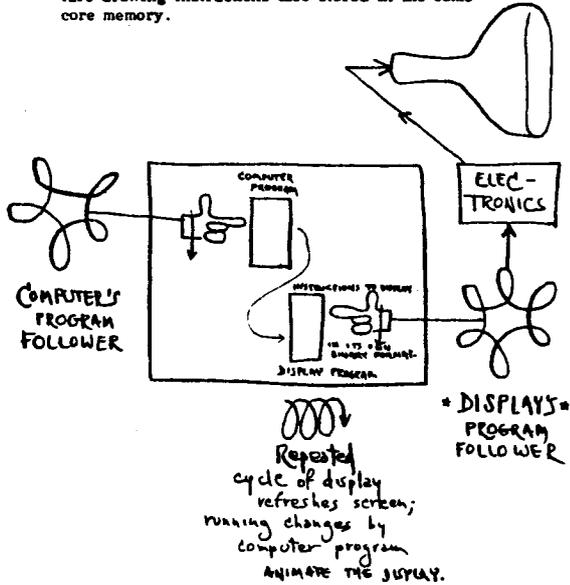
6.4.a. "3/78" - Larry Cuba

6.4.b.1. Real Time 3D Display
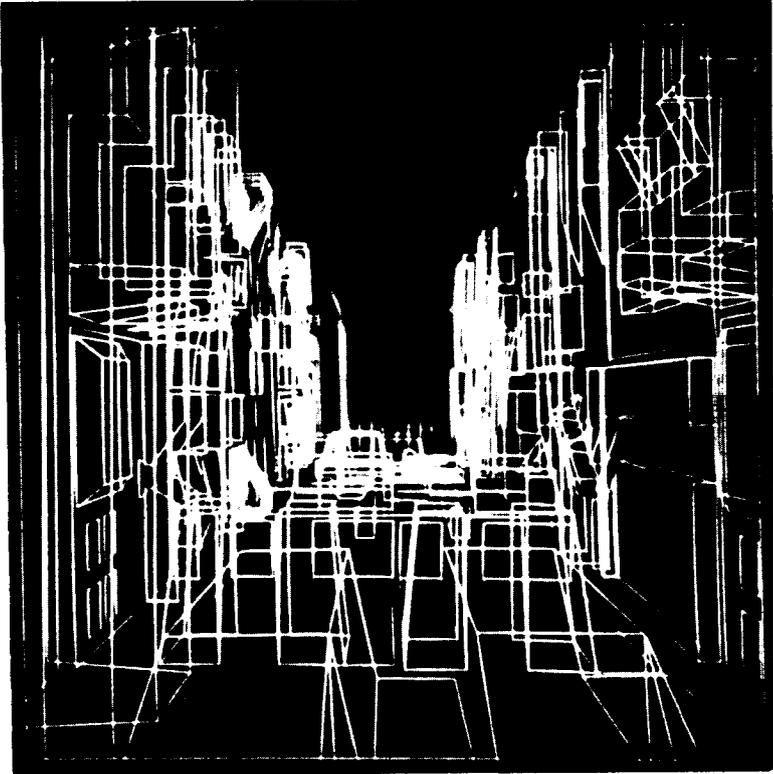
4. THE SECOND PROGRAM FOLLOWER

On the other side of the book, I explained that a computer is basically a zippy device, never mind how constructed, which follows a program somehow stored symbolically in a core memory. Such a device we call here a _program follower_. While programs may be in many computer languages-- all of them contrived systems for expressing the user's wishes, in different styles and with different general intent-- underneath they all translate to an inner language of _binary patterns_, which may just be thought of as patterns of X and O, or light bulbs on and off. The innermost program follower of the computer goes down lists of binary patterns stored in the core memory, and carries them out as specific instructions. It also changes its sequences of operations under conditions that the programmer has told it to watch for.

, The most powerful and responsive computer displays are those which build a _second_ program follower which goes down lists of picture-drawing instructions also stored in the same core memory.
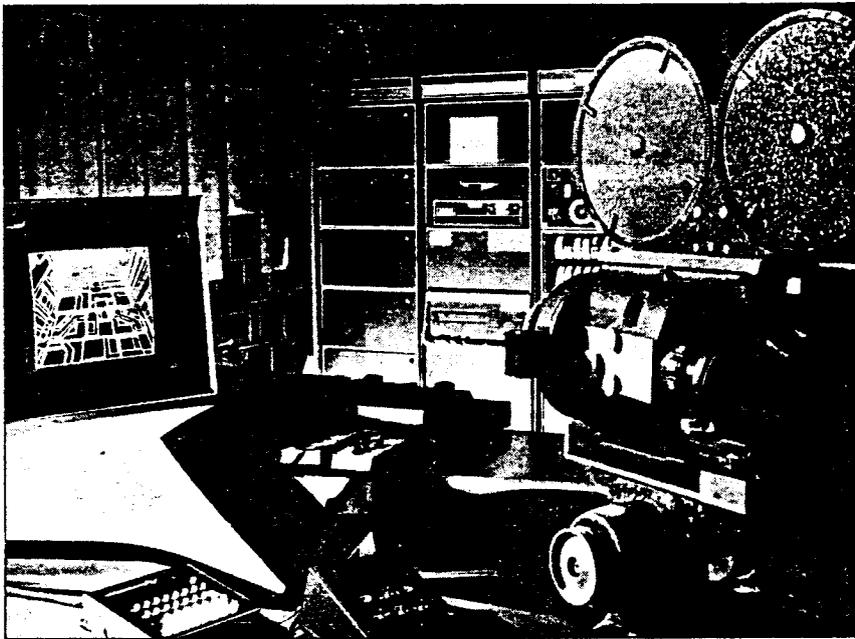

COMPUTER'S
PROGRAM
FOLLOWER

ELEC-
TRONICS

* DISPLAYS*
PROGRAM
FOLLOWER

Repeated
cycle of display
refreshes screen;
running changes by
computer program
ANIMATE THE DISPLAY.

We may call this also a "list-of-lines" system, since the commands recognized by the ... display program follower are typically patterns that tell it what lines to draw.
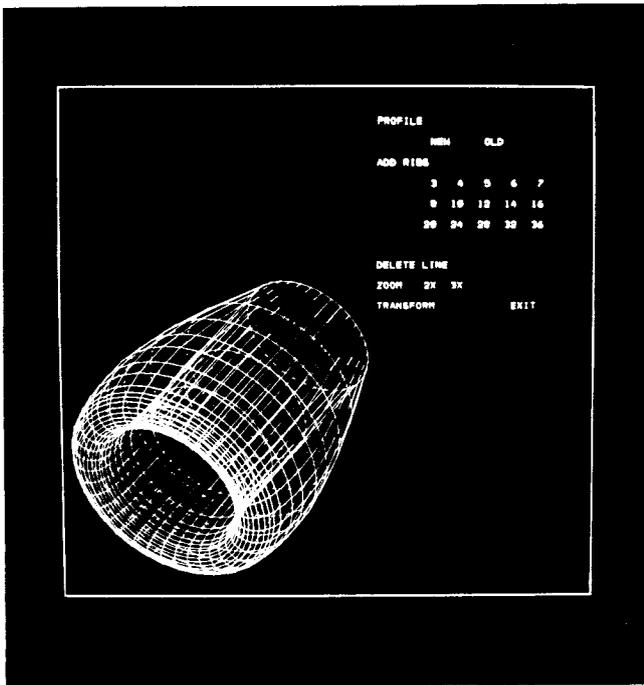
6.4.b.1. Real Time 3D Display
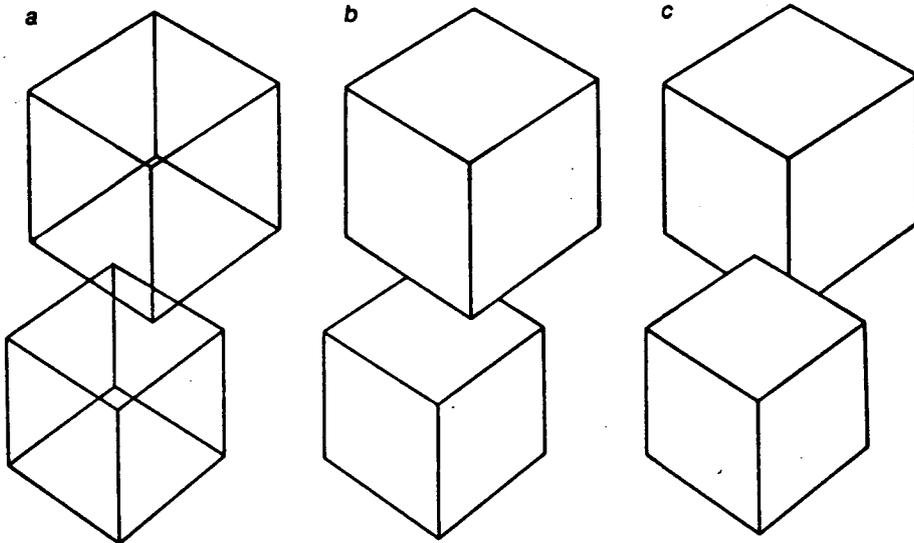
6.5.a. Star Wars Animation - Larry Cuba

6.5.b.5. The Filming Process

PROFILE

NEW   OLD

ADD RIBS

3   4   5   6   7

8   10 12 14 16

20 24 28 32 36

DELETE LINE

ZOOM   2X 3X

TRANSFORM   EXIT

## 6.6. Perspective Projection (Real Time Animation)

6.6.b.1. Real Time Perspective Display

HIDDEN-LINE PROBLEM must be dealt with by a computer program designed to yield clear representations of three-dimensional objects in displays of the "wire line" type. If all the lines of the object are displayed (a), the picture is confusing. The computer must be given instructions for removing the lines that could not be seen in a three-dimensional object or the result can be ambiguous. Removal of the obviously hidden lines in the figure at a could result in either b or c as the display unless the instructions were quite precise.

6.9. Hidden Line Removal

Selected frames from movie of the three-dimensional projection of a rotating four-dimensional hypercube.
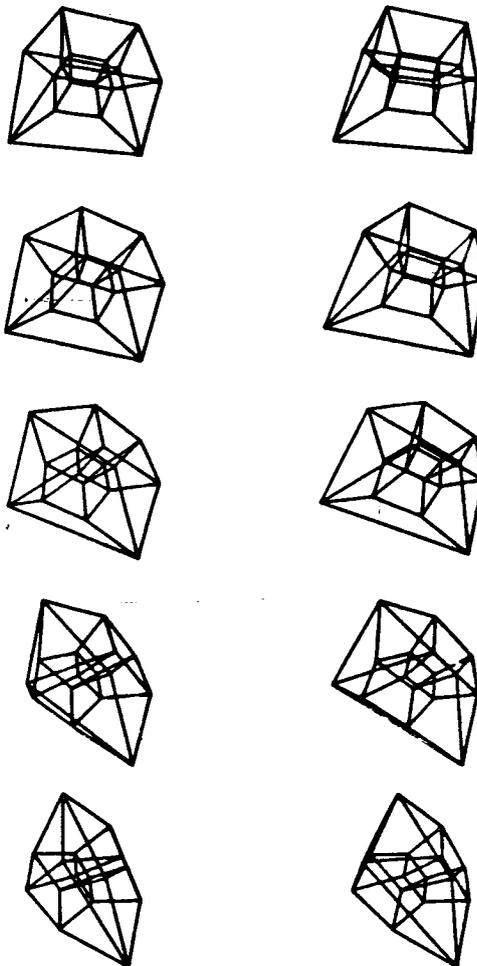
6.7. Projections from Higher Dimensions

A COMPUTER ANIMATION PRIMER

7.0 SYSTEM #6 - COMPUTER: DIGITAL
                DISPLAY: ELECTRONIC (RASTER SCAN)
    a. Raster Scan vs. Vector Scan (w/intensity can simulate raster)
    b. Resolution: height x width x depth (bits/pixel)
        1. number of colors per image
        2. number of colors in pallette
        3. effect of jagged lines
    c. Home Computers
    d. Frame Buffers vs. Vector Lists
    e. Color Maps: pseudo color & image scanning

SHADED GRAPHICS

7.1 ON RASTER DISPLAYS: 2D PAINT PROGRAMS; COLOR MAP ANIMATION
    a. videotape: Sunstone - Ed Emshwiller
    b. process: 2 1/2 Dimensions & paint programs @ NYIT
    c. film: NASA simulations - Dick Shoup
    d. process: color map animation @ Xerox PARC

7.2 ON RASTER DISPLAYS: 3D MODELLING (ANIMATED TIME)
    a. film: Synthavision sample reel - Phil Mittleman
    b. process: combining basic forms

7.3 ON RASTER DISPLAYS: 3D MODELLING (REAL TIME)
    a. film: Euclidean Illusions - Stan Vanderbeek
    b. process: Real Time system @ NASA JSC, Houston
    c. other real time systems: Case Western Reserve

7.4 ON RASTER DISPLAYS: 3D MODELLING COMBINED WITH 2D PAINT
    a. film: Voyager flight simulation - Jim Blinn
    b. process: combining 3D modelling w/ 2D paint
        (texture mapping)

7.5 ON RASTER DISPLAYS: 3D MODELLING: SHADOW PROJECTION
    a. film: ?
    b. process: Cornell (Hanna-Barbera)?

7.6 ON MICROFILM PLOTTERS
    a. film: III sample reel - Gary Demos, J.Whitney,Jr.
    b. process: object digitizing, light effect simulations
    c. other: LLL, Bell Labs Holmdel

7.7 COMPUTER-CONTROLLED LIGHTBOARDS
    a. Skytacular - Goodyear Blimp
    b. Spectacolor - Times Square, NY; Saturday Night Live
    c. Scoreboards - Houston Astrodome
   d. Disco lights - Ron Hays

Raster versus random

Although computer-graphics displays incorporate many diverse technologies, two techniques are fundamental to all graphics-display devices. They are known as raster scan and random position. (See illustration, right.)

Random positioning offers high resolution, as would typically be required in engineering and scientific applications. Its drawbacks include limited color capability and low flicker-free information content. In comparison, raster scanning offers excellent color presentation and high flicker-free information content. For raster scan, the limitation is resolution—typically one half to one fourth that of random position. Television, the most common raster-scan system, employs a 512- by 512-element display, whereas a typical random-position system uses a 1024- by 1024-element display.

In broadcast TV, the scanning spot moves horizontally across alternate lines of the entire frame during one downward sweep, then returns to the top in a continuous, regular pattern. Lines alternate from frame to frame in a bandwidth-conserving process known as interlacing—which is not always applied in digital TV.

The random-position technique simultaneously moves the CRT beam in an arbitrary X and Y direction. The beam is moved directly to the point at which the graphics element is to be displayed—with the beam off—and then the beam is deflected to trace the desired graphics element—with the beam on. This technique is often referred to as random scanning, beam steering, or calligraphy. Function generators driving a random-position system must provide X- and Y-axis analog deflection waveforms and Z-axis intensity waveforms. The amount of information that can be displayed before the picture appears to flicker depends on both the speed with which the beam may be deflected and the display's phosphor characteristics.
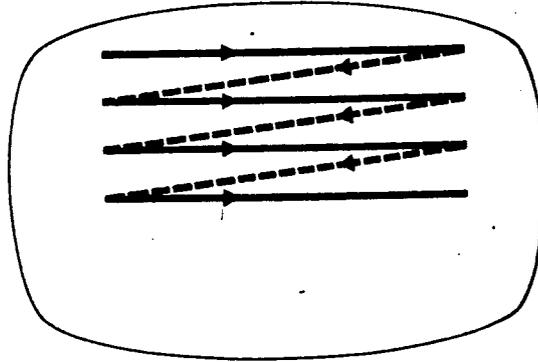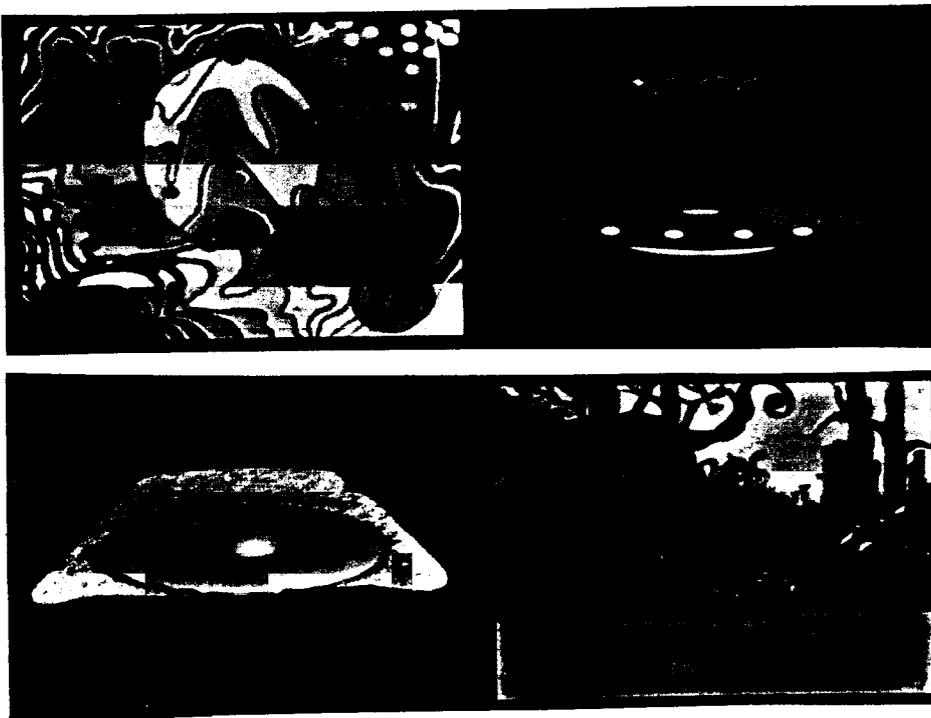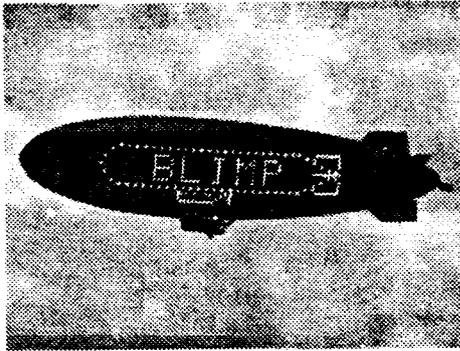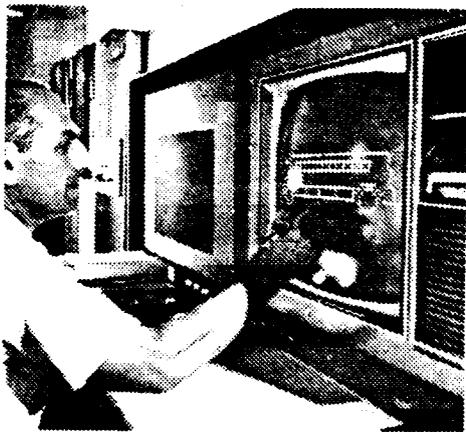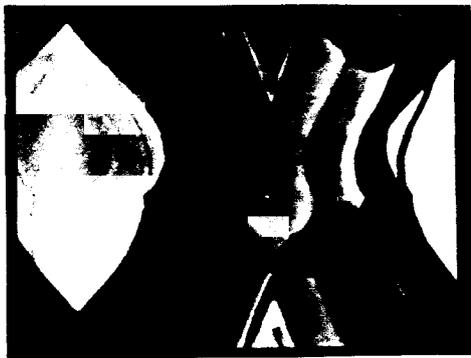

Raster scan
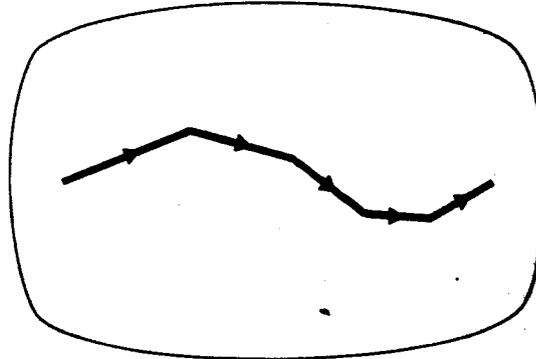
Random position

7.0.1. Raster Scan vs. Vector Scan

7.1. 2D Paint Programs - NYIT

7.7.a. Computer Controlled Lightboards - 'Skytacular'
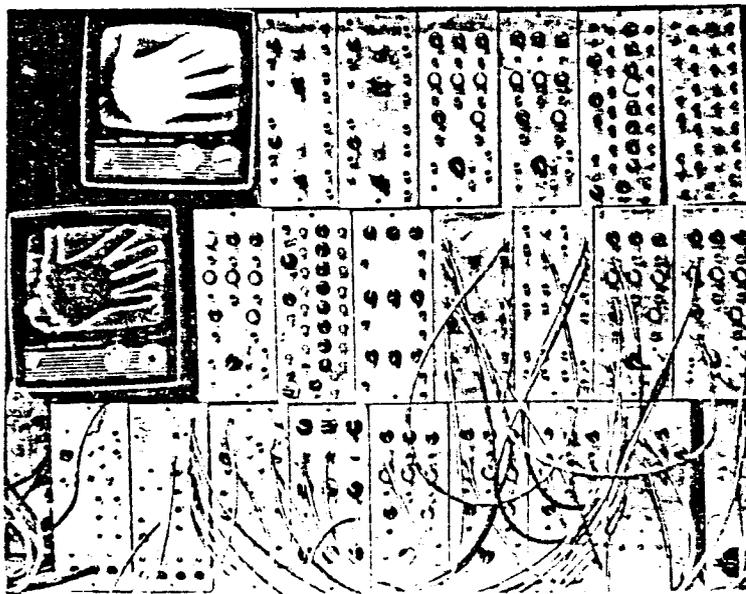

8.1. Videotape - Barbara Sykes

Fig. I. The Image Processor is shown with two monitors and the 'patch' cabling required to extract edges and intensify the result.
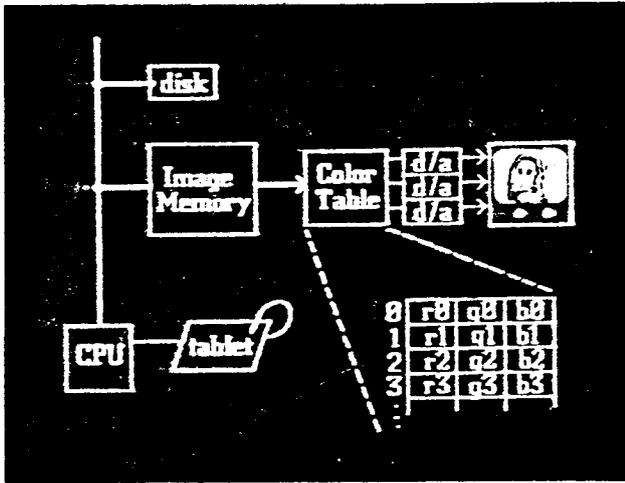
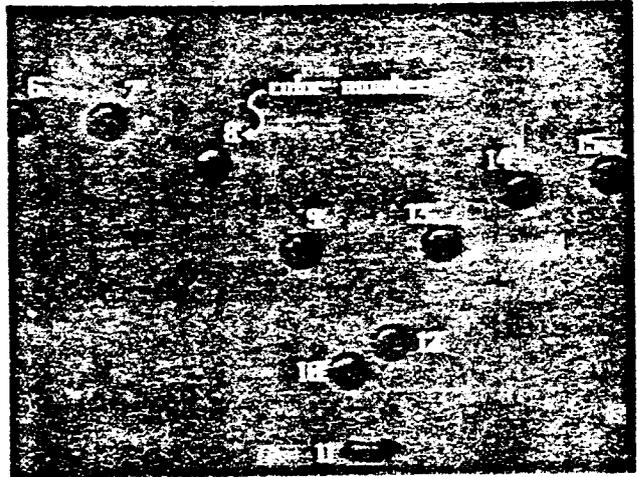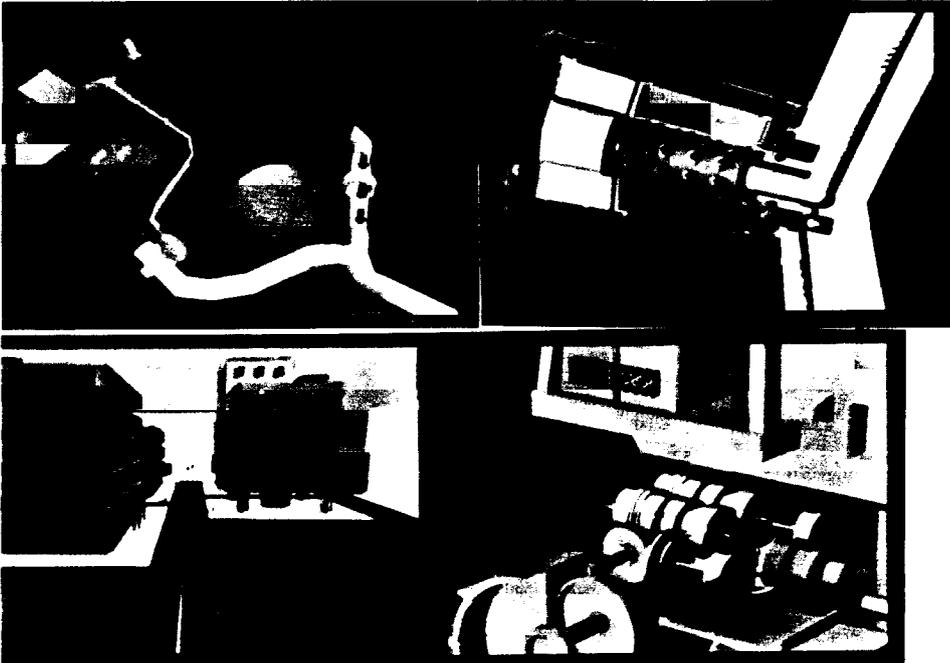8.1.b.1. Sandin Image Processor

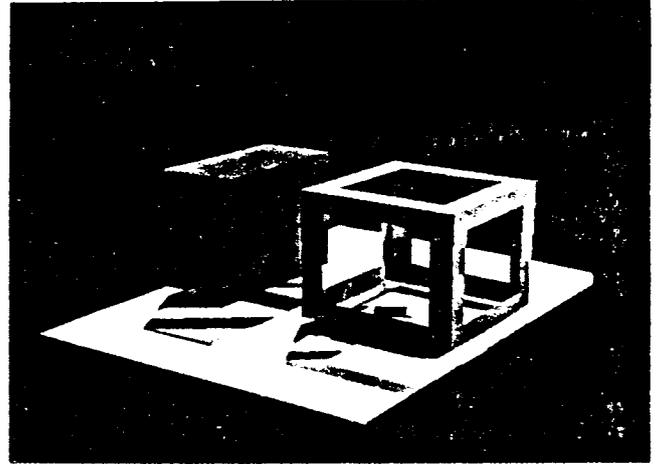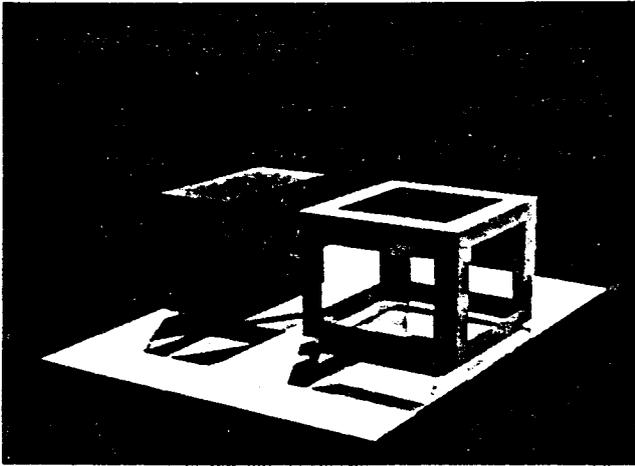Figure 1. Frame buffer with color table.

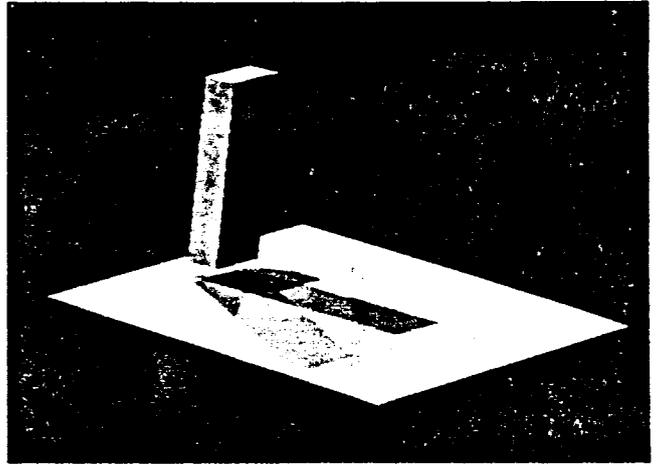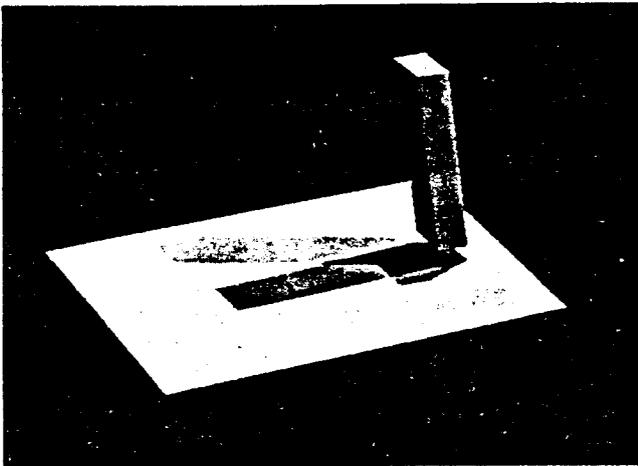Figure 3a. Alternate-color animation - bouncing ball.

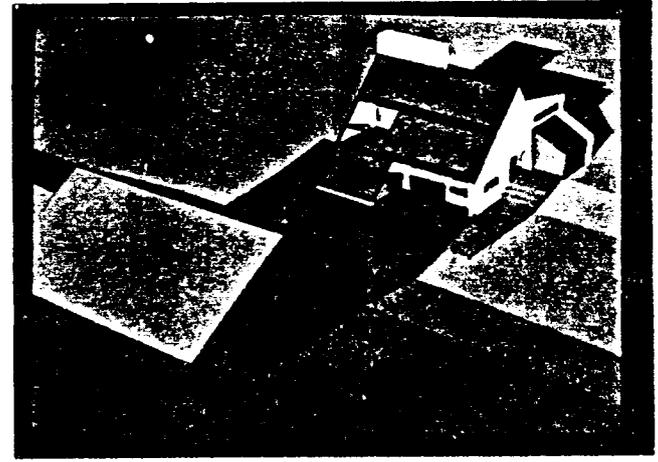7.1.d. Color Map Animation - Xerox PARC

7.2.a. Synthavision Sample Reel

Figures 6. Shadowed Image Displays with Two Light Sources at Different Locations.
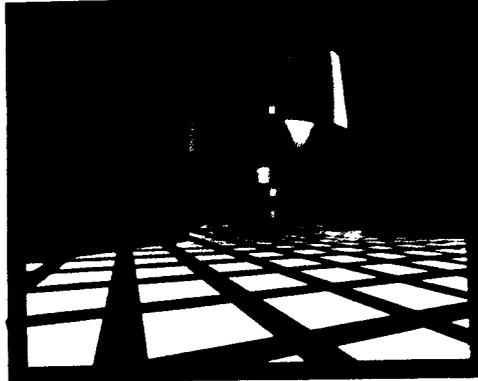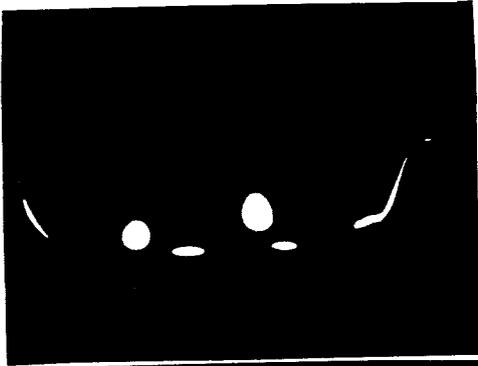
Figures 7. Shadowed Image Displays with Three and Four Distinct Light Sources.

Figures 8. Visual Examination of Simulated Shadowed Site from Two Observer Positions.

7.5. 3D Modelling - Shadow Projection

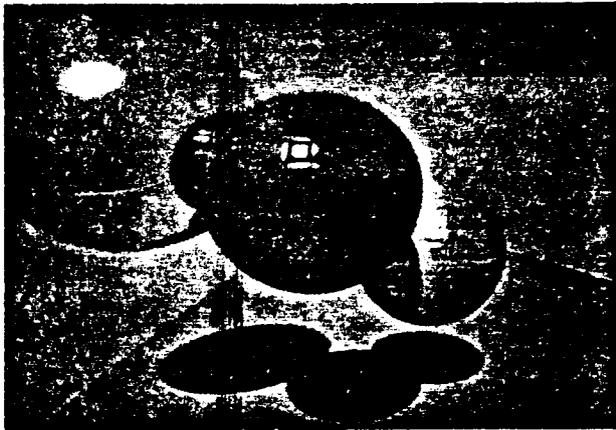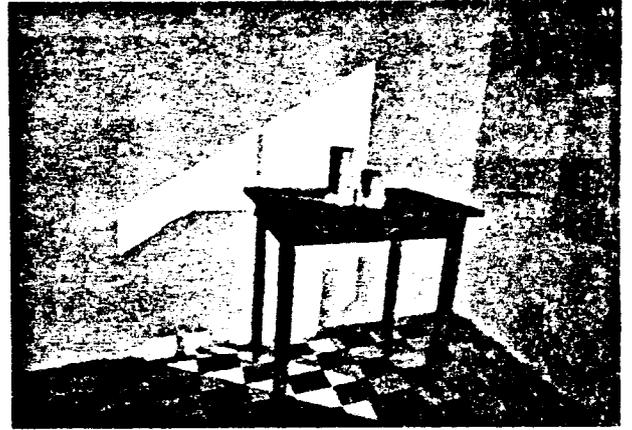7.6.a. Information International Sample Reel
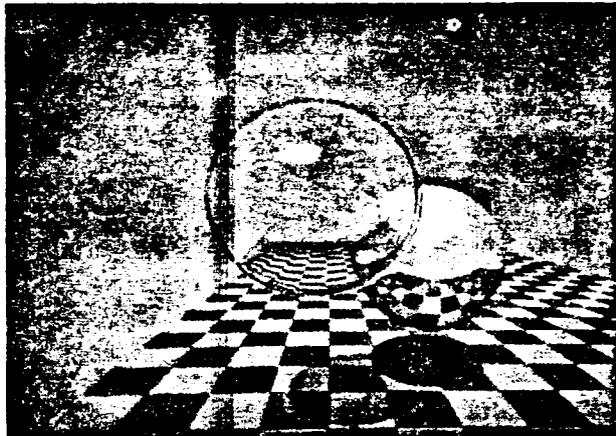

Figure 5

Figure 7

Figure 6

Figure 8

7.6.c. Bell Labs Holmdel - Turner Whitted

8.0 SYSTEM #7 - COMPUTER: ANALOG
                 DISPLAY: RASTER
    a. video signal generation: all real time; no frame store

8.1 "Z-AXIS" MANIPULATIONS
    a. tape: Electronic Masks - Barbara Sykes
    b. process:
        1. Sandin Image Processor (IP)
        2. modular signal generator (like in 1.3)
        3. oscillators: wave forms (tonal effect)
        4. standard studio effects: supers & keying
        5. other modules: value scrambler, etc.

8.2 RASTER MANIPULATIONS
    a. tape: ? - Woody Vasulka
    b. process:
        1. Rutt-Etra Synthesizer
        2. oscillators: wave forms (geometric effect)
        3. other systems: Scanimate (Computer Image Corp)
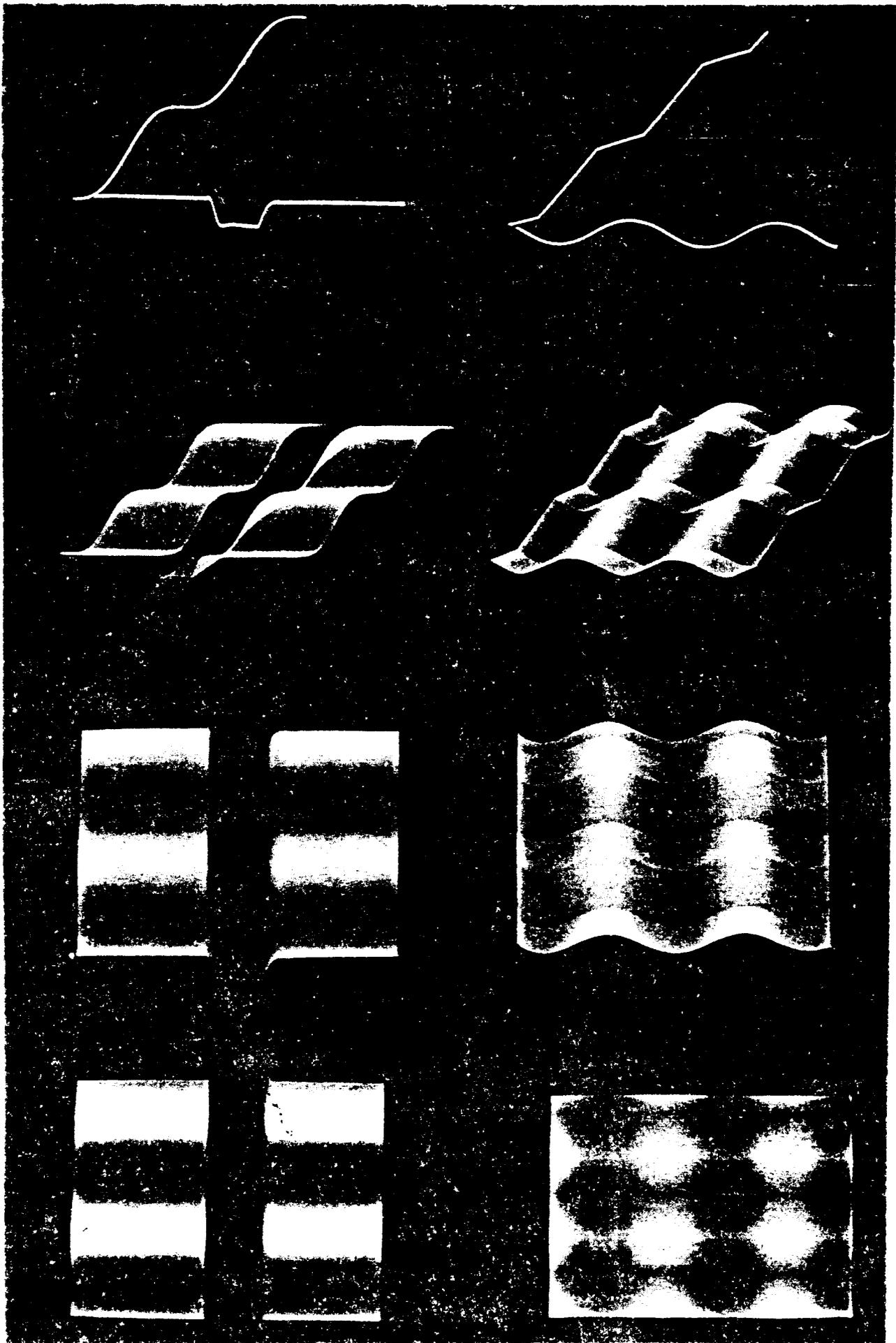
8.2. Raster Manipulations - videotape: Woody Vasulka
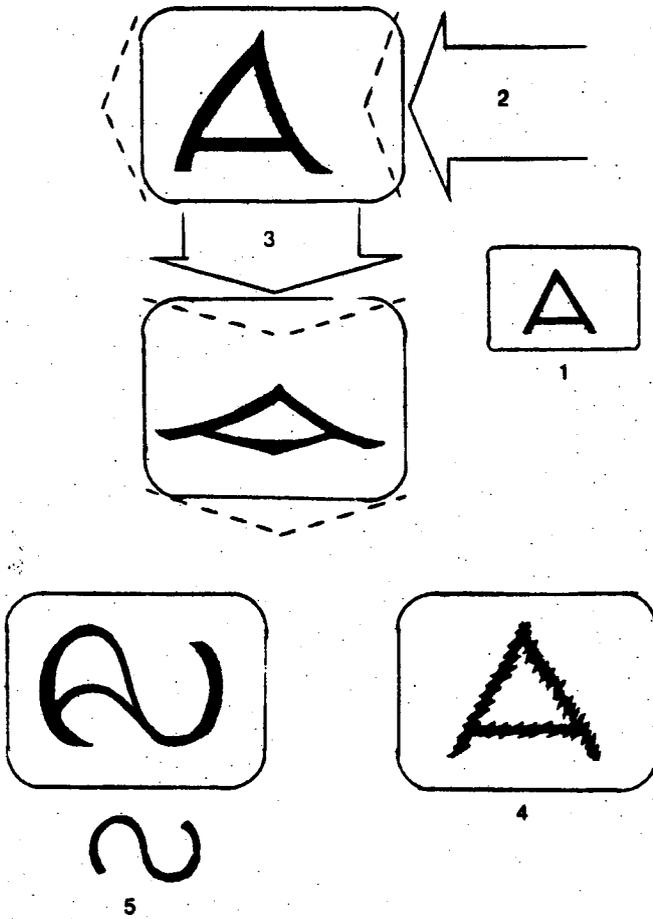
7-24. In the Scanimate system a raster-bending electronic signal causes the displayed image to follow the wave-form shape: (1) normal image, (2) delta wave, (3) delta wave, (4) high-frequency delta wave, (5) sine wave.
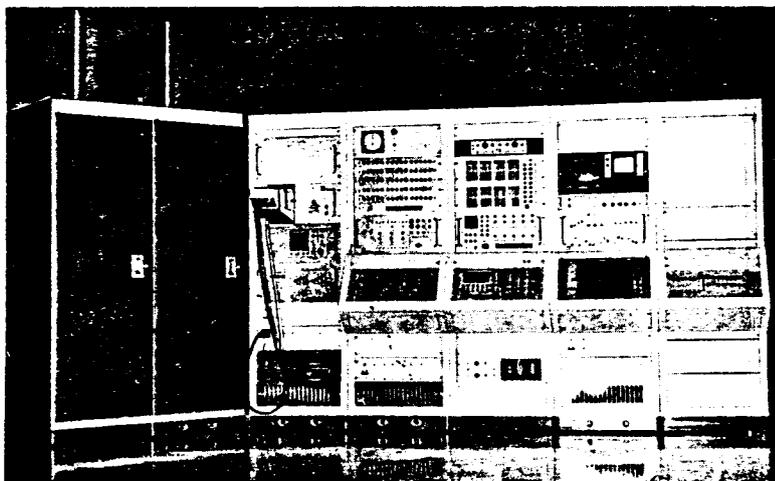
8.2.3. 'Scanimate' System (Computer Image Corp)

black-and-white 945-line high-resolution vidicon TV camera

artist manual control
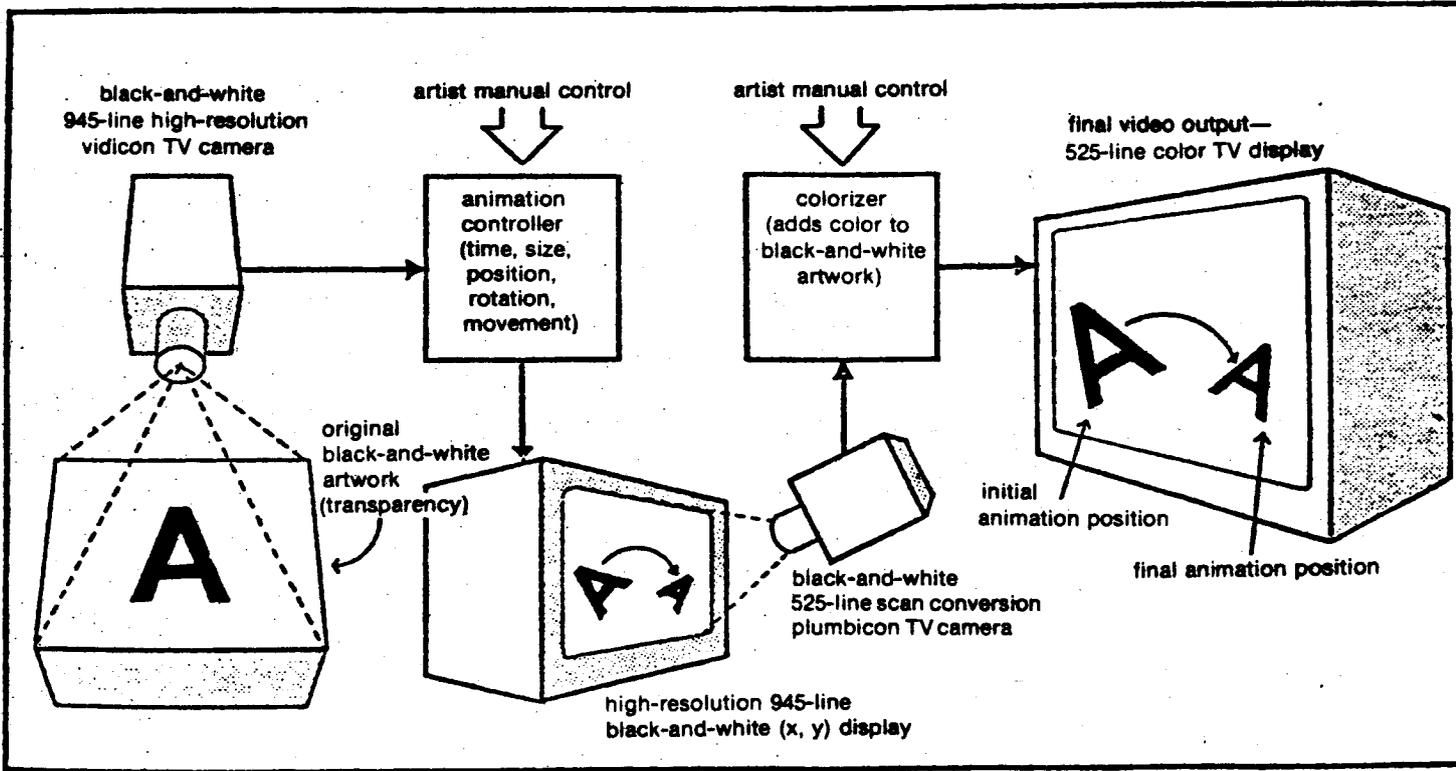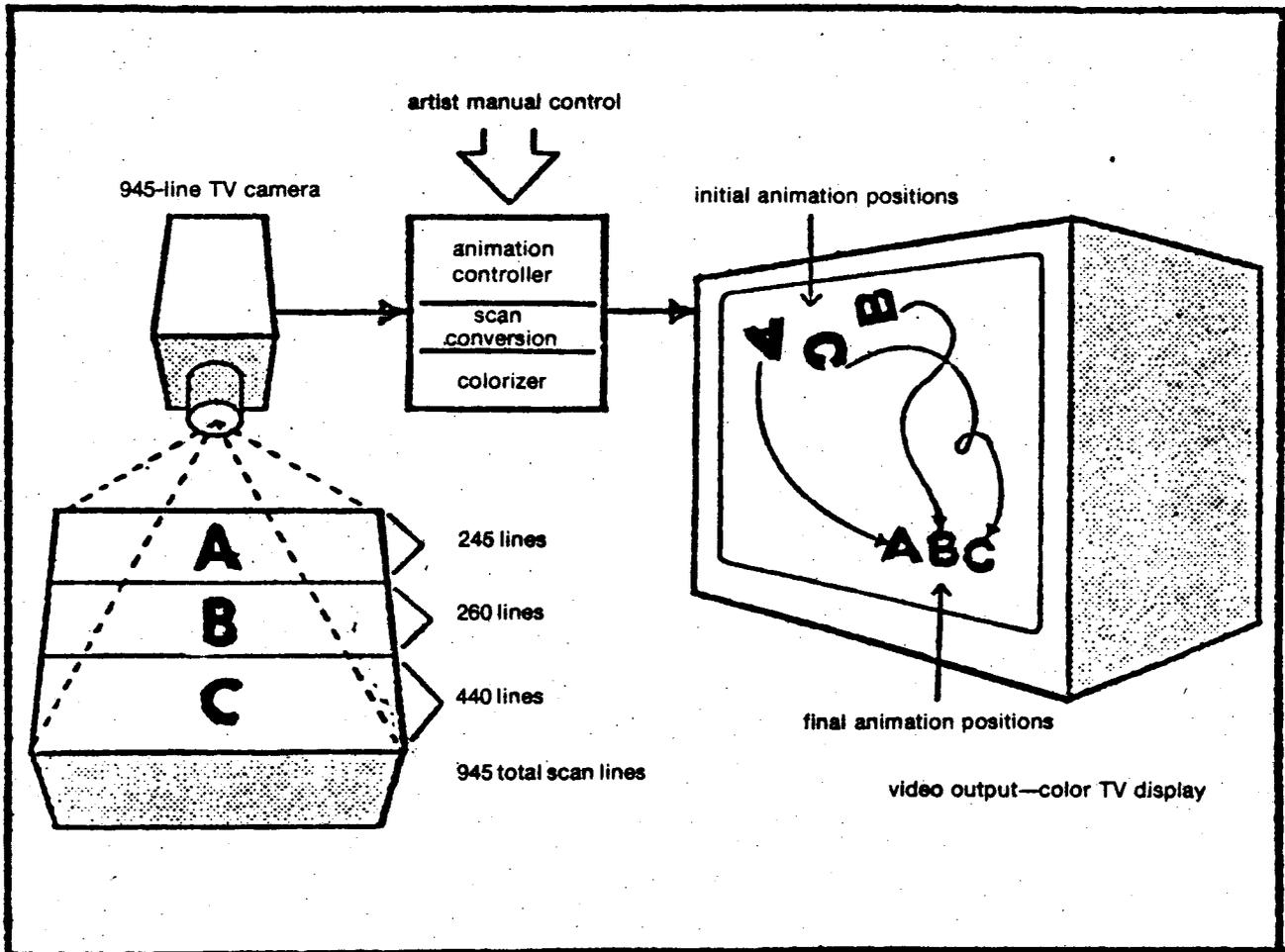
artist manual control

final video output— 525-line color TV display

animation controller (time, size, position, rotation, movement)

colorizer (adds color to black-and-white artwork)

original black-and-white artwork (transparency)

A

initial animation position

final animation position

black-and-white 525-line scan conversion plumbicon TV camera

high-resolution 945-line black-and-white (x, y) display

7-25. Block diagram of the Scanimate animation computer. (Courtesy of computer Image Corporation.)

artist manual control

945-line TV camera

initial animation positions

animation controller

scan conversion

colorizer

A B C

245 lines

260 lines

440 lines

945 total scan lines

final animation positions

ABC

video output—color TV display
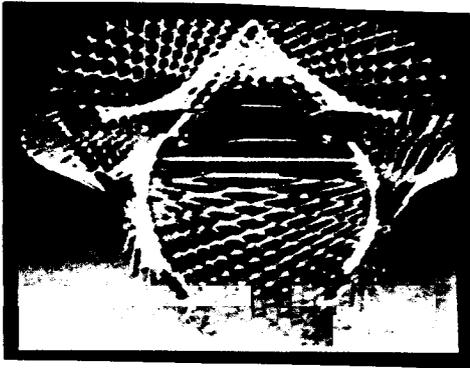
7-26. Multiple-image animation. (Courtesy of Computer Image Corporation.)

8.2.3. 'Scanimate' System
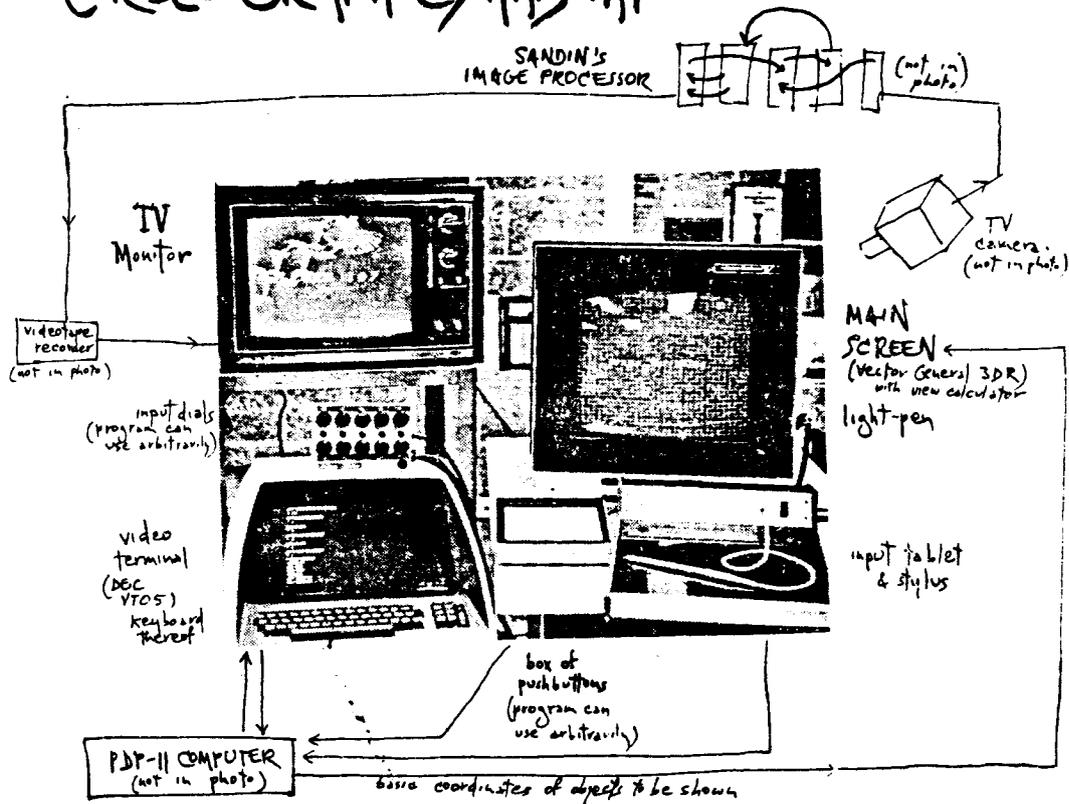
9.0 COMBINING TECHNIQUES
1. Digital & Analog/Raster: Ceaser
2. Analog/Vector & Raster: Bob Snyder's system
3. Digital/Vector & Analog/Raster: Circle Graphics Habitat
4. Digital/Vector & Raster: Jim Blinn & JPL
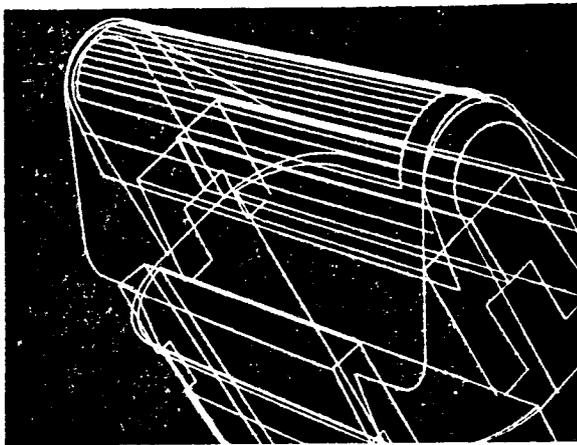5. Digital/Vector & Digital/Mechanical: Abel's picture system

9.0.3. videotape - Gunther Tetz, Phil Morton

THE CIRCLE GRAPHICS HABITAT

SANDIN's
IMAGE PROCESSOR

(not in photo)

TV Monitor

TV camera (not in photo)

videotape recorder
(not in photo)

MAIN SCREEN
(Vector General 3DR)
with view calculator

light-pen

input dials
(program can use arbitrarily)

video terminal
(DEC VT05)
keyboard thereof

input tablet & stylus

box of pushbuttons
(program can use arbitrarily)

PDP-11 COMPUTER
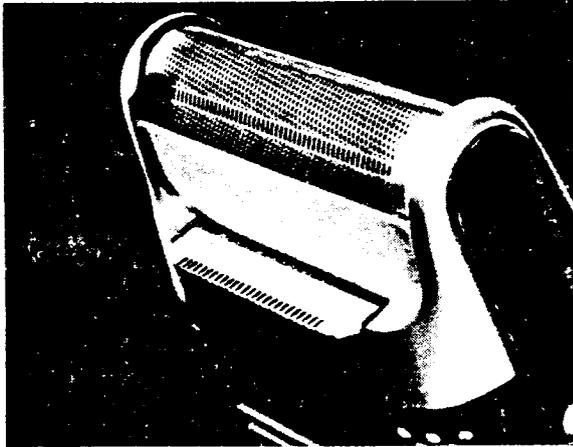(not in photo)

basic coordinates of objects to be shown

9.0.3. The Circle Graphics Habitat

Steps in the pro-
duction of the
Braun Micron
Shaver commer-
cial, in which the
Evans &
Sutherland system
is used to
choreograph the
assembly of the
shaver from free-
floating parts.
First: The E&S
version of the
Braun shaver.

Second: A model
version of the
shaver with its
position arrived
at via the E&S
simulation shown
above.

Third: The E&S
version of the
Braun shaver
showing a comb
and hairplane ef-
fect.

Fourth: The
model version of
the shaver show-
ing the comb and
hairplane effect,
its position
arrived at from
the E&S simula-
tion.

9.0.5 Bob Abel's Picture System