Chapter 2:

Graphics System - Hardware and Software

Objectives

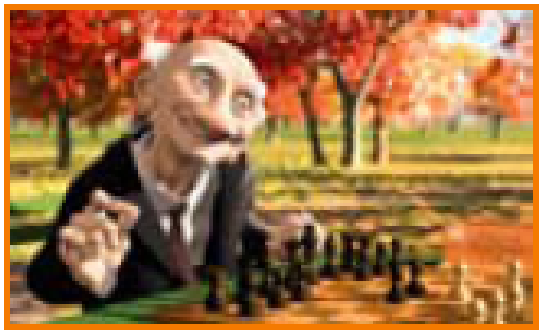
- In this lecture, we learn some fundamental computer graphics such as:
  - Applications
  - Graphic Systems
  - Hardware
  - Standard Software

Computer Graphics Applications

- Entertainment
- Computer-aided design
- Scientific visualization
- Training
- Education
- E-commerce
- Computer art

Computer Graphics Applications

- **Entertainment**
- Computer-aided design
- Scientific visualization
- Training
- Education
- E-commerce
- Computer art



Geri's Game
(Pixar Animation Studios)

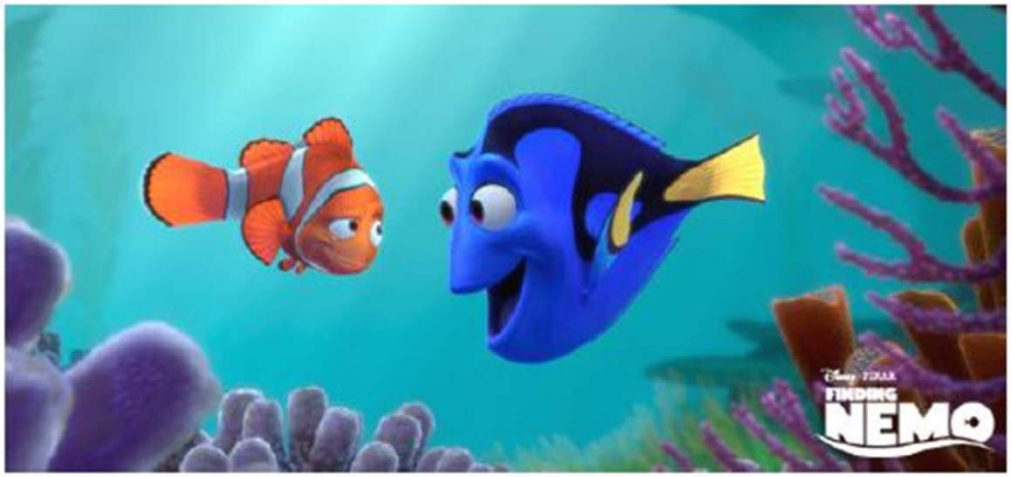
Jurasic Park
(Industrial, Light, & Magic)

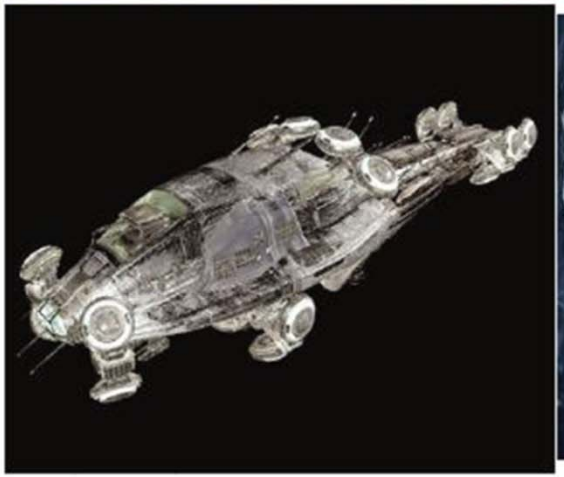
Entertainment

- Television productions, motion pictures and music videos routinely use computer graphics.

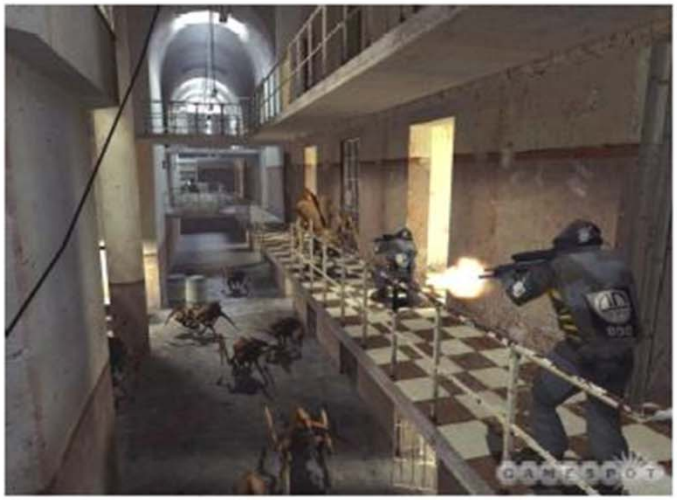
- Some combines with live actors and scenes and others completely generated using computer-rendering and animation techniques.

Movies





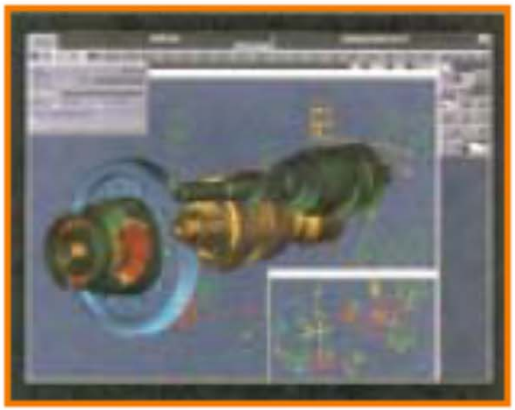
Games



Computer Graphics Applications

- Entertainment
- **Computer-aided design**
- Scientific visualization
- Training
- Education
- E-commerce
- Computer art

Los Angeles Airport
(Bill Jepson, UCLA)



Gear Shaft Design
(Intergraph Corporation)

Boeing 777 Airplane
(Boeing Corporation)

Computer-Aided Design

- Major use in:
  - design processes,
  - engineering and architectural systems.
- Generally referred to as CAD (Computer Aided Design) or CADD (Computer Aided Drafting and Design).
- These methods are routinely used in design of buildings, automobiles, aircraft, watercraft, spacecraft, computers, textiles, home appliances etc.

9

- For some design applications, objects are displayed as *wire-frame* outline that shows overall shape & internal features of the objects.

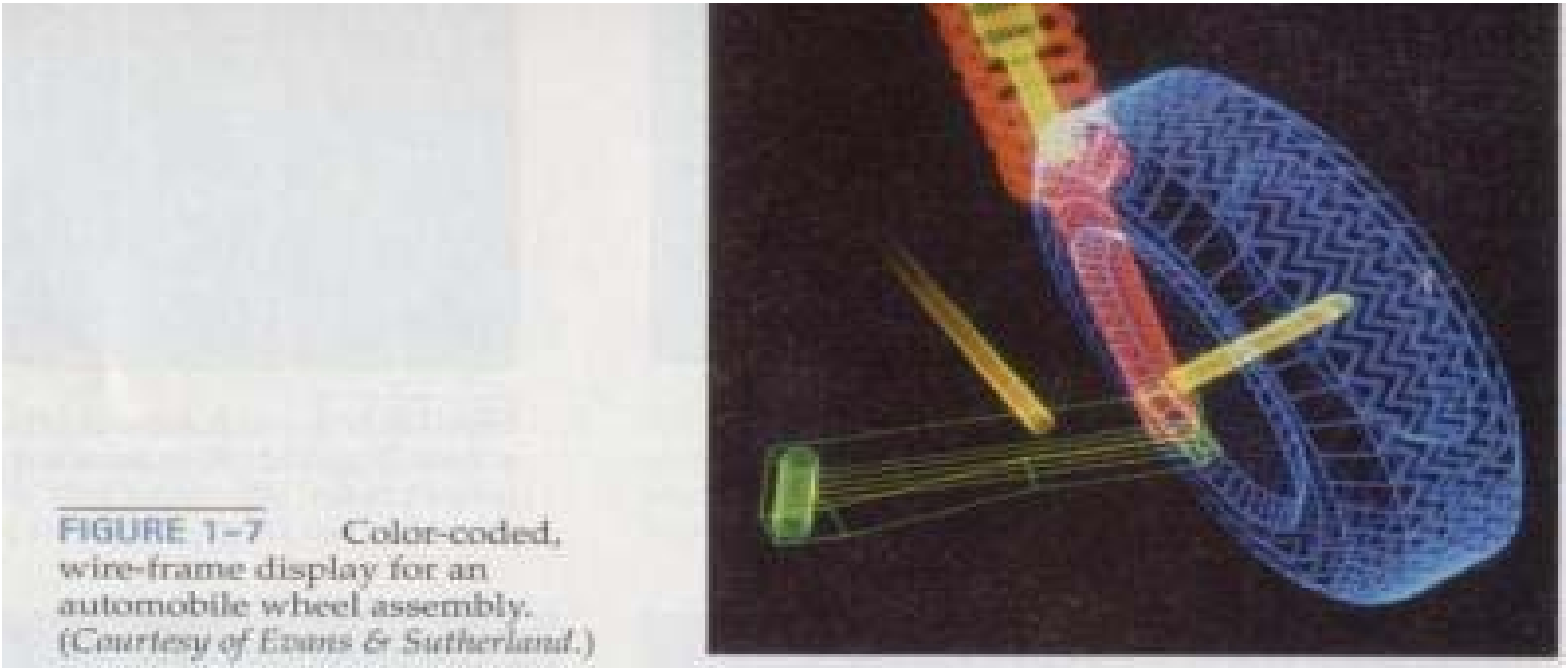
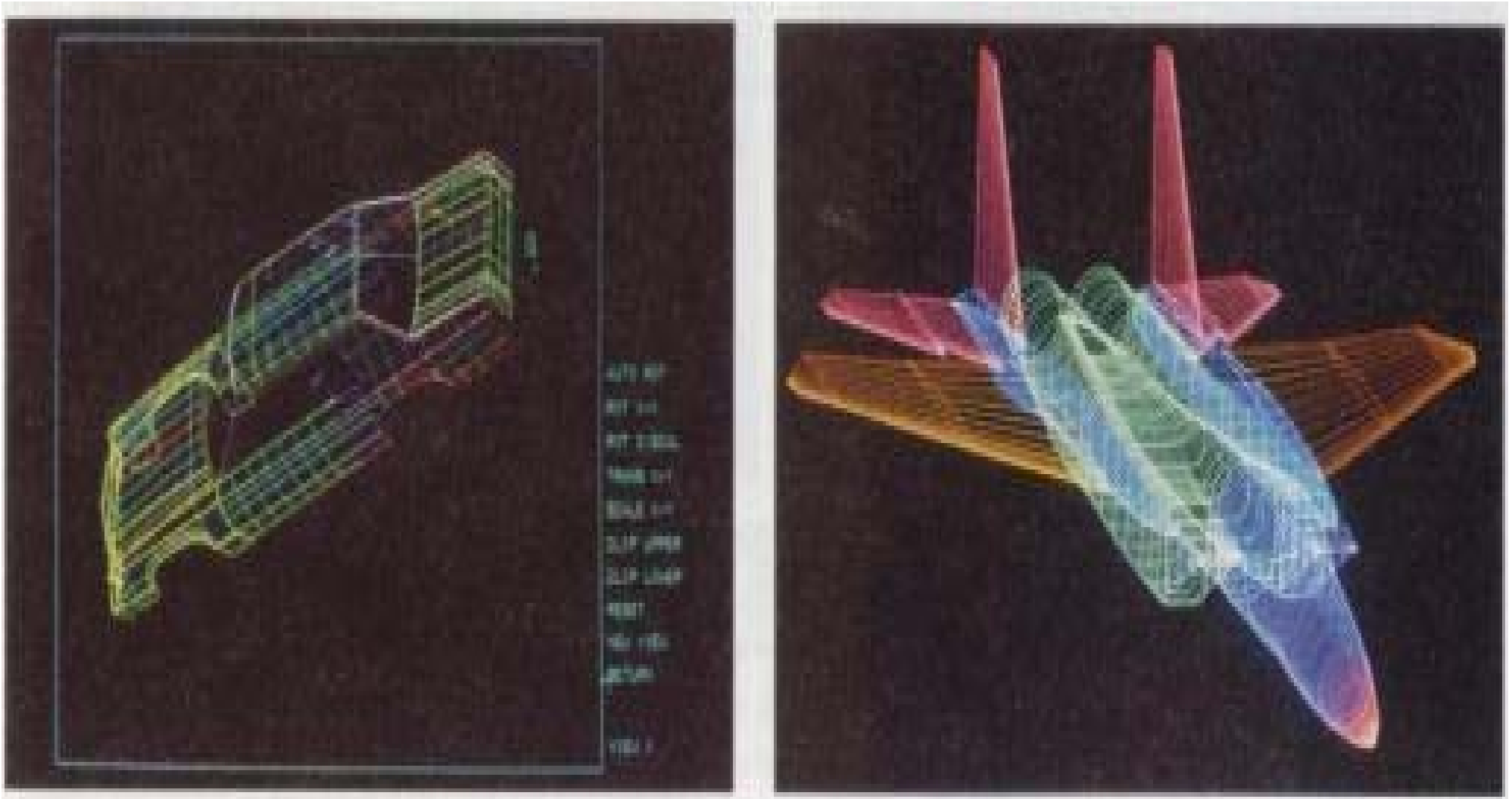


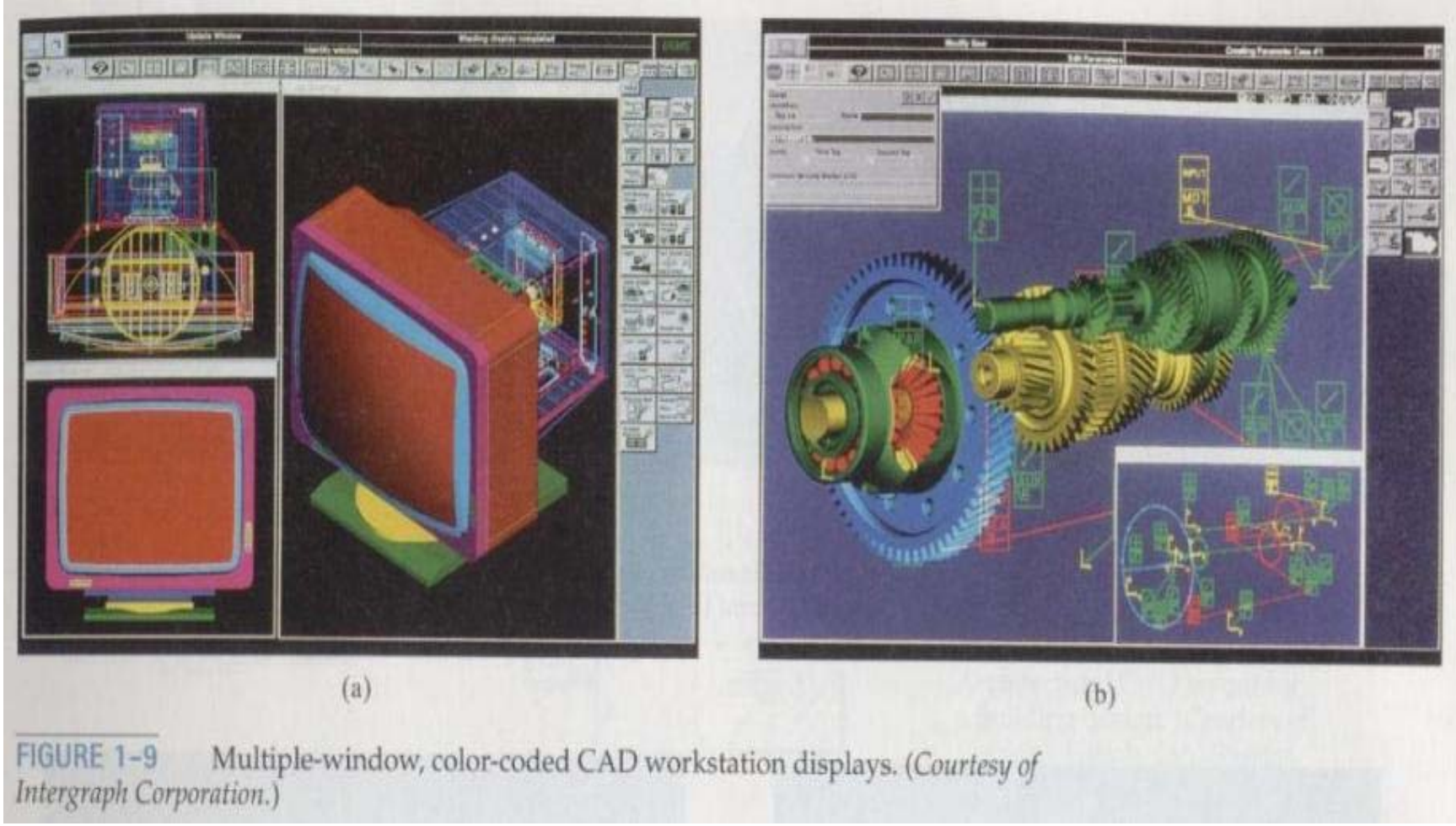
FIGURE 1–7 Color-coded, wire-frame display for an automobile wheel assembly. (*Courtesy of Evans & Sutherland.*)



(a) (b)

FIGURE 1-8 Color-coded, wire-frame outlines of body designs for an automobile and an aircraft. (*Courtesy of* (a) *Peritek Corporation and* (b) *Evans & Sutherland.*)

- Software packages such as CAD, provide designer with *multi window environment*.



(a) (b)

FIGURE 1-9 Multiple-window, color-coded CAD workstation displays. (*Courtesy of Intergraph Corporation.*)

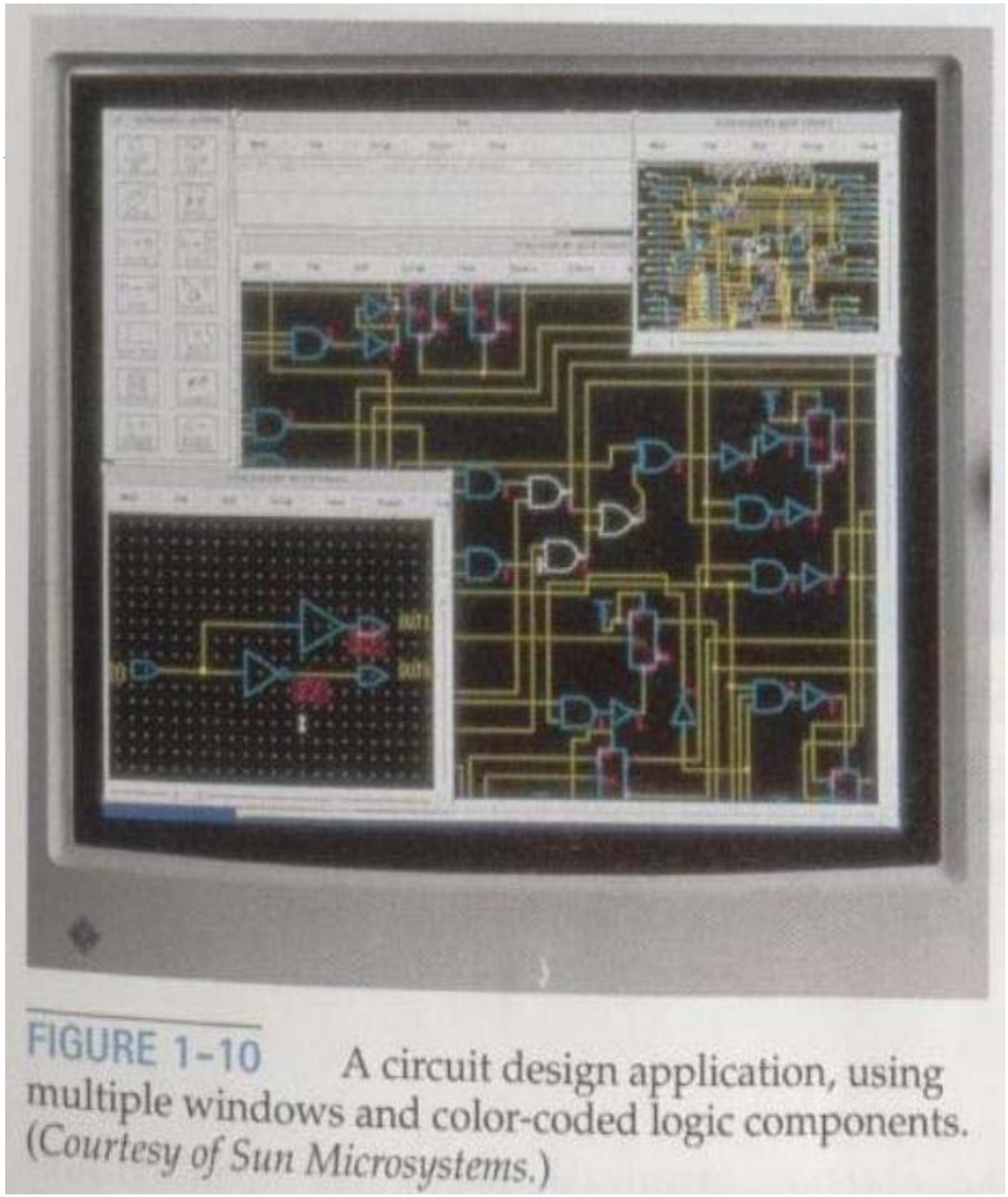


FIGURE 1-10 A circuit design application, using multiple windows and color-coded logic components. (*Courtesy of Sun Microsystems.*)

- Circuits and networks for communications, water-supply or other utilities are constructed with repeated placement of a few *graphical shapes*

- *Animations* using wire-frame shapes are useful for quickly testing the performance of a vehicle or system. It allows the designer to see into the interior of the vehicle and to watch the behavior of inner components during motion.

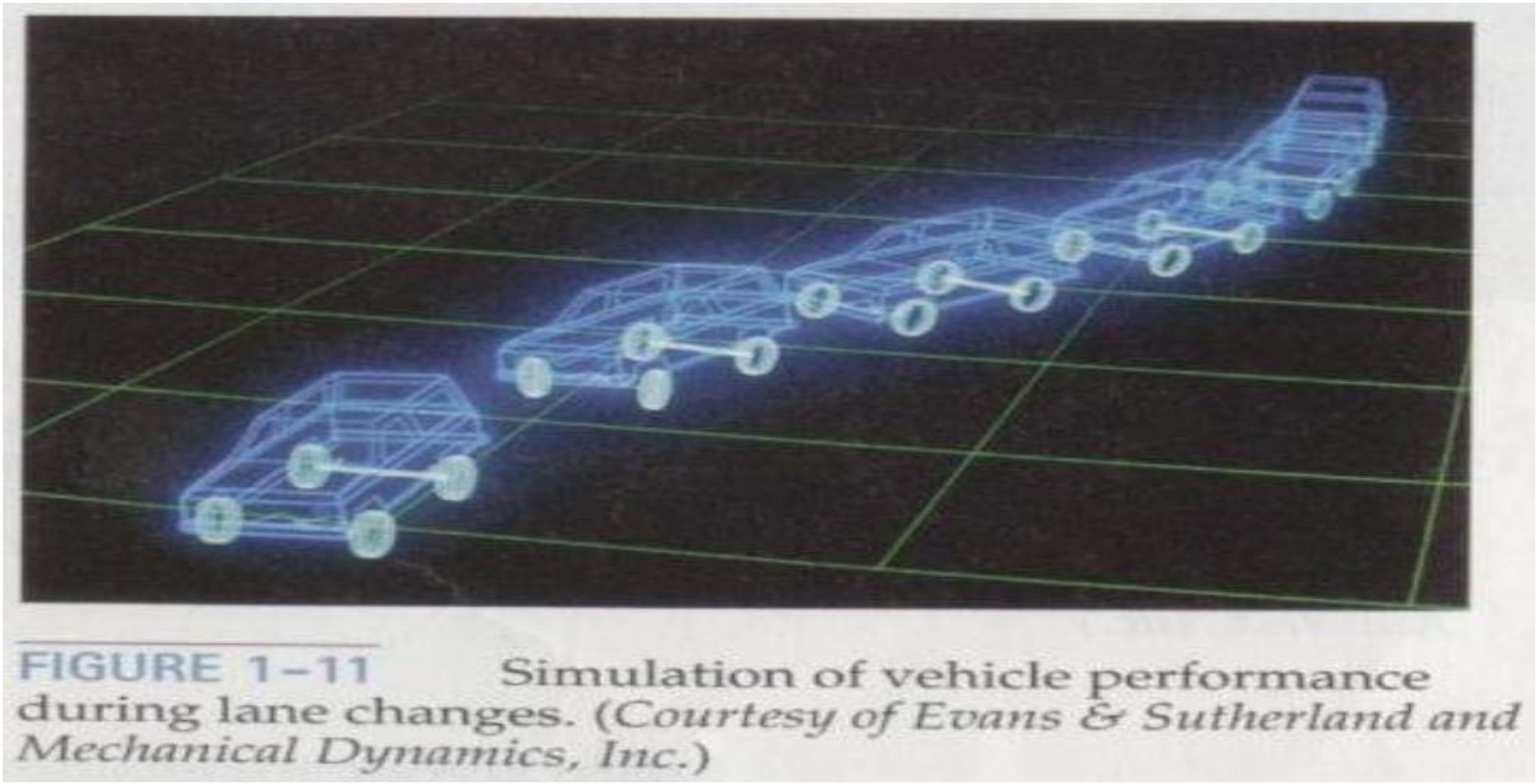


FIGURE 1–11 Simulation of vehicle performance during lane changes. (*Courtesy of Evans & Sutherland and Mechanical Dynamics, Inc.*)

FIGURE 1-13 Studio lighting effects and realistic surface-rendering techniques are applied by computer-graphics programs to produce advertising pieces for finished products. This computer-generated image of a Chrysler Laser automobile was produced from data supplied by the Chrysler Corporation. (*Courtesy of Eric Haines, Autodesk, Inc.*)

- *Realistic lighting conditions* and *surface rendering* are applied to produce displays that will show the appearance of the final projects.

Architectural CAD Layout for Building Design

- Shows positioning of rooms, doors, windows, stairs, etc. This will help electrical designer for example, to try out different arrangements for wiring, electrical outlets & fire warning systems

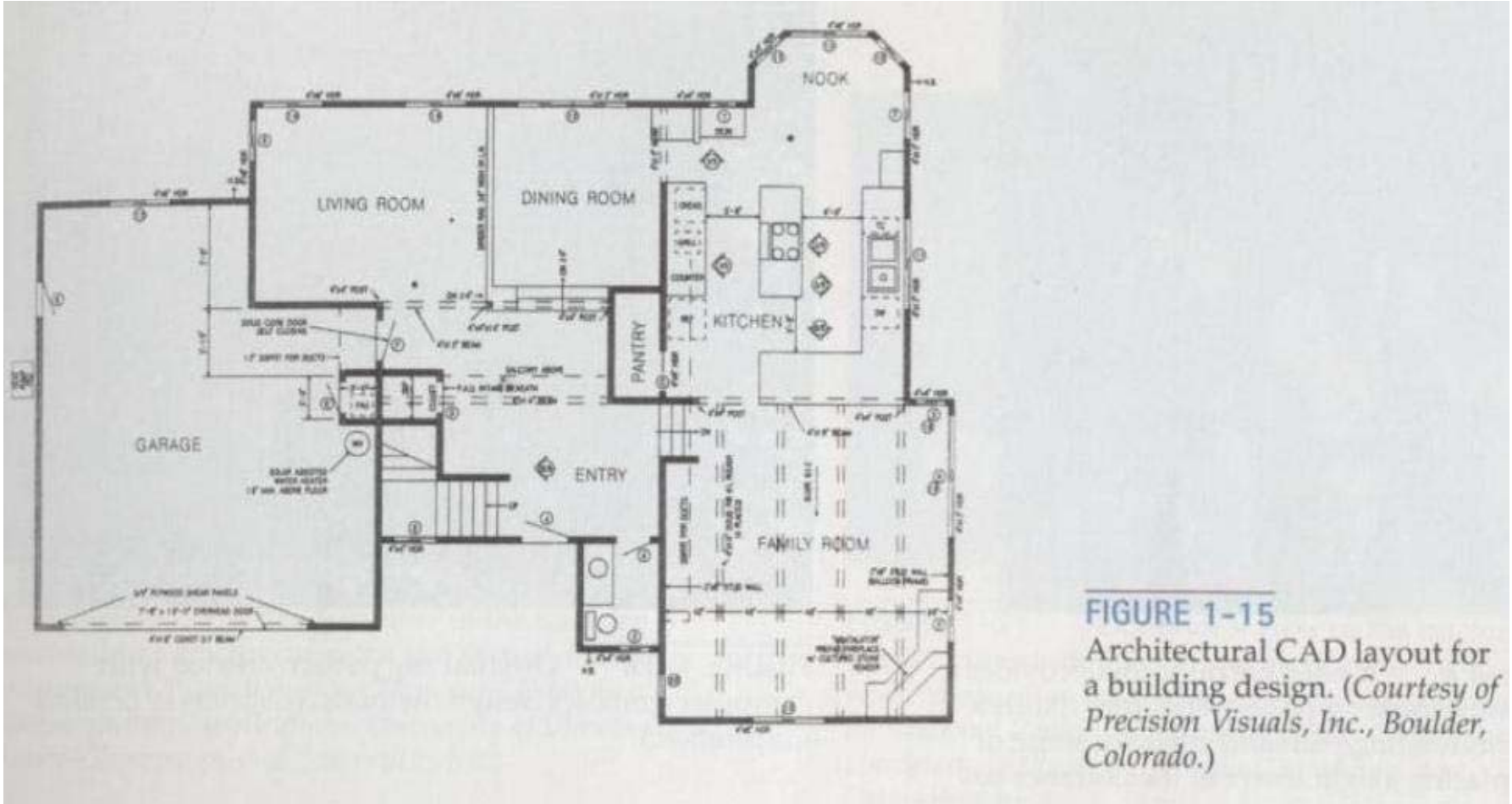


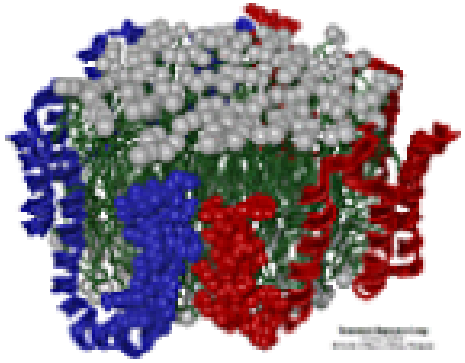
FIGURE 1-15
Architectural CAD layout for a building design. (*Courtesy of Precision Visuals, Inc., Boulder, Colorado.*)

Computer Graphics Applications

- Entertainment
- Computer-aided design
- **Scientific visualization**
- Training
- Education
- E-commerce
- Computer art

Airflow Inside a Thunderstorm

(Bob Wilhelmson,
University of Illinois at Urbana-Champaign)



Apo A-1

(Theoretical Biophysics Group,
University of Illinois at Urbana-Champaign)

Visible Human

(National Library of Medicine)

Data Visualization

- Scientific Visualization
  - For scientists, engineering and medical dataset and processes.
- Business Visualization
  - Data sets related to commerce, industry and other nonscientific areas.

Why Graphics is Preferred?

- Researchers and analysts often deal with large amounts of information or study the behavior of highly complex process.
- Satellite and other recording devices produce data files that are very big to browse through to determine trends and relationships.
- Visual form allows faster trends and patterns to be recognized.

- Ways to visualize data:
  - Color coding, contour plots, *renderings* for constant-value surfaces or other spatial regions, and specially designed shapes to represent different data types.
  - Visual techniques are also used to aid understanding and analysis of complex processes and mathematical functions.

Some Examples of Data Visualization

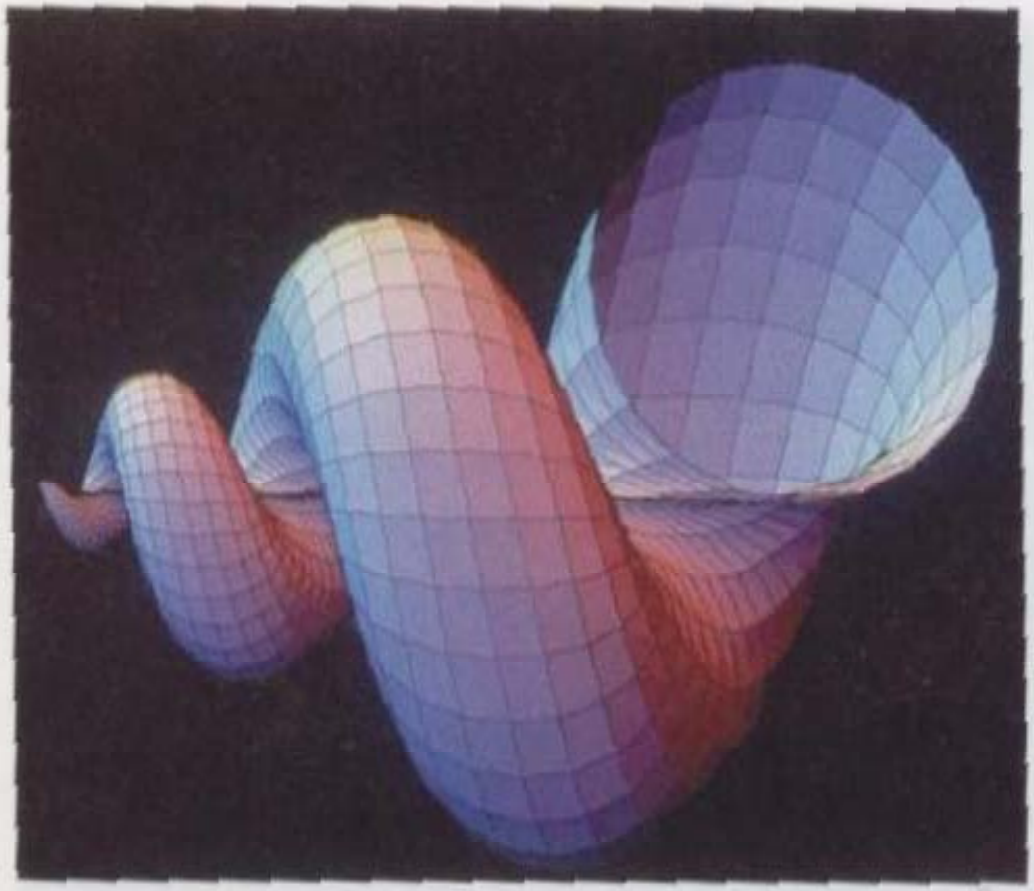


FIGURE 1-25 Lighting effects and surface-rendering techniques were applied to produce this surface representation for a three-dimensional function. (*Courtesy of Wolfram Research, Inc., The Maker of Mathematica.*)

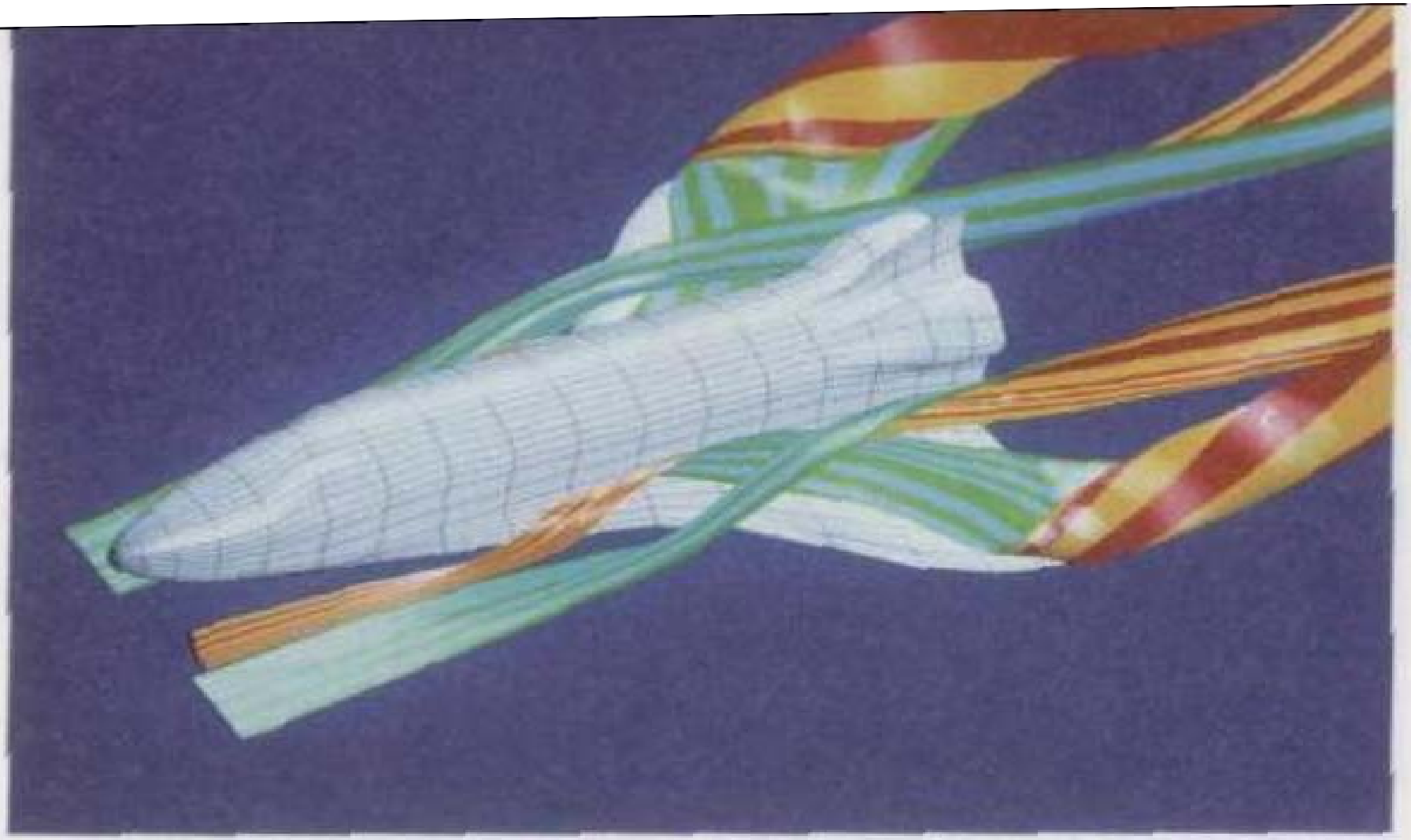


FIGURE 1-29 A visualization of stream surfaces flowing past a space shuttle, devised by Jeff Hultquist and Eric Raible, NASA Ames. (*Courtesy of Sam Uselton, NASA Ames Research Center.*)

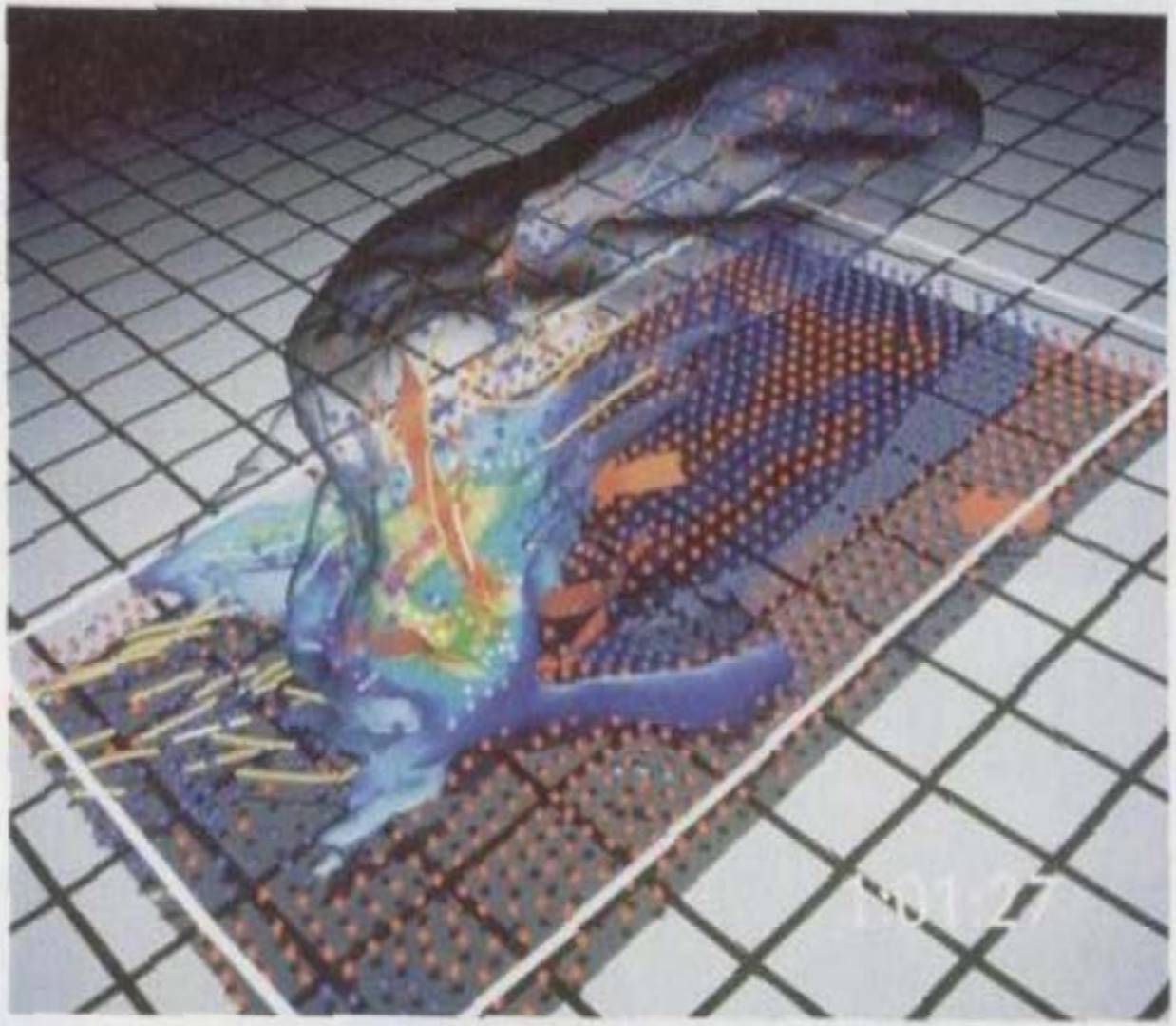


FIGURE 1-30 Numerical model of airflow inside a thunderstorm. (*Courtesy of Bob Wilhelmson, Department of Atmospheric Sciences and the National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign.*)

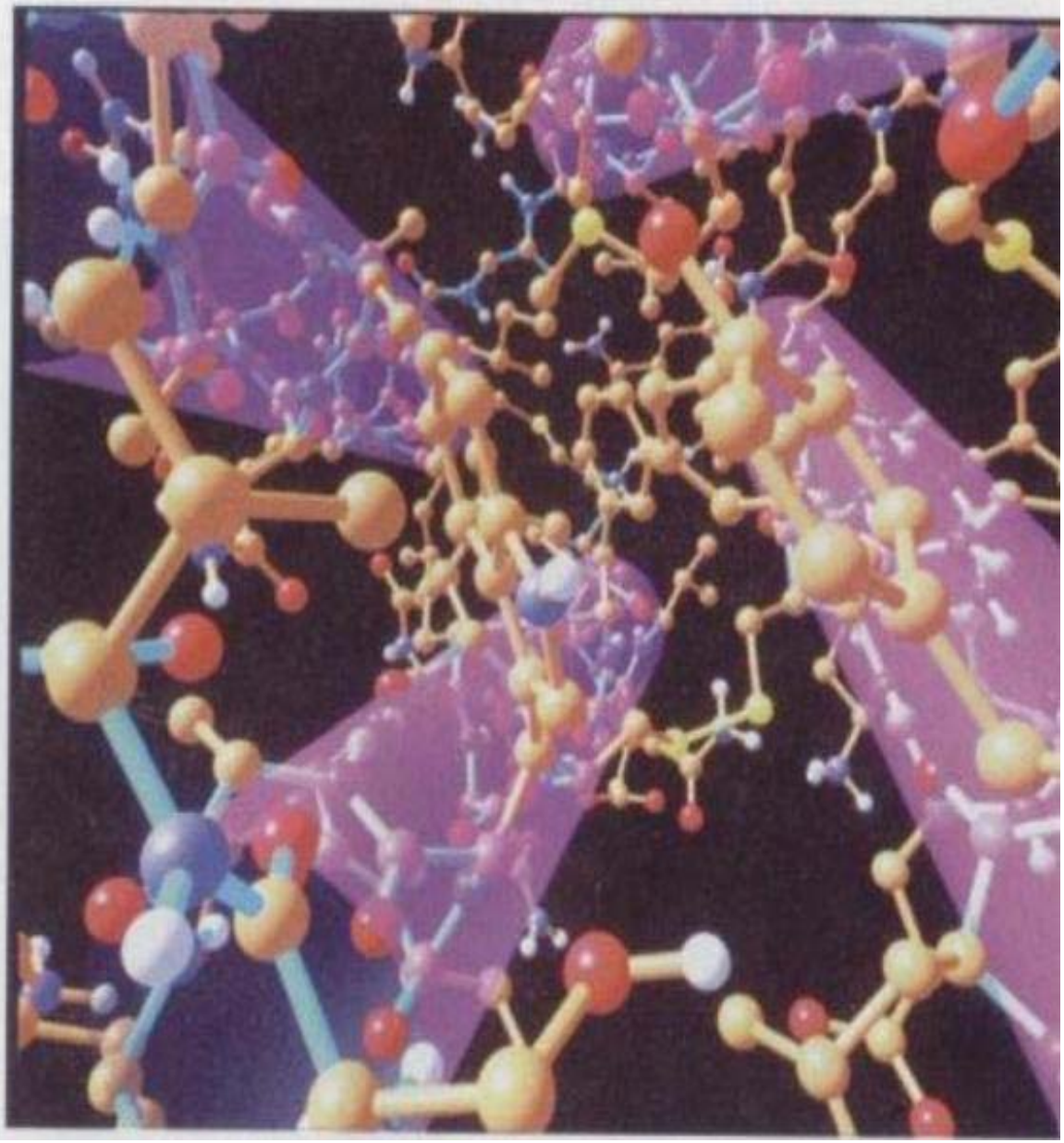


FIGURE 1-35 Visualization of a protein structure, created by Jay Siegel and Kim Baldridge, SDSC. (*Courtesy of Stephanie Sides, San Diego Supercomputer Center.*)

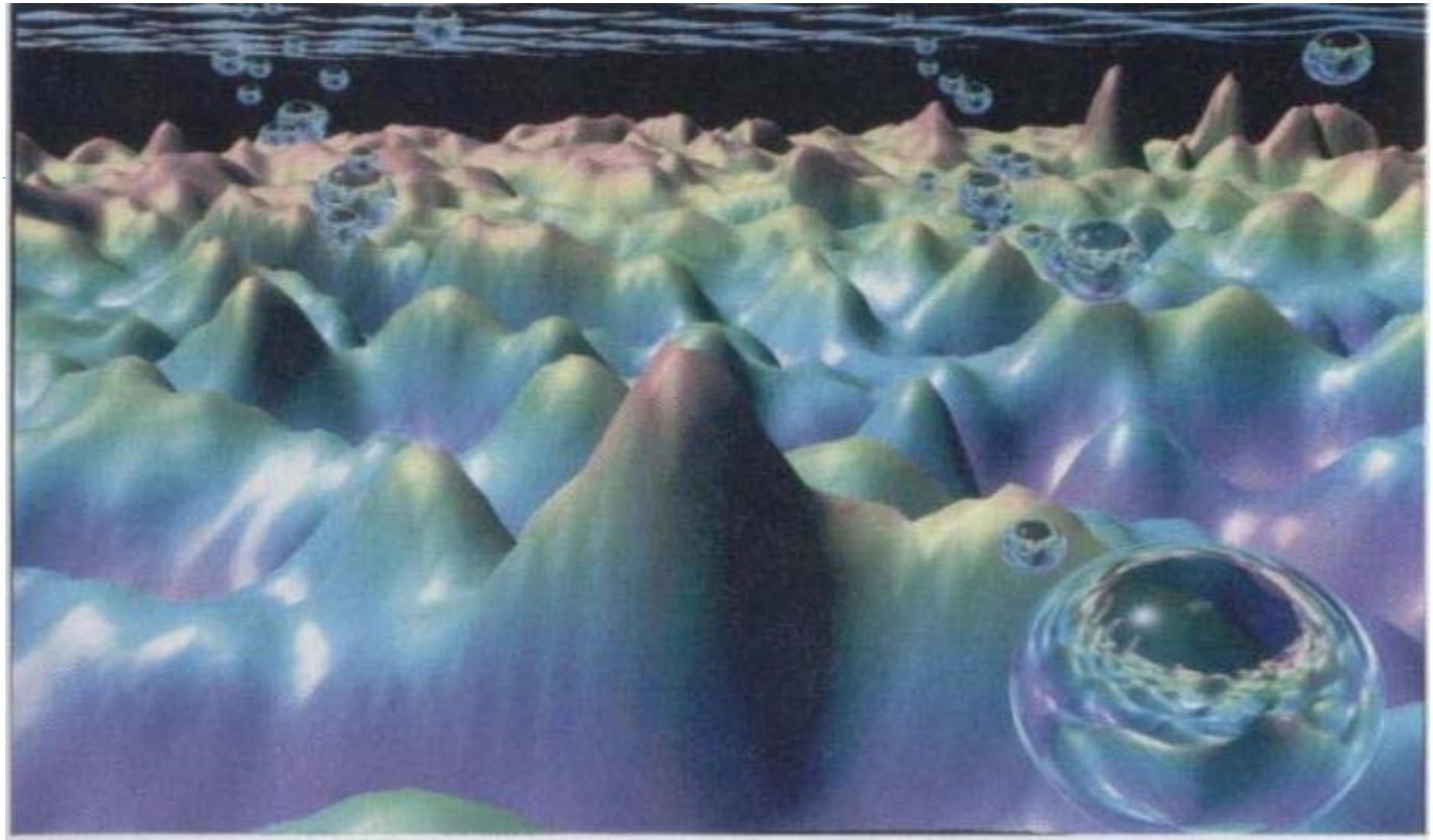


FIGURE 1–37 One image from a stereoscopic pair, showing a visualization of the ocean floor obtained from satellite data, created by David Sandwell and Chris Small, Scripps Institution of Oceanography, and Jim Mcleod, SDSC. (*Courtesy of Stephanie Sides, San Diego Supercomputer Center.*)

Computer Graphics Applications

- Entertainment
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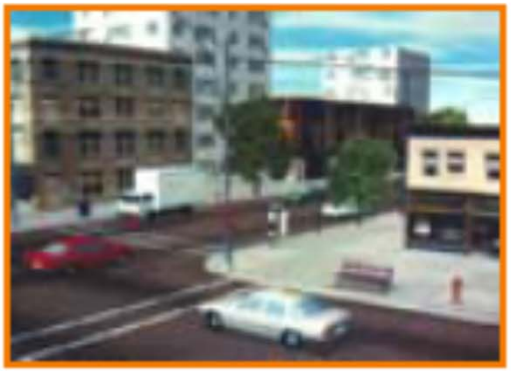
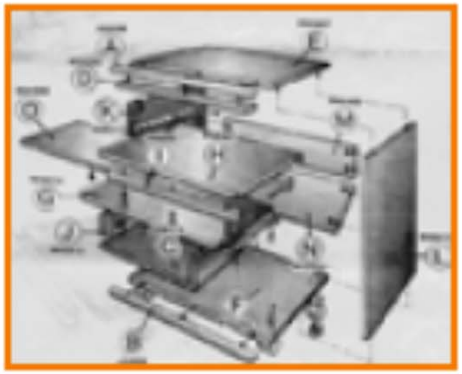
- E-commerce
- Computer art



Driving Simulation
(Evans & Sutherland)



Desk Assembly
(Silicon Graphics, Inc.)

Flight Simulation
(NASA)

Computer Graphics Applications

- Entertainment
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Forum of Trajan
(Bill Jepson, UCLA)

Human Skeleton
(SGI)

Education and Training

- Computer generated models of physical, financial, social, political, economic and other systems are often used as educational aids.

- For training application special hardware systems are designed e.g. systems are simulators for practice session or training of ship captains, aircraft pilots, heavy equipment operators and air traffic-control personnel.

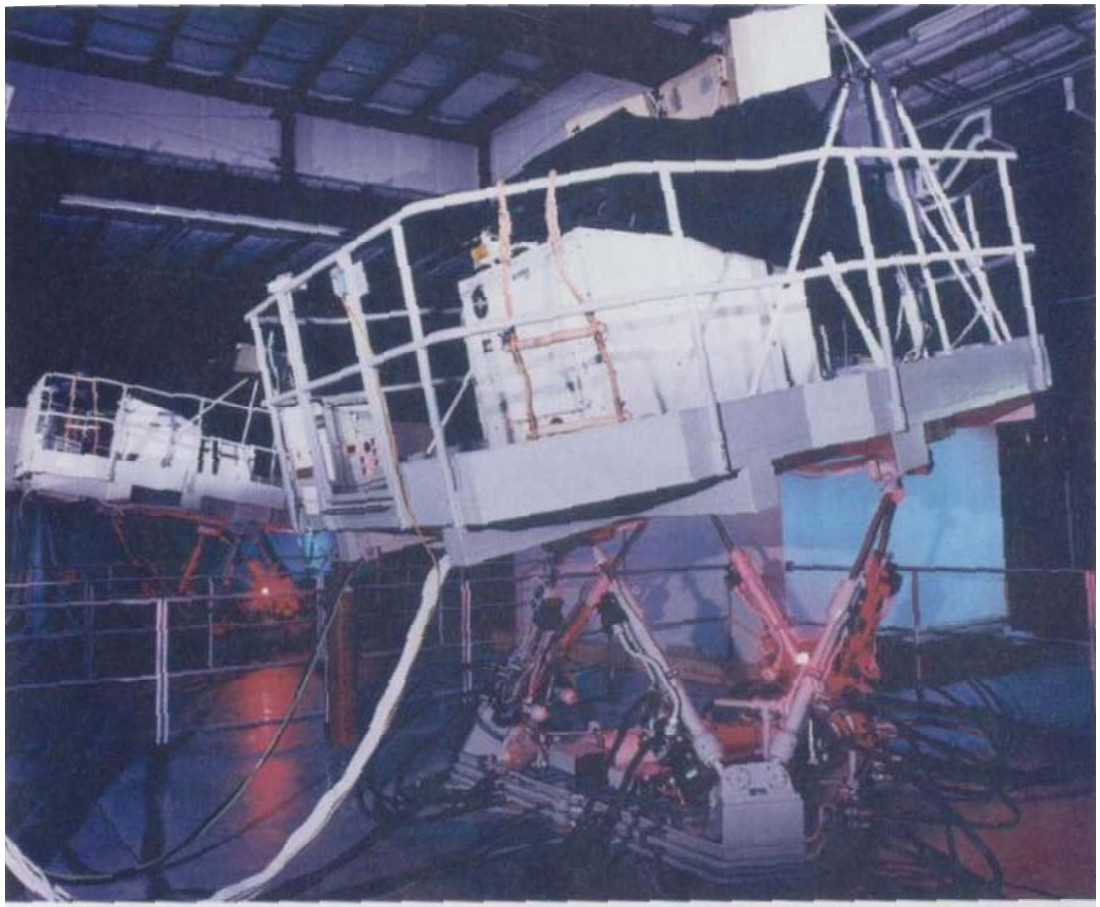
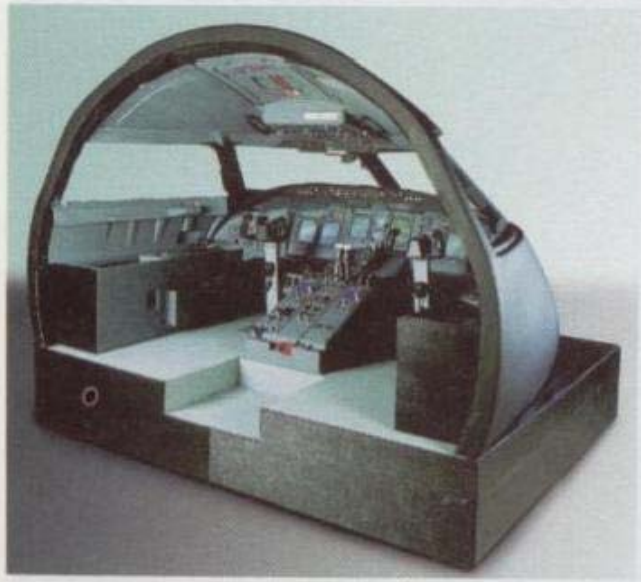
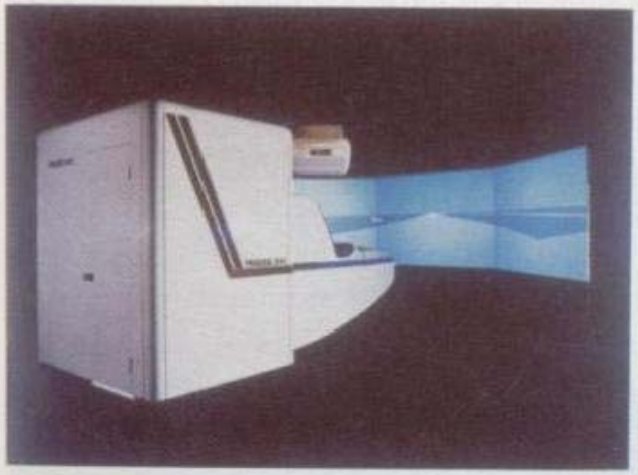


FIGURE 1-45 A military tank simulator with a visual imagery system. (*Courtesy of Mediatech and GE Aerospace.*)



(a)

(b)



(c)

FIGURE 1–46 The cabin interior (a) of a dual-control flight simulator, and an external full-color viewing system (b) and (c) for a small flight simulator. (*Courtesy of Frasca International.*)

Computer Graphics Applications

- Entertainment
- Computer-aided design
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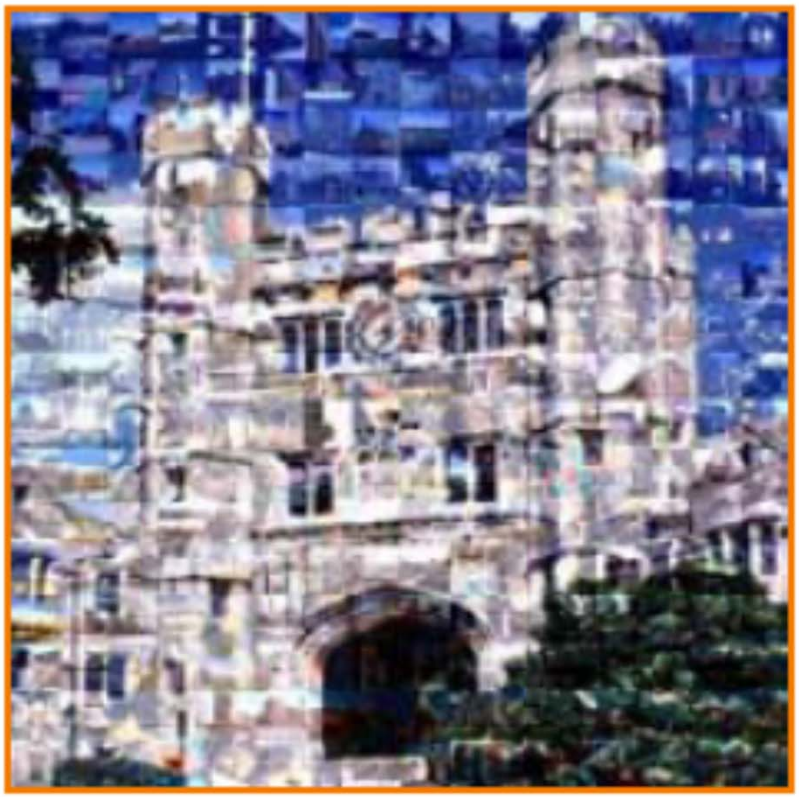
Interactive Kitchen Planner
(Matsushita)

Virtual Phone Store
(Lucent Technologies)

Computer Graphics Applications

- Entertainment
- Computer-aided design
- Scientific visualization
- Training
- Education
- E-commerce
- **Computer art**



Blair Arch
(Marissa Range '98)

Computer Art

FIGURE 1-54 A Van Gogh look-alike created by graphics artist Elizabeth O'Rourke with a cordless, pressure-sensitive stylus. (*Courtesy of Wacom Technology Corporation.*)

Visualization of Fermat's Last Theorem

FIGURE 1-59 This creation is based on a visualization of Fermat's Last Theorem, $x^n + y^n = z^n$, with $n = 5$, by Andrew Hanson, Department of Computer Science, Indiana University. The image was rendered using Mathematica and Wavefront software. (*Courtesy of the Williams Gallery. © 1991 Stewart Dickson.*)

An Electronic Watercolor Painting

FIGURE 1-55 An electronic watercolor, painted by John Derry of Time Arts, Inc. using a cordless, pressure-sensitive stylus and Lumena gouache-brush software. (*Courtesy of Wacom Technology Corporation.*)

Graphs and Charts

- Earliest application of graphics are to display simple data graphs.
- Graphs showing complex data relationships are not uncommon nowadays.
- Graphs and charts are often used for summarizing:
  - ✓ Financial, statistical, mathematical, scientific, engineering and economic data for research report.
  - ✓ Managerial summaries.
  - ✓ Consumer information bulletin.

- Typical examples of data plot are:

- Line graphs
- Bar charts
- Pie charts
- Surface graphs
- Contour plots
- Display showing multiple relationships between multiple parameters in two dimensions or higher dimensional space.

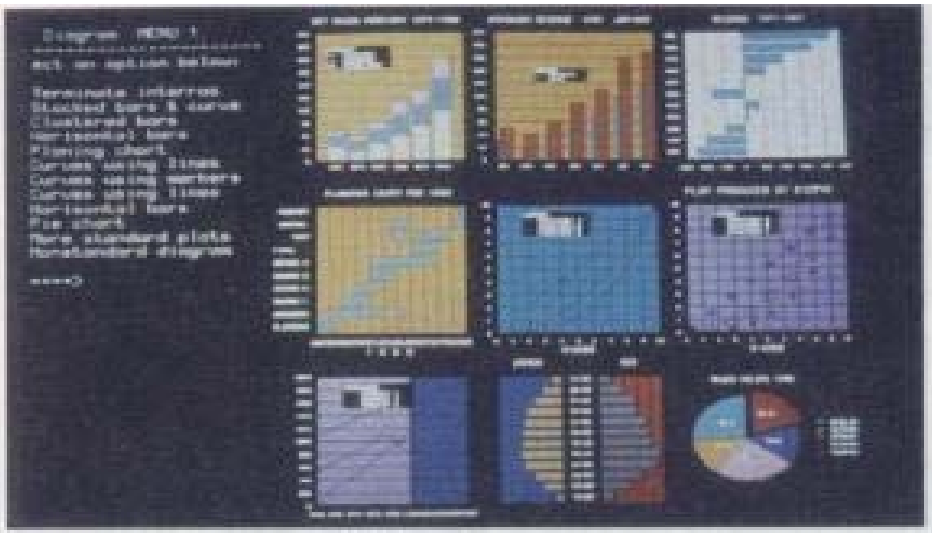
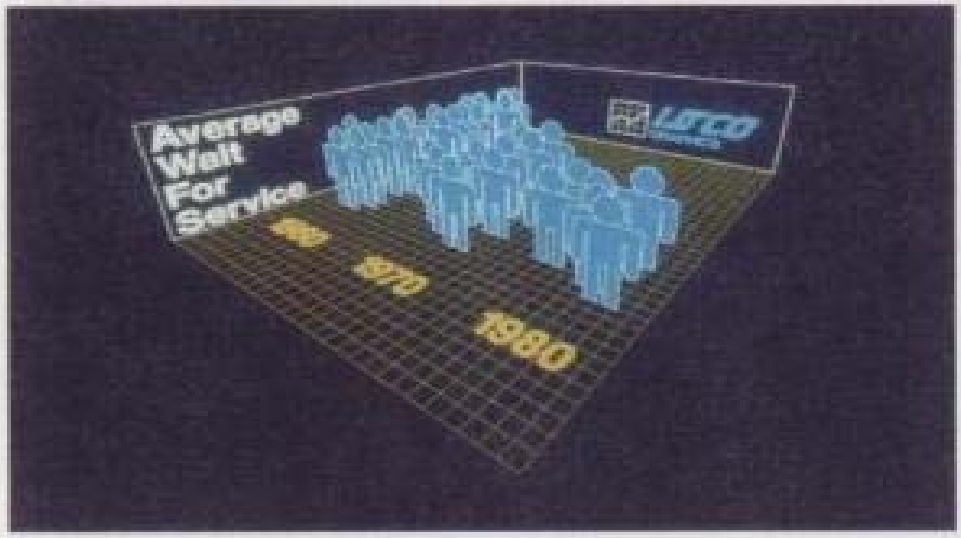


FIGURE 1-2 Two-dimensional line graphs, bar charts, and a pie chart. (*Courtesy of UNIRAS, Inc.*)

FIGURE 1-3 Two color-coded data sets displayed as a three-dimensional bar chart on the surface of a geographical region. (*Reprinted with permission from ISSCO Graphics, San Diego, California.*)



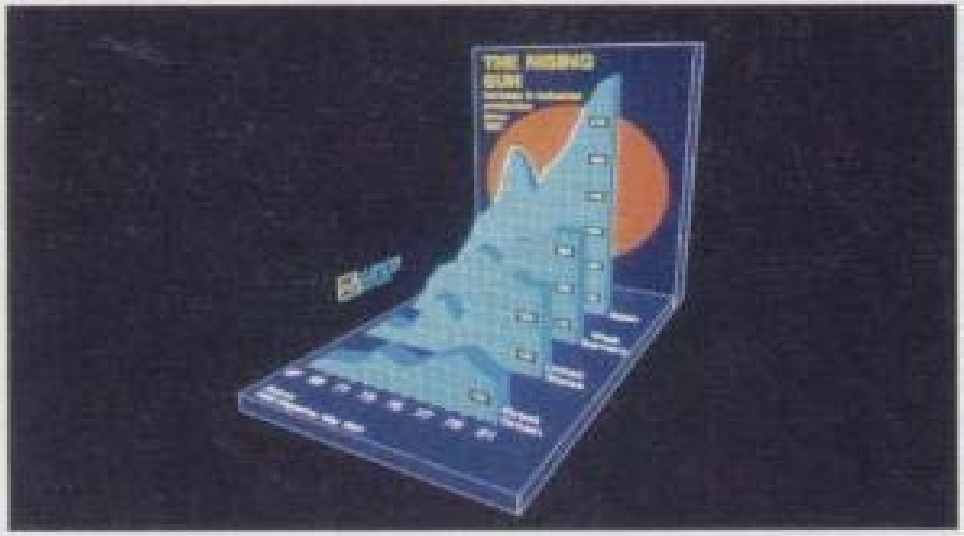


FIGURE 1-4 Two three-dimensional graphs designed for dramatic effect. (*Reprinted with permission from ISSCO Graphics, San Diego, California.*)

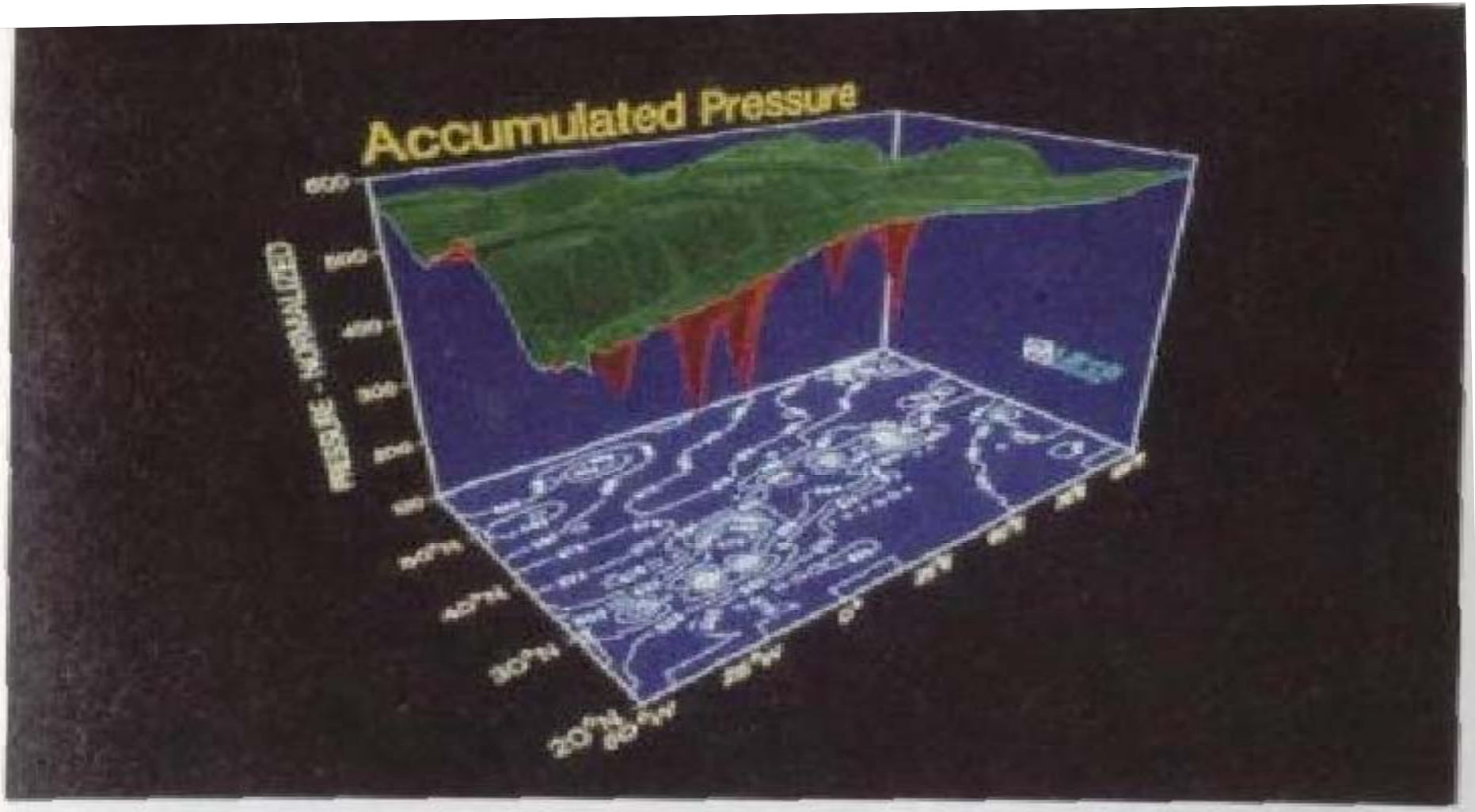


FIGURE 1-5 Plotting two-dimensional contours in a ground plane, with a height field plotted as a surface above the ground plane. (*Reprinted with permission from ISSCO Graphics, San Diego, California.*)

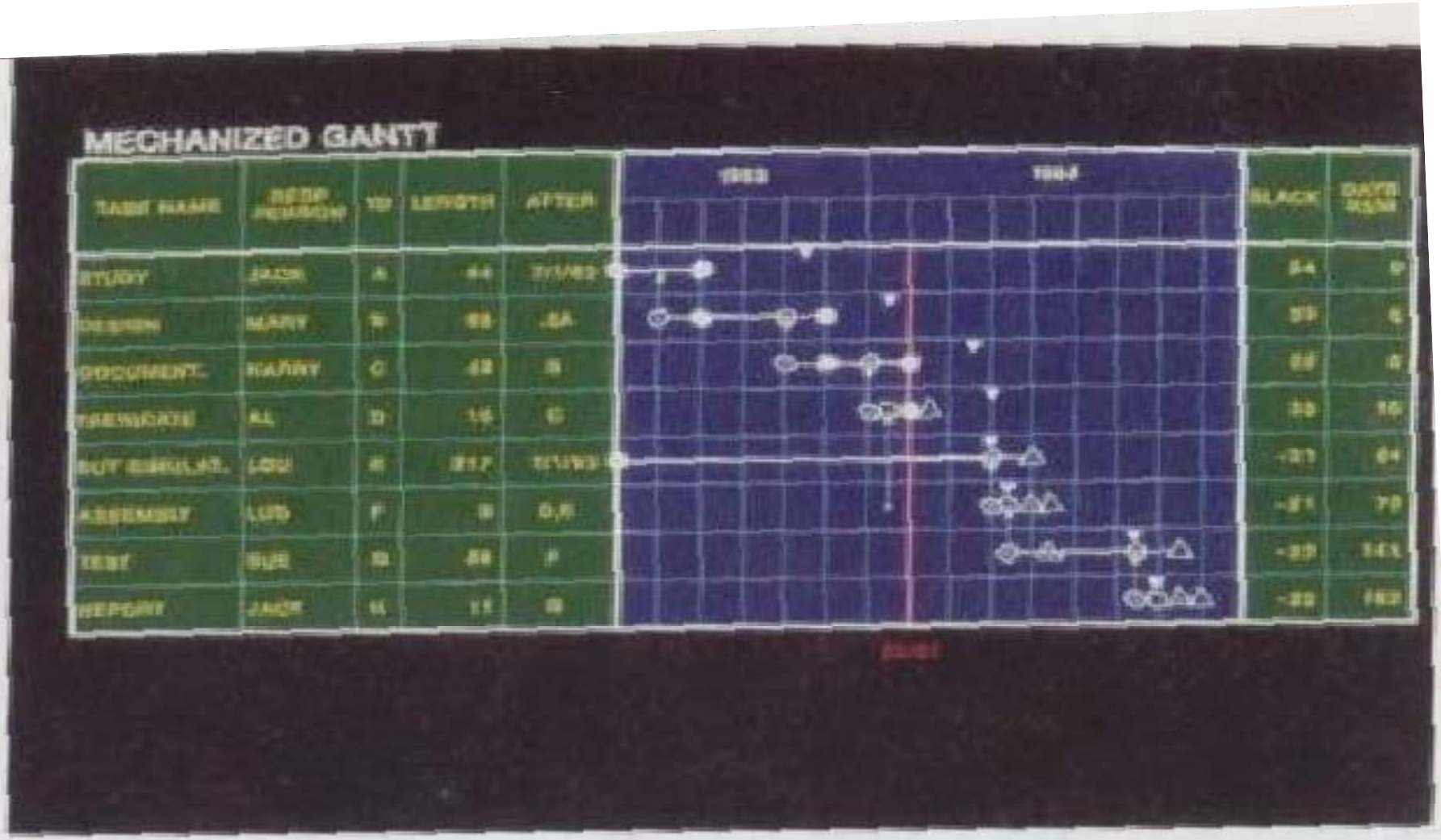
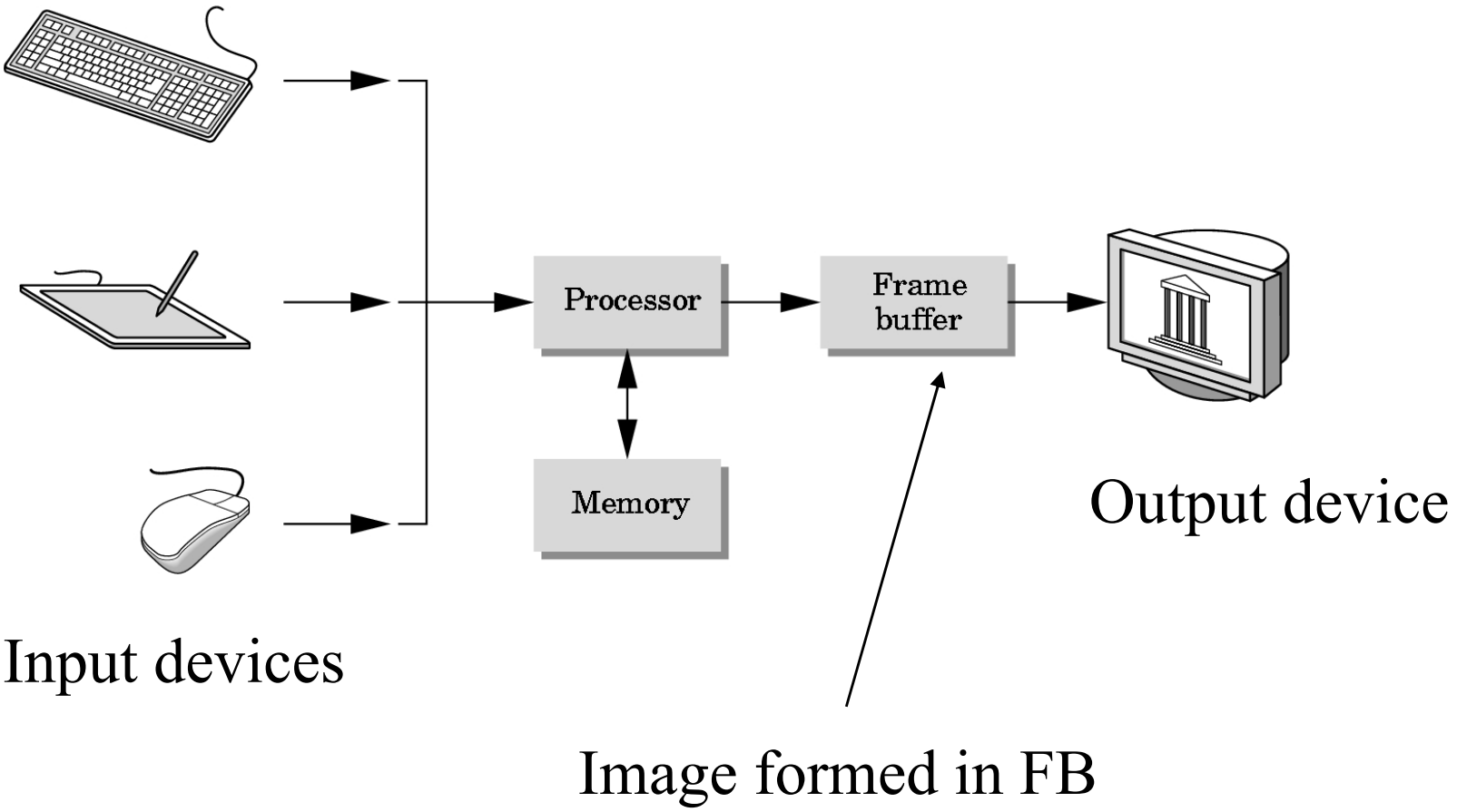


FIGURE 1–6 A time chart displaying scheduling and other relevant information about project tasks. (*Reprinted with permission from ISSCO Graphics, San Diego, California.*)

Graphics Systems

- Display Hardware
  - How are images displayed?
- Raster Graphics systems
  - How are imaging systems organized?

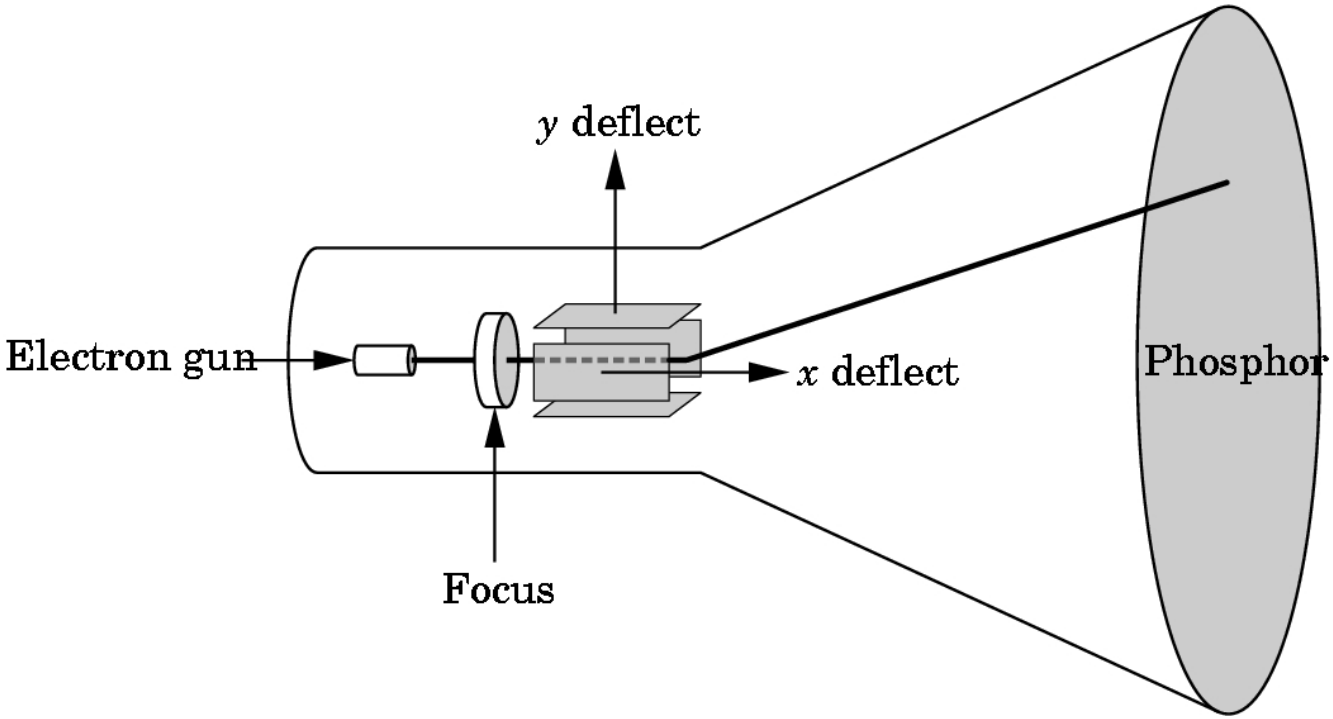
Basic Graphics System



Display Hardware

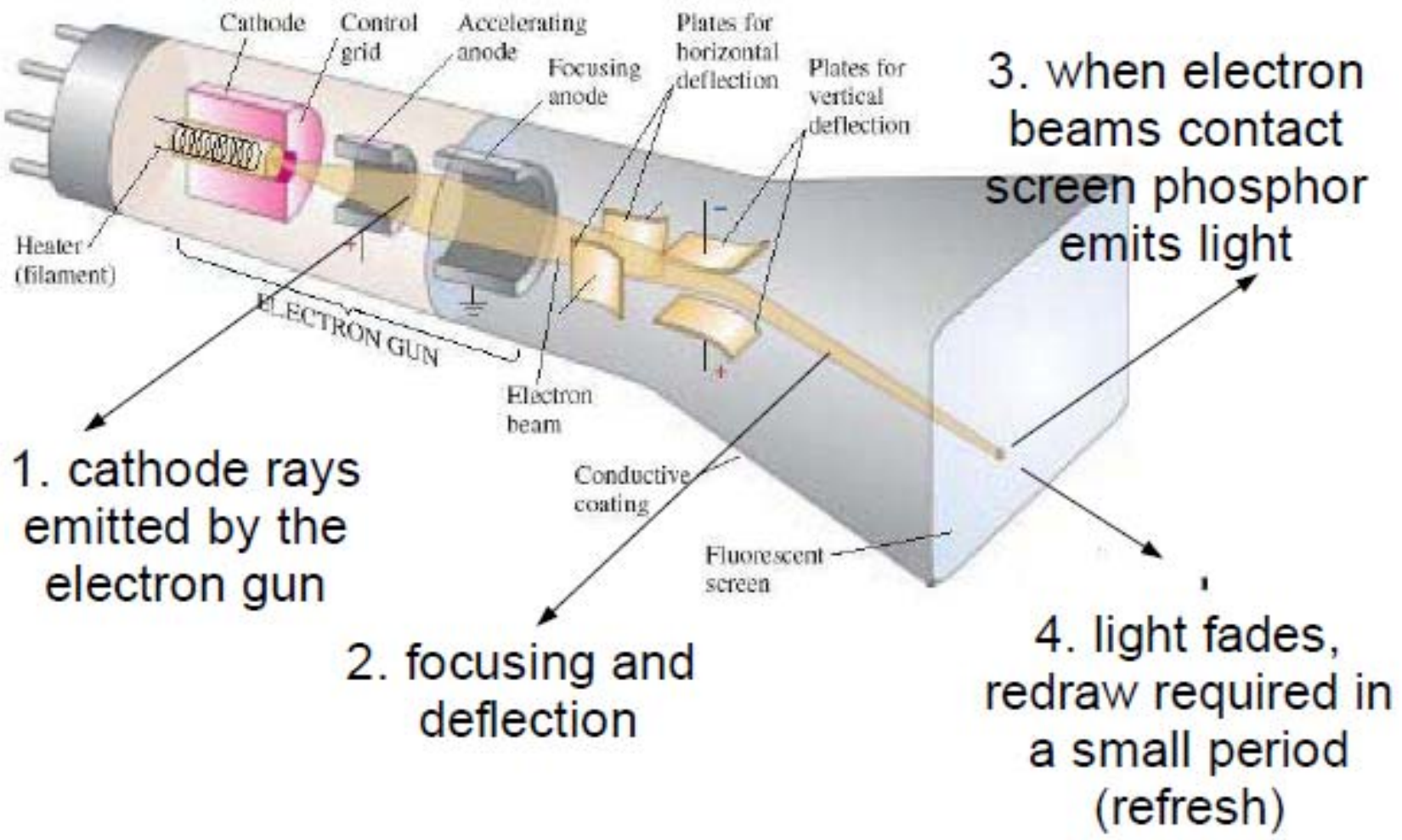
- Video display devices
  - Cathode Ray Tube (CRT)
  - Liquid Crystal Display (LCD)
  - Plasma panels
  - Thin-film electroluminescent displays
  - Light-emitting diodes (LED)
- Hard-copy devices
  - Ink-jet printer
  - Laser printer
  - Film recorder
  - Electrostatic printer
  - Pen plotter

Cathode Ray Tube (CRT)



Can be used either as a line-drawing device (calligraphic) or to display contents of frame buffer (raster mode)

CRT in Detail



Liquid Crystal Display (LCD)

- Thinner and lighter. No tube and electron beams.
- Blocking/unblocking light through polarized crystals.
- A matrix of LC cells one for each pixel.
- No refresh unless the screen changes.
- Color 3 cells per pixel.

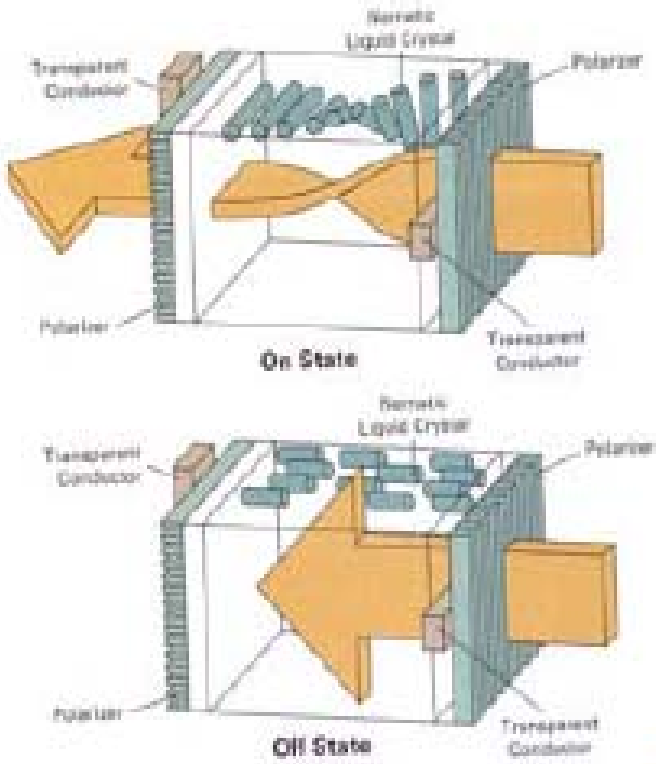
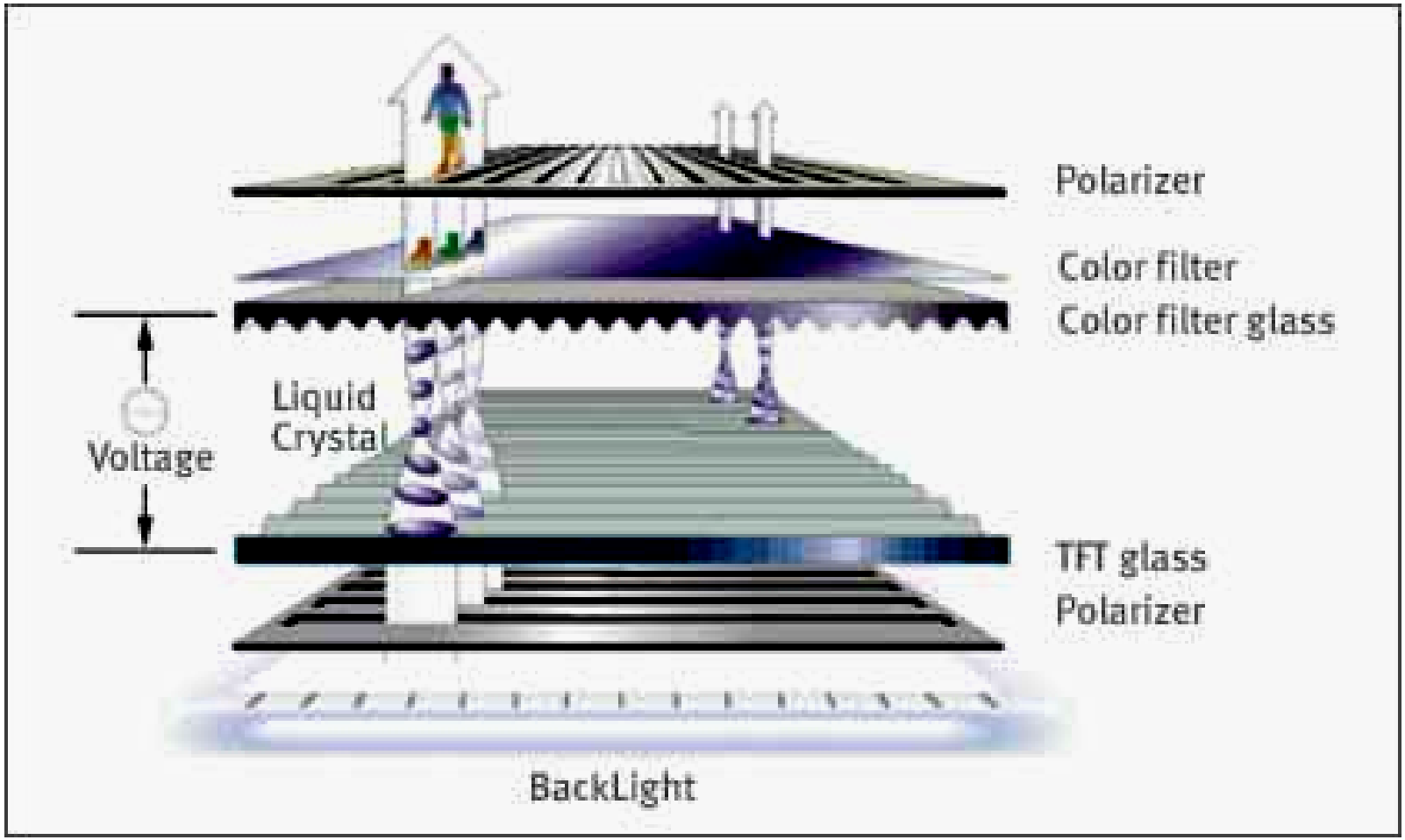


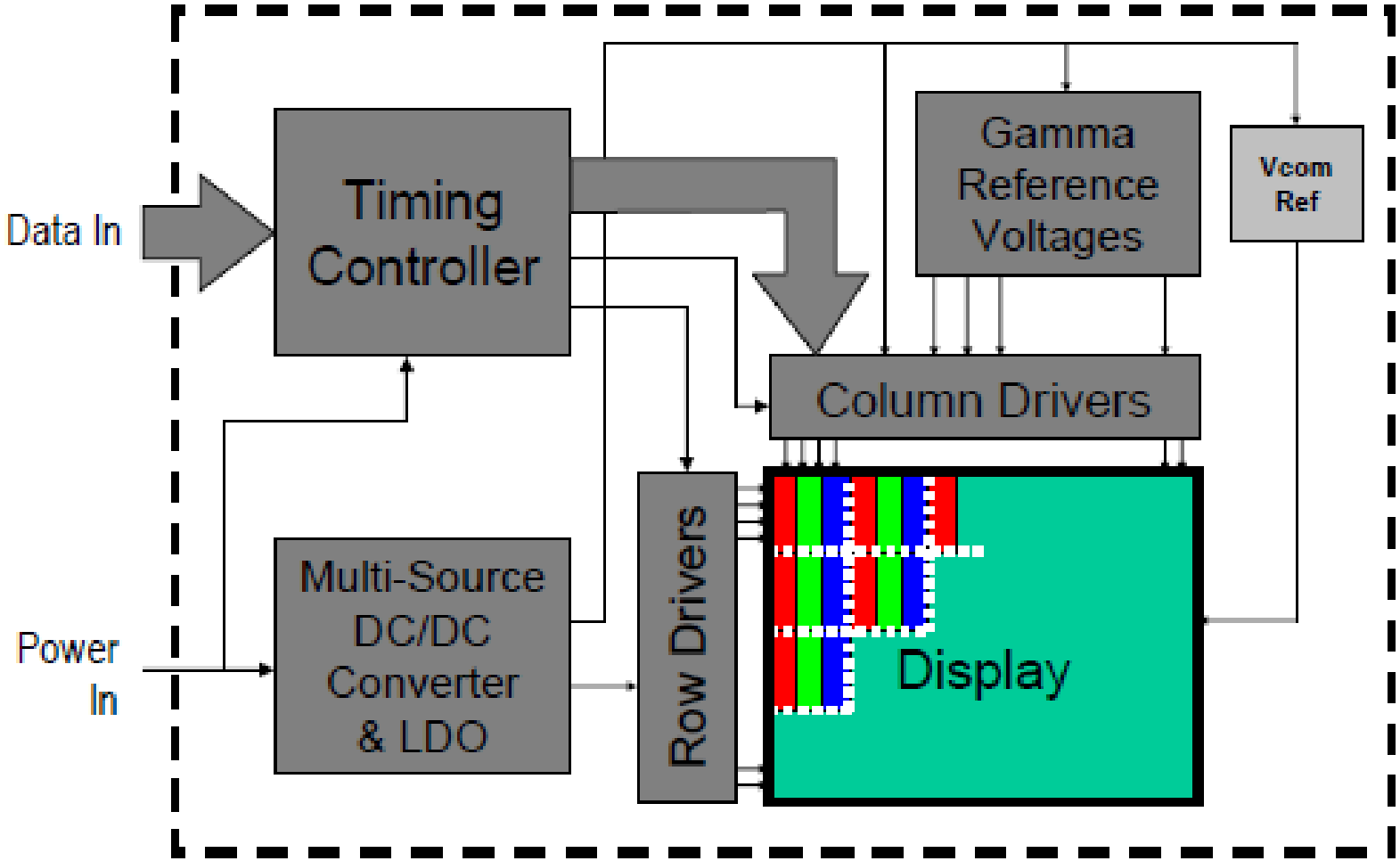
Figure 2.16 from H&B

LCD Structure



TFT: Thin Film Transistor

Display Panel



The World's Largest LCD-TV 82"

The World's Largest PDP TV 102"

Samsung 70 inch Full HDTV

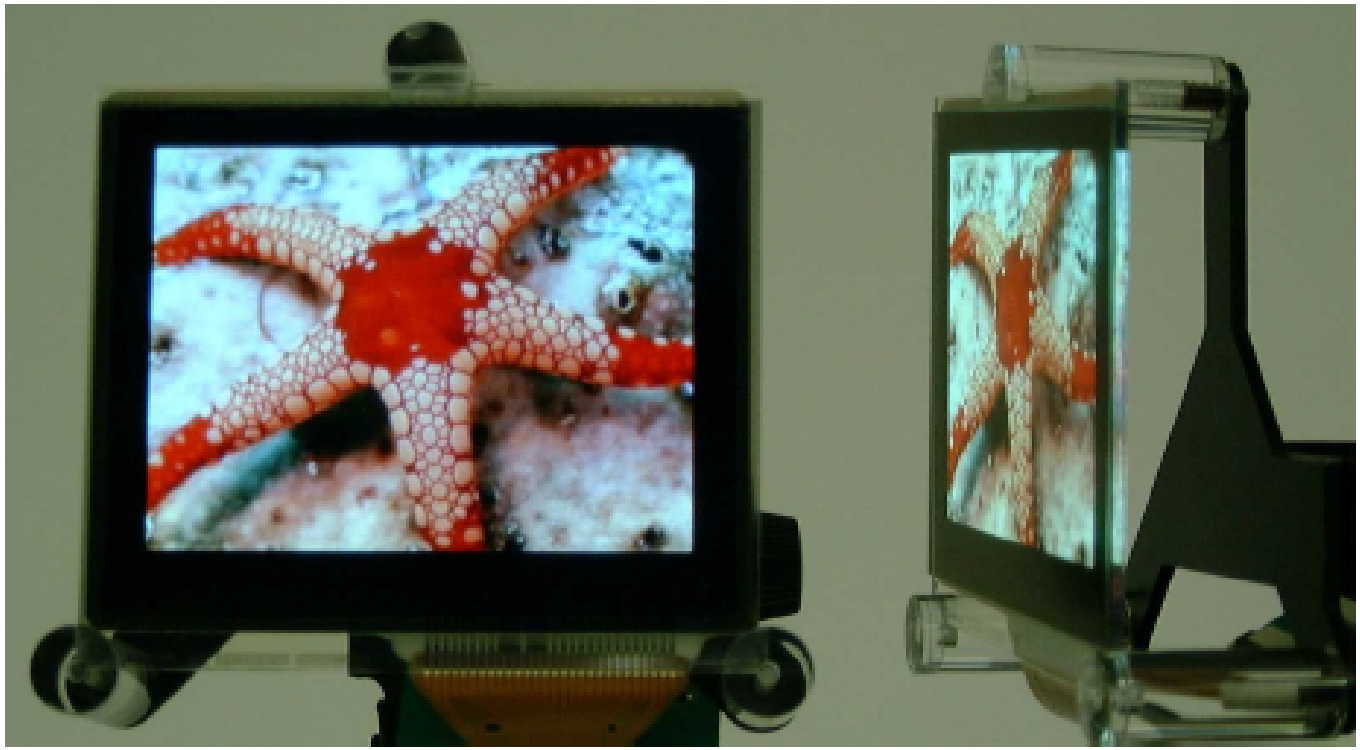
1920 x 1080 Pixels

1200:1 Contrast Ratio

800 cd/m^2

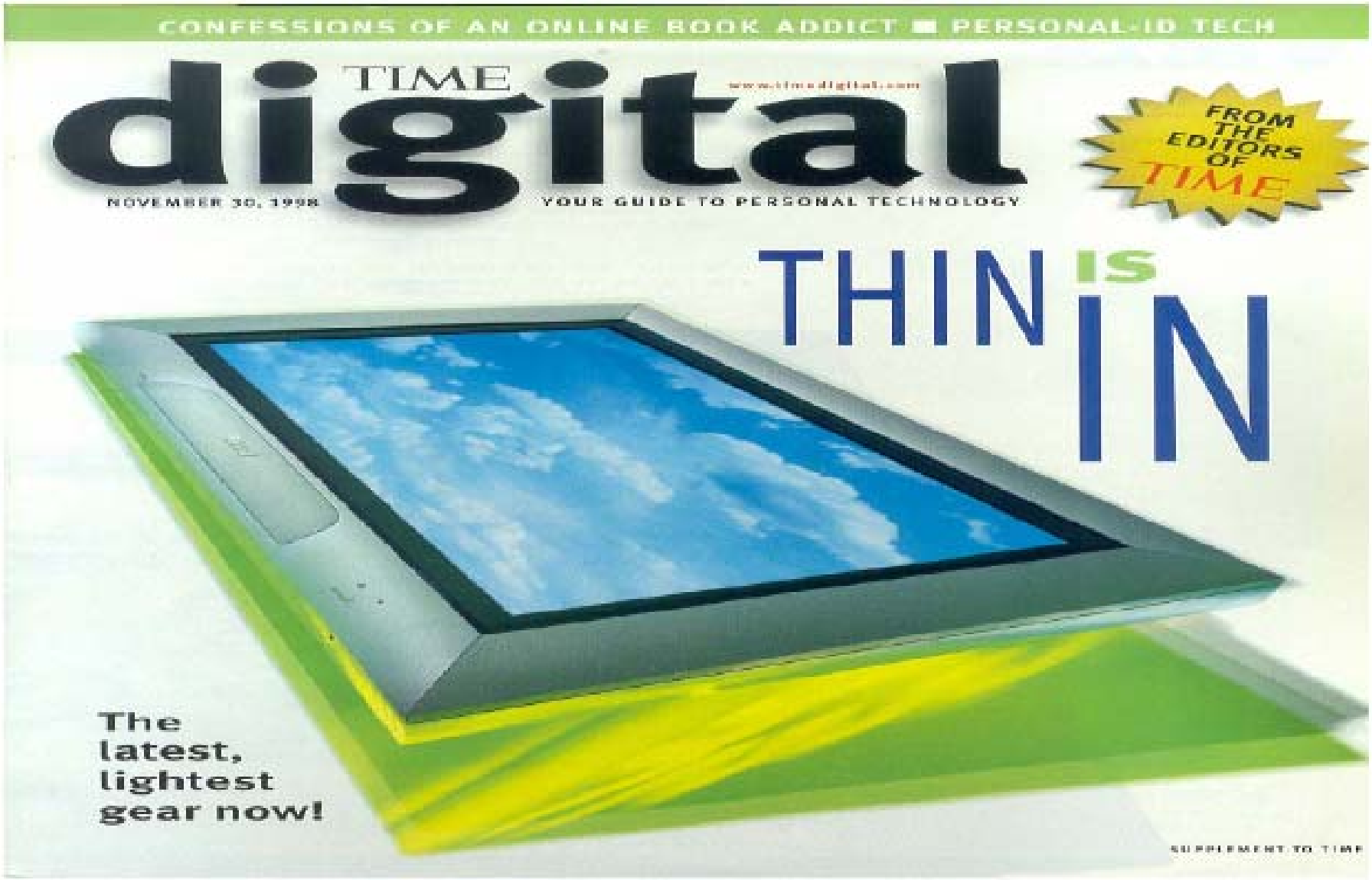
1.0 us Address Time

Kodak/Sanyo 2.4” AMOLED Display



AMOLED: Active Matrix Organic LED

40” a-Si based 1280 x 800 Pixel AMOLED


CONFESSIONS OF AN ONLINE BOOK ADDICT ■ PERSONAL-ID TECH
TIME
digital
www.timedigital.com
NOVEMBER 30, 1998
YOUR GUIDE TO PERSONAL TECHNOLOGY
FROM THE EDITORS OF TIME
THIN IS IN
The latest, lightest gear now!
SUPPLEMENT TO TIME

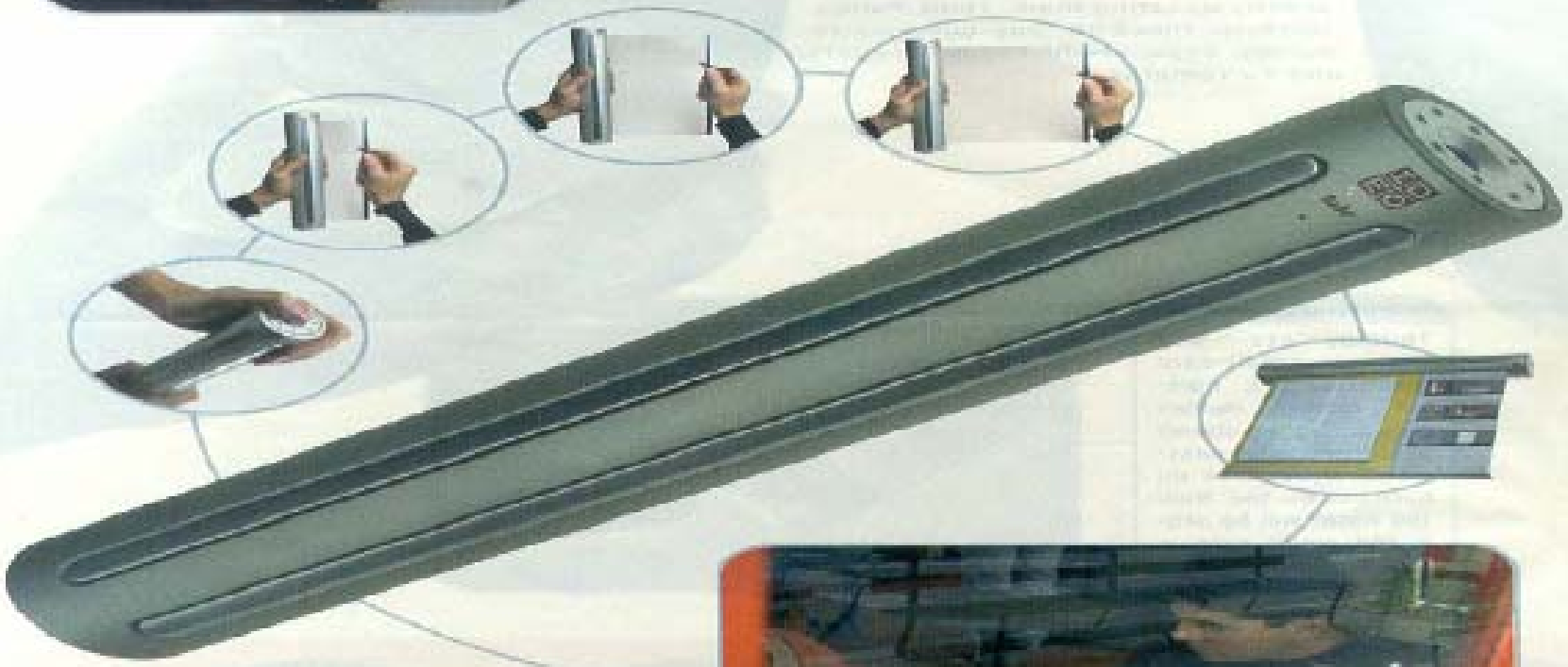
Smart Cubicles

Workstations open completely, and the space becomes "alive," with computing and communication technology embedded in furniture and walls. Desks become optional as interactive screens hang from canopies, programmed to do documents, multimedia, spreadsheets, or ambient art. Smart chairs cancel noise and maximize comfort. Holographic videoconferencing puts overseas colleagues—and the boss—in your face.

THIN IS IN

Computer displays and TV monitors are replaced by one lightweight, flat LCD panel that can be placed on a desk or hung on a wall. Your Agent pulls up your personal desktop configuration for work or for play. And so do the Agents for each member of your work team or family.

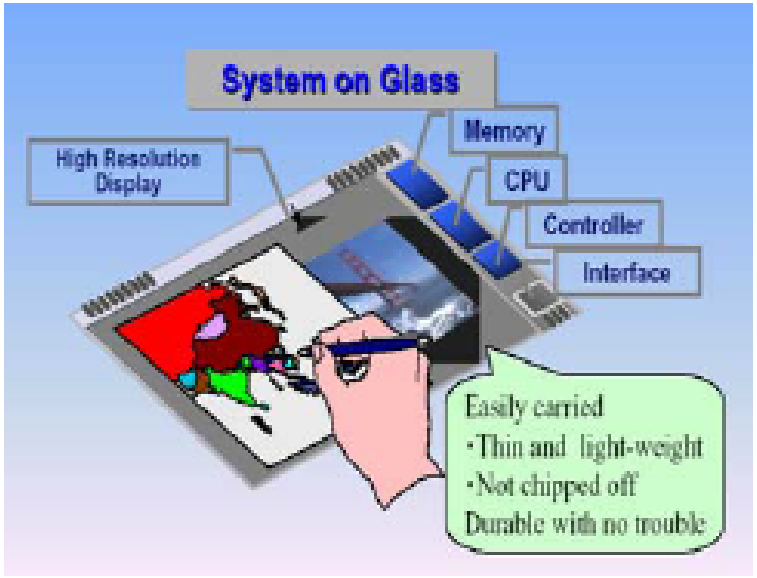
The Tube It is tomorrow's laptop. Voice recognition makes a keyboard optional and a flexible liquid-crystal display changes the form from a square to a scroll that rolls out. Low voltage lets a pared-down processor do most tasks, and wireless access connects you to the Net for such heavy-duty applications as language translation.



ON A ROLL
A flexible LCD provides a large screen to read any Web-based information, anywhere at any time. Dials on the tube itself show messages or data received.

Future Displays

Sheet Computer



Wall Hanging Big Screen

Paper-like Display

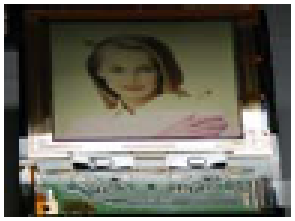
Flexible Display

Paper Like Display

- Glass → Plastic
- Low Temp. (150℃) process
- Display materials : LC, e-INK, OLED

⇒

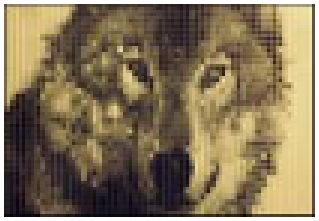
- Portability improve
- Rugged
- Eventually extreme Low Cost



[Sharp 4"]

[8" LTPS LCD]

[Sony 1.6"]



[Philips 2.1"]

Raster Graphics Systems

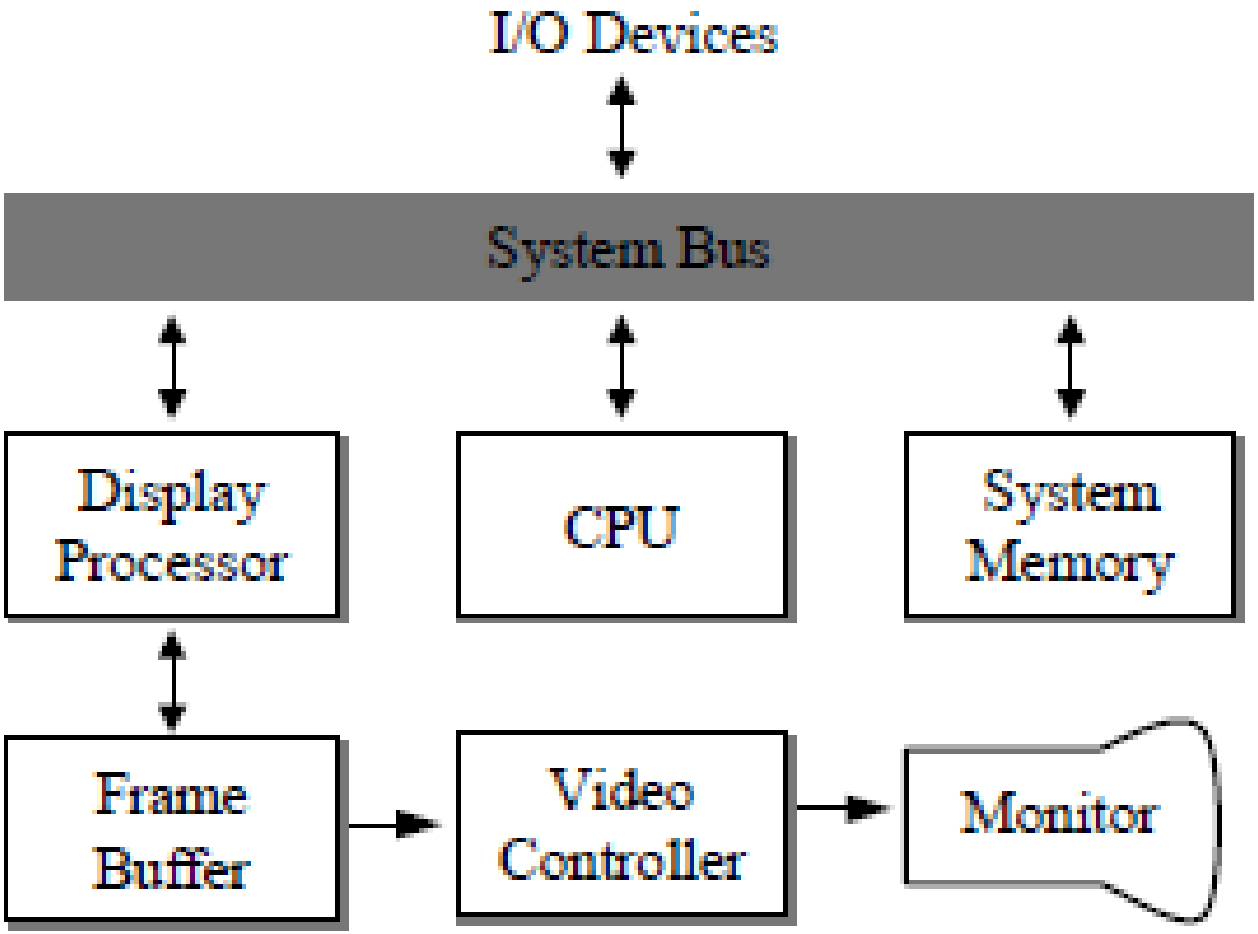


Figure 2.29 from H&B

Frame Buffer

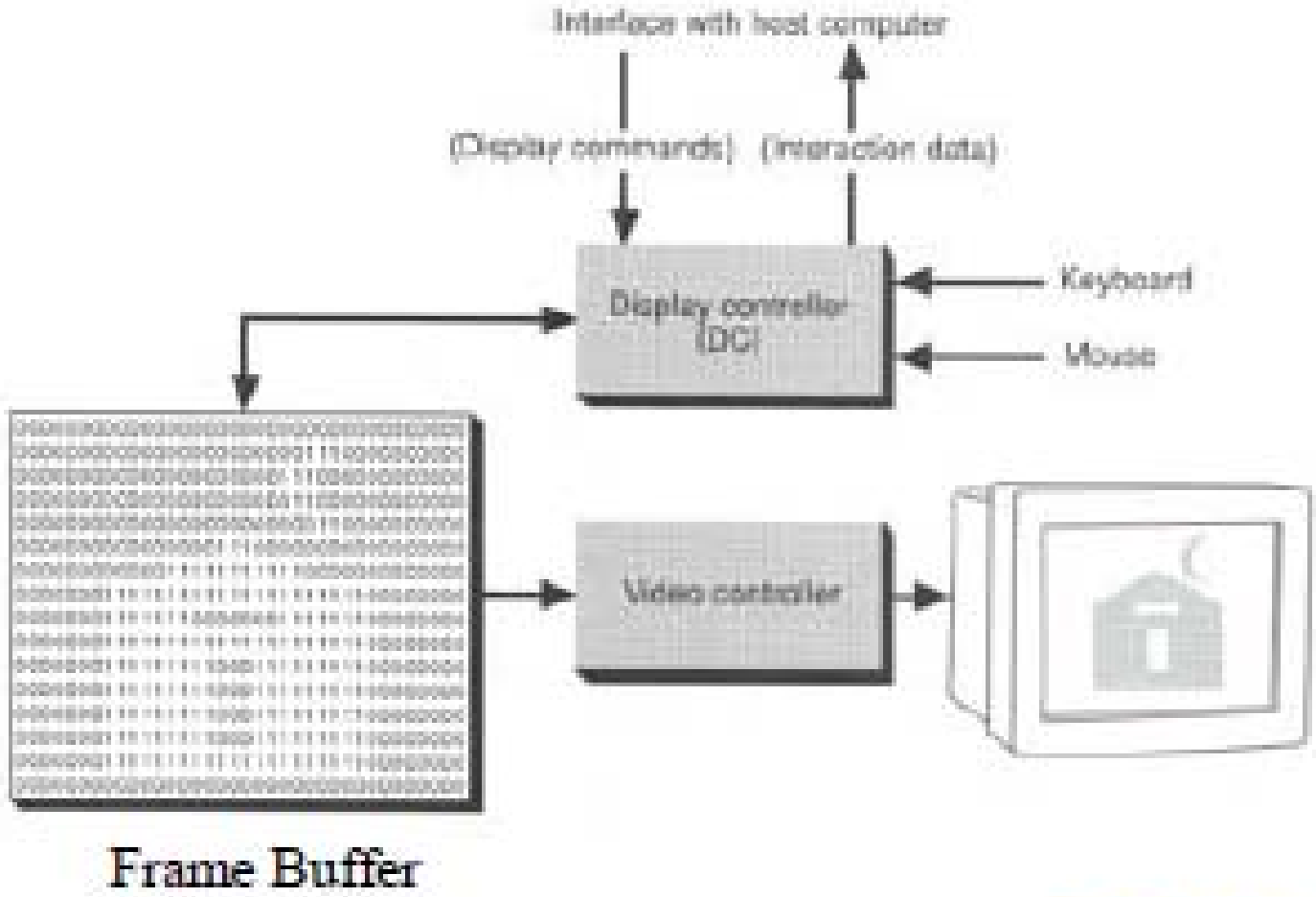
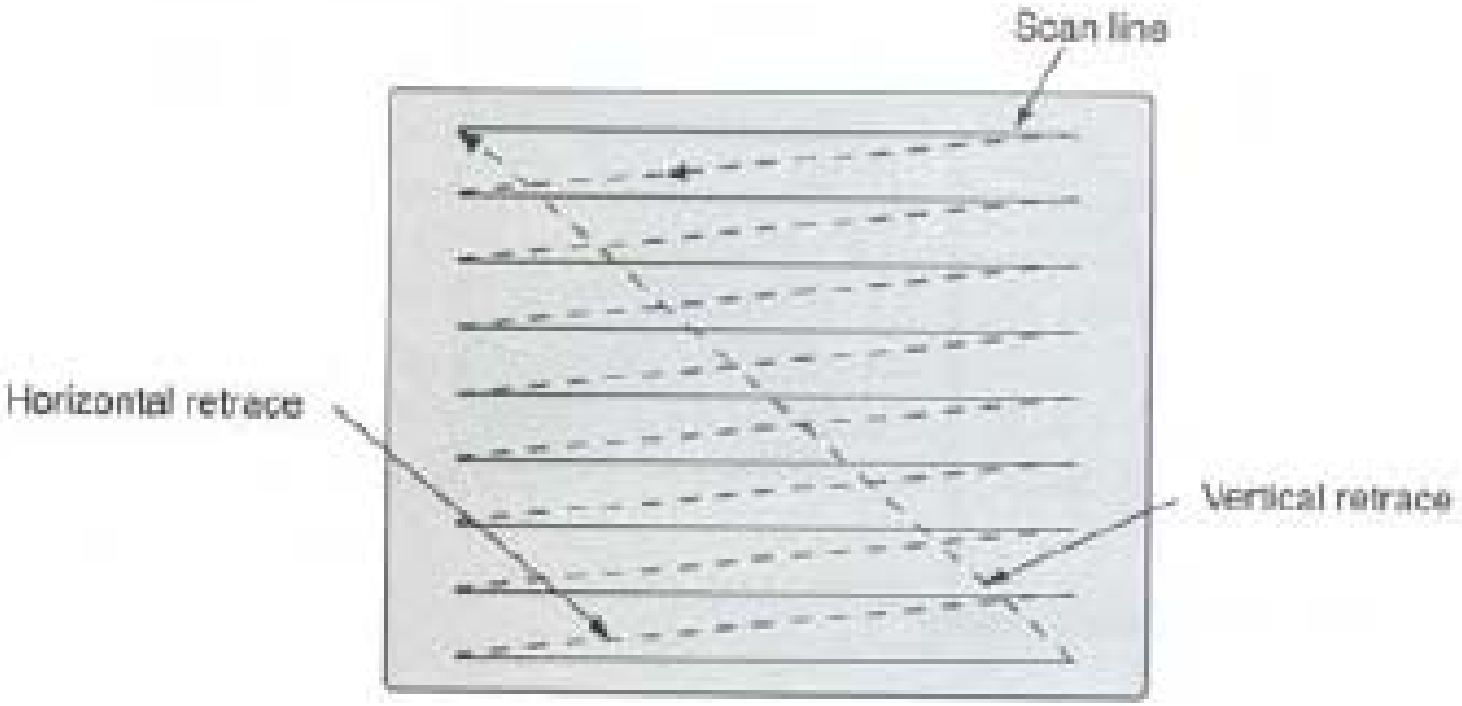


Figure 1.2 from FvDFH

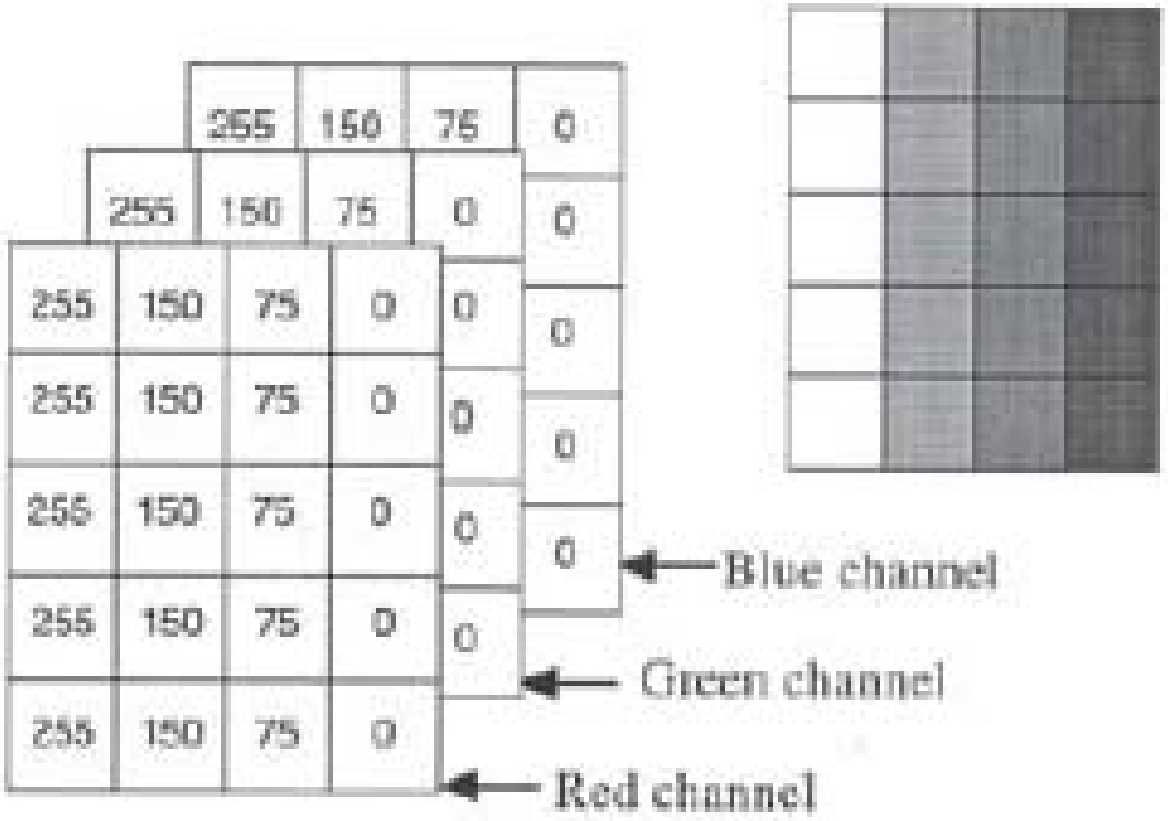
Frame Buffer Refresh



Refresh rate is usually 30-75Hz

Figure 1.3 from FvDFH

Color Frame Buffer

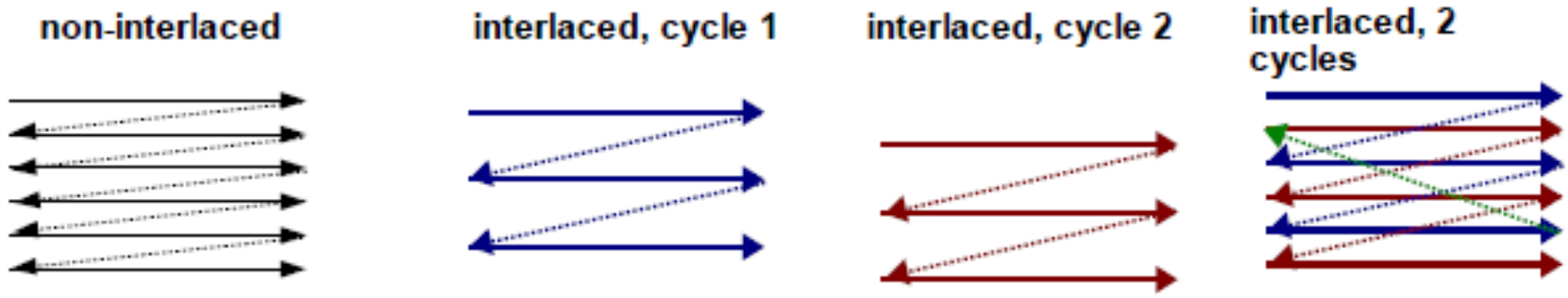


Vector Scan

- Picture definition is stored as a set of line-drawing commands in a refresh buffer.
- to display a picture, the system cycles through the set of commands in the buffer
- Designed for line drawing applications (CAD)

Raster Scan

- Screen is a regular grid of samples called **pixels** (**pict**ure **el**ement)
- Screen is refreshed line by line



- Interlacing: Avoid flickering affect for small refresh rates. interlaced 50Hz: actually 25Hz

Vector vs Raster Scan

- raster scan monitors:
  - inexpensive
  - filled areas, patterns
  - refresh process is independent (constant for any complex scene)
- vector scan monitors:
  - Smooth lines. no need for scan conversion: lines to pixels. (raster scan solution antialiasing)
  - sometimes memory and CPU efficient 1000 lines:
    Vector scan: 2000 endpoints and 1000 operations
    Raster scan: whole frame buffer 1000 scan conversions.

Terms

- **resolution:** a 2D term that measures the number of scan-lines and the number of pixels on each line (maximum number of points that can be displayed without overlap on a CRT)
- **black and white** display only binary pixels.
- **intensity** of a pixel can be achieved by the force of electron beam (gray scale)
- **color** display?

Color Display

- Beam penetration method:
  special phosphors emitting different colors for different intensity of electron. Slow, limited colors.
- Shadow mask method:
  3 electron guns + a shadow mask grid. Intensities of 3 colors result in an arbitrary color pixel. (most TVs and monitors)

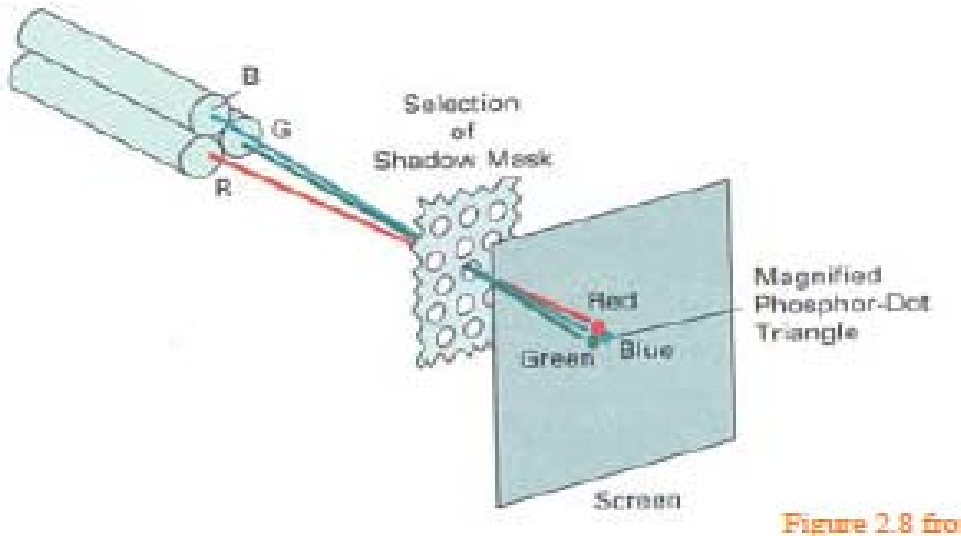


Figure 2.8 from H&B

Color Display

- black and white: 1 bit per pixel.
- gray scale: 1 byte per pixel (256 gray levels)
- true color: 3 bytes=24pits per pixel (2^{24} colors)
- indexed color frame buffer: each pixel uses 1 byte, an index entry in a colormap table matching the color to the actual color.

Computer Graphics Software

- Rendering Primitives
  - Models are composed of, or can be converted to, a large number of **geometric primitives**.
  - Typical rendering primitives directly supported in hardware include:
    - Points (single pixels)
    - Line segments
    - Polygons (perhaps simple, triangle, rectangle)

Computer Graphics Software

- Modeling primitives include these, but also
  - Piecewise polynomial (spline) curves
  - Piecewise polynomial (spline) surfaces
  - Implicit surfaces (quadrics, blobbies, etc.)
  - Other...
- Software renderer may support modeling primitives directly, or may convert them into polygonal or linear approximations for hardware rendering

Programming Interfaces

- X11: 2D rasterization
- Postscript, PDF: 2D transformations, 2D rasterization
- Phigs+, GL, OpenGL, Direct3D: 3D pipeline
- APIs provide access to rendering hardware via conceptual model.
- APIs abstract the hardware implementations and algorithms in standard software calls.
- For 3D interactive applications, we might modify the scene or a model directly or just the change the attributes like viewing information.
- We need to interface to input devices in an event-driven, asynchronous and device independent fashion. APIs and toolkits are also defined for this task. GLUT, Qt, GTK, MFC, DirectX, Motif, Tcl/Tk.