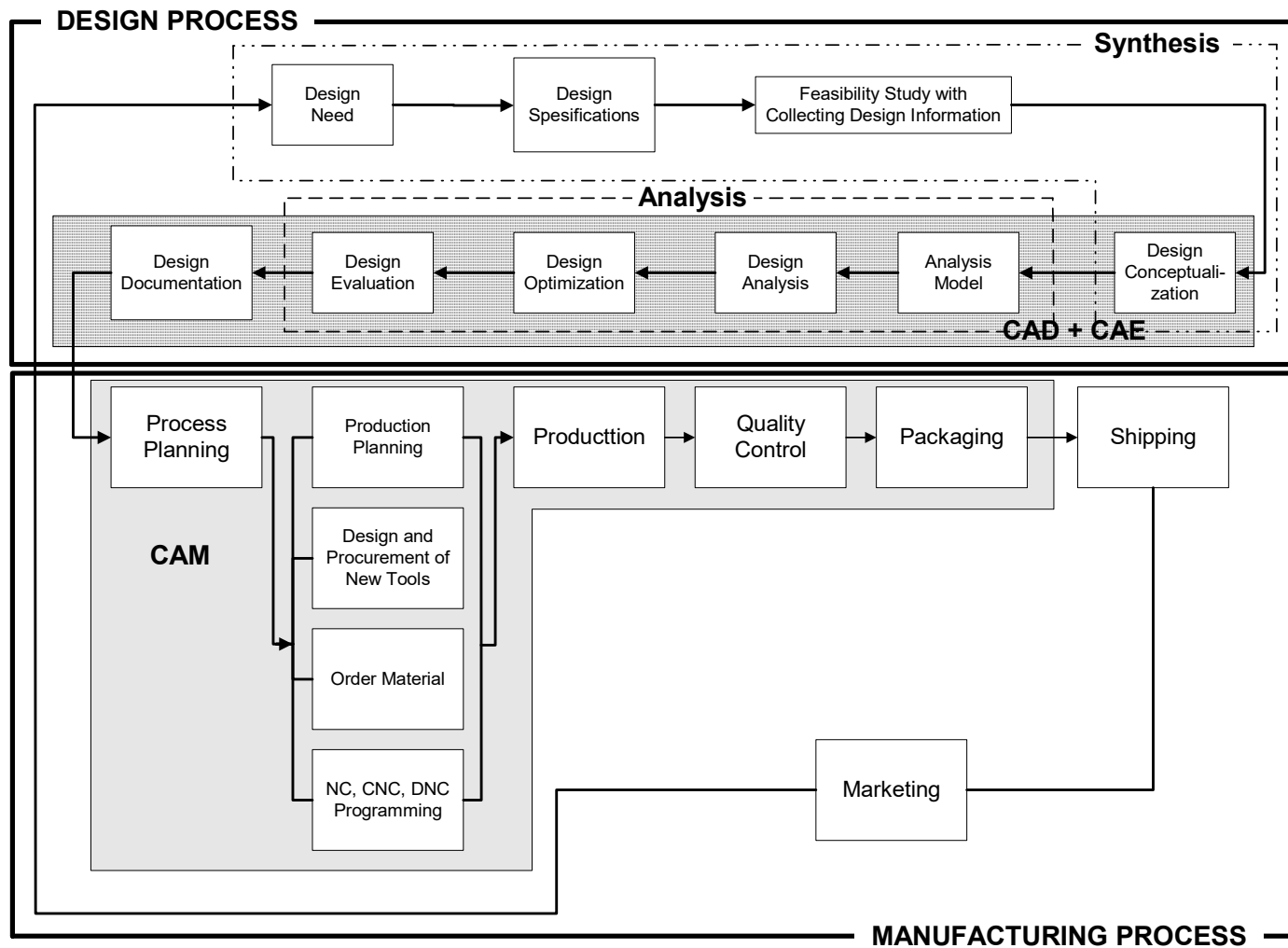# Contents

- Definitions of CAD/CAM/CAE

- Product development

  - Practical example

- Design models

- Hardware components

  - I/O devices

  - Graphics display

    - Vector-refresh

    - Raster

Product Cycle (CAD/CAM/CAE)

DESIGN PROCESS

Synthesis

- Design Need
- Design Spesifications
- Feasibility Study with Collecting Design Information

Analysis

- Design Documentation
- Design Evaluation
- Design Optimization
- Design Analysis
- Analysis Model
- Design Conceptualization

CAD + CAE

CAM

- Process Planning
- Production Planning
- Design and Procurement of New Tools
- Order Material
- NC, CNC, DNC Programming
- Producttion
- Quality Control
- Packaging
- Shipping
- Marketing

MANUFACTURING PROCESS

Computer-Aided Design

- Technology concerned with the use of computer systems to assist in the creation, modification, analysis, and optimization of a design
  - Computer graphics and an application program facilitating engineering functions in the design process
  - From geometric tools to manipulate shapes to customized application programs (analysis and optimization)
  - Most basic role: define the geometry of design
  - Important components: computer-aided drafting system and geometric modeling system

Computer-Aided Manufacturing

- Technology concerned with the use of computer systems to plan, manage, and control of manufacturing operations
  - Most mature area: NC(Numerical Control)
  - Robot programming for material handling, welding, assembling, etc.
  - Process planning
    - Group Technology
    - Feature recognition of feature based modeling
  - MRP(Material Requirement Planning)
 - Rapid Prototyping
    - Stereolithography
   - Selective Laser Sintering
    - Fused Deposition
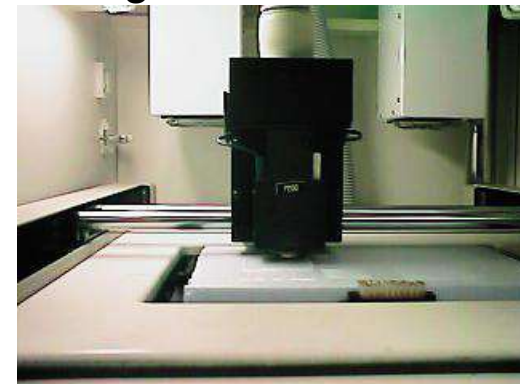
CAM: Example

Computer-Aided Engineering

- Technology concerned with the use of computer systems to analyze CAD geometry, allowing the designer to simulate and study how the product will behave so that the design can be refined and optimized
  - Kinematic program, large-displacement dynamic analysis, etc.
  - Most widely used method of computer analysis: FEM
    - Stress, deformation, heat transfer, fluid flow, magnetic field, continuous field problem
  - Pre-processor: construction of the abstract model and generation of the finite elements
  - Post-processor: visualization of results
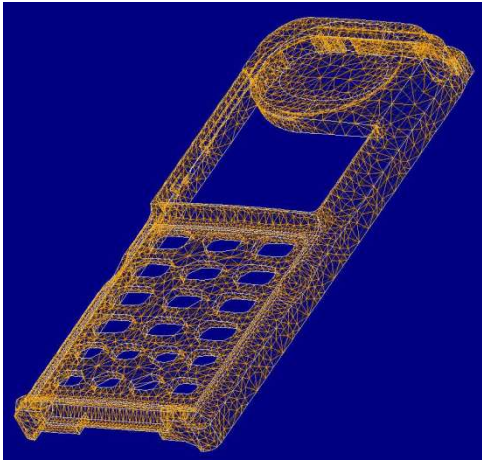 - Design optimization

CAE: Example
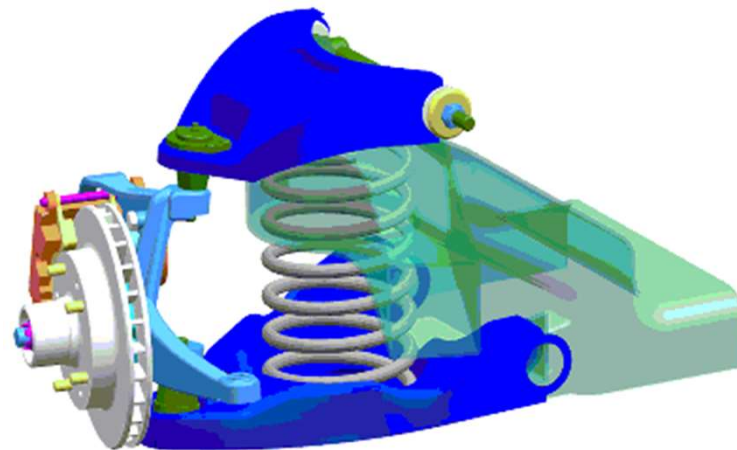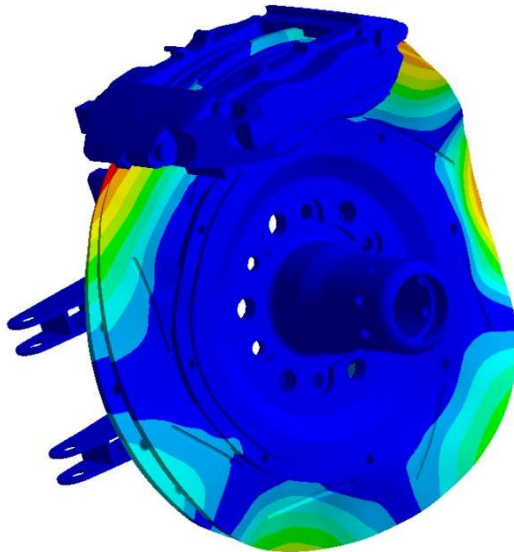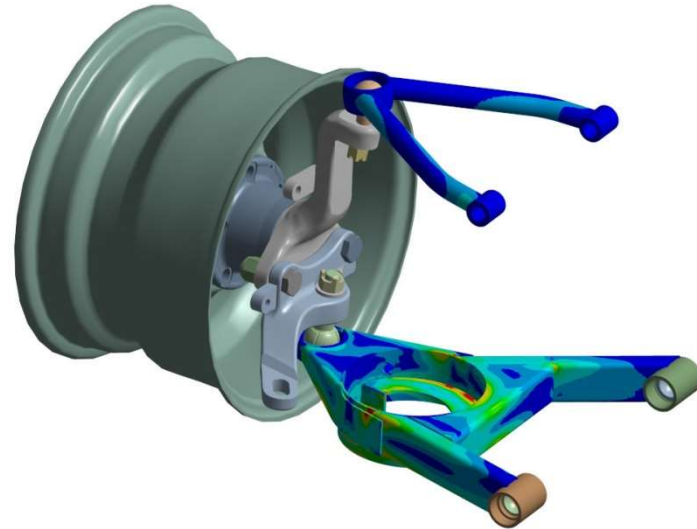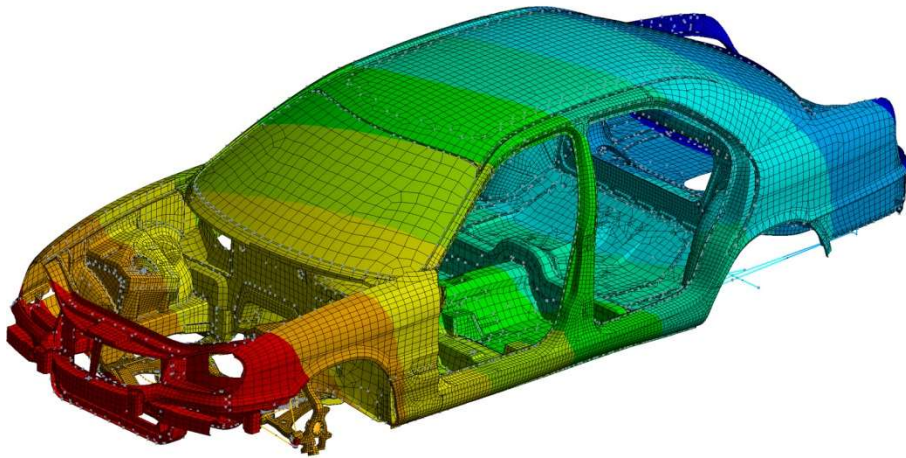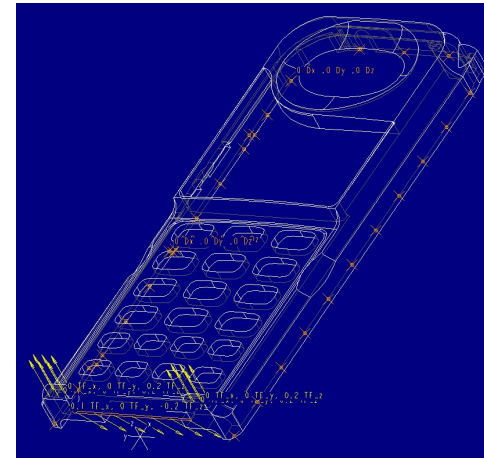
Example: Cellular Phone (CAD)
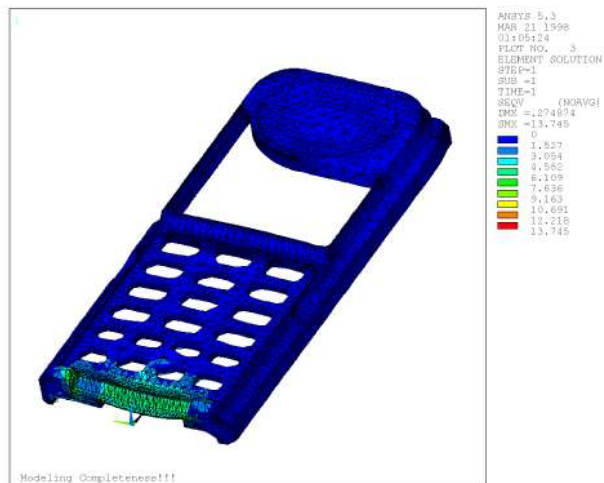

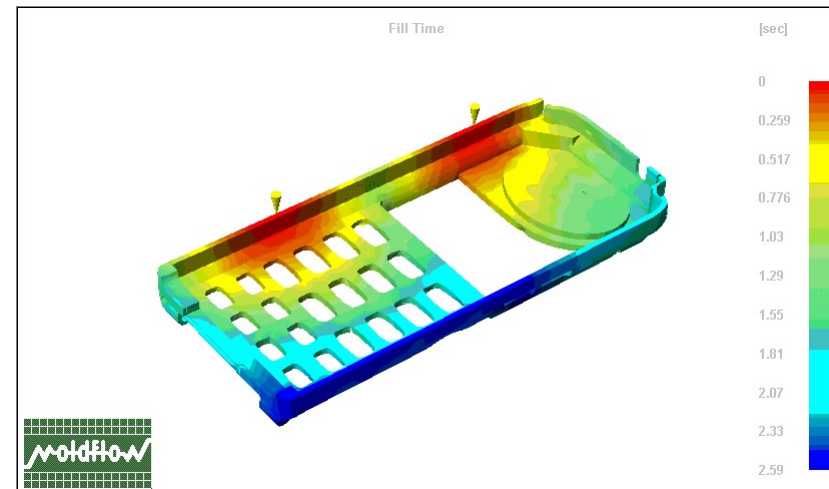Solid Model

Example: Cellular Phone (CAE)

Finite Element Analysis Model

Boundary Conditions

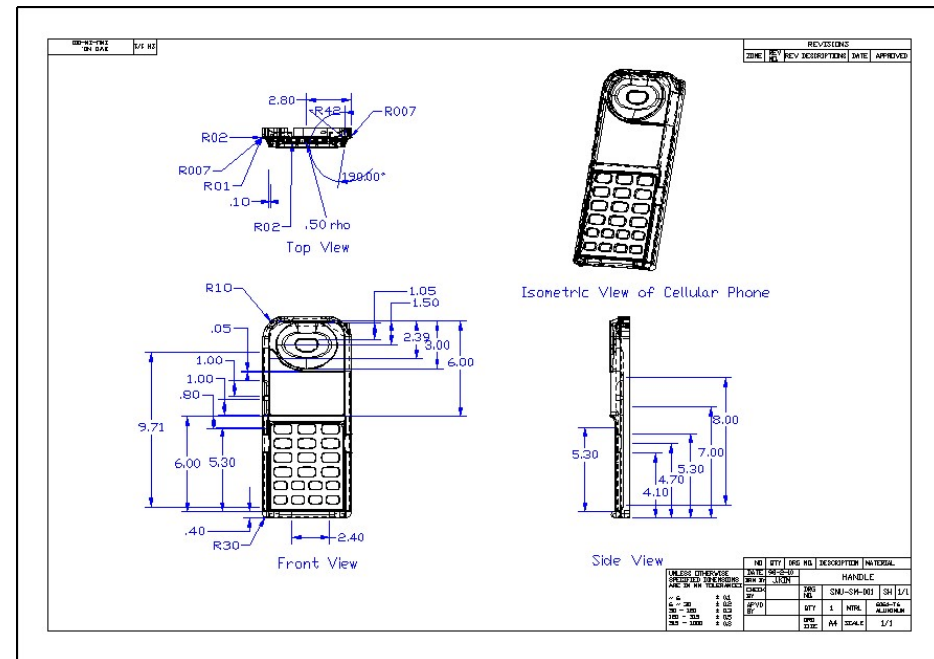Stress Distribution

Fill-time Distribution

Example: Cellular Phone (RP/CAD)
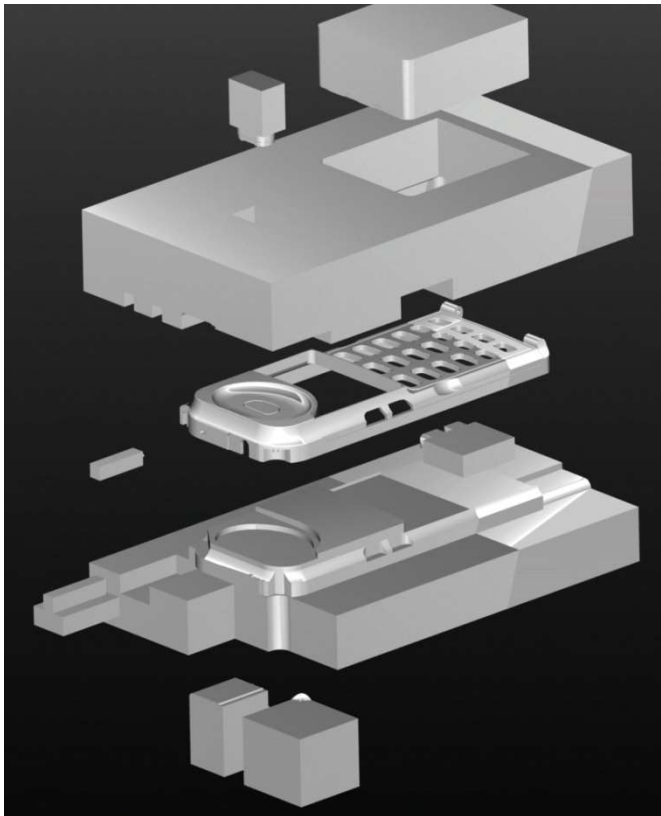

Physical Prototype
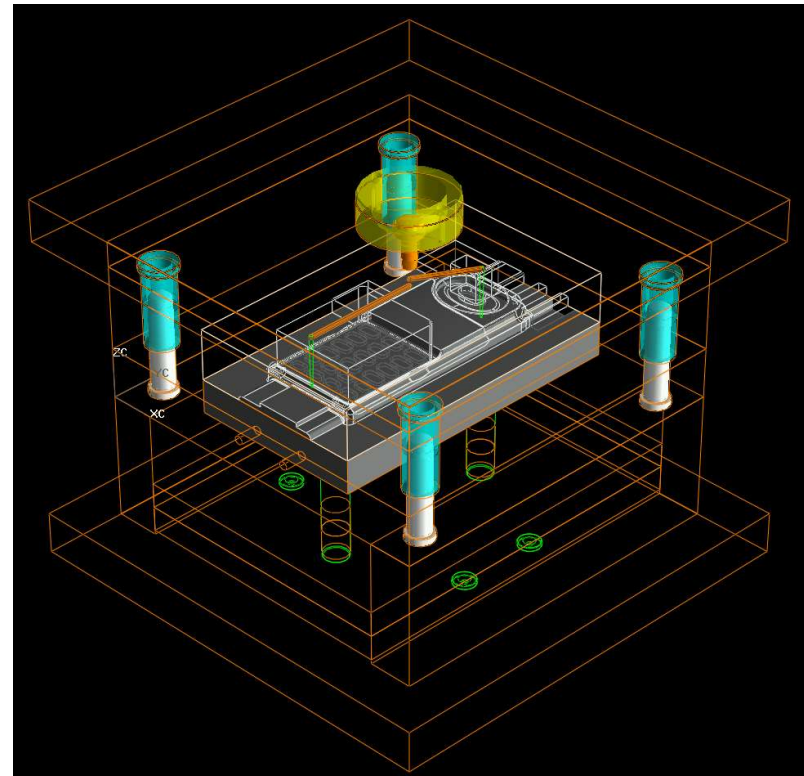

Part Drawing

Example: Cellular Phone (CAD)

Injection Mold Design
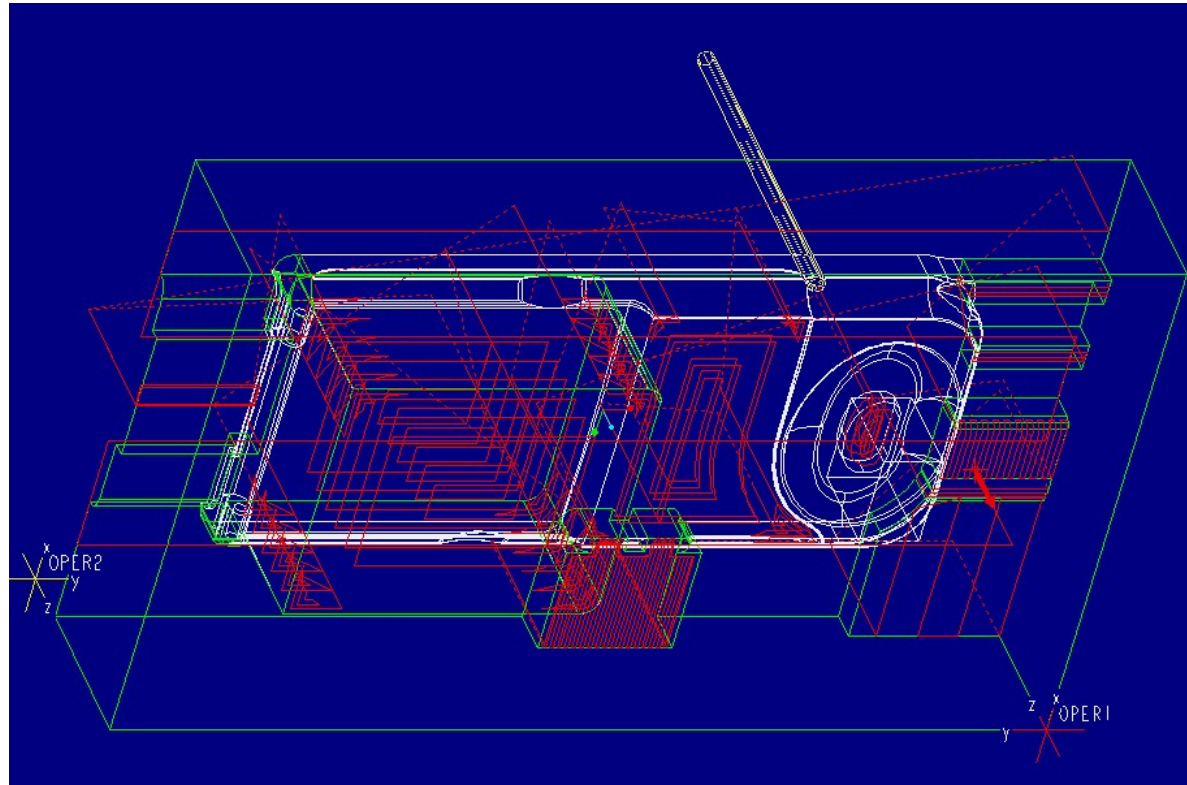
- Core plate
- Cavity plate
- Side cores

- Mold base
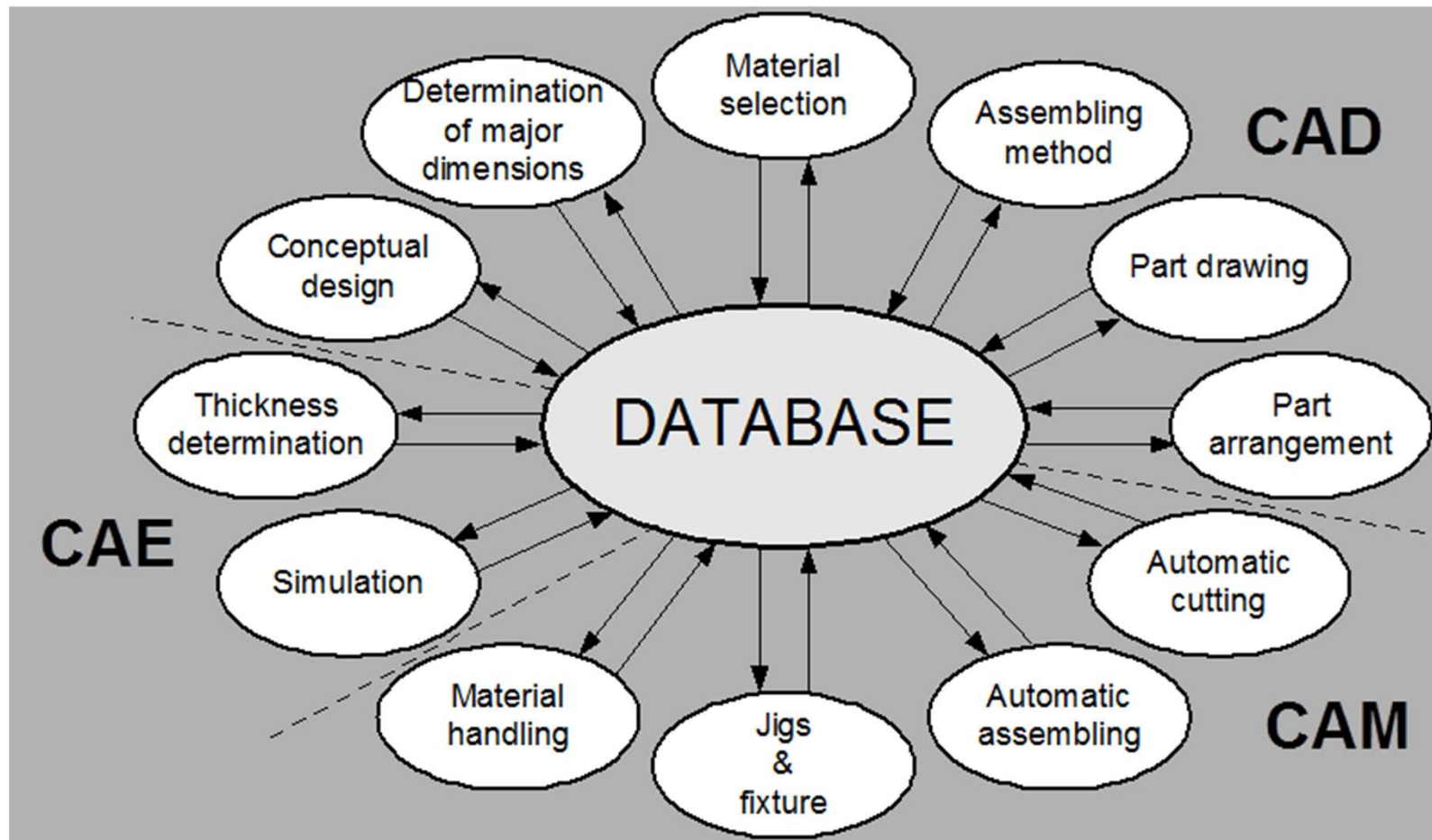- Ejector pins
- Cooling channels

Example: Cellular Phone (CAM)

NC Tool Path to machine mold

Computer-Integrated Manufacturing (CIM)

생산공정의 디지털화 (Digital Manufacturing)

- CAD/CAE/CAM과 같은 컴퓨터에 의한 디지털 정보기술을 개발, 설계, 제조, 검사 등의 생산 프로세스에 활용

CAD

상세 설계

CAE/CAD

개발
기본 설계

CAM

제조
(생산 준비)

제품 검사

제조
(양산)

CAT

CAE
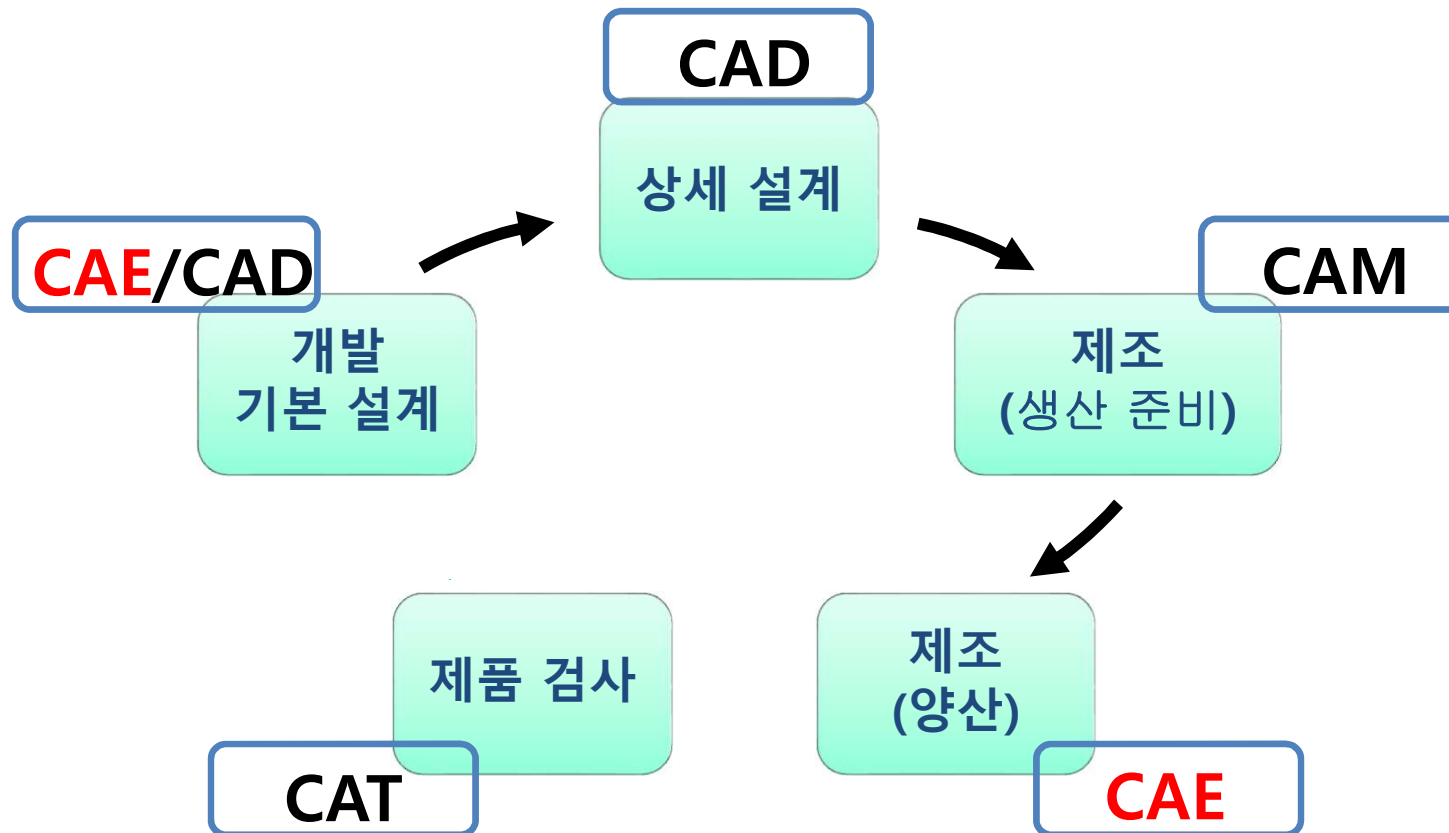
Kinds of Design Models

- **Product development models**
  - Generic product knowledge (design process models)
  - Product models (geometric & non-geometric)
  - Generic mfg process models (with physics-based and economic models)
  - Factory models (specific instances)

- **Non-geometric models**
  - wiring schematics
  - hydraulic piping diagrams
  - flowcharts
  - graph-based models

Different Design Models of Same Component

(a) Form   (b) Kinematic structure   (c) Discretized for strength
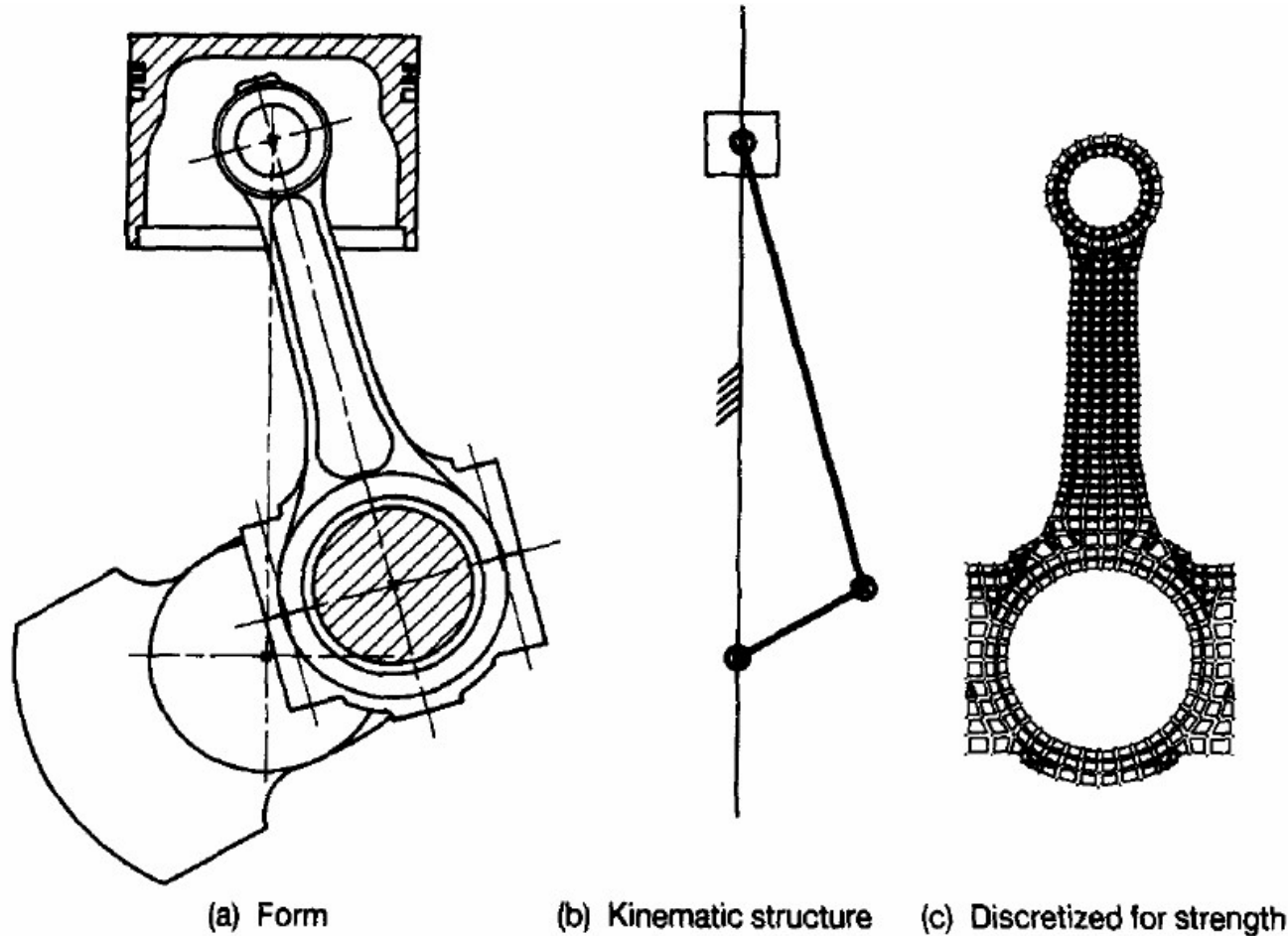
Some Non-geometric Models
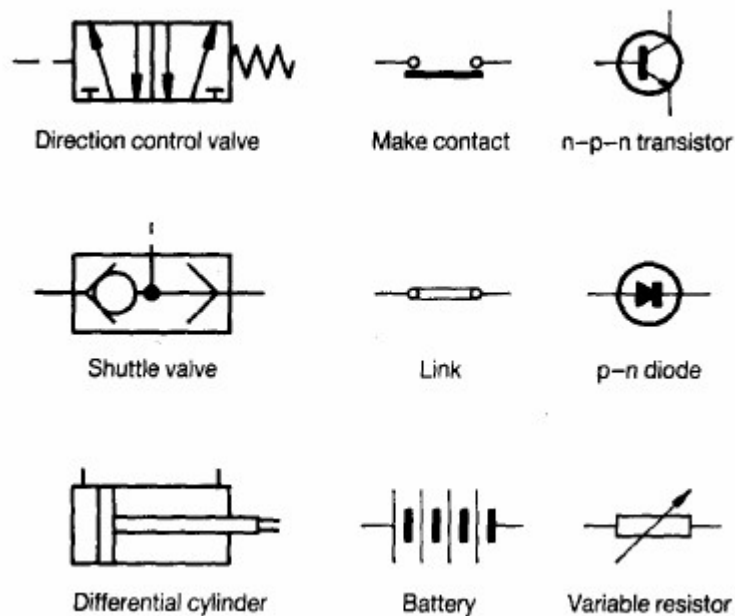
Hydraulic Components

Control System Flowchart

CAD vs. System Modeling

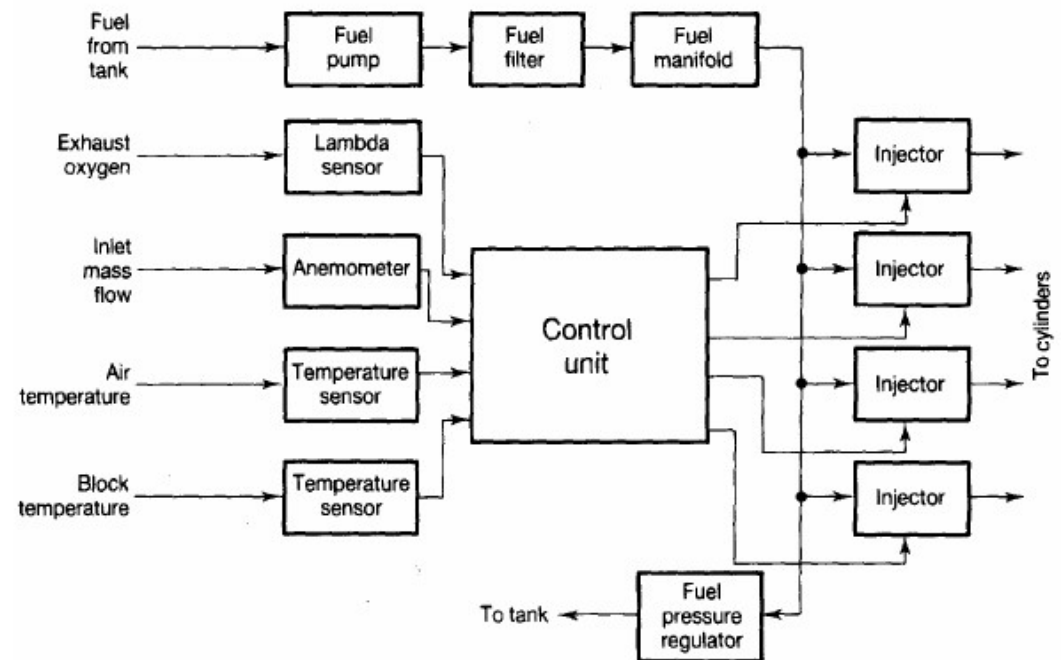|	CAD Modeling	System Modeling
Model	detailed 3D assembly model, complete with electric components, standard mechanical parts, wire harnesses and manufacturing information	schematic (mostly 2D) representing the data flow, input-output relationship and component hierarchy that depict the inner workings of a vehicle, plane, robot, plant or another complex system
Input	wall thickness, extrusion lengths, trim angles and other values that define the geometry of the design (geometric values and component shapes)	fan speed, valve modulation, temperature and power
Simulation	studying how stress, pressure and forces would affect the integrity of the design (mechanical behaviors)	computing the effects of varying inputs on the overall structure of the design

CAD vs. System Modeling: Component
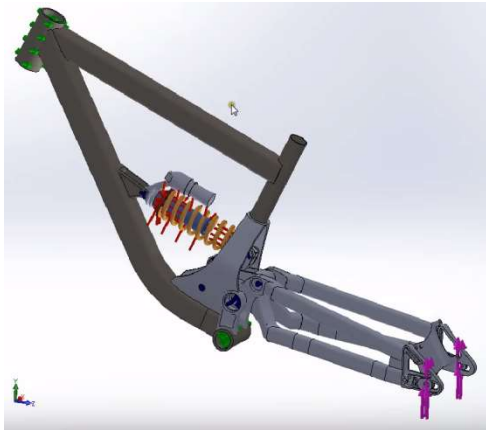
3D Geometric Model
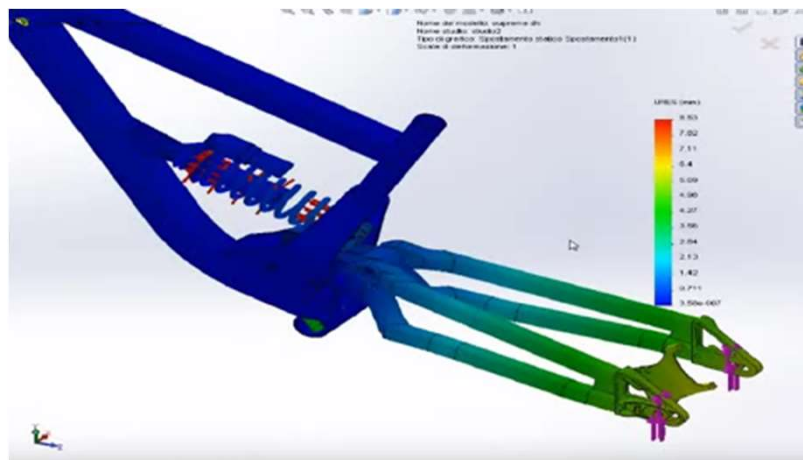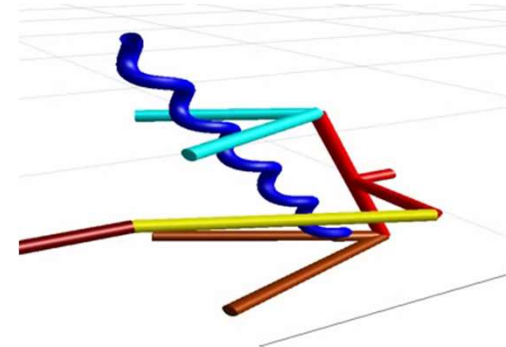
1D Model

CAD vs. System Modeling: Vehicle

3D Geometric Model
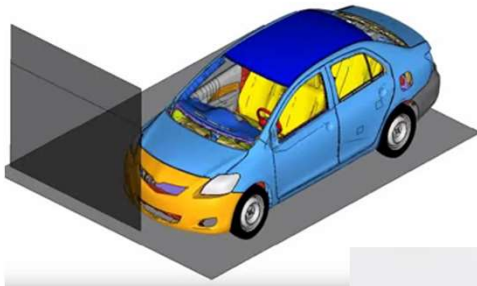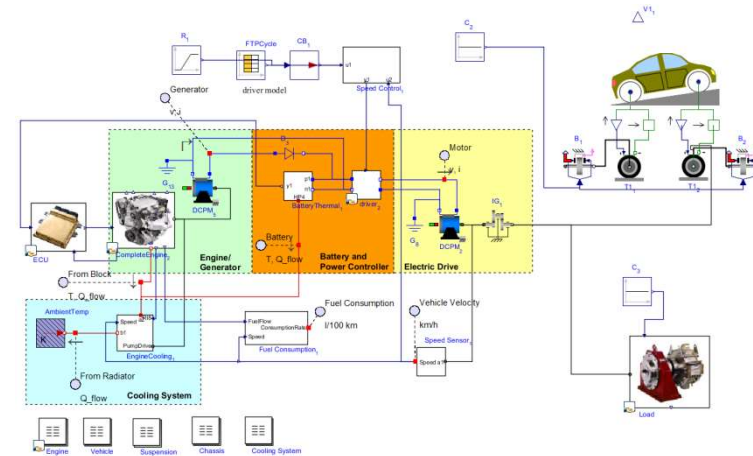
1D Model

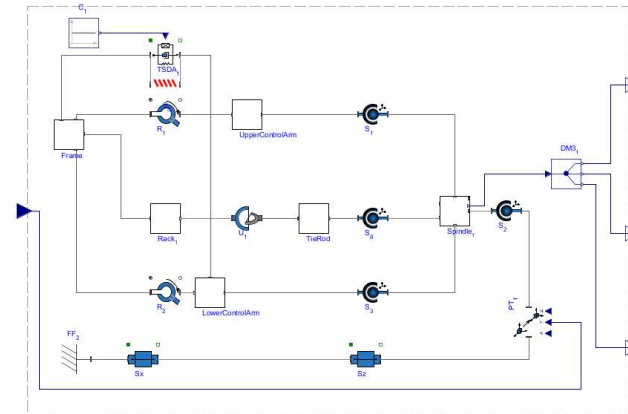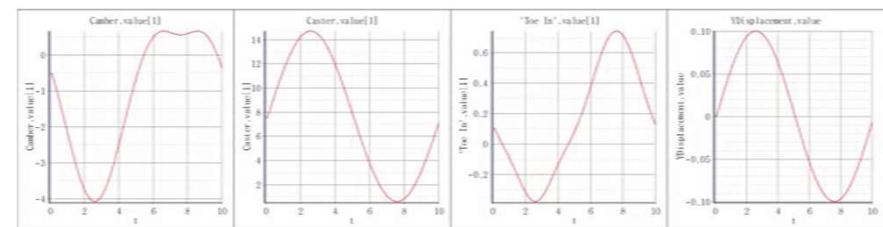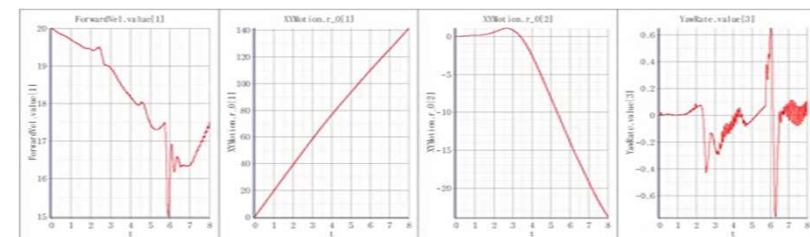# Components of CAD/CAM/CAE Systems

```
                    ┌─────────────────────────┐
                    │   CAD/CAM/CAE SYSTEM     │
                    └─────────────────────────┘
                                 │
                 ┌───────────────┴───────────────┐
          ┌─────────────┐                 ┌─────────────┐
          │  Hardware   │                 │  Software   │
          └─────────────┘                 └─────────────┘
                 │
        ┌────────┴────────┐
 ┌──────────────────┐ ┌──────────────────┐
 │ Computing machine│ │  Graphic device  │
 └──────────────────┘ └──────────────────┘
                              │
                   ┌────────────────────────┐
                   │ Display processing unit│
                   │     Display device     │
                   │      Input device      │
                   │      Output device     │
                   └────────────────────────┘
```
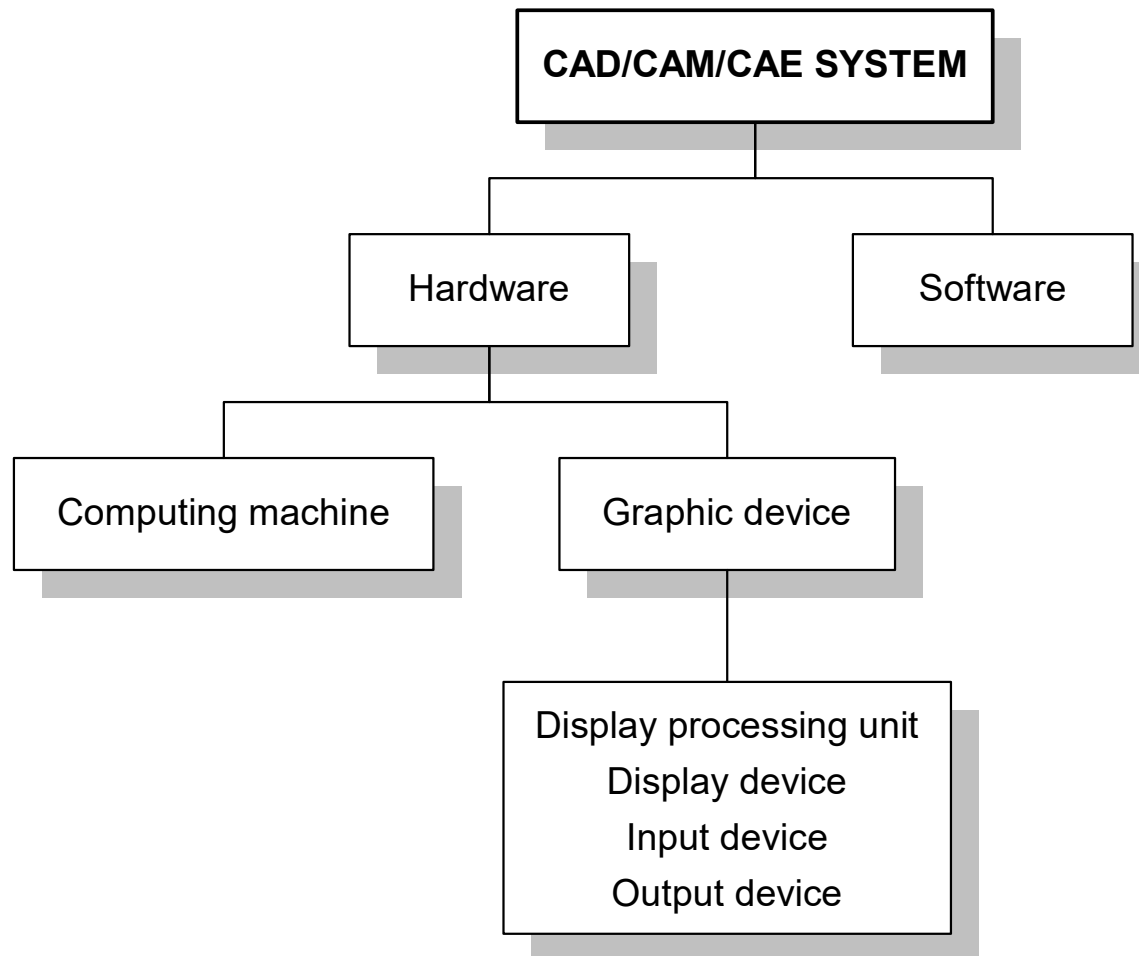
Input Devices (1)

- To locate points and lines: cross-hair cursors on the screen
- To select menu items
- To manipulate parts of constructed images

Mouse

Data tablet with
a puck and a stylus
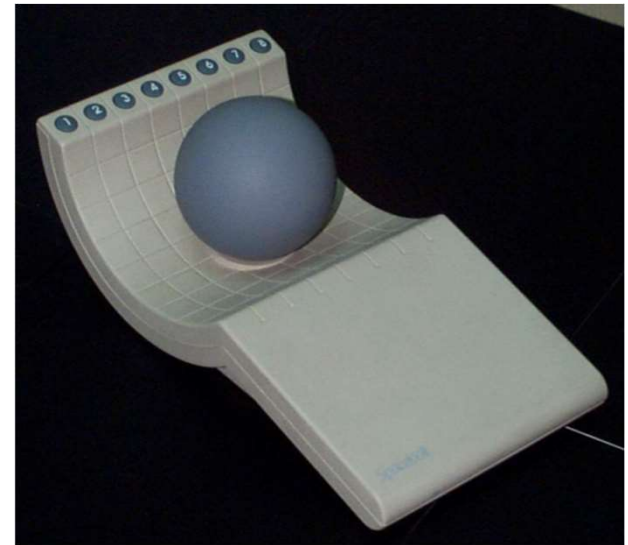
Space ball

Input Devices (2)

- Digitizer
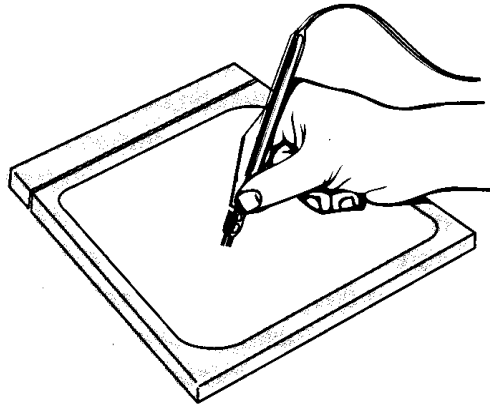
- Lightpen
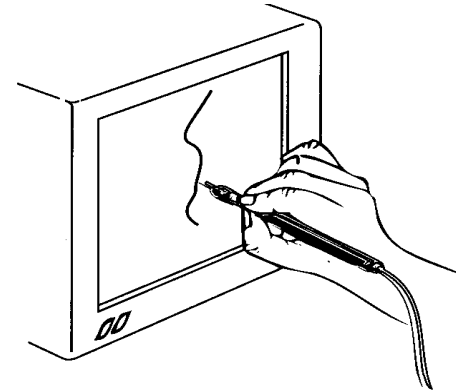
- Touch-sensitive screens
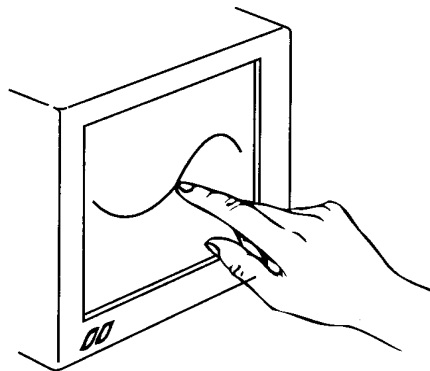
- Image scanner
- Joysticks, trackball

Input Devices (3)

- Keyboard

- Mouse

- Trackball
  - A 2D input device, usually used on a mouse or a laptop computer

- Space ball
  - Hand held, non-movable; It uses a strain gauge to detect pull, push and twist applied to the ball, and translate them into 3D locations; used for navigation in virtual environments, CAE, etc.

- Head Mounted Display
  - Although it is primarily a display device, it can also track position and orientation

- Joystick
  - Similar to the space ball, can be movable and non-movable

Input Devices (4)

- **Data globe**
  - A globe with sensors, used to control virtual hand for grasping, dropping and moving an object in a virtual environment

- **Image scanner**
  - Input still picture, photo or slides as images into computer

- **Touch panel**
  - Highly transparent and embedded over a display surface

- **Digital camera**
  - Directly stores photo shots as images on a diskette

- **Digital video recorder**
  - Input a video clip in digital form; often used for teleconferencing

Input Devices (5)

- **Laser range scanner**
  - Input discrete and scattered points on a 3D surface model from which a digital one can be built

- **Motion capture**
  - Input full-body, facial, hand movements

Output Devices (1)

- Printer
- Plotter
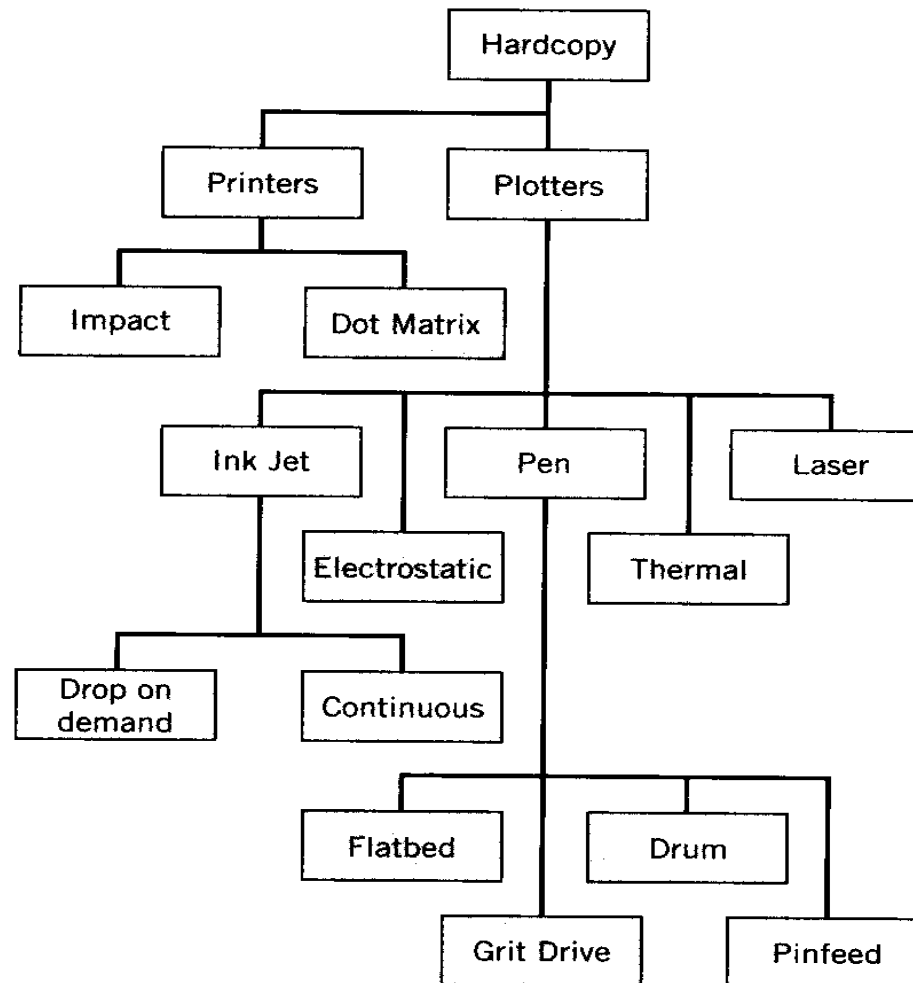
Output Devices (2)

- **Stereoscopic viewing glasses**
  - User wears them to perceive stereoscopic view of 3D scenes displayed on screen
  - Used in screen-based Virtual Reality (VR)
  - High resolution, limited head-movement

- **Head-mounted display (HMD)**
  - Two small TV screens are embedded in a rack and placed in front of the two eyes
  - It allows full-freedom head movement and gives the feel of immersion
  - Widely used in Virtual Reality (VR)

- **Wide screen**

I/O Devices for Virtual Reality

- Graphics display changes dynamically in response to body motion
  - Headset (provides Window), Glove
- Haptic technology
  - 컴퓨터의 기능 가운데 촉각과 힘, 운동감 등을 느끼게 하는 기술

Graphics Display Devices

- Memory requirement
- Method of refresh
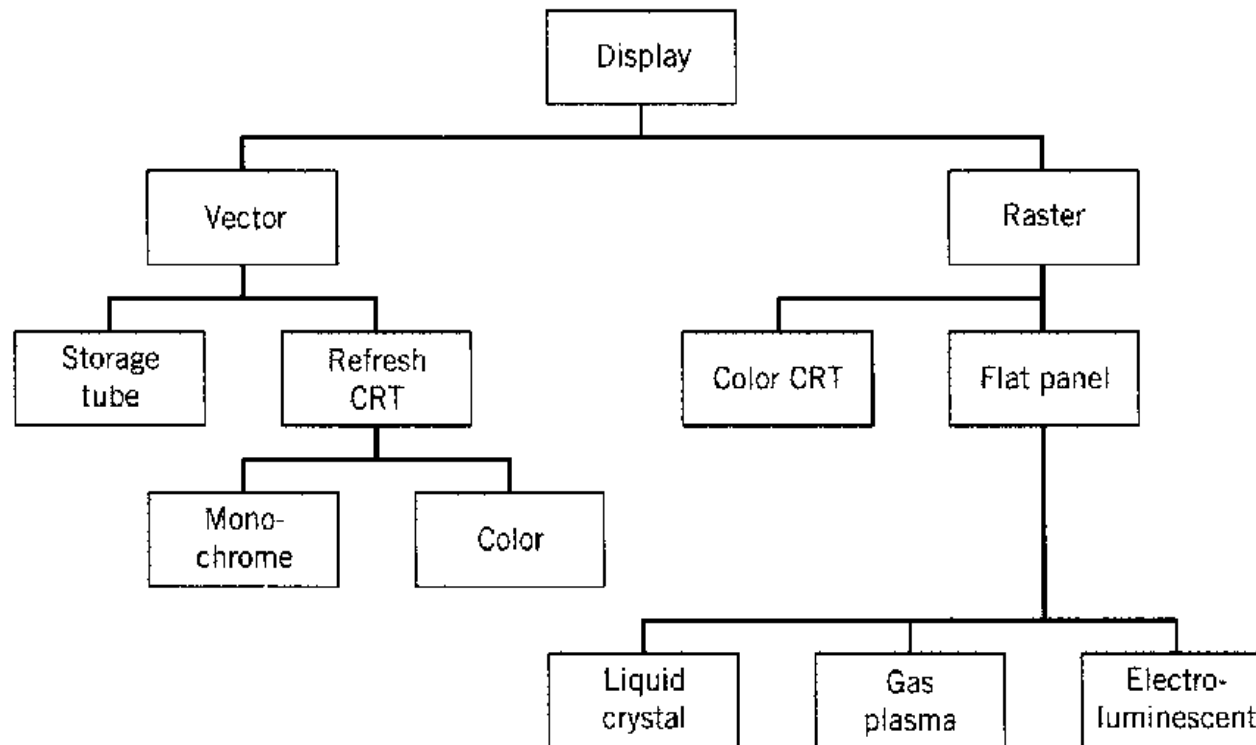
Video Display Devices

- Cathode Ray Tube (CRT) was the most common display device
  - High resolution
  - Good color fidelity
  - High contrast (400:1)
  - High update rates
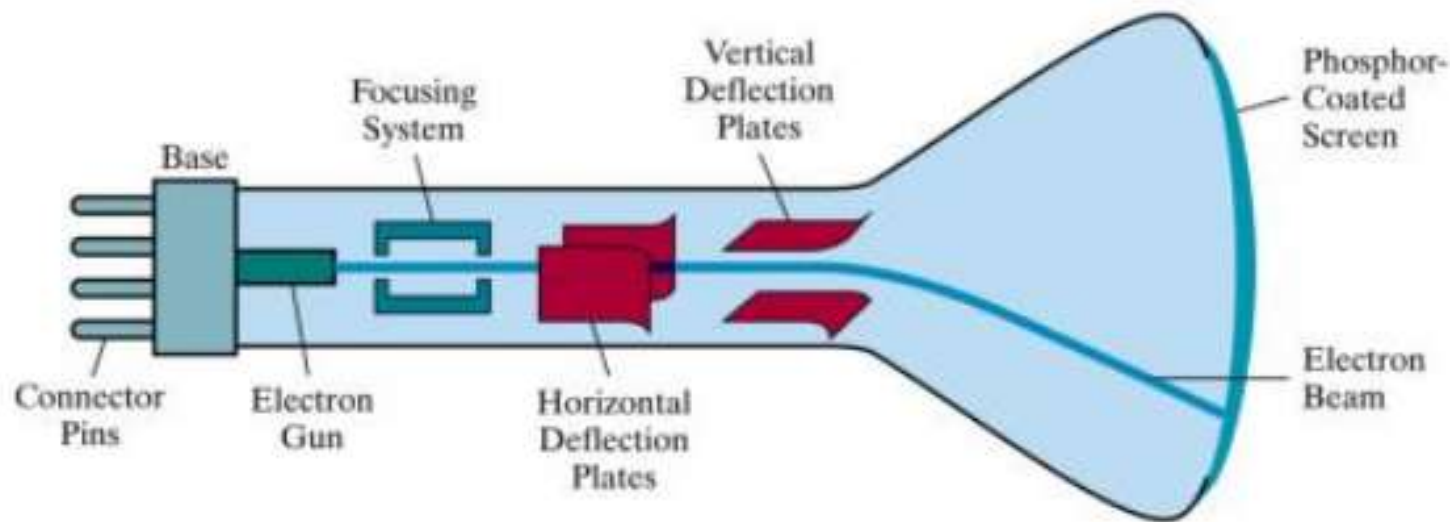
Vector vs Raster CRT

- Vector displays
  - A list of line endpoints was used to move the electron beam along some random path, so called vector scan

- Raster displays
  - (TVs etc.) drive the beam in a regular pattern called a raster scan

- Vector displays are almost extinct

- Scan conversion
  - Convert geometric primitives from vector scans description (endpoints etc.) to raster scan descriptions (Sets of pixels to turn on)
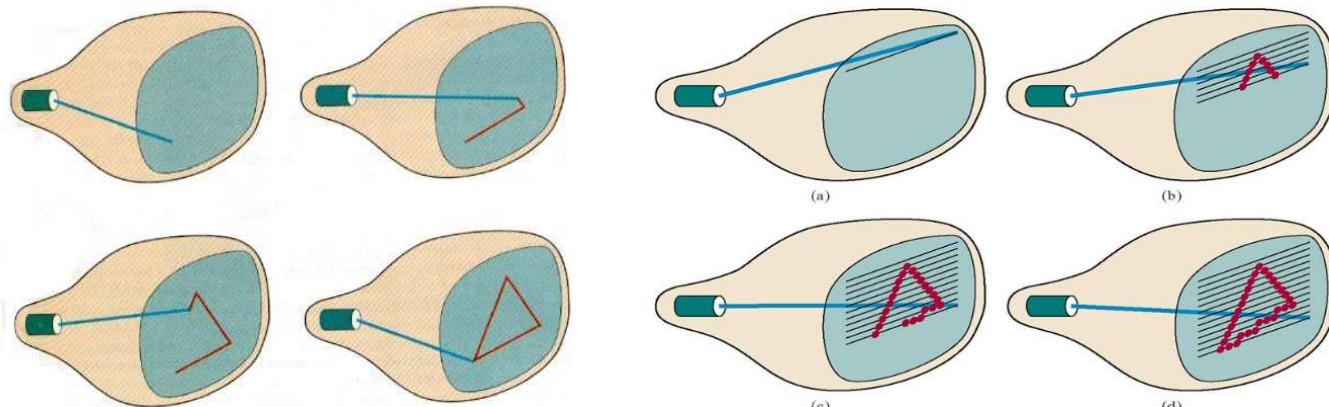
Vector-Refresh Graphic Device
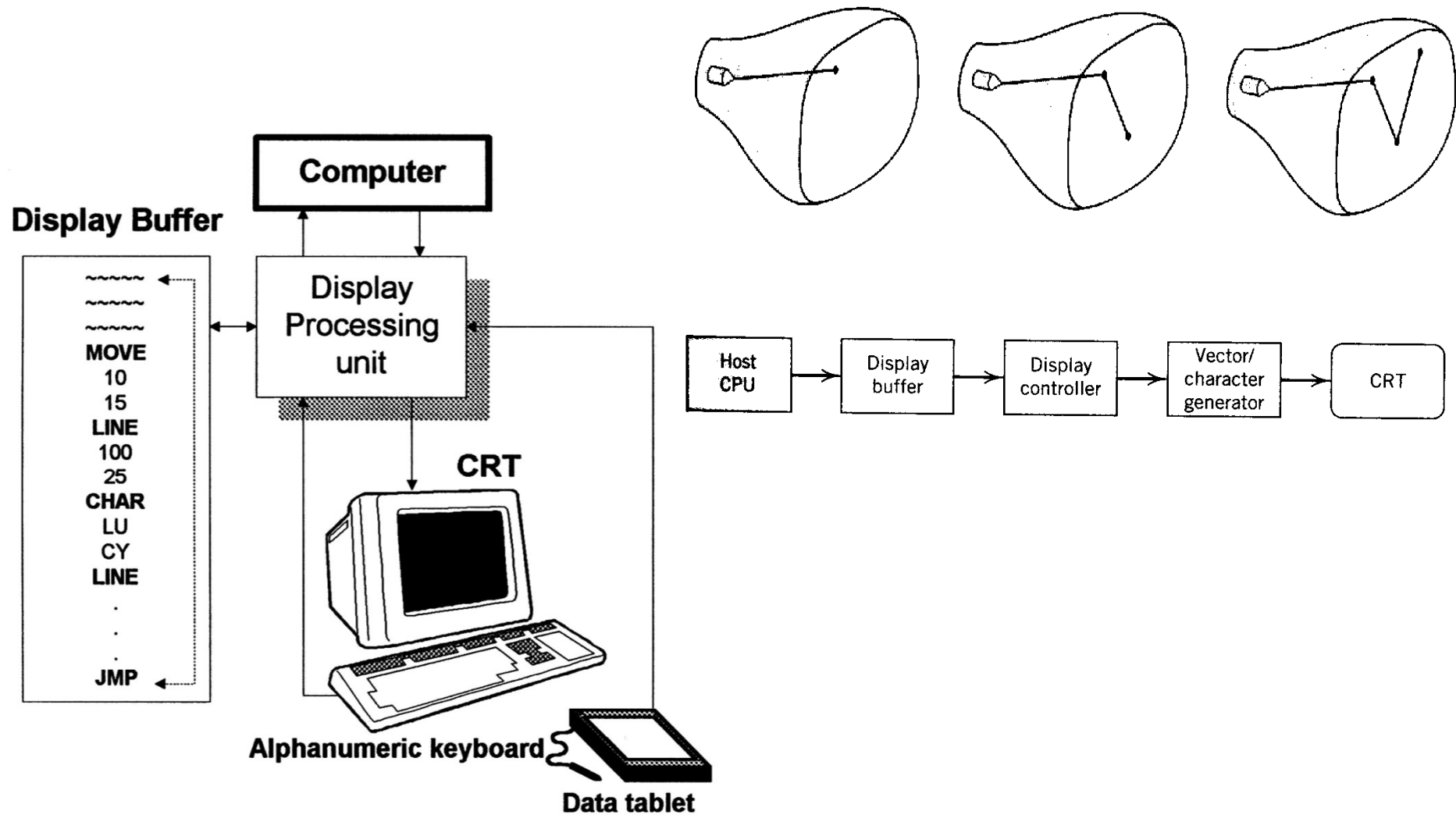
Raster Graphic Device (1)

- **Introduced in the mid 1970s**

- **Based on TV Technology**

- **Main type of graphic device**
  - High performance-to-price-ratio

- **Scanning pattern for refresh or frame buffer**
  - Need scan conversion or rasterization
    - Implemented at the hardware level
  - A point plotting device
    - XY matrix of dots
    - Pixels - "pointillist" method
  - Need to address each pixel individually

Raster Graphic Device (2)

Bits in memory
(refresh buffer)

Pixels

COMPUTER

Graphic command   Data

Display Processor

Frame buffer

CRT
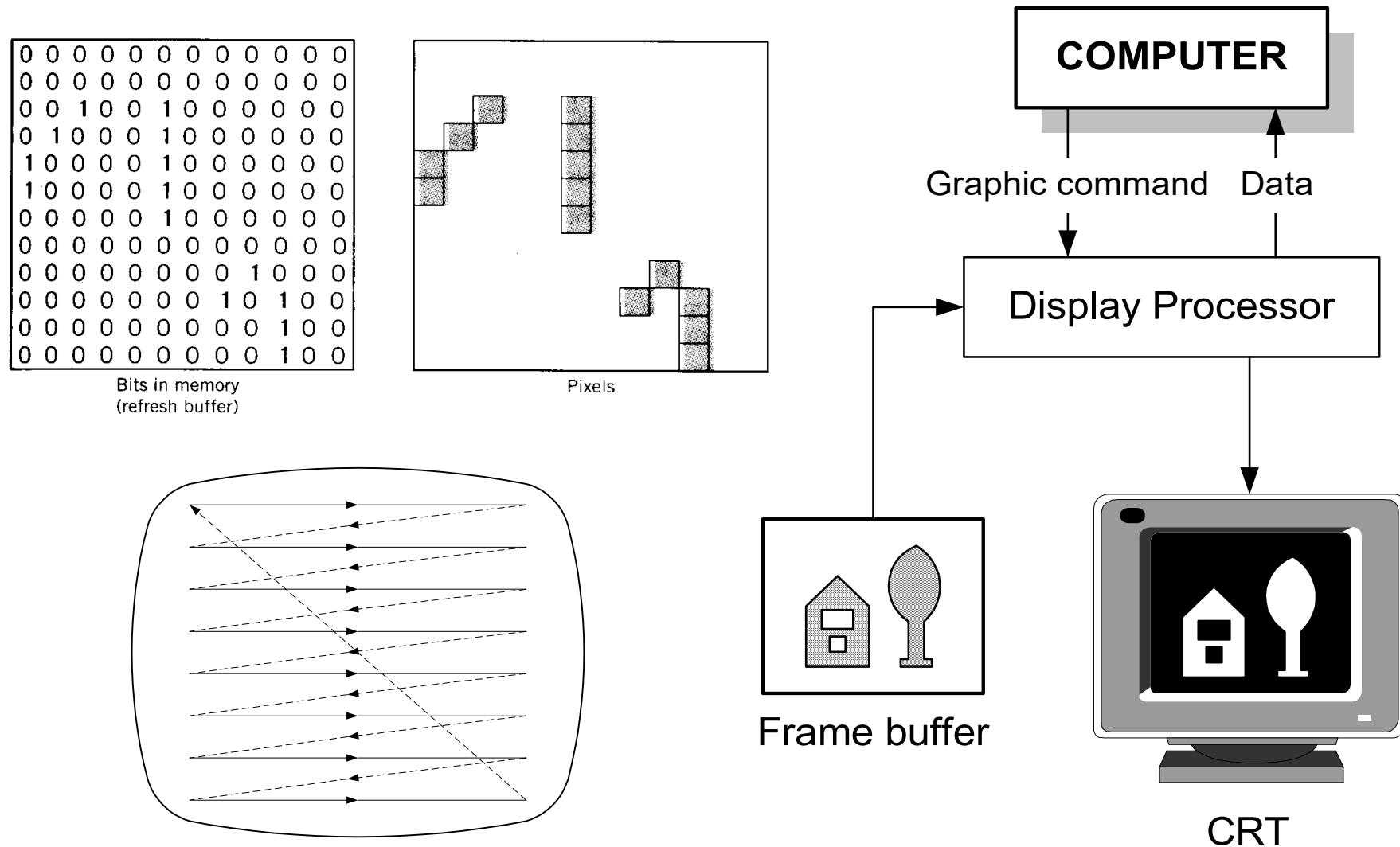
Colors of 3 Bit Planes (Frame Buffers)

Frame buffer

Registers

Color guns

0	→	DAC	→	Blue
1	→	DAC	→	Green
0	→	DAC	→	Red

CRT Raster
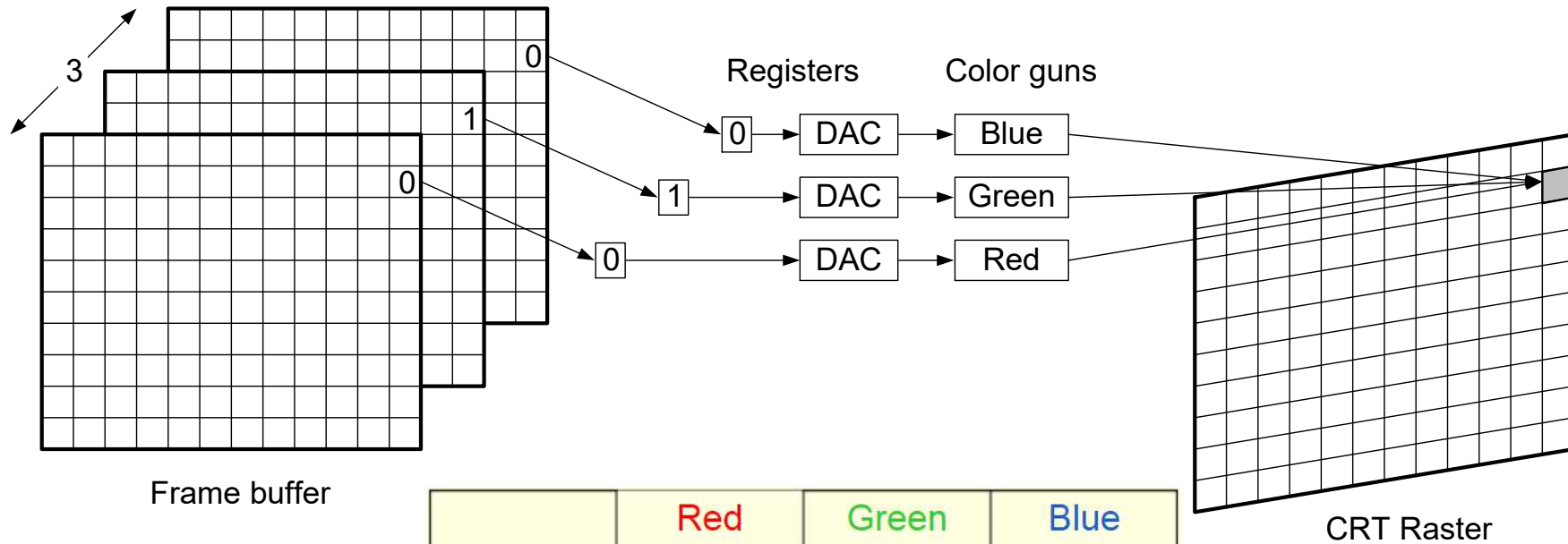
	Red	Green	Blue
Black	0	0	0
Red	1	0	0
Green	0	1	0
Blue	0	0	1
Yellow	1	1	0
Cyan	0	1	1
White	1	1	1

24 Bit Planes

each color (R/G/B): $2^8 = 256$ levels

$\rightarrow$ total: $2^{24} = 16,777,216$ colors

8

8

8

8

Registers

| 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | → 8 Bit DAC

Blue 75

| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | → 8 Bit DAC

Green 172

| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | → 8 Bit DAC

Red 10

Blue

Green

Red

Color guns

Frame buffer

CRT Raster
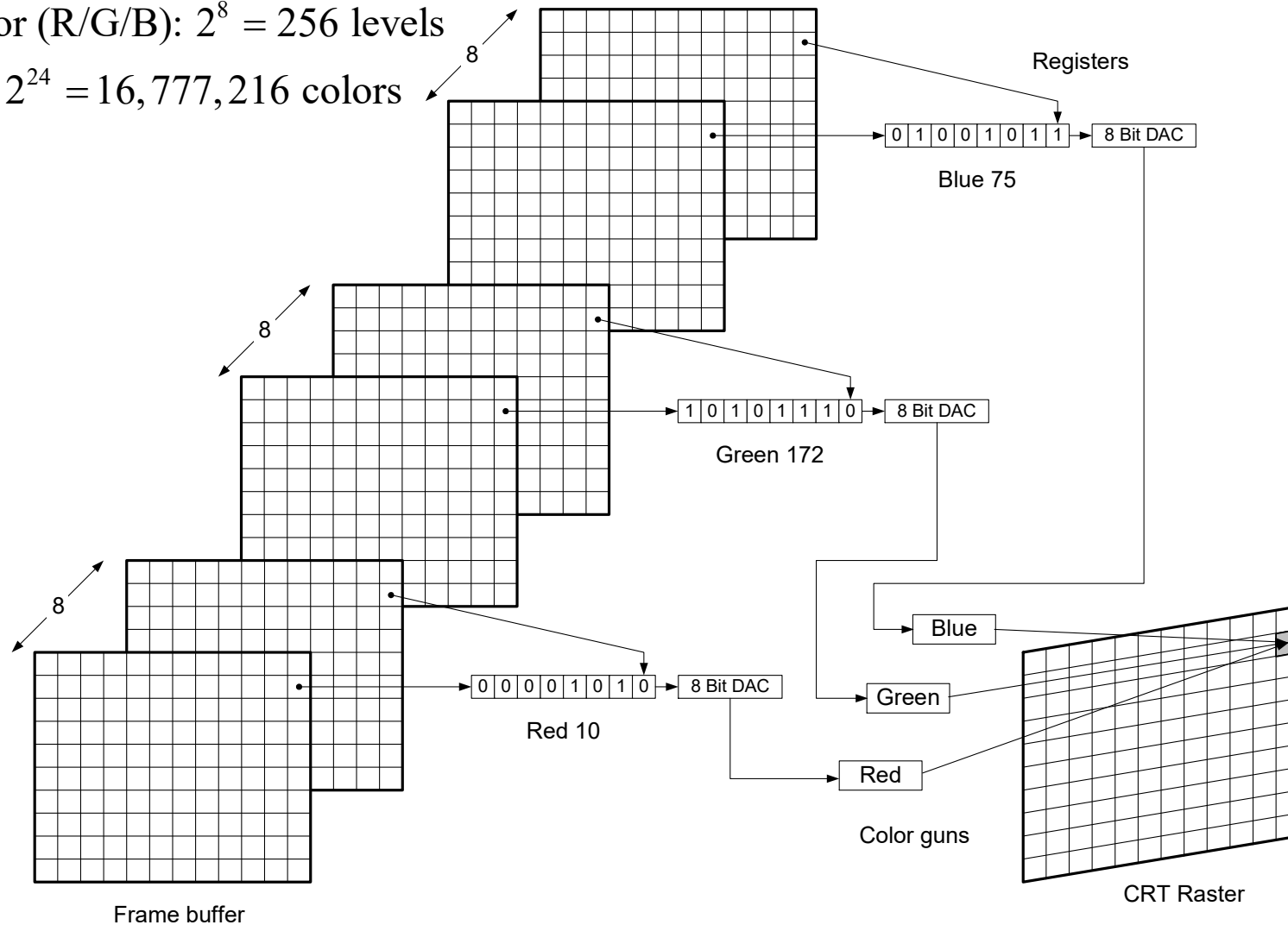
Color Raster Graphic Device

Distribution of phosphors
for RGB colors

Shadow mask

Shadow mask

Phosphors on glass faceplate

Green beam

Blue beam

Red beam

Beam convergence

Electron Guns

Section of Shadow Mask

Magnified Phosphor-Dot Triangle

Red
Green Blue

Screen
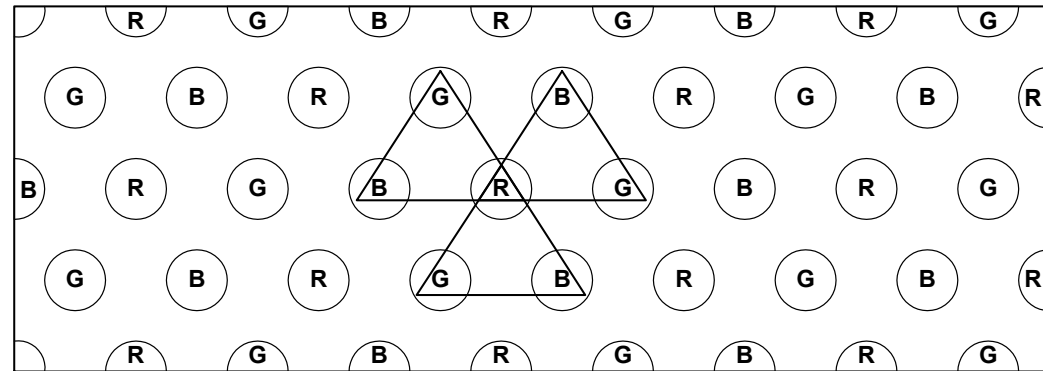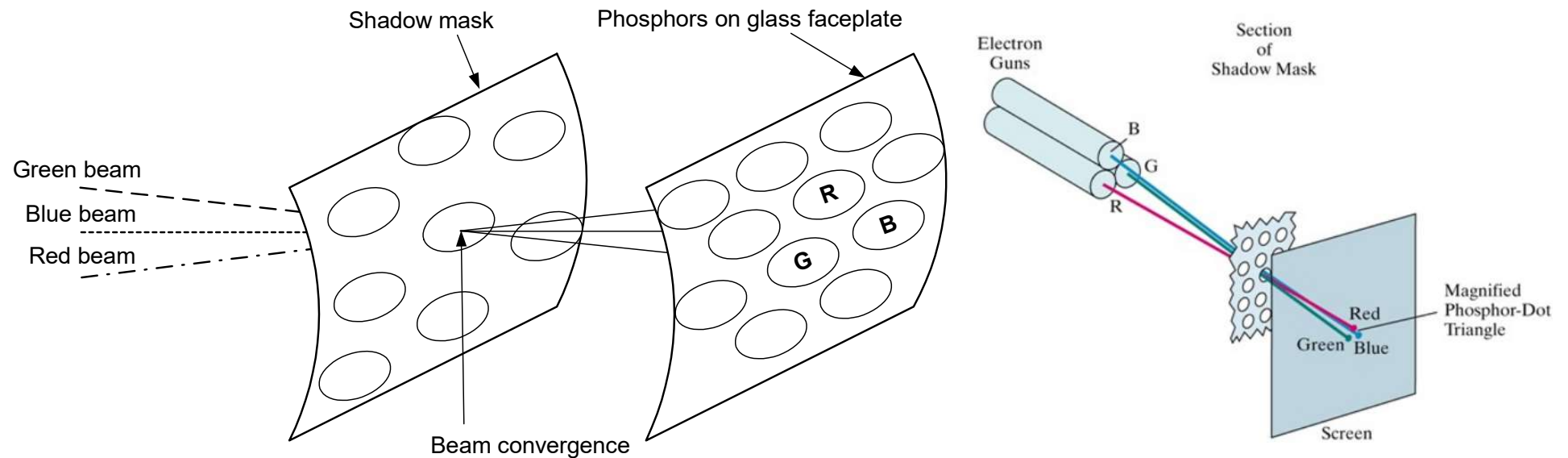
Aliasing Effect

- Highlights pixels in the proximity of the line
- "Stair-stepped" appearance of diagonal lines
- Reduce the problem using various intensity levels to blend the edges of lines
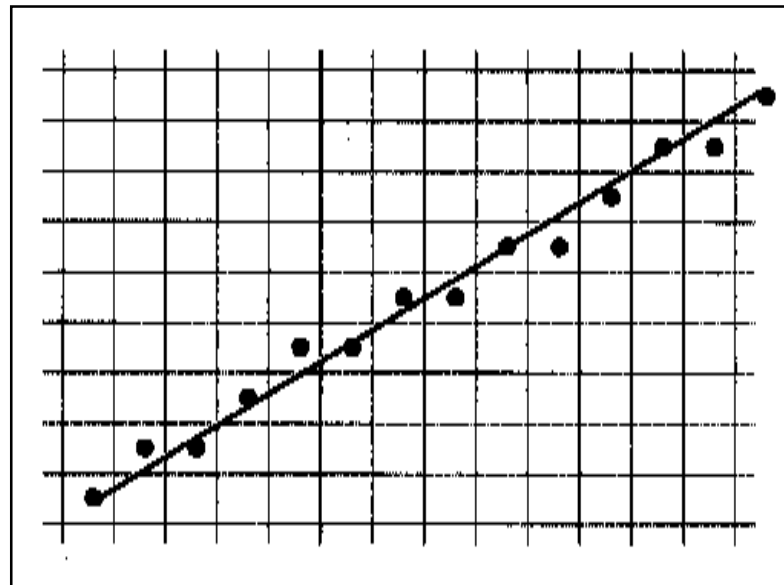
Comparisons

- **Vector Refresh Displays**

- Advantages
  - Low persistent phosphor with refreshing
  - Useful in representing dynamic motion
  - Produce a bright and clear picture
  - Have a high resolution

- Disadvantages
  - High cost
  - No capability of filling area with color

- **Raster Scan Display**

- Advantages
  - Inexpensive
  - Bright pictures
  - Color
  - Dynamic motion
  - Independent on picture complexity

- Disadvantages
  - Large amounts of storage requirement
  - Aliasing Effect

Flat Panel Displays

- **Emissive display (or emitters)**
  - Device that convert electrical energy into light
  - Plasma-panel (gas-discharging) display, thin-film electroluminescent displays, Light Emitting Diodes (LED)

- **Nonemissive display**
  - Use optical effect to convert sunlight or light from some other source into graphics patterns
  - Liquid crystal displays (LCD)

- **Comparison to CRT**
  - Thin, light
  - Flicker free
  - Narrower color gamut

Image File Formats (1)

- **GIF (Graphics Interchange Format)**
  - the CompuServe Information Service and F&R Block Company
  - Copyrighted bitmap format
  - Uses compression
  - Can store only 256-color images, any size

- **TIFF (Tag-based Image File Format)**
  - Aldus Corp. and Microsoft to support digital scanner manufacturers and desktop publishing systems to describe and store raster image data
  - Run-length encoding with compression
  - Independent of OS, processors, compilers and filing systems
  - Become a standard for image storage and communication

Image File Formats (2)

- JPEG
  - International compression standard (1992)
  - High compression rate can be acquired by removing the following redundancy in an image:
    - Spatial (between neighboring pixels)
    - Spectral (between color planes)
    - Temporal (between adjacent frames in a sequence)
  - Highly lossy compression, but objectionable blocking artifacts may occur
  - Poor lossless compression efficiency (less than 3)
  - Lossy compression method limited to input images with maximum bit depth of 8 bits/pixel
  - Lossless support 2 to 16 bits/pixel
  - No support for true-color

Image File Formats (3)

- **JPEG 2000**
  - New international compression standard (2002.1)
  - Significantly higher compression efficiency than JPEG
  - New functionalities
    - Integrated lossy/lossless compression
    - Region-of-interest (ROI) encoding
    - Multi-resolution capability
    - Progressive decoding

- **EPS (Encapsulated PostScript)**
  - Abode Systems Incorporated
  - Importing and exporting PostScript language files
  - Grayscale or color
  - Usually ASCII
  - No compression
  - Can be mix of raster and geometric data

Image File Formats Comparison

	Bits per pixel	File size	Comments
JPEG	24	Small	Lossy, good for archives
TIFF	8, 24	Medium	Good
GIF	1, 4, 8	Medium	No good for colorful images
EPSP	1, 2, 4, 8, 24	Huge	Good for printing