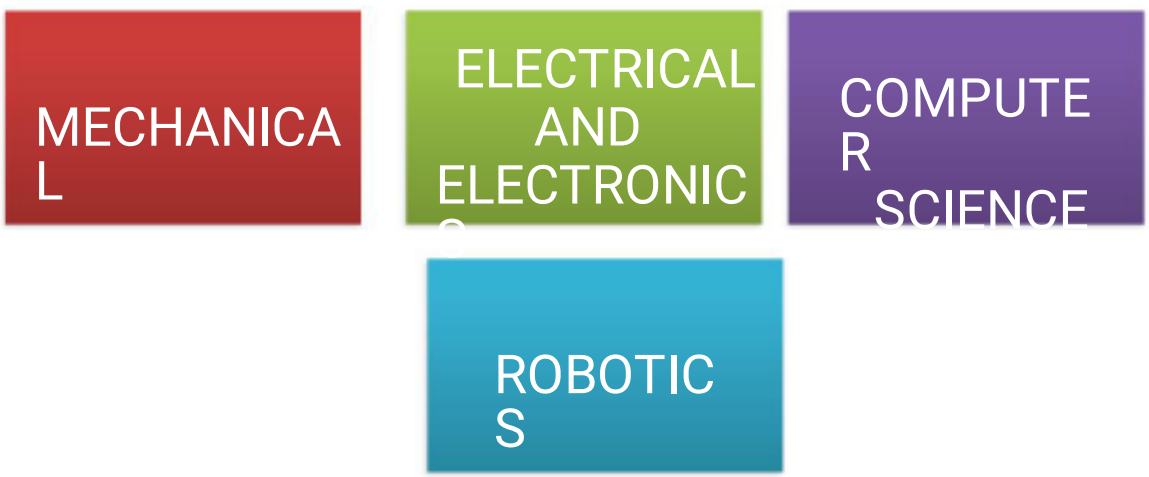
INTRODUCTION TO ROBOTICS

ROBOTICS

It is the science of designing and building robots suitable for real-life applications in

automated manufacturing and other non-manufacturing environments.



FACTORS FOR INTRODUCTION OF ROBOTICS TO INDUSTRIAL WORLD

- Improved Quality of Products
- Lesser Preparation time
- Lower rejects and less waste
- Skilled labour shortage
- Demand of improvement quality
- Rising costs
- Pressure to increase the production

ROBOT

"A robot is an automatic device that performs functions normally ascribed to humans or a machine in the form of a human."

OR

"A robot is a software-controllable mechanical device that uses sensors to guide one or more end-effectors through programmed motions in a workpiece in order to manipulate physical objects.

OR

"An industrial robot is a reprogrammable multifunctional manipulator

designed to move material, parts, tools or specialized devices through

various programmed motions for the performance

of a variety of tasks"

FUNCTIONS OF ROBOT

The functions of a robot can be classified into three areas :

• Sensing the environment by external sensors.
Example : Vision, voice, touch, proximity and so on.

• Decision making" based on the information received from the sensors.

• "Performing" the task decided.

DIFFERENCE BETWEEN A ROBOT AND AN AUTOMATED MACHINE

- In automation, the machine produces a job following a set of operational sequence, while a robot can be made to do different jobs at different times and in different sequences. This can be achieved by programming.
- A robot can be programmed to change the sequence of task while a fixed machine set to perform certain tasks in sequence can not be programmed. An automated machine does not have sensory feedback to reprogramme the predetermined path.

OBJECTIVES OF USING INDUSTRIAL ROBOTS

- To reduce production time.
- To minimise the labour requirement.
- To raise the quality level of products.
- To increase productivity.
- To enhance the life of production machines.
- To minimise the loss of man-hours on account of accidents and diseases

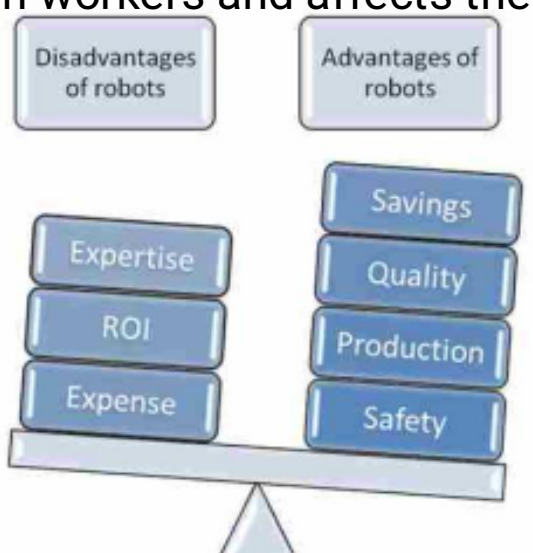
ADVANTAGES AND DISADVANTAGES

ADVANTAGES

- Working during unfavorable hours.
- Increasing productivity, quality of products
- Achieve more accuracy
- Providing repeatability and consistency
- Lifting and moving heavy objects

DISADVANTAGES

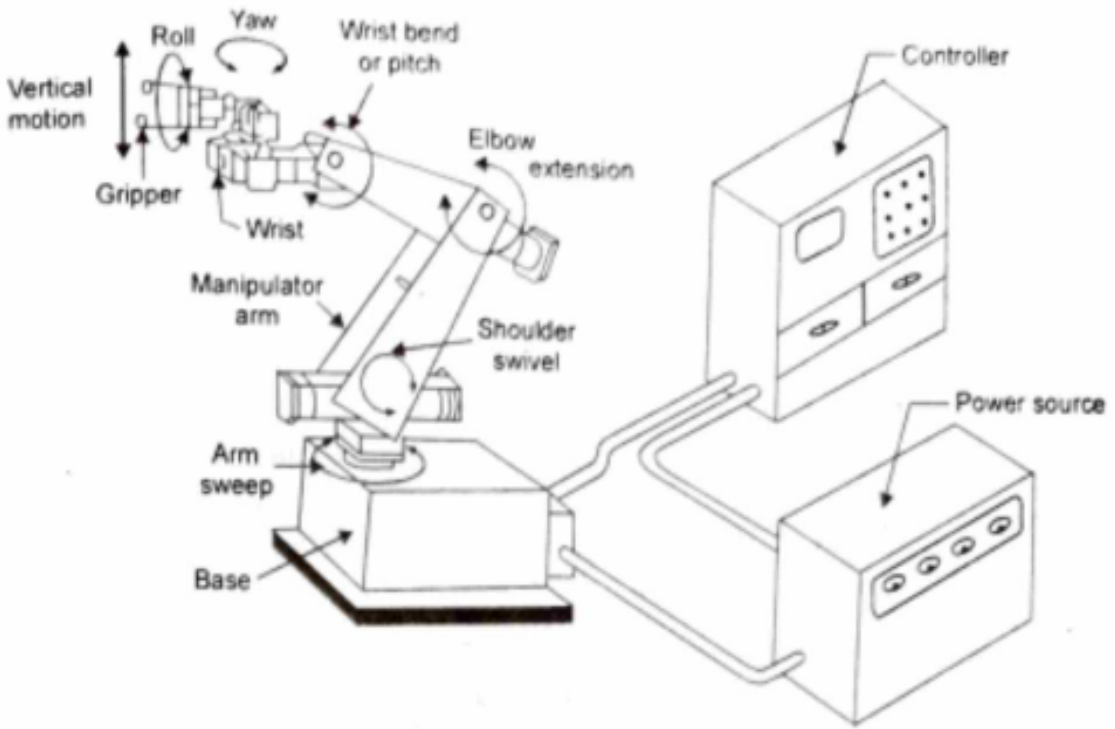
- Lack in capability of responding in emergencies
- Cost of installation is very high
- Replace human workers and affects their life style.



ROBOT COMPONENTS :

The various components of a robot :

1. Base
2. Manipulator arm
3. End-effector
4. Actuators and transmissions
5. Controller
6. Sensors



Base:

The base may be fixed or mobile

Manipulator arm:

The most obvious mechanical configuration of the robot is the manipulator arm. A robotic manipulator arm consists of
several separate links making a chain. The arm is located relative to the ground on either a fixed base or a movable base. It has a free-end where an end-deflector or gripper or some times a specialised tool holder (for holding, say, a welding gun) or any powered device (say, a drill) is attached.

End-effector:

Robot end-effector is the gripper or end of arm tooling mounted on the wrist of the robot manipulator arm.
The wide range of gripping methods include :
(i) Mechanical clamping.
(ii) Magnetic gripping
(iii) Vacuum (suction) gripping

Actuators and Transmissions:

Actuators :

The robot arm can be put to a desired motion with its payload if actuator modules are fitted in to provide power drives to
the systems i.e. Pnumatic drive, hydraulic drive, Electric drives.

Transmissions:

"Transmissions" are elements between the actuators and the joints of the mechanical linkage

Controller:

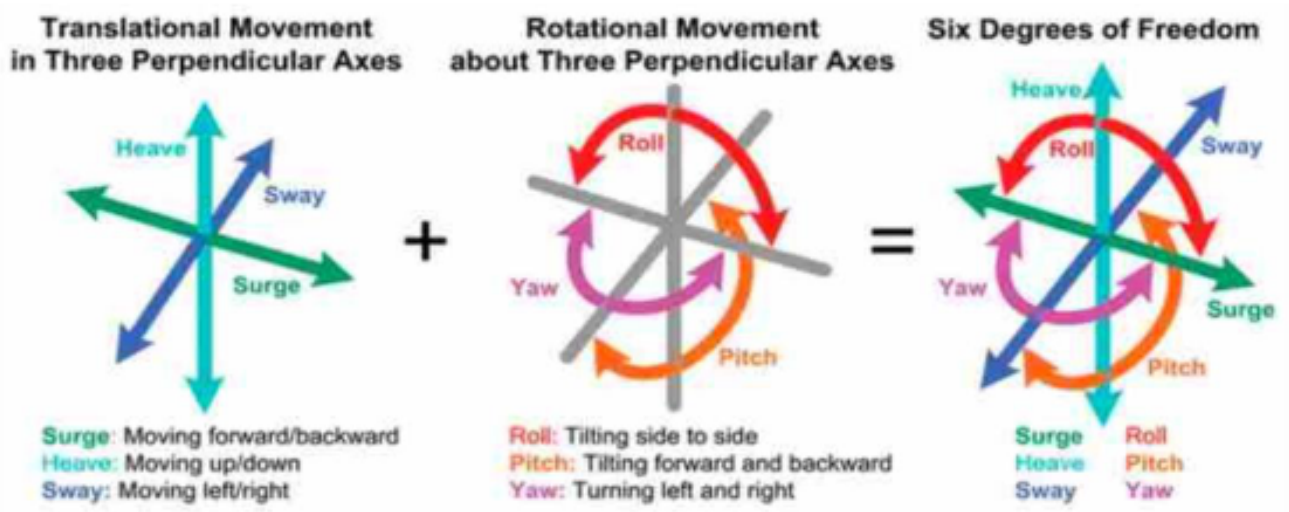
The "controller" provides the intelligence that is necessary to control the manipulator system.

Sensor:

The sensors perform the following functions :

• To act as feedback devices to direct further actions of the manipulator arm and the end effector (gripper), and

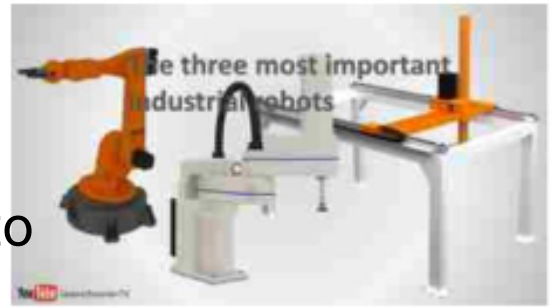
• To interact with the robot's working environment.



BASIC MOTIONS:

• The six basic motions or degrees of freedom (DOFs) are as follows:

• **Vertical motion:** The entire manipulator arm can be moved up and down vertically either by means of the shoulder swivel, i.e., turning it about a horizontal axis, or by sliding it in a vertical slide.



• **Radial motion:** Radial movement, i.e., in and out movements, to the manipulator arm is provided by Elbow extension by extending it and drawing back

• **Rotational motion:** Clock wise or anti-clock wise rotation about vertical axis of manipulator arm.

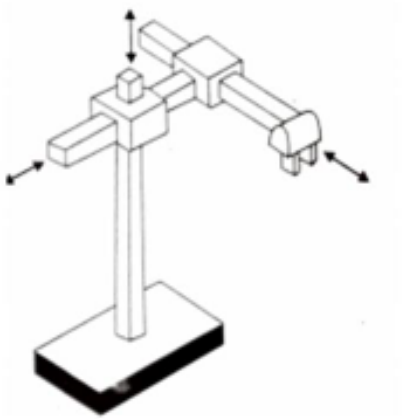
• **Yaw:** Enables rightward and leftward swiveling movement of the wrist.

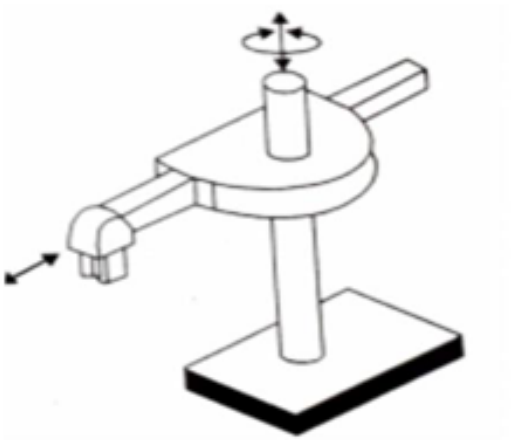
• **Pitch motion:** Up and down movement of wrist

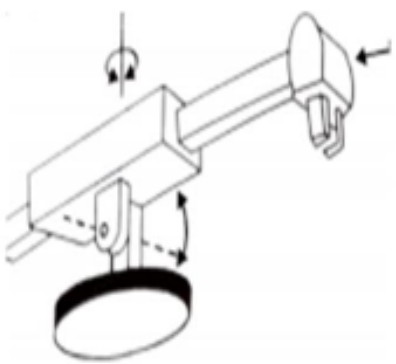
• **Roll motion:** Enables of rotation of wrist

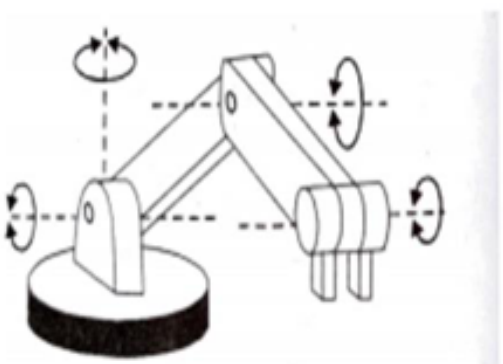
ROBOT CLASSIFICATION:

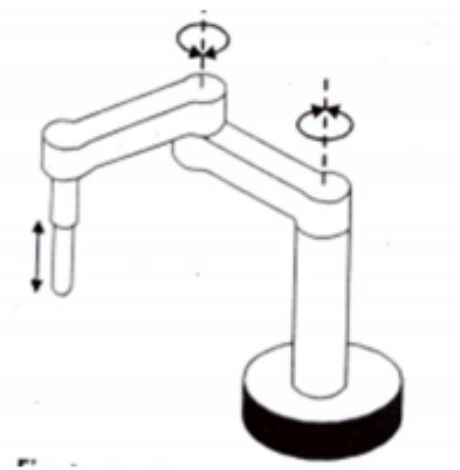
The majority of commercially available robots can be
grouped into four basic configurations :
(i) Cartesian coordinate configuration.
(ii) Cylindrical configuration.
(ii) Spherical configuration.
(iv) Jointed-arm configuration (Revolute)
(v) SCARA



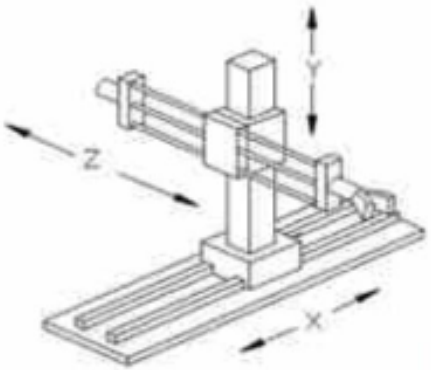






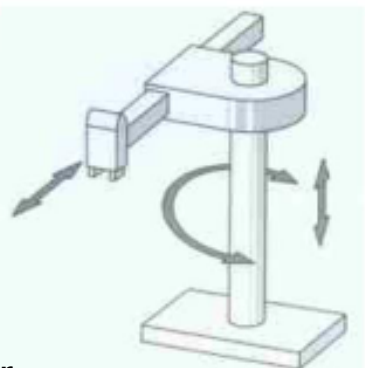


Cartesian coordinate configuration



- In this there are three orthogonal directions X,Y and Z.
    - X-coordinate axis may represent left and right motion.
    - Y-coordinate axis may represent forward and backward motion.
    - Z-coordinate axis may represent up and down motions.
- Example of Cartesian System is Overhead Crane Movement

Cylindrical Configuration Robot



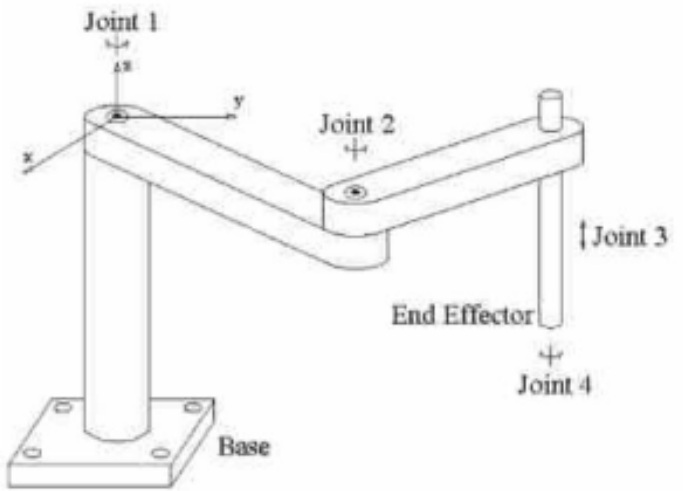
- It uses a vertical column and a slide that can be moved up or down along the column.
- The robot arm is attached to the slide so that it can be moved radially with respect to the column.
- By rotating the column, the robot is capable of achieving a work space that approximates a cylinder
- It contains two linear motions and one rotational motion. Angular Motion, θ along vertical axis; Translation Motion, z along z-direction that corresponds to up and down motion; Radial, r in or out translation.

Spherical Configuration Robot

- It uses an arm that can be raised or lowered about a horizontal pivot.
- The pivot is mounted on a rotating base.
- The various joints provide the robot with capability to move its arm within a spherical space, and hence it is also called as " Spherical Coordinate Robot."
- It has one linear and two rotary motions.

SCARA Robot

• SCARA is a special type of jointed arm configuration.
• It stands for Selective Compliance Automated Robot Arm (or) Selective Compliance Articulated Robot Arm .
• It is similar to jointed-arm except that the vertical axes are used for shoulder and elbow joints to be compliant in
horizontal direction vertical insertion tasks.



Revolute or Articulated Configuration

• The Revolute configuration comprises a number of rigid arms connected by rotary joints, rotary movement at the
base is also provided.
• Since all movements are by angular rotation of the joints complex calculations are often needed to move the arm
in straight lines.

INTRODUCTION TO CNC

What is manufacturing process ?

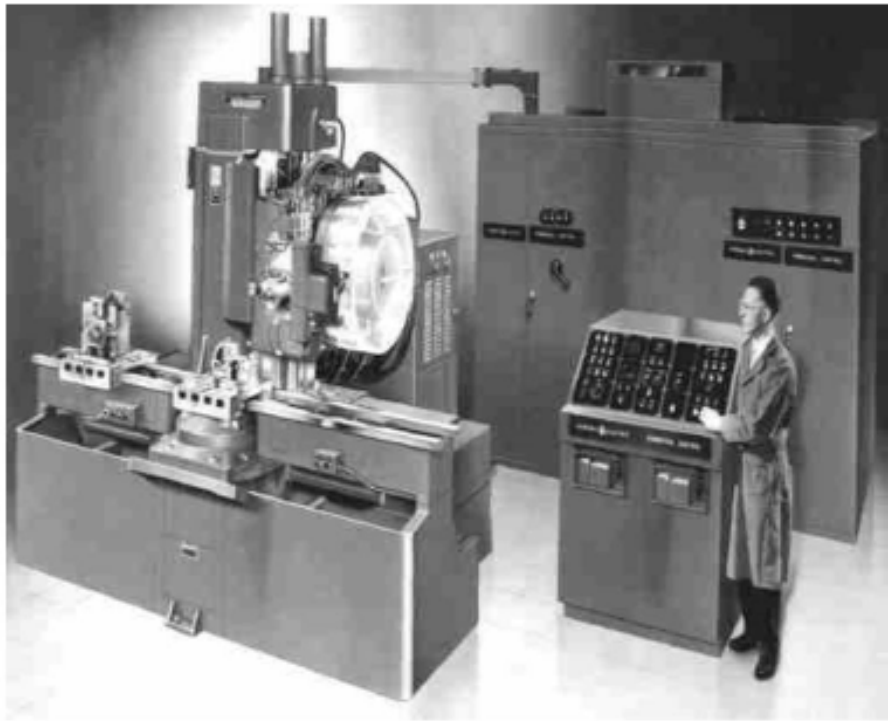
- A sequence of operations and processes designed to create a specific product .

- The process of converting raw materials into a product .

Examples:
welding, casting, cutting, assembling,
etc.

History

- The first NC machines were built in the 1940s and 1950s by Prof. John T Parson.
- CNC machine came into existence after evolution of computer around 1980.
- Modern CNC Machine are improving further as the technology is changing with a variety of functions according to applications.



- In the early 1950s the Massachusetts Institute of Technology developed a more advanced vacuum tube computer called Whirlwind.

Cont…

 To ensure that all U.S. military airplanes were manufactured identically after world war II the

US Air Force invited several top companies to develop and manufacture numerical control

systems which can handle the quantity and repeatability of machine.

 In 1952, The first three axis Numerically controlled tape fed machine tool was created. A

Cincinnati Milacron Hydro-Tel Vertical Spindle Milling (VMC) machine was retrofitted and

controlled by the Whirlwind Computer. The controller was equipped with optical sensors and

used a straight binary perforated tape to hold the instructions; The tape was read via a

mechanical feeding mechanism. In 1954, Numerical control was announced to the public, and

Numerical Control

- Form of programmable automation.
- Mechanical actions of machine tool are controlled by program.
- The program is in form of alphanumeric data.
- After a job is finished the program of instructions can be changed to process a new job.

Numerical Control

Advantages

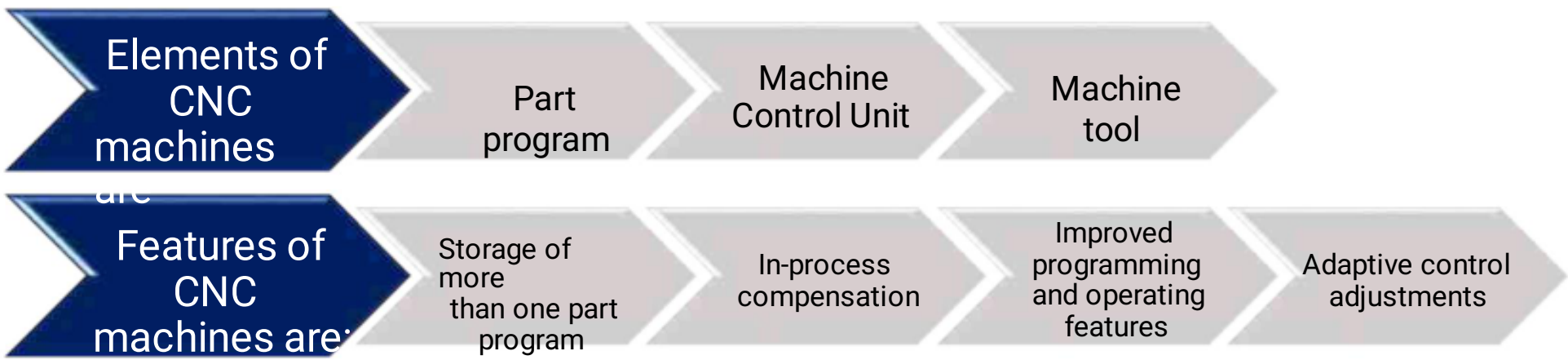
- Reduces non productive time
- Reduces manufacturing lead time
- Greater manufacturing flexibility
- Improves quality control
- Reduced inventory

Disadvantages

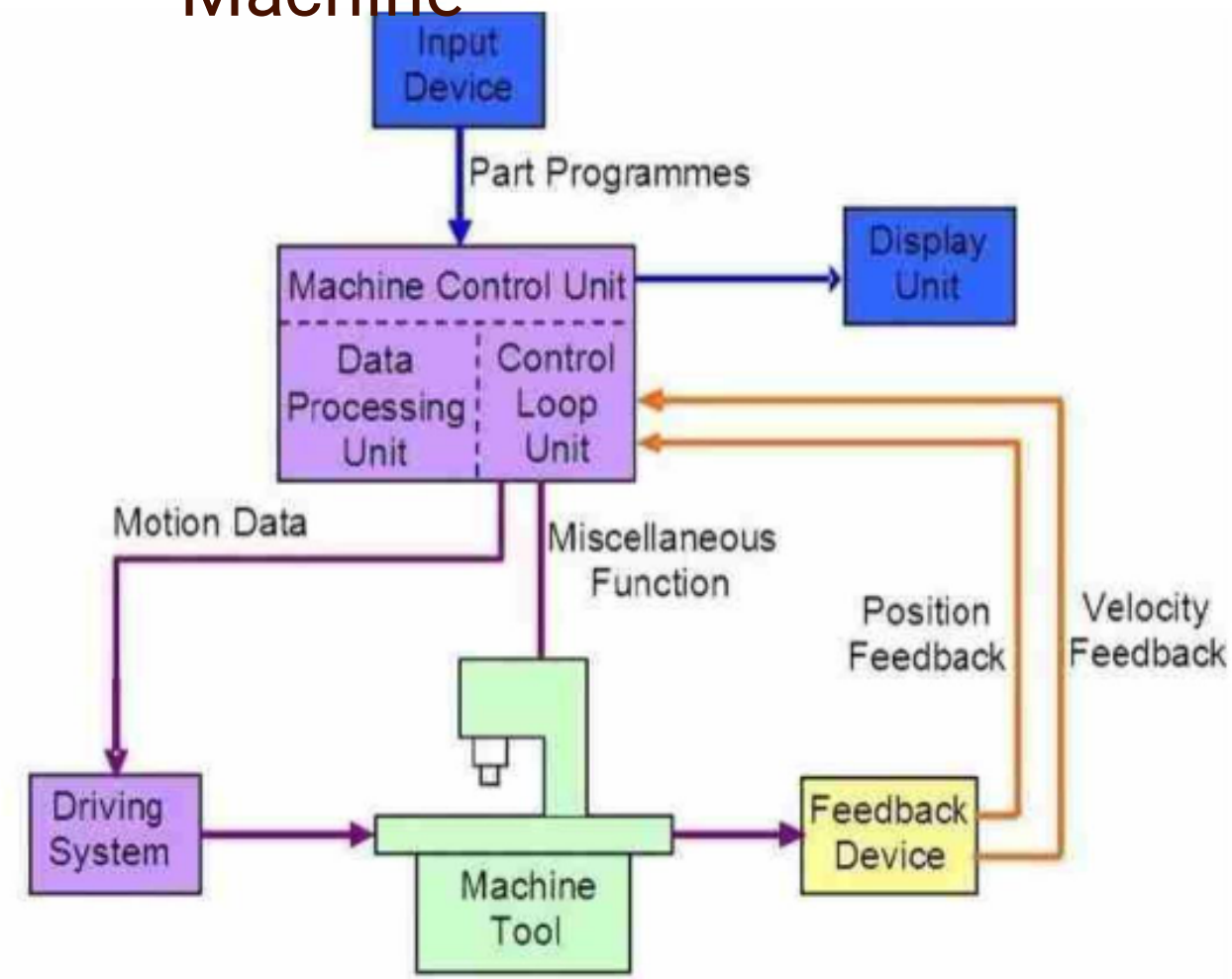
- High investment cost.
- High maintenance effort.
- Part programming.
- Higher utilization of NC Equipment's.

CNC Machine

- To overcome the shortcomings of the NC machines CNC machines evolved.
- CNC machines are the NC machines whose MCU is based on the micro computer rather than the hardwired controller.



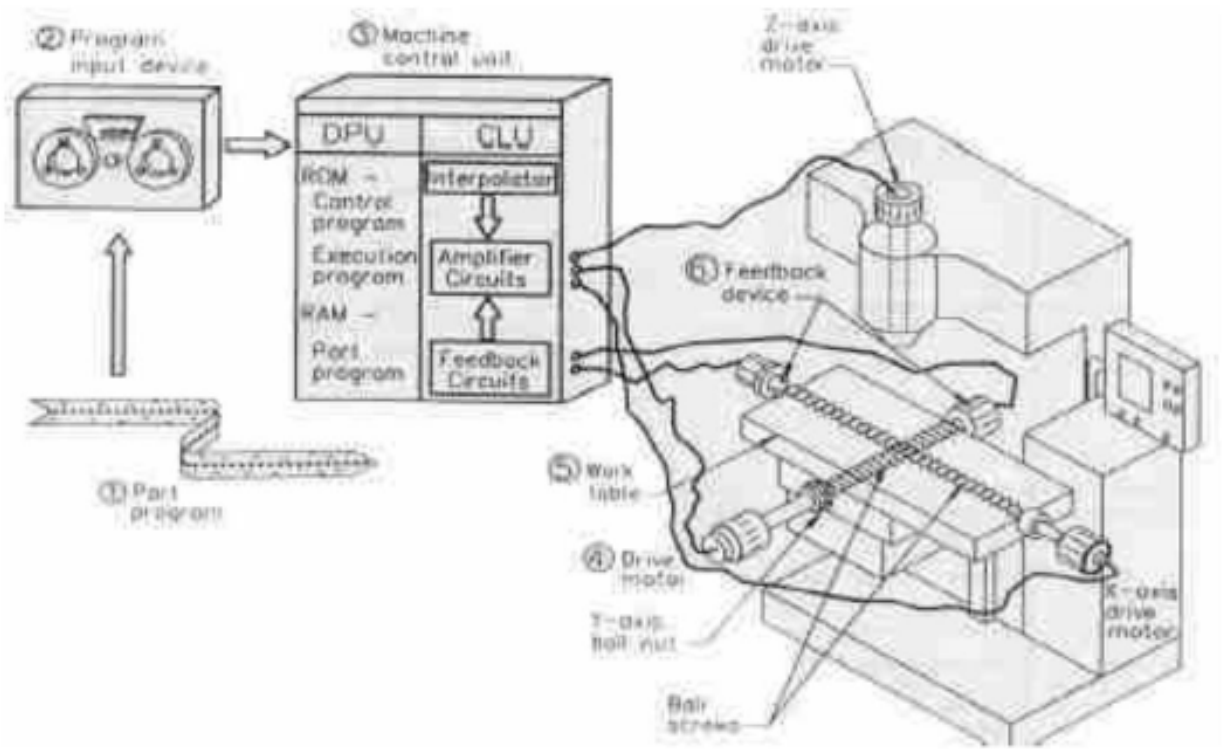
Block diagram of CNC Machine



Elements of CNC

Elements of CNC machine tool essentially consists of the following parts:

- Part Program
- Program Input Device
- Machine Control Unit (MCU)
- Drive System
- Machine Tool
- Feedback System.



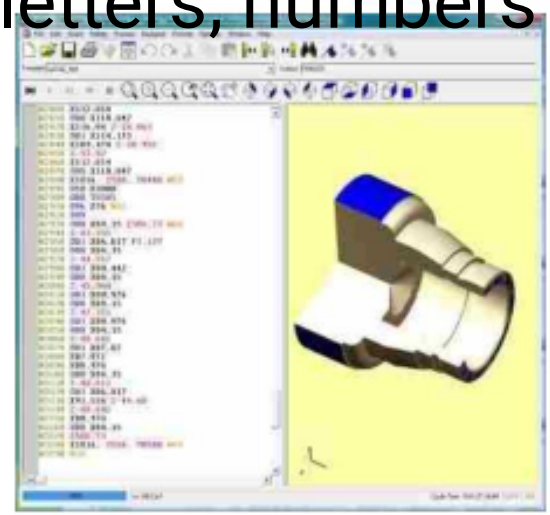
Part

A part program is a series of coded instructions required to produce a part.

- It controls the movement of the machine tool and on/off control
  of auxilary functions such as spindle rotation and coolant
- The coded instructions are composed of letters, numbers and symbols.

E.g:

```
N10 G01 X5.0Y2.5
F15.0
 | | |          |      |
 | | |          | Feed rate (15 in/min)
 | | |          Y-coordinate (2.5")
 | | X-coordinate (5.0")
 | Linear interpolation mode
Sequence number
```

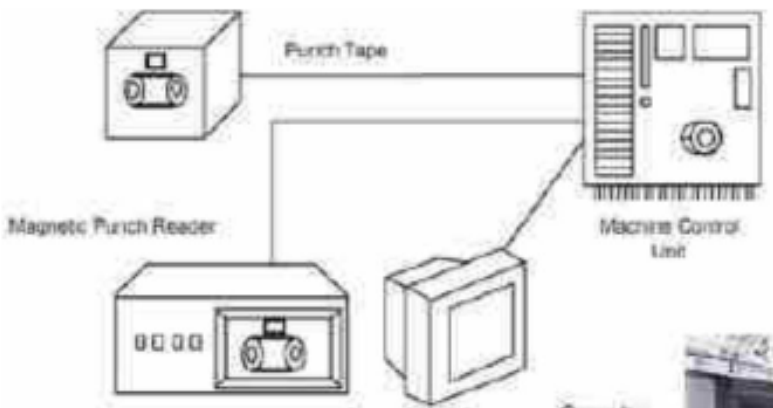


Program Input

The program input device is the means for

part program to be entered into the CNC control.

Three commonly used program input devices are punch tape reader, magnetic tape reader, and computer or USB communication.



Machine Control Unit

The machine control unit (MCU) is the heart of a CNC system. It is used to perform the

following functions

a) To read the coded instructions.

b) To decode the coded instructions.

c) To implement interpolations (linear, circular, and helical) to generate axis motion commands.

d) To feed the axis motion commands to the amplifier circuits for driving the axis mechanisms.

e) To receive the feedback signals of position and speed for each drive axis.

f) To implement auxiliary control functions such as coolant or spindle on/off and tool change.

Drive

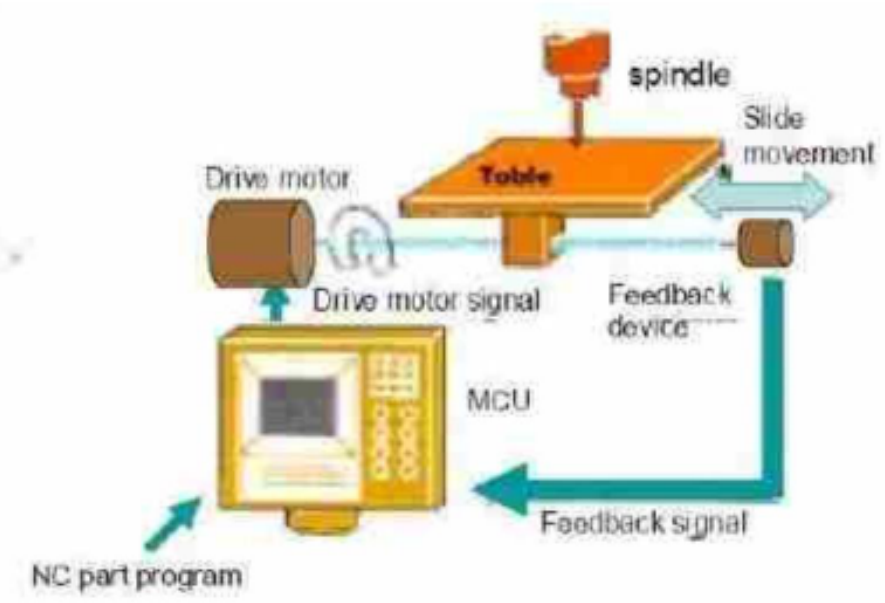
- A drive system consists of **amplifier circuits**, **drive motors**, and **ball lead-screws**.
- The MCU feeds the control signals (position and speed) of each axis to the amplifier circuits.
- The control signals are augmented to actuate drive motors which in turn rotate the ball lead-screws to position the machine table.

Feedback

The feedback system is also referred to as the

measuring system.

- It uses position and speed transducers to continuously monitor the position at which the cutting tool is located at any particular instant.
- The MCU uses the difference between reference signals and feedback signals to generate the control signals for correcting position and speed errors.



Machine Axis

Machine axes are designated according to the " right-

hand rule“ When the thumb of right hand points in the direction

of the positive X axis, the index finger points toward

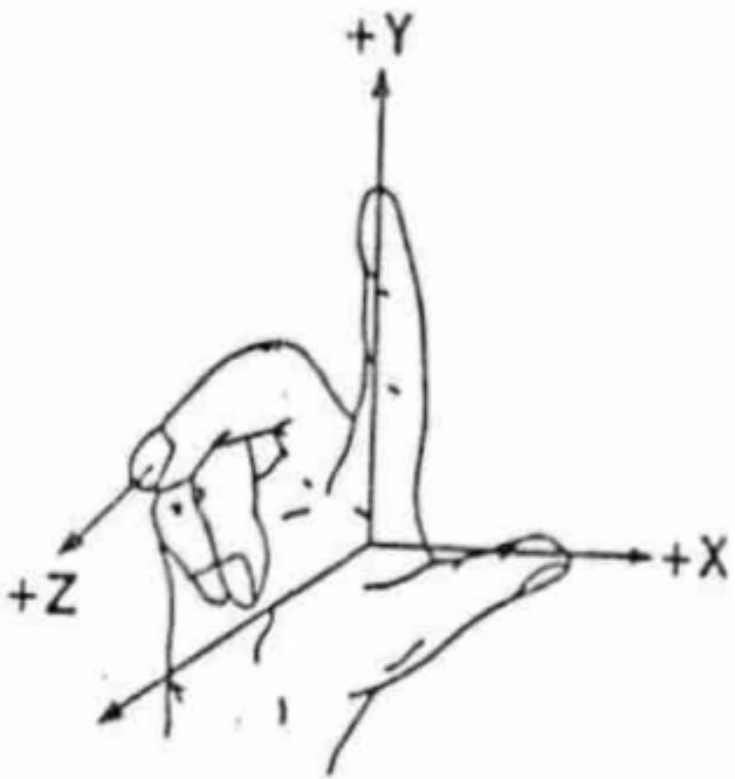
the positive Y axis, and the middle finger toward the

positive Z axis. The main axes to be designated are

First axis to be identified is the Z-axis. This is then followed by

the linear axes and the rotary axes.

the X and Y axes respectively.



CNC PROGRAMMING

Offline programming linked to CAD programs.
MDI ~ Manual Data Input.
Manual Control using jog buttons or `electronic handwheel'.
Word-Address Coding using standard G-codes and M-codes.

The position of the tool is described by using Cartesian coordinate
system.
If (0,0,0) position can be described by the operator, then it is called floating zero.
In defining the motion of the tool from one point to another, either
absolute positioning mode or incremental positioning mode can be used.

1. Absolute positioning:

In this mode, the desired target position of the tool for a particular move is
given relative to the origin point of the program.

2. Incremental positioning:

In this mode, the next target position for the tool is given relative to the
current tool position.

INFORMATION NEEDED by a CNC

1. Preparatory Information: units, incremental or absolute positioning

2. Coordinates: X,Y,Z, RX,RY,RZ
3. Machining Parameters: Feed rate and spindle speed

4. Coolant Control: On/Off, Flood, Mist
5. Tool Control: Tool and tool parameters
6. Cycle Functions: Type of action required
7. Miscellaneous Control: Spindle on/off, direction of rotation, stops for part movement

This information is conveyed to the machine through a set

of instructions arranged in a desired sequence – Program.

WORD-ADDRESS CODING

Example CNC Program

```
N5 G90 G20
N10 M06 T3
N15 M03 S1250
N20 G00 X1 Y1
N25 Z0.1
N30 G01 Z-0.125
F5
N35 X3 Y2 F10
N40 G00 Z1
N45 X0 Y0
N50 M05
N55 M30
```

Each instruction to the machine consists of a letter followed by a number.

Each letter is associated with a specific type of action or piece of information needed by the machine.

G Codes

G00 Rapid traverse
G01 Linear interpolation
G02 Circular interpolation,CW
G03 Circular interpolation, CCW
G04 Dwell
G08 Acceleration
G09 Deceleration
G17 X-Y Plane
G18 Z-X Plane
G19 Y-Z Plane
G20 Inch Units (G70)
G21 Metric Units (G71)

G40 Cutter compensation – cancel
G41 Cutter compensation – left
G42 Cutter compensation- right
G70 Inch format
G71 Metric format
G74 Full-circle programming off
G75 Full-circle programming on
G80 Fixed-cycle cancel
G81-G89 Fixed cycles
G90 Absolute dimensions
G91 Incremental dimensions

M Codes

M00 Program stop
M01 Optional program stop
M02 Program end
M03 Spindle on clockwise
M04 Spindle on counterclockwise
M05 Spindle stop
M06 Tool change
M08 Coolant on
M09 Coolant off
M10 Clamps on
M11 Clamps off
M30 Program stop, reset to start

Common types of CNC machines

CNC Lathe machine

CNC Milling machine

CNC Drilling machine

CNC Grinding machine

CNC Laser cutting machine

Water jet cutting machine

Electro discharge machine

DIFFERENCE BETWEEN NC, CNC AND DNC

1. Numerical Control Machine

. The program is fed to the machine through magnetic tapes or other such media.

. The original NC machines were essentially basic machine tools which were modified to have motors for

movement along the axes.

. An NC machine is numerically controlled but has no memory storage and is run off of the "tape" each

time the machine cycles

2. Computer Numerical Controlled machine

. The machines are interfaced with computers.

. This makes them more versatile in the sense that, suppose a change in dimension of a part is required.

. A CNC machine has memory storage and the program can be stored in its control.

3. DNC

. Number of machines are controlled by a central computer.

Applications

- Parts needed in a hurry
- Parts with complicated contours
- Parts requiring expensive jigs and fixtures
- Parts those have several engineering changes
- Cases where human errors can be extremely costly
- Parts requiring close tolerance or good repeatability

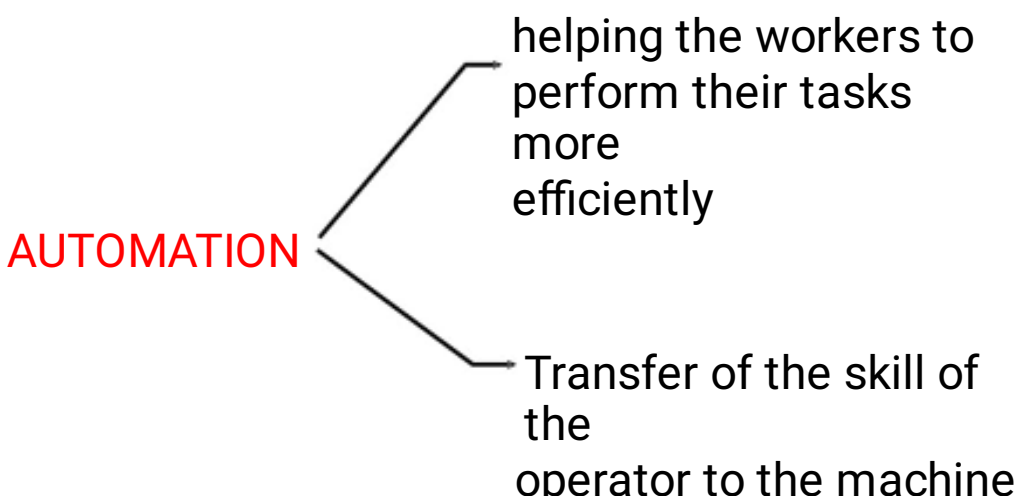
ADVANTAGESOF CNC MACHINE

- **Productivity**

  Machine utilization is increased because more time is spent cutting and less time is
  taken by positioning. Reduced setup time increases utilization too.

PROFIT increases as COST decreases and as PRODUCTIVITY increases.

PRODUCTIVITY through AUTOMATION



- **Quality**
  1. Parts are more accurate.
  2. Parts are more repeatable.
  3. Less waste due to scrap.
- **Machining Complex shapes**
  1. Slide movements under computer control.
  2. Computer controller can calculate steps.
- **Management Control**
  1. CNC leads to CAD
  2. Process planning
  3. Production planning

- Higher accuracy
- Reduce lead time
- Higher flexibility
- Reduce scrap rate
- Reliable operation
- Consistent quality
- Reduced manpower
- Increased productivity
- Reduced non productive time

- Increased dimension precision of the work part through high basic precision of the machine tool (1/1000mm)

.

DISADVANTAGES OF CNC MACHINE

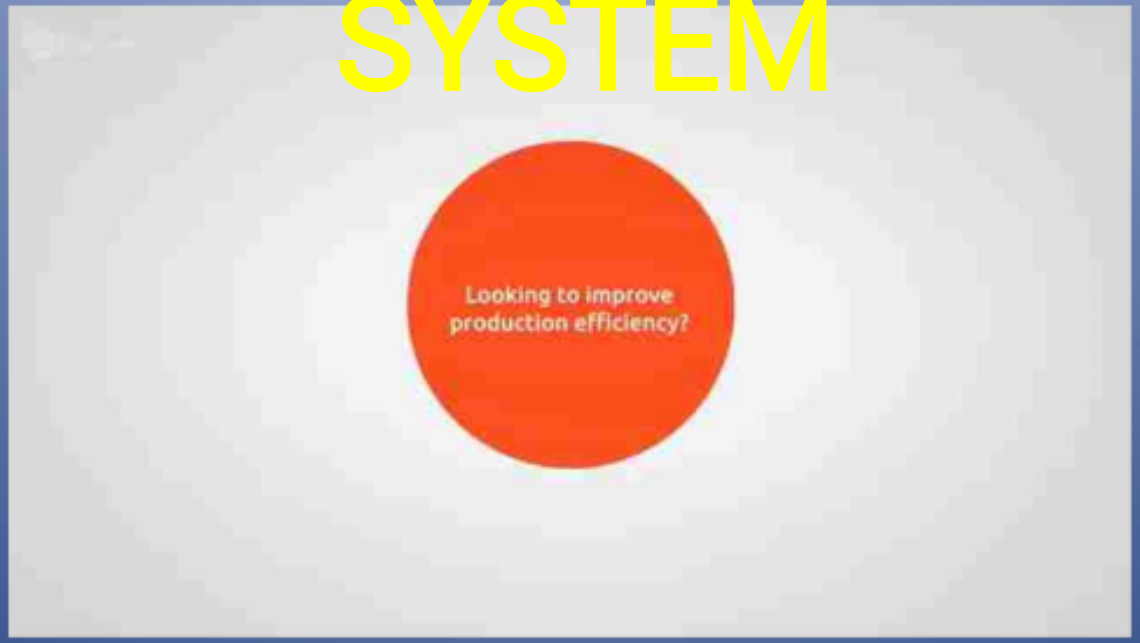
1. Machine Cost is Higher than Conventional Machine.

2. Higher Maintenance Costs .
3. Higher Labor Costs .

4. Higher Machine Attachment Costs.

5. Higher Tooling Costs.
6. High maintenance requirements

FLEXIBLE MANUFACTURING SYSTEM



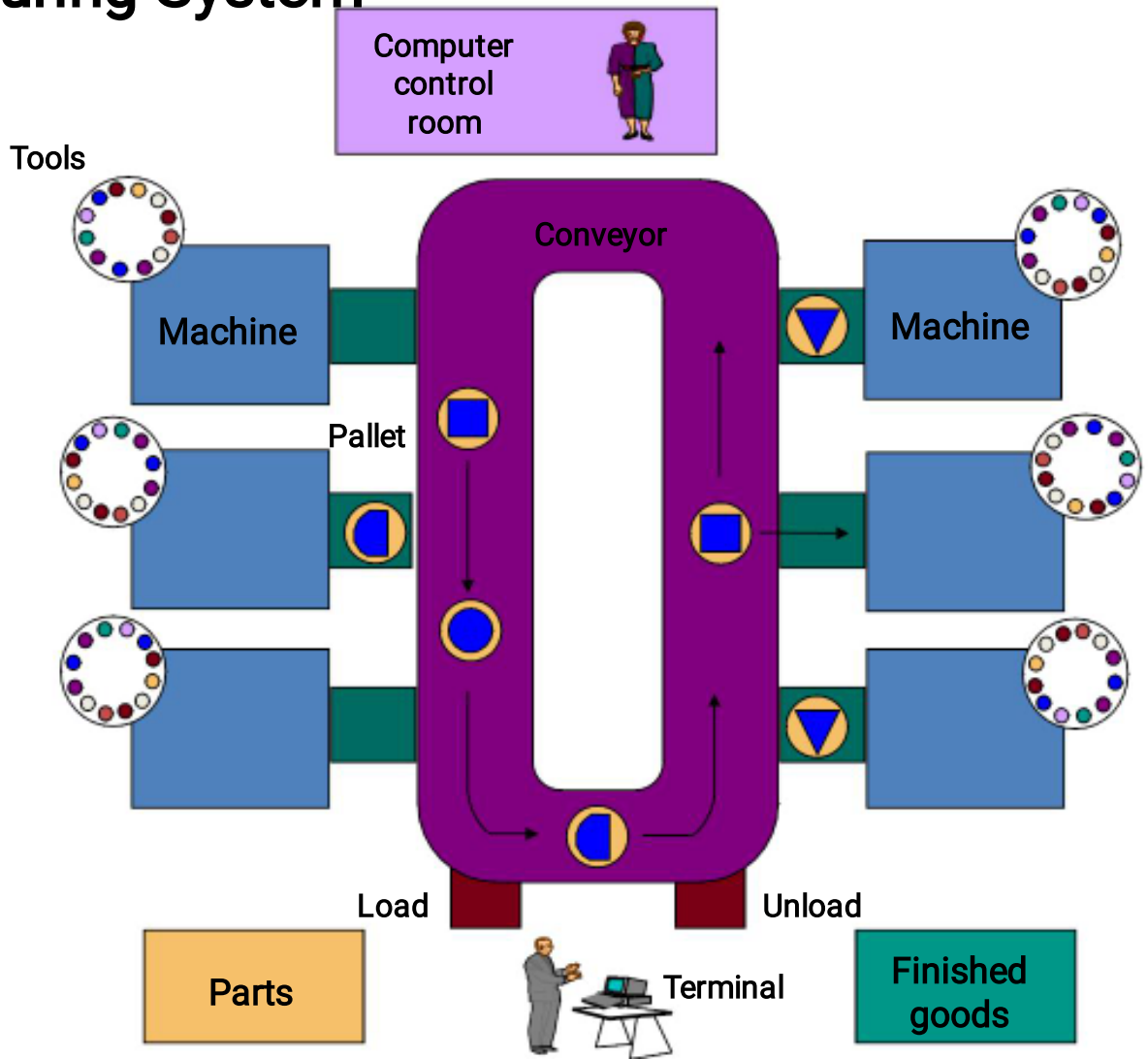
FLEXIBLE MANUFACTURING SYSTEMS (FMS)

- An FMS is a “reprogrammable” manufacturing system capable of producing a variety of products automatically.
- Conventional manufacturing systems have been marked by one of two distinct features:
  - The capability of producing a variety of different product types, but at a high cost (e.g., job shops).
  - The capability of producing large volumes of a product at a lower cost, but very inflexible in terms of the product types which can be produced (e.g., transfer lines).
- An FMS is designed to provide both of these features.

FMS Components

- Numerical Control (NC) machine tools
- Automated material handling system (AMHS)
    - Automated guided vehicles (AGV)
    - Conveyors
    - Automated storage and retrieval systems (AS/RS)
- Industrial Robots
- Control Software

Flexible Manufacturing System



A flexible manufacturing system (FMS) is a production method that is designed to easily adapt to changes

in the type and quantity of the product being manufactured.
A flexible manufacturing system may include a configuration of interconnected processing workstations

with computer terminals that process the end-to-end creation of a product, from loading/unloading

functions to machining and assembly to storing to quality testing and data processing. The system can

be programmed to run a batch of one set of products in a particular quantity and then automatically

switch over to another set of products in another quantity.

Disadvantages of Flexible Manufacturing System FMS

1. FMS is a Complex System
2. Requires Highly Skilled Technicians
3. Needs High Level of Planning
4. Demands High Initial Investment

Advantages of Flexible Manufacturing System FMS

1. Large variety of Same Products
2. Profitable Investment
3. Requires Limited Inventory
4. Low Labour Cost
5. Flexible System
6. Speedy Production


Thank you