Flexible Manufacturing Systems (FMS)

Module 5 - CO3

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Outline

- Definition
- History of FMS
- FMS equipment
- Types of FMS
- Applications of FMS
- FSM different approaches
- Advantages
- Disadvantage
- Development of FMS
- Nuts and Bolts
- How FMS works
- A real world example
- Summary

Definition

- A Flexible Manufacturing System (FMS) is a production system consisting of a set of identical and/or complementary numerically controlled machine which are connected through an automated transportation system.

- each process in FMS is controlled by a dedicated computer (FMS cell computer).

History of FMS

- At the turn of the century FMS did not exist. There was not a big enough need for efficiency because the markets were national and there was no foreign competition. Manufacturers could tell the consumers what to buy.
- Henry Ford is quoted as saying people can order any color of car as long as it is black.
- This was the thinking of many big manufacturers of the time. After the Second World War a new era in manufacturing was to come. The discovery of new materials and production techniques increased quality and productivity. The wars end open foreign markets and new competition. Now the market focused on consumer and not the manufacturer.
- **The first FMS was patent in 1965** by **Theo Williamson** who made numerically controlled equipment. Examples of numerically controlled equipment are like a CNC lathes or mills which are called varying types of FMS.
- In the 70s manufacturers could not stay to date with the ever-growing technological knowledge manufacturers competitors have, so FMS became mainstream in manufacturing.
- In the 80s for the first time manufacturers had to take in consideration efficiency, quality, and flexibility to stay in business.

Equipment of FMS

- Primary equipment

  work centers
  - Universal machining centers (prismatic FMSs)
  - Turning centers (rotational FMSs)
  - Grinding machines
  - Nibbling machines

  Process centers
  - Wash machines
  - Coordinate measuring machines
  - Robotic work stations
  - Manual workstations

Equipment of FMS

- Secondary equipment

  Support stations

  - Pallet/fixture load/unload stations
  - Tool commissioning/setting area

  Support equipment

  - Robots
  - Pallet/fixture/stillage stores
  - Pallet buffer stations
  - Tools stores
  - Raw material stores
  - Transport system(AGVs,RGVs,robots)
  - Transport units(pallets/stillages)

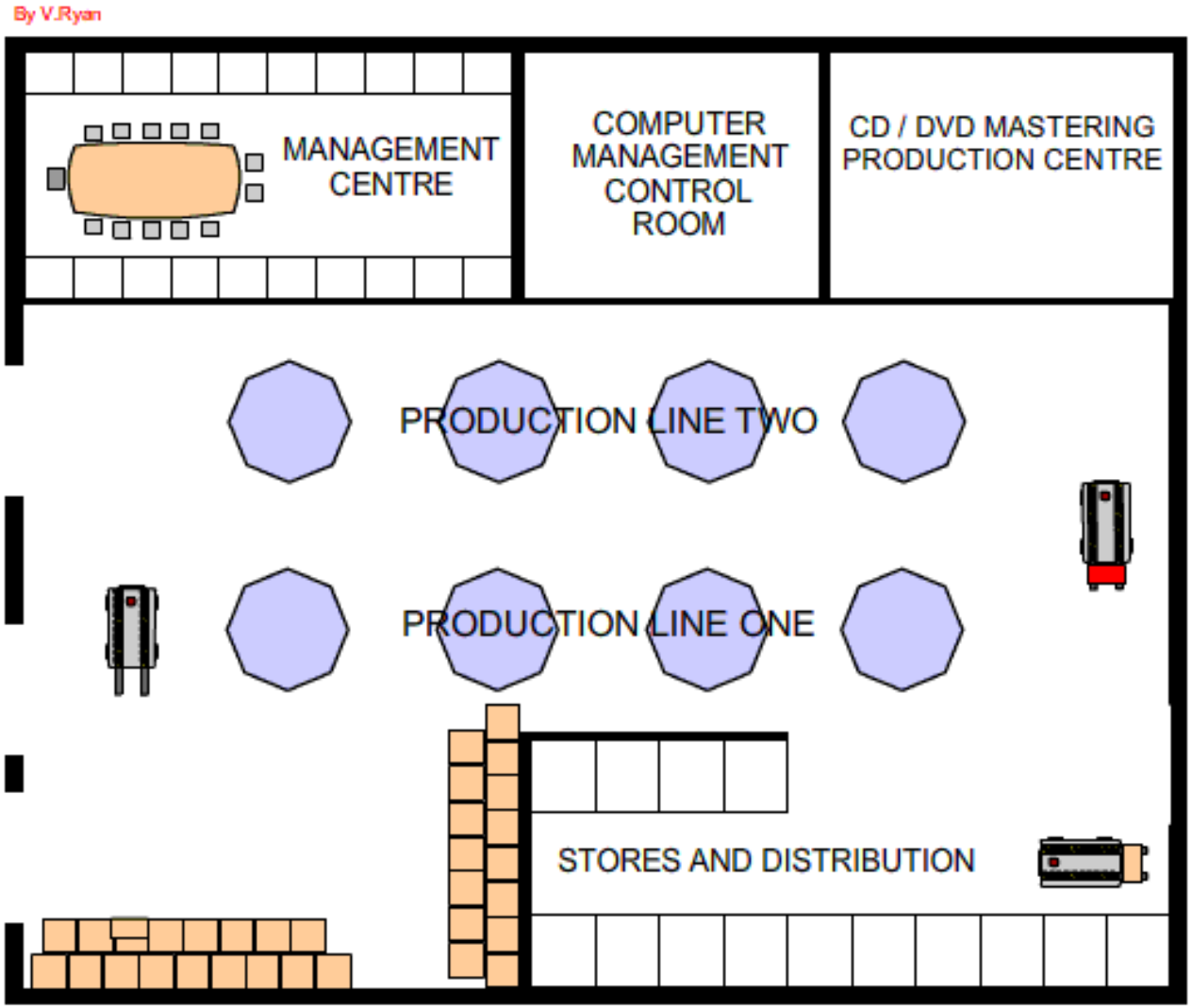
Types of FMS

- Sequential FMS
- Random FMS
- Dedicated FMS
- Engineered FMS
- Modular FMS

Application of FMS

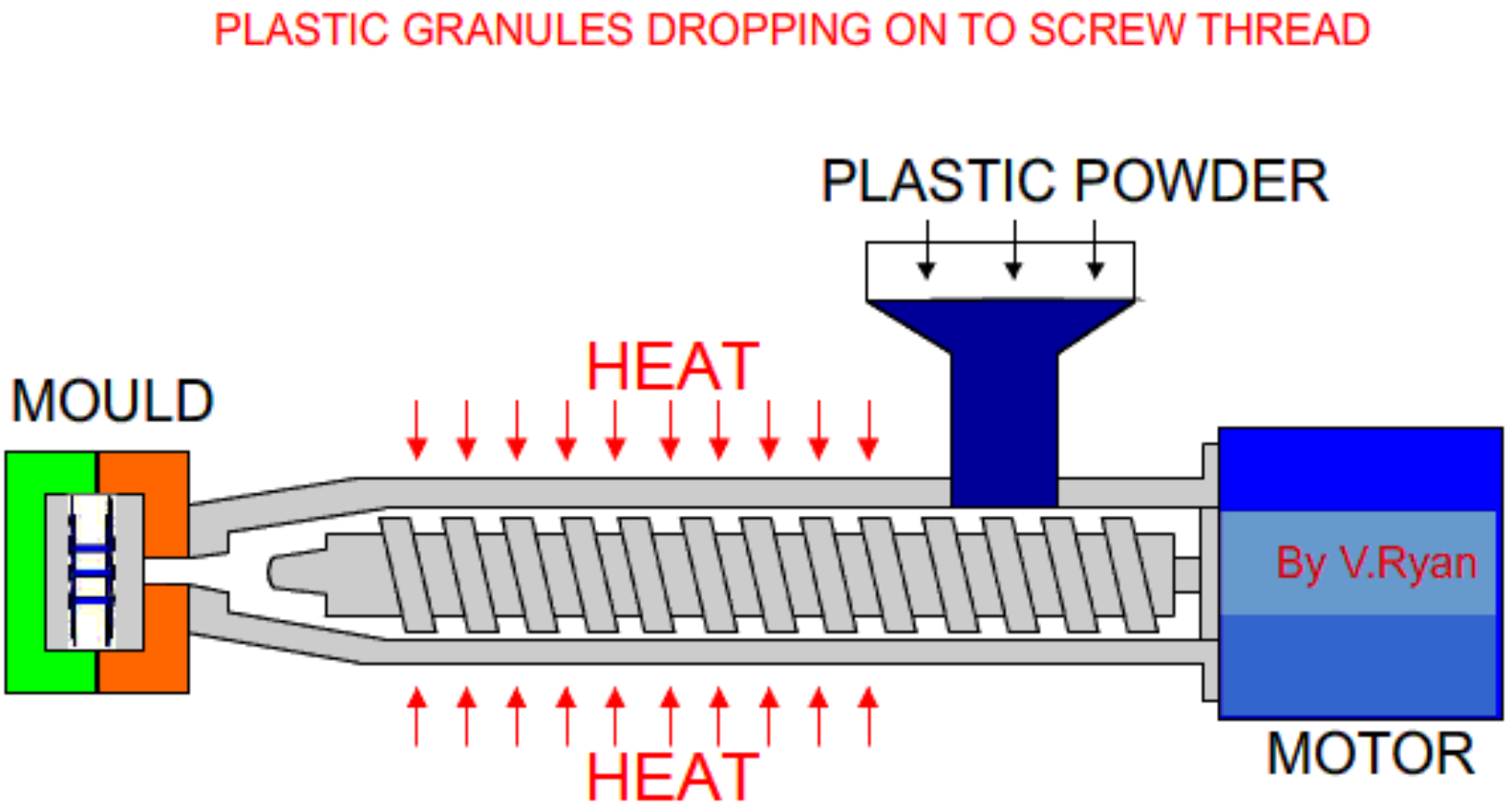
- Metal-cutting machining
- Metal forming
- Assembly
- Joining-welding (arc , spot), glueing
- Surface treatment
- Inspection
- Testing

Application of FMS



AN IMPORTANT ASPECT OF FLEXIBLE MANUFACTURING SYSTEMS IS COMPUTER CONTROL

Application of FMS



FMS different approaches

- The capability of producing different parts without major retooling

- A measure of how fast the company converts its process/es from making an old line of products to produce a new product

- The ability to change a production schedule, to modify a part, or to handle multiple parts

Advantages of using FMS

- To reduce set up and queue times
- Improve efficiency
- Reduce time for product completion
- Utilize human workers better
- Improve product routing
- Produce a variety of Items under one roof
- Improve product quality
- Serve a variety of vendors simultaneously
- Produce more product more quickly

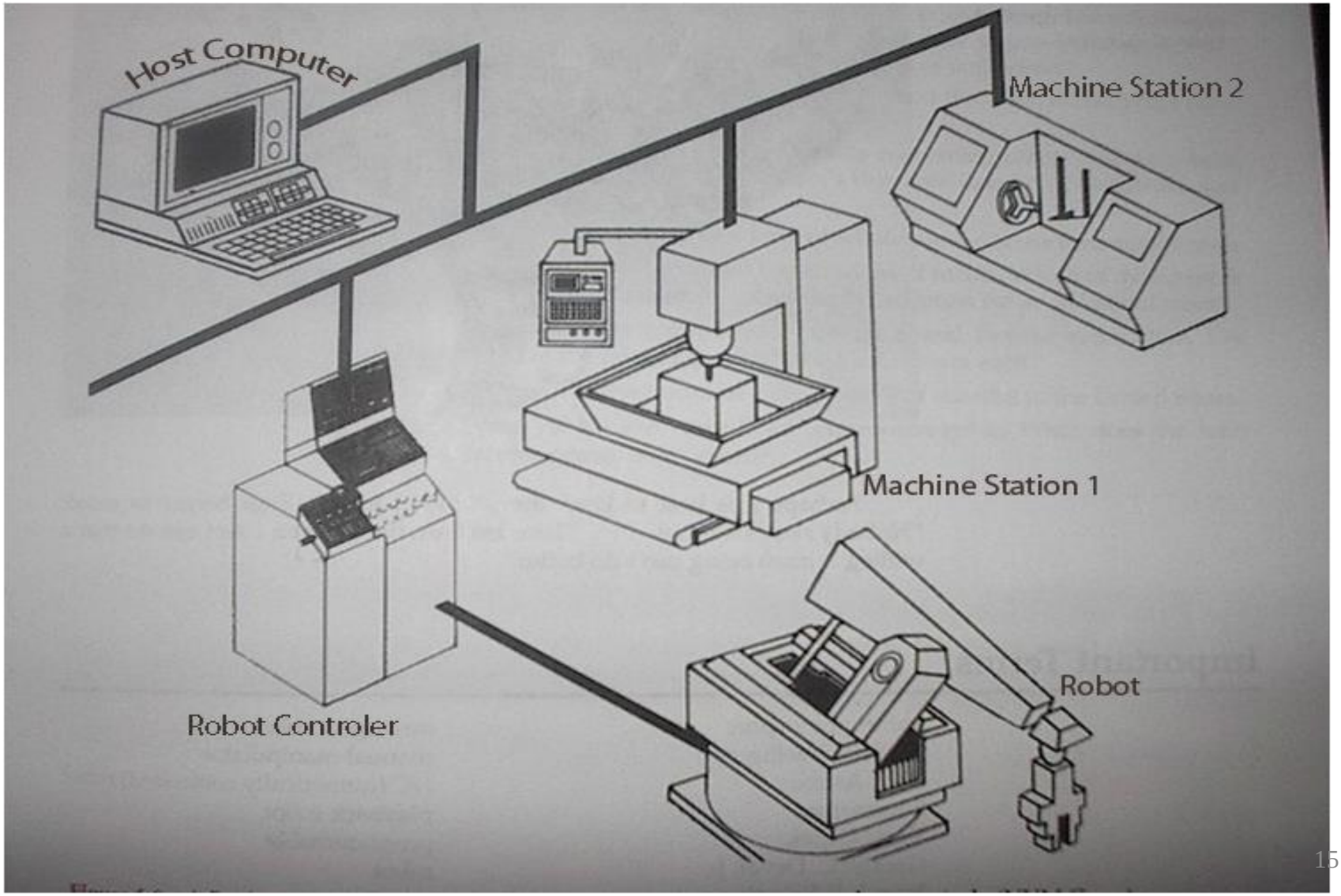
Disadvantage of using FMS

- Limited ability to adapt to changes in product or product mix (ex:machines are of limited capacity and the tooling necessary for products, even of the same family, is not always feasible in a given FMS)
- Substantial pre-planning activity
- Expensive, costing millions of dollars
- Technological problems of exact component positioning and precise timing necessary to process a component
- Sophisticated manufacturing systems

Development of FMS

- Several actions must be decided on before you can have a have a FMS. These actions include.
- **Selecting operations** needed to make the product.
- Putting the operations in a **logical order**.
- **Selecting equipment** to make the product.
- **Arranging** the equipment for efficient use.
- **Designing special devices** to help build the product.
- Developing ways to **control product quality**.
- **Testing** the manufacturing system.

Example of a FMS



FMS Layout Configurations

1. In-line layout
2. Loop layout
3. Ladder layout
4. Open field layout
5. Robot-centered cell

Nuts and Bolts of FMS

FMS Layouts

- Progressive Layout:
  - Best for producing a variety of parts

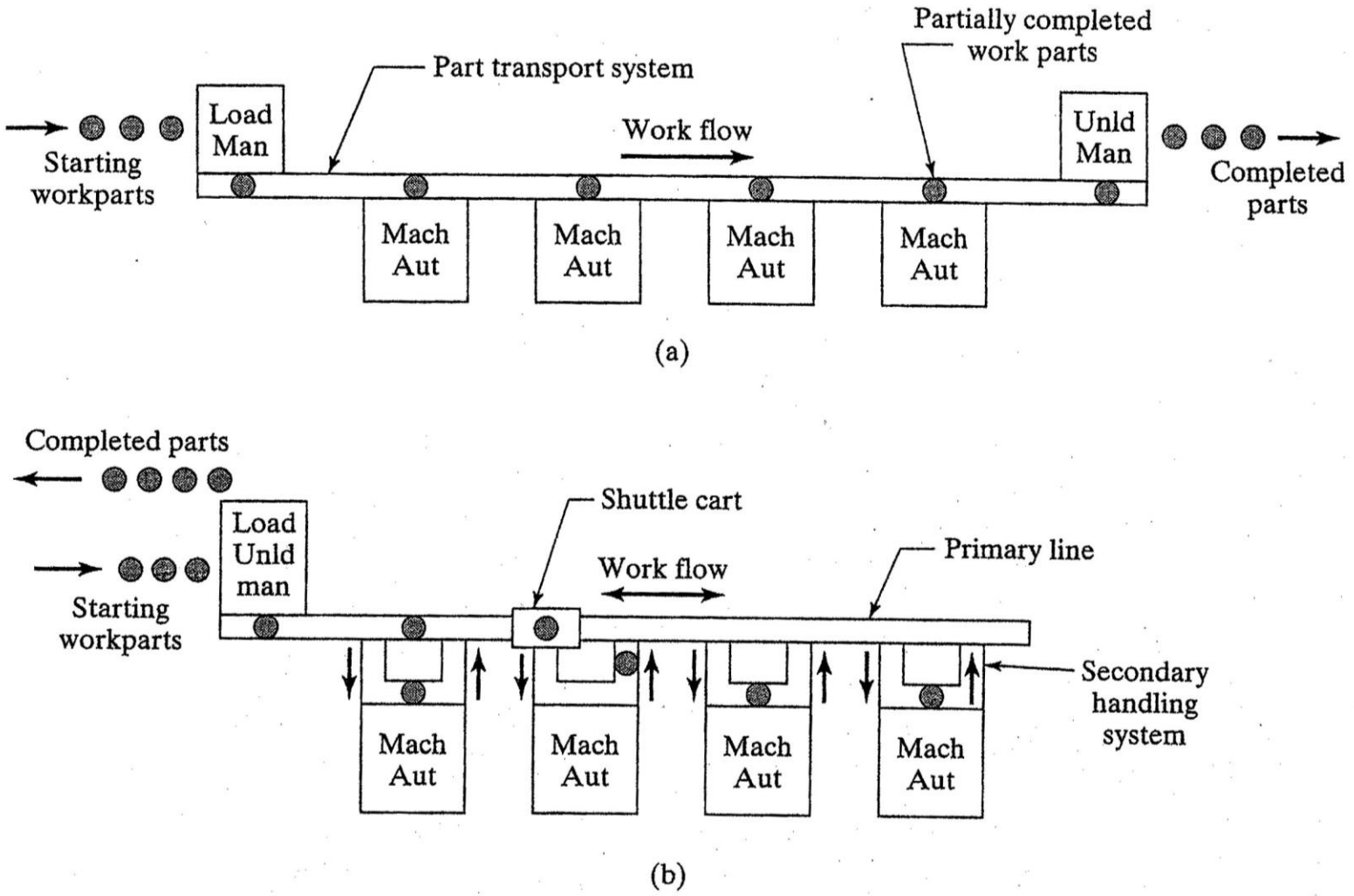


Figure 16.7 In-line FMS layouts: (a) one direction flow similar to a transfer line and (b) linear transfer system with secondary part handling system at each station to facilitate flow in two directions. Key: Load = parts loading station, UnLd = parts unloading station, Mach = machining station, Man = manual station, Aut = automated station.

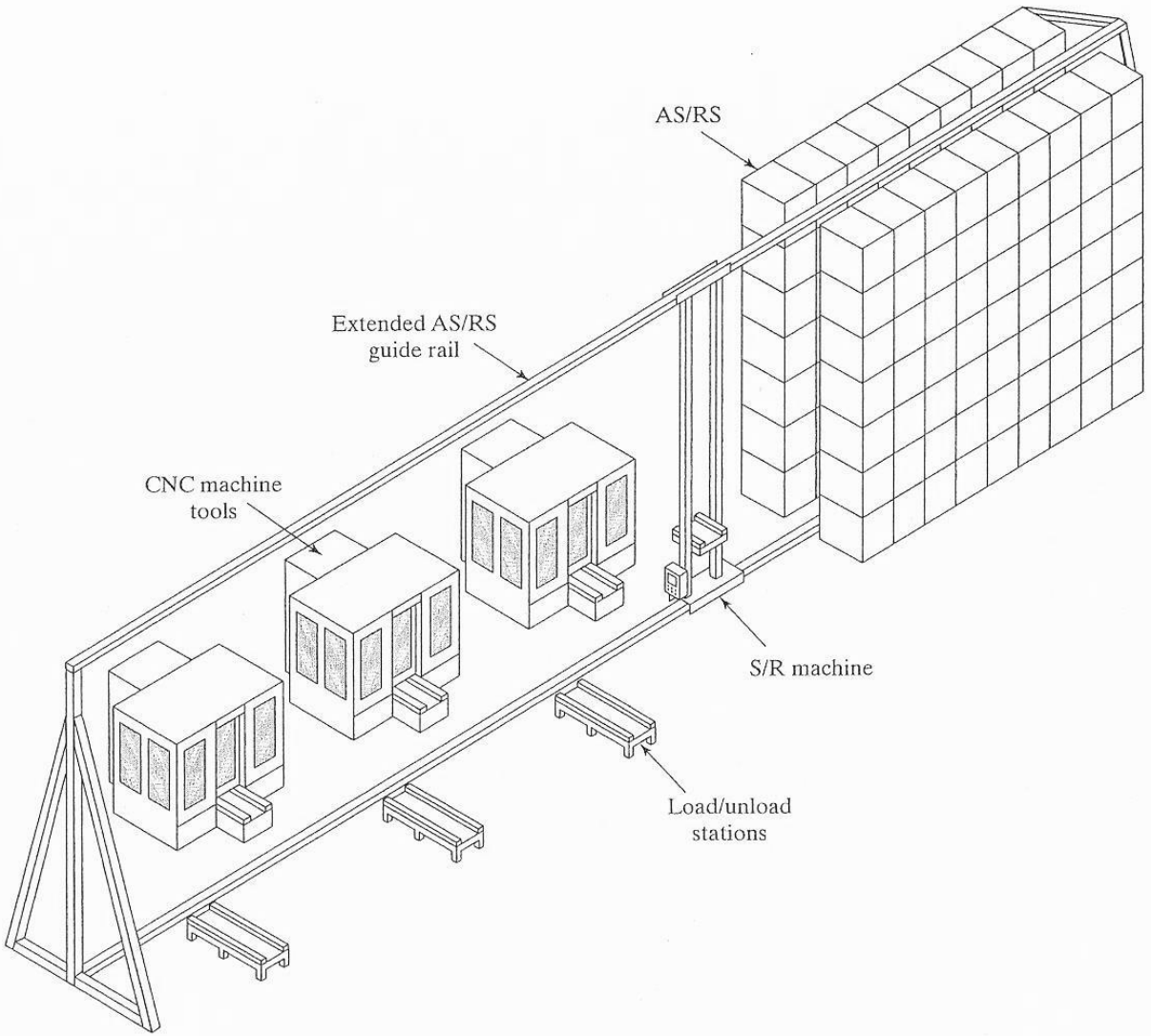


Figure 16.6 FMS that incorporates an automated storage and retrieval system for handling and storing parts. Key: AS/RS = automated storage/retrieval system, S/R = storage/retrieval machine (also known as a stacker crane), CNC = computer numerical control.

Nuts and Bolts of FMS

FMS Layouts

- Closed Loop Layout:
  - Parts can skip stations for flexibility
  - Used for large part sizes
  - Best for long process times

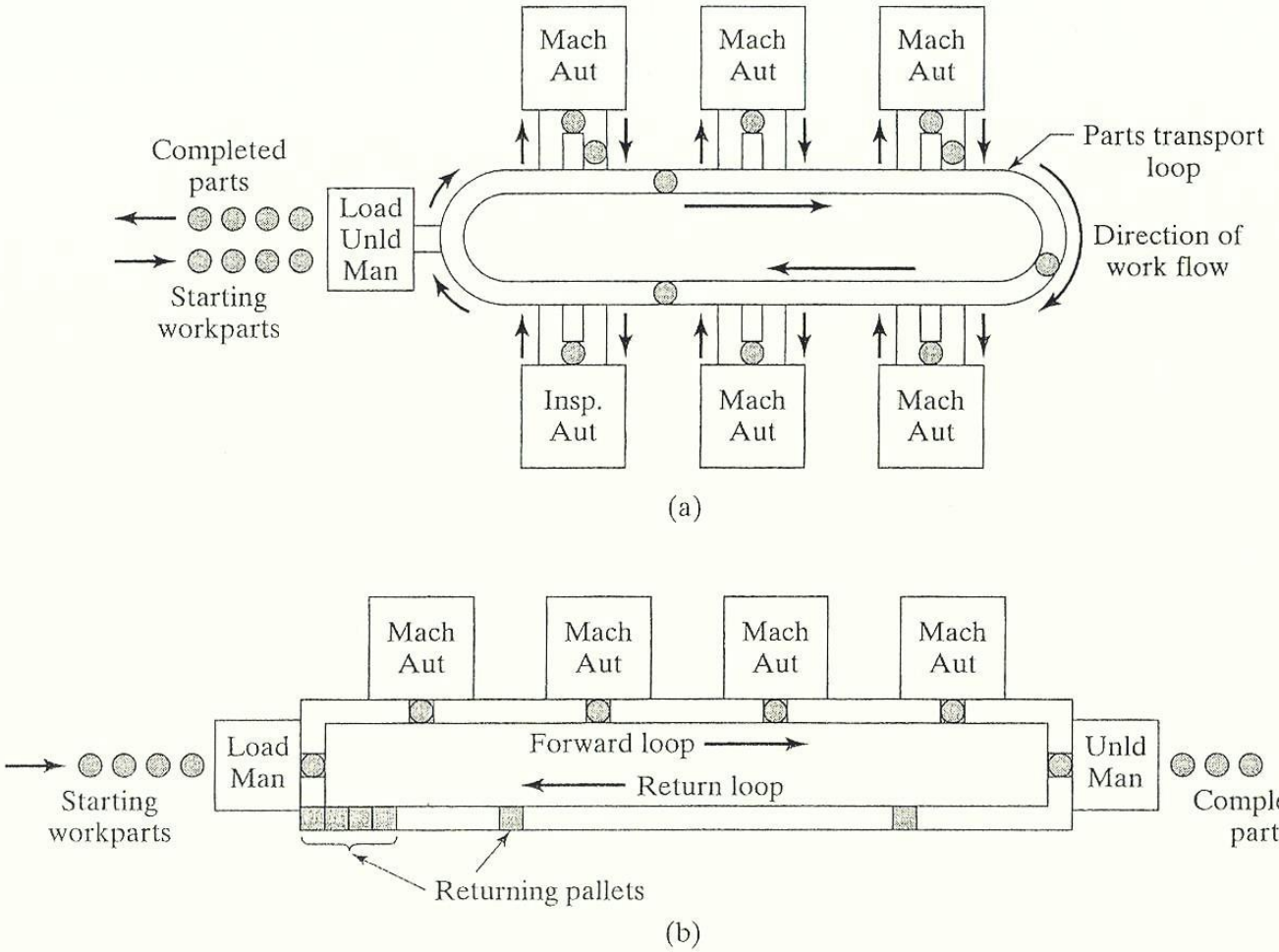


Figure 16.8 (a) FMS loop layout with secondary part handling system at each station to allow unobstructed flow on loop and (b) rectangular layout for recirculation of pallets to the first workstation in the sequence. Key: Load = parts loading station, UnLd = parts unloading station, Mach = machining station, Man = manual station, Aut = automated station.

FMS Layouts Continued

- Ladder Layout:
  - Parts can be sent to any machine in any sequence
  - Parts not limited to particular part families

- Open Field Layout:
  - Most complex FMS layout
  - Includes several support stations

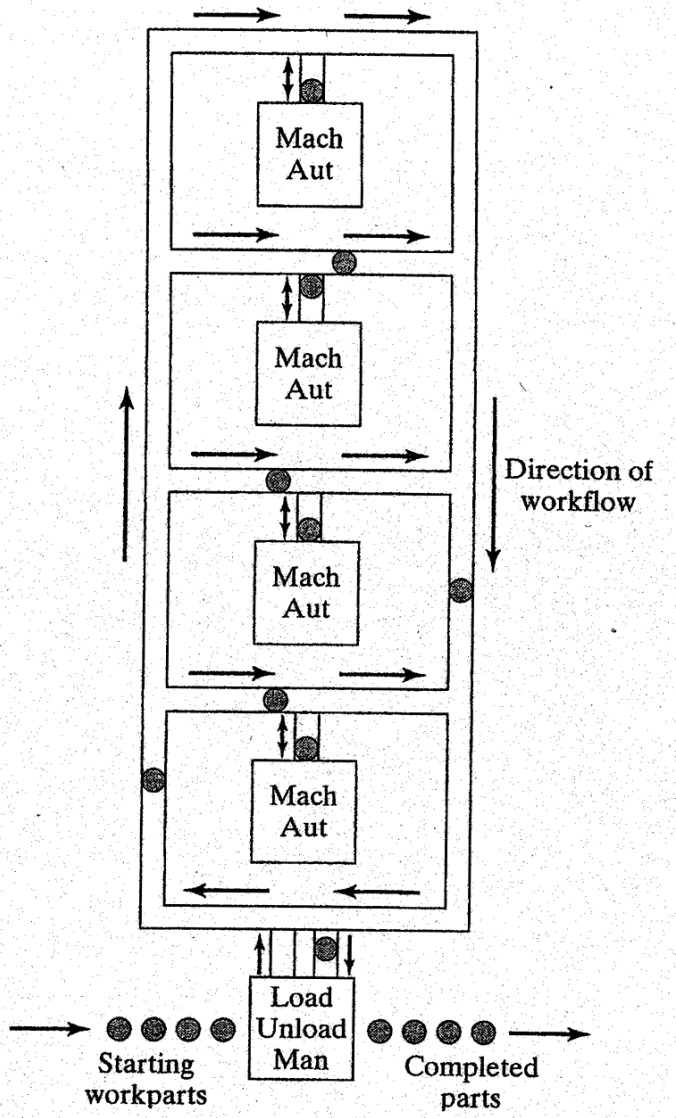


Figure 16.9 FMS ladder layout. Key: Load = parts loading station, UnLd = parts unloading station, Mach = machining station, Man = manual station, Aut = automated station.

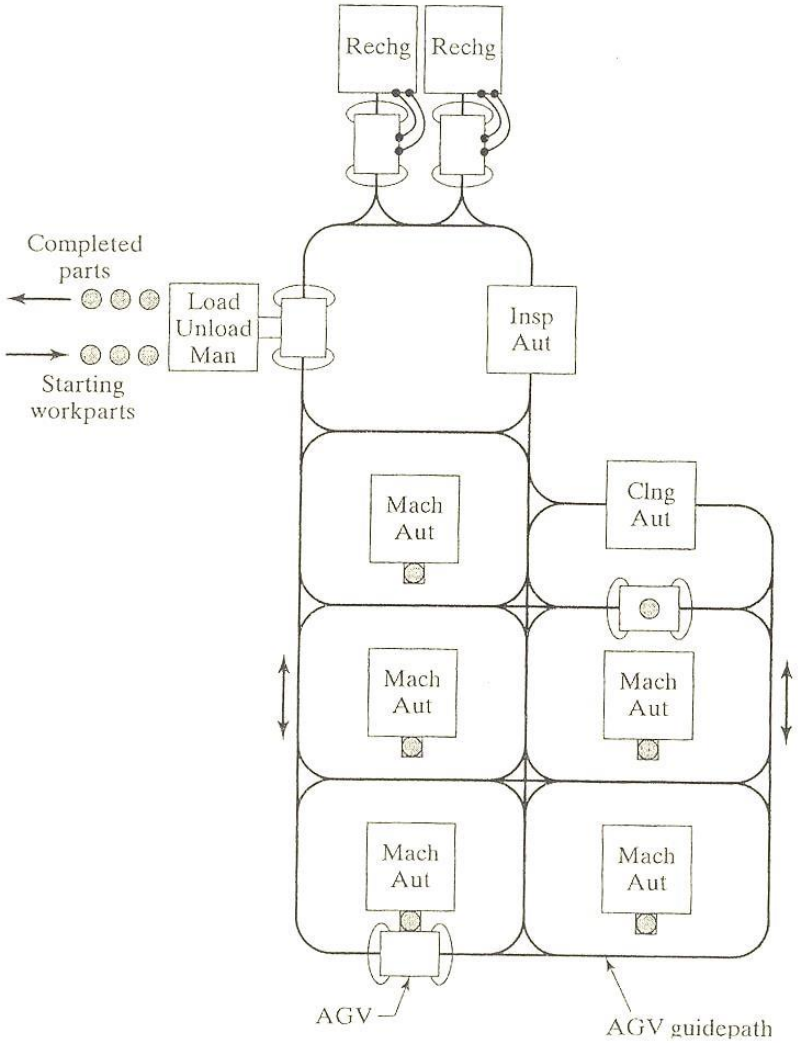


Figure 16.10 Open field FMS layout. Key: Load = parts loading, UnLd = parts unloading, Mach = machining, Clng = cleaning, Insp = inspection, Man = manual, Aut = automated, AGV = automated guided vehicle, Rechg = battery recharging station for AGVs.

Material Handling and Storage System

Functions of the Handling System

- ***Random, independent movement of workparts between stations***.
- ***Handle a variety of workpart configurations***.
- ***Temporary storage***.
- ***Convenient access for loading and unloading workparts***.
- ***Compatible with computer control***.

Material Handling Equipment

The material handling function in a FMS is often shared between two systems:

1. ***Primary handling system*** - establishes the basic layout of the FMS and is responsible for moving workparts between stations in the system.

2. ***Secondary handling system*** - consists of transfer devices, automatic pallet changers, and similar mechanisms located at the workstations in the FMS.

Equipment used as primary handling system

Layout configuration	*Typical material handling system*
In-line layout	In-line transfer system Conveyor system Rail guided vehicle system
Loop layout	Conveyor system In-floor towline carts
Ladder layout	Conveyor system Automated guided vehicle system Rail guided vehicle
Open field layout	Automated guided vehicle system In-floor towline carts
Robot-centered layout	Industrial robot

Computer Control System

Function performed by FMS computer control:

1. ***Workstation control***.
2. ***Distribution of control instructions to workstations***.
3. ***Production control***.
4. ***Traffic control***. - Primary handling system

Function performed by FMS computer control:

5. ***Shuttle control***. – Secondary handling system
6. ***Workpiece monitoring***.
7. ***Tool control***. - concerned with managing two aspects of the cutting tools: (a) tool location, (b) tool life monitoring.
8. ***Performance monitoring and reporting*** - see table.
9. ***Diagnostics***.

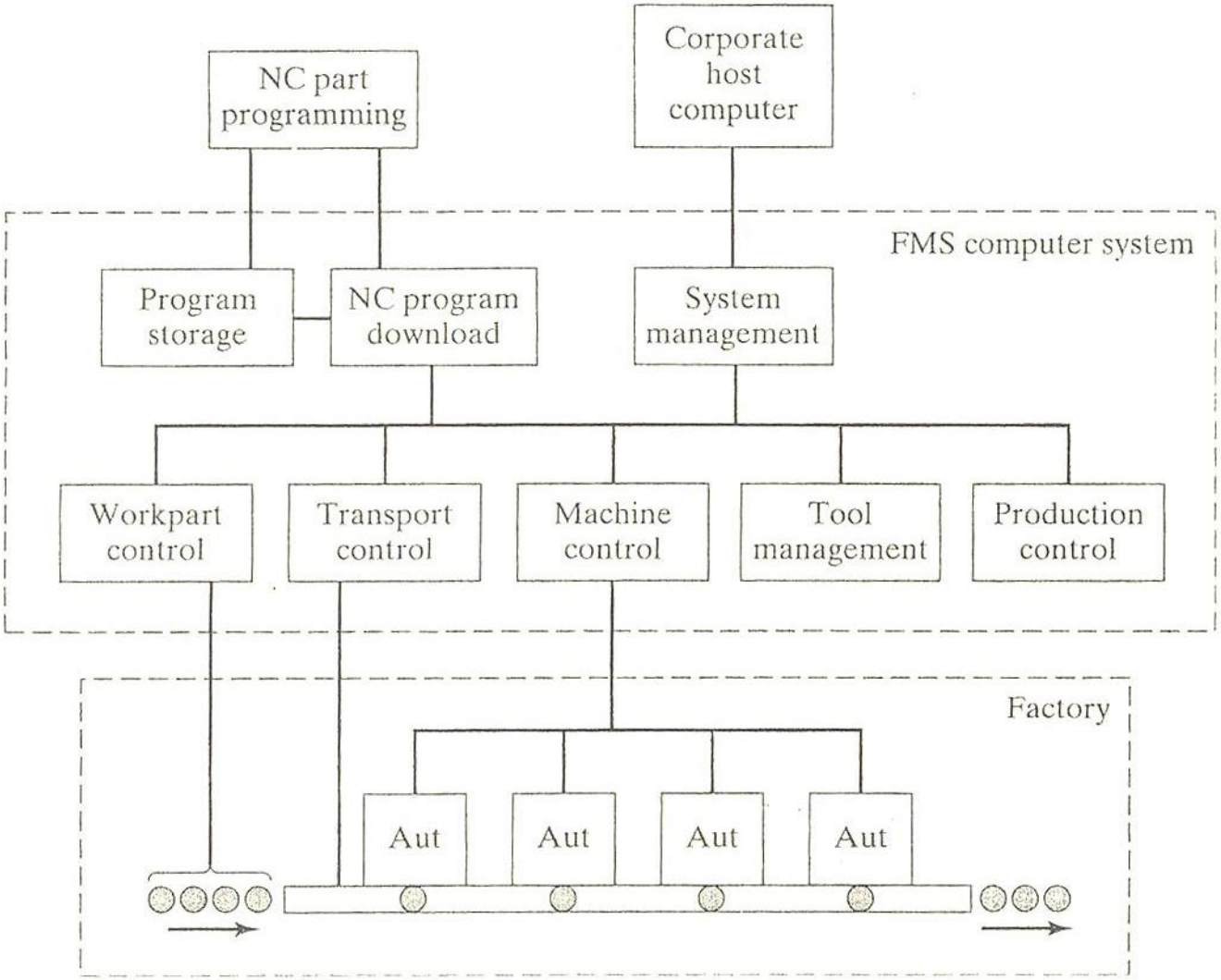


Figure 16.11 Structure of FMS application software system. Key: NC = numerical control, Aut = automated workstation.

Typical FMS performance reports

Type of report	Description
Availability	Uptime proportion of workstations. Details such as reasons for downtime are included to identify recurring problem areas.
Utilization	Summarizes the utilization of each workstation in the system as well as the average utilization of the FMS for specified periods (days, weeks, months).
Production performance	Summarizes daily and weekly quantities of different parts produced. Compares actual quantities against production schedule.
Tooling	Provides information on various aspects of tool control, such as a listing of tools at each workstation and tool life status.
Status	Instantaneous "snapshot" of the present condition of the FMS. Line supervision can request this report at any time to learn the current status of any of the above operating parameters.

Human Resources

Humans are needed to manage the operations of the FMS. Functions typically performed by humans:

- Loading raw workparts onto the system
- Unloading finished parts (or assemblies) from the system
- Changing and setting tools
- Equipment maintenance and repair
- NC part programming in a machining system
- Programming and operating the computer system
- Overall management of the system.

FMS Benefits

- ***Increased machine utilization***.

  FMSs achieve a higher average utilization than stand-alone machines in a conventional machine shop. Reasons include:

(1) 24 hour per day operation,

(2) automatic tool changing at machine tools,

(3) automatic pallet changing at workstations,

(4) queues of parts at stations, and

(5) dynamic scheduling of production that takes into account irregularities from normal operations.

It should be possible to approach 80% to 90% asset utilization.

- ***Fewer machines required***. Because of higher machine utilization.
- ***Reduction in factory floor space required***. Compared to a job shop of equivalent capacity, a FMS generally requires less floor area. Reductions in floor space requirements = 40% to 50%.
- ***Greater responsiveness to change***. A FMS improves response capability to part design changes, introduction of new parts, changes in production schedule and product mix, machine breakdowns, and tool failures. Adjustments can be made in the production schedule from one day to the next to respond to rush orders and special customer requests.

- ***Reduced inventory requirements***. Because different parts are processed together rather than separately in batches, WIP is less than in batch production. Inventories of starting and finished parts reduced also. Reductions = 60% to 80%.
- ***Lower manufacturing lead times***. Closely correlated with lower WIP is MLT. This means faster customer deliveries.
- ***Reduced direct labor requirements*** and ***higher labor productivity***. Savings = 30% to 50%
- ***Opportunity for unattended production***.

FMS Planning and Design Issues

- ***Part family considerations***.

  The part family that will be processed on the FMS must be defined. Part families can be based on product commonality as well as part similarity. The term ***product commonality*** refers to different components used on the same product.

- ***Processing requirements***.

  In machining applications, nonrotational parts are produced by machining centers, milling machines, and like machine tools; rotational parts are machined by turning centers and similar equipment.

FMS Planning and Design Issues
(continued)

- ***Physical characteristics of the workparts***.

  Part sizes and weights determine the size of the machines and the size of the material handling system.

- ***Production volume***.

  The production quantities determine how many machines will be required. Production volume is also a factor in selecting the most appropriate type of material handling equipment for the system.

FMS Planning and Design Issues (continued)

- ***Variations in process routings***. If variations in process sequence are minimal, then an in-line flow is most appropriate. As product variety increases, a loop is more suitable. If there is significant variation in the processing, a ladder layout or open field layout are most appropriate.
- ***Work-in-process*** and ***storage capacity***. If WIP is too low, then stations may become starved. If WIP is too high, then congestion may result. The WIP level should be planned.

FMS Planning and Design Issues (continued)

- ***Pallet fixtures***. The number of pallet fixtures required in the system must be decided. Factors include: levels of WIP allowed in the system, and differences in part style and size. Parts that differ too much require different fixturing. Consider ***modular fixturing***.

- ***Tooling***. Tooling decisions include types and numbers of tooling at each station. Consideration should also be given to the degree of duplication of tooling at the different stations. Tool duplication tends to increase routing flexibility.

FMS Operational Issues

- ***Scheduling and dispatching***.

  Scheduling of production dictated by the master production schedule. Dispatching = launching of parts into the system at the appropriate times.

- ***Machine loading***.

  Allocating operations and tooling resources among the machines in the system to accomplish the required schedule.

- ***Part routing***.

  Selecting routes to be followed by each part in the production mix so as to maximize use of workstation resources.

FMS Operational Issues

- ***Part grouping***.

  Selecting groups of part types for simultaneous production, given limitations on available tooling and other station resources.

- ***Tool management***.

  Managing available tools includes decisions on when to change tools, allocation of tools to stations, and similar issues.

- ***Pallet and fixture allocation***.

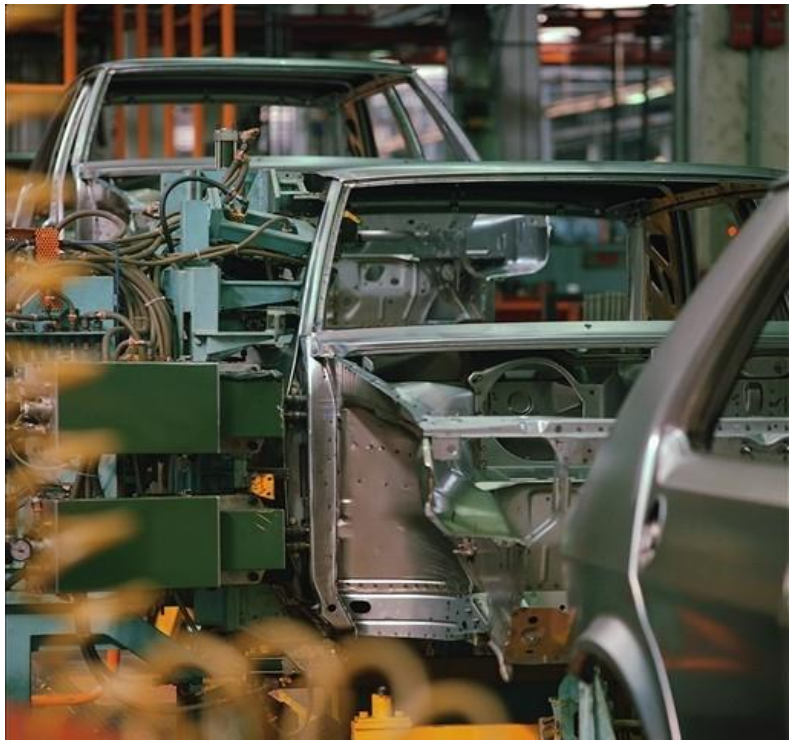
  Allocation of pallets and fixtures to parts in the system.

Making FMS Work

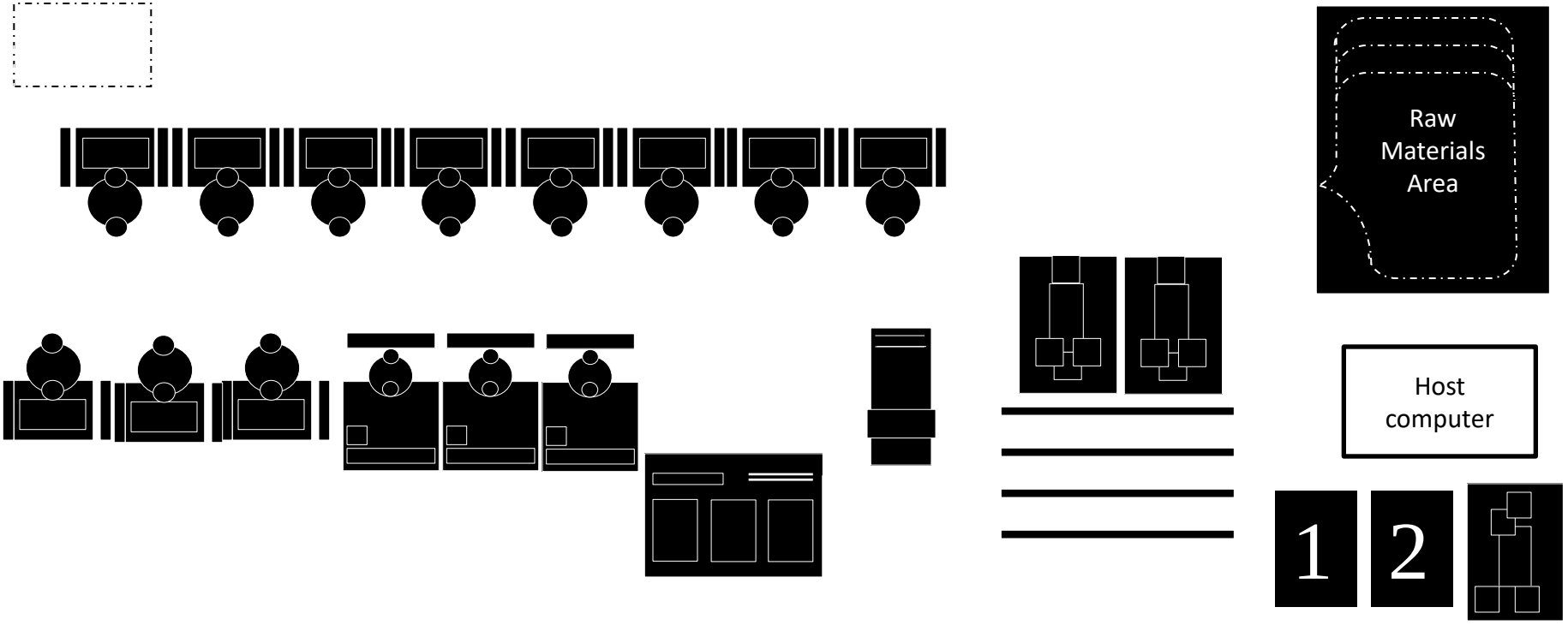
– By implementing the components of robotics, manufacturing technology and computer integrated manufacturing in a correct order one can achieve a successful Flexible Manufacturing System

Computer integrated manufacturing and PLC

In today's manufacturing units several PLCs are used to switch on or off robots ,conveyer belts and other part of manufacturing systems. The advantages of PLC in automated systems made PLC one of the main component of any Manufacturing unit.

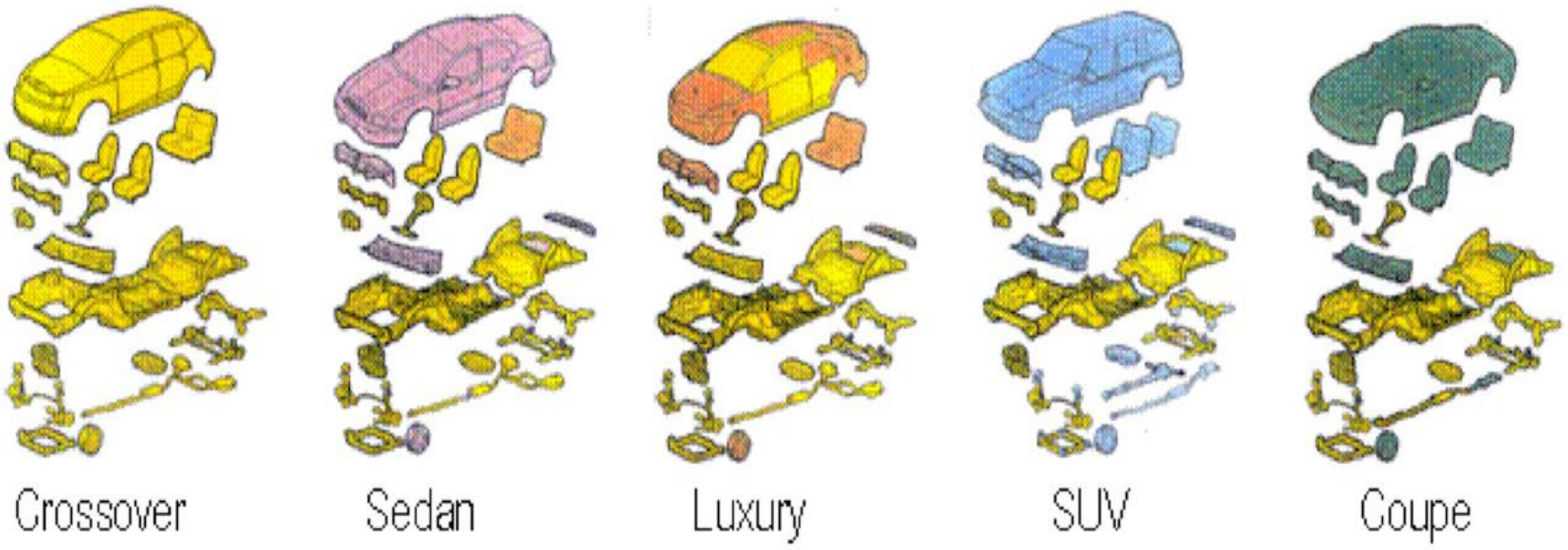


An example of a simple and modern manufacturing



FMS Example

One Design + One Assembly Process = Multiple Models

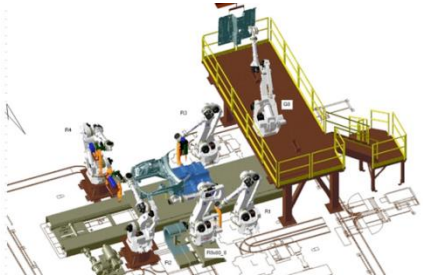


When different models are designed to be assembled in the same sequence they can be built in the same plant.
This maximizes efficiency and allows the company to respond quickly to changing customer

FMS Example

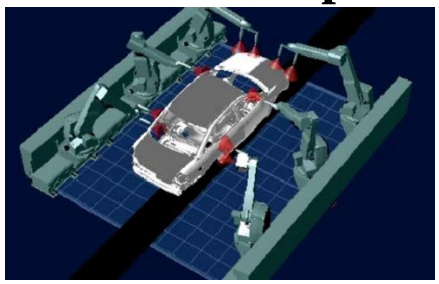
Through the use of reprogrammable tooling in the body shop, standardized equipment in the paint shop and common build sequence in final assembly, Ford can build multiple models on one or more platforms in one plant.

Body Shop



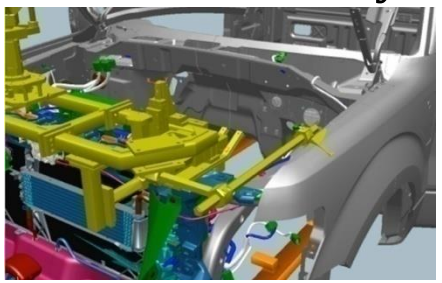
In the body shop, where the sheet metal comes together to form the vehicle's body, flexibility means more than 80 percent of the tooling is not specific to one model. It can be reprogrammed to weld a car or a truck or a crossover of similar size.

Paint Shop



In the paint shop, flexibility means robotic applicators are programmed to cover various body styles – as they move through the paint booth – with equal precision. This results in minimizing waste and environmental impact while maximizing quality.

Final Assembly

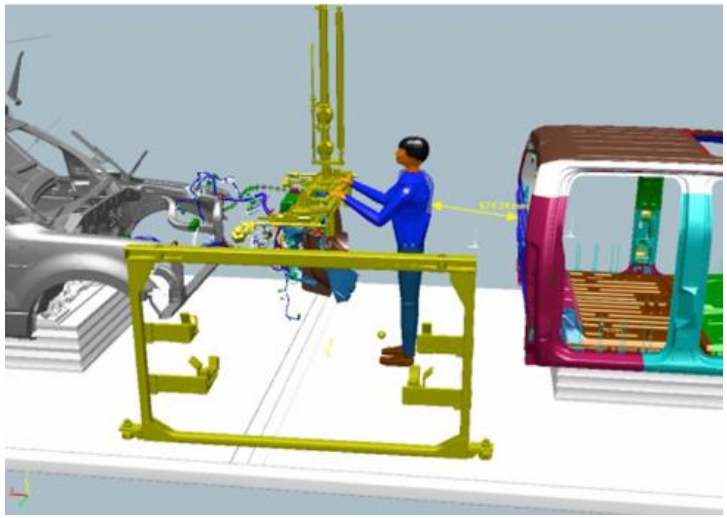


In the final assembly area, flexibility means the build sequence is the same among multiple models on one or more platforms allowing for efficient utilization of people and equipment.

FMS Example

Virtual Verification

Virtual manufacturing technology allows Ford to quickly add various models into an existing facility – or to reconfigure an existing facility to produce a new model. In the virtual world, manufacturing engineers and plant operators evaluate tooling and product interfaces before costly installations are made on the plant floor. This method of collaboration improves launch quality and enables speed of execution.



MACHINING CENTER

CONTENT

- Types of Machining Center
- Tooling for Machining Center
- Automated features and capabilities

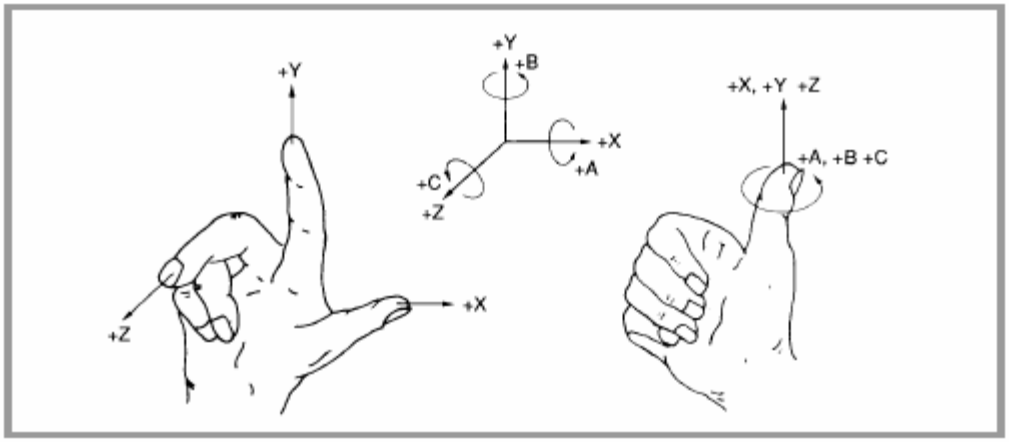
Types of Machining Center

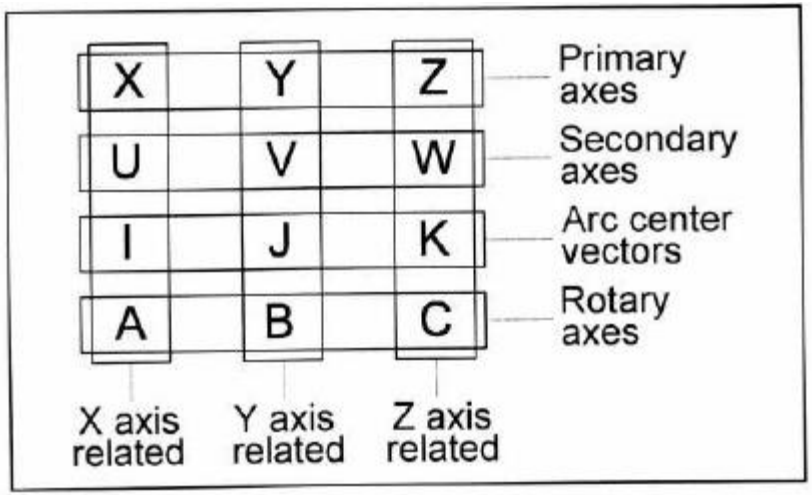
- Based on
- Capabilities
  - CNC Mill, CNC Machining center
- Number of axes:
  - two, three, or more
- Orientation of axes:
  - Vertical (VMC) or Horizontal (HMC)
- Presence or absence of a tool changer
- Presence or absence of a pallet changer

Classification - Capabilities

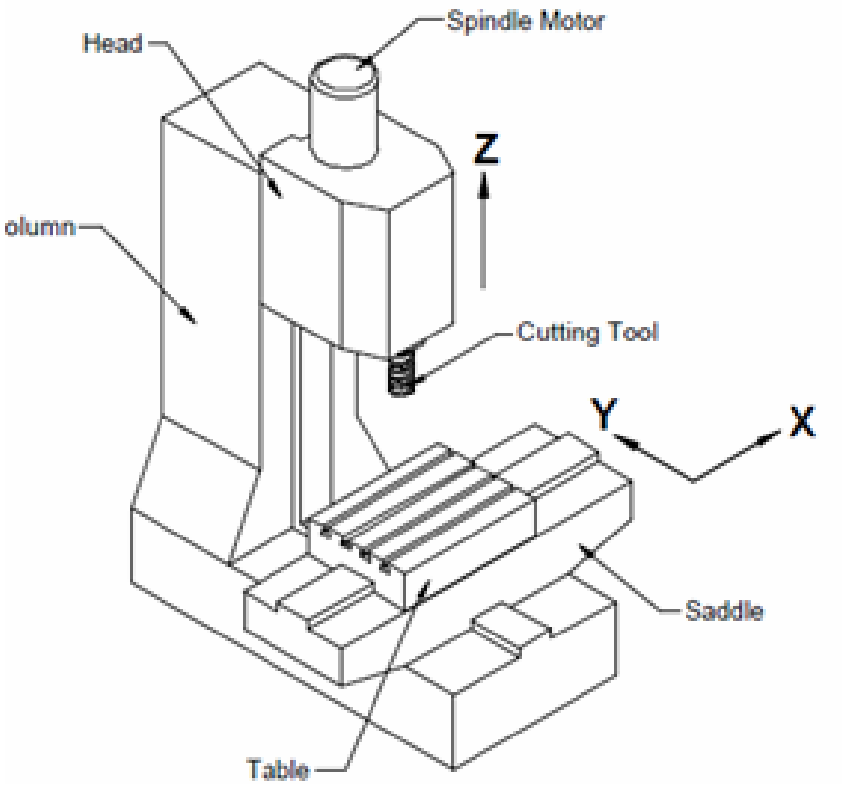
- CNC Mill
  - ✓ Simple, small
  - ✓ Without a tool changer or other automatic feature
  - ✓ Tool room work, maintenance work, small part production
- CNC Machining Center
  - ✓ Several operations can be performed
  - ✓ With automatic tool change and other automatic feature
  - ✓ Production machine

Classification – Based on no. of axis

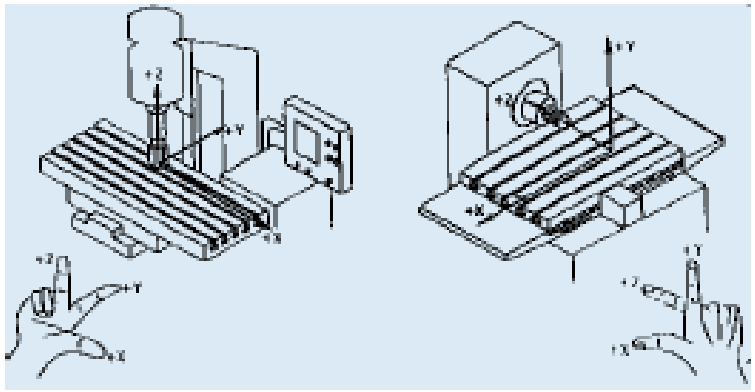




Classification – Based on no. of axis

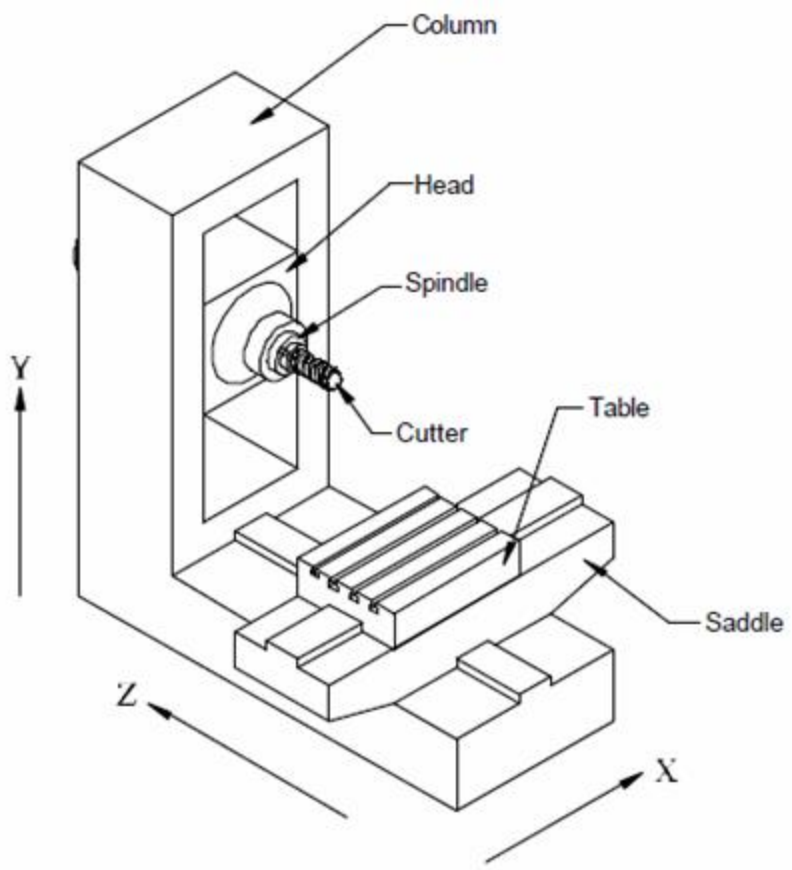


3-Axis Machining Center (VMC)



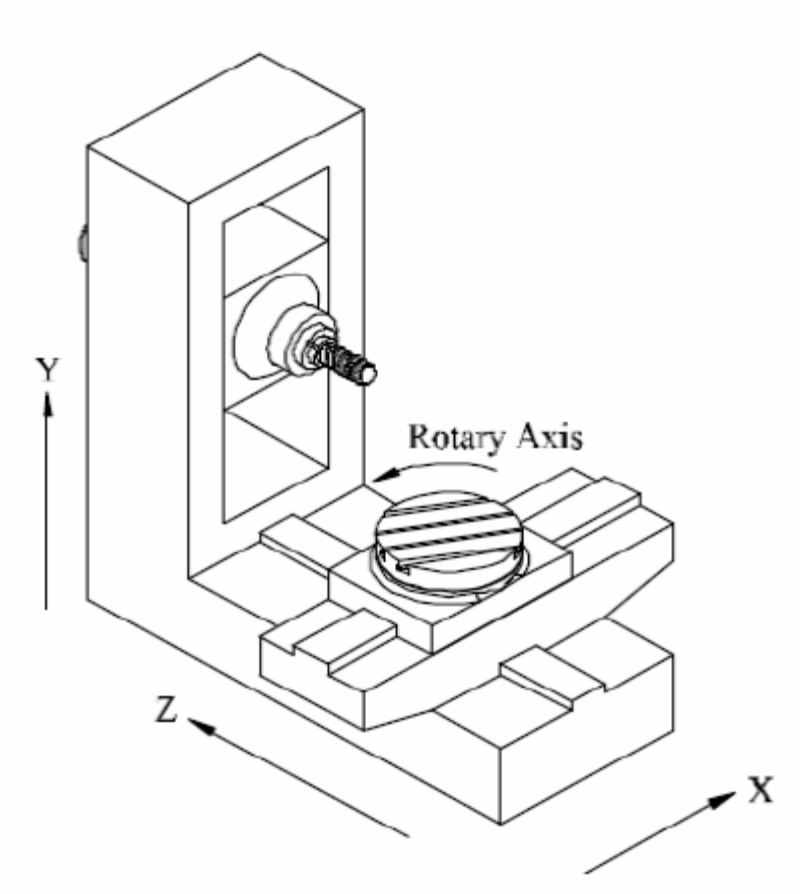
Right hand rule of axis designation

Classification – Based on no. of axis



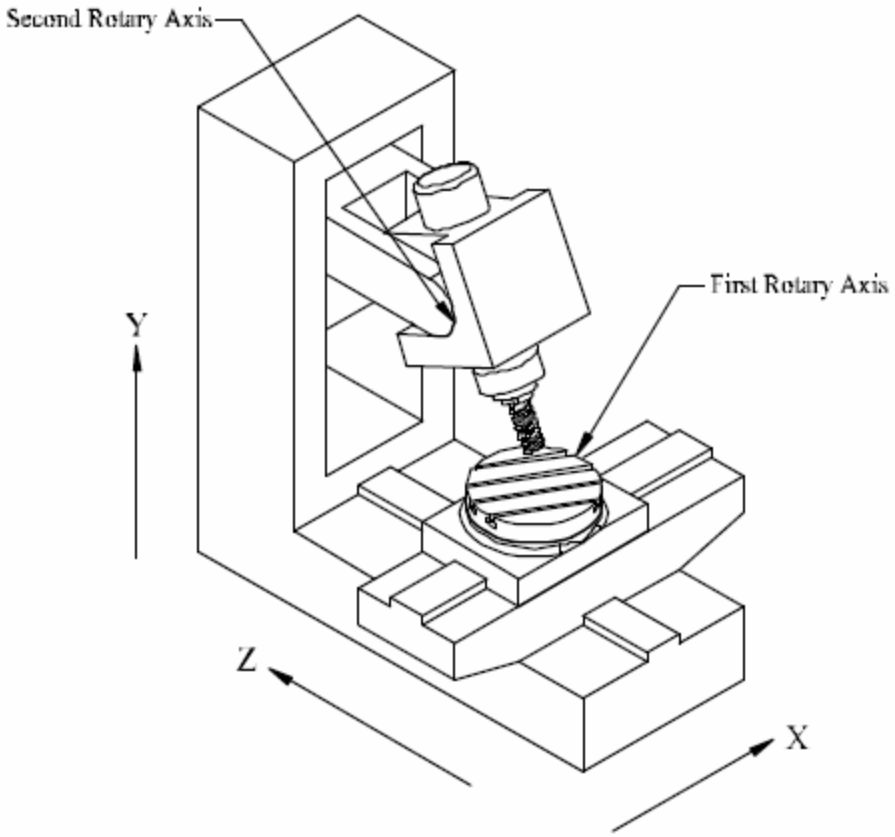
3-Axis Machining Center (HMC)

Classification – Based on no. of axis



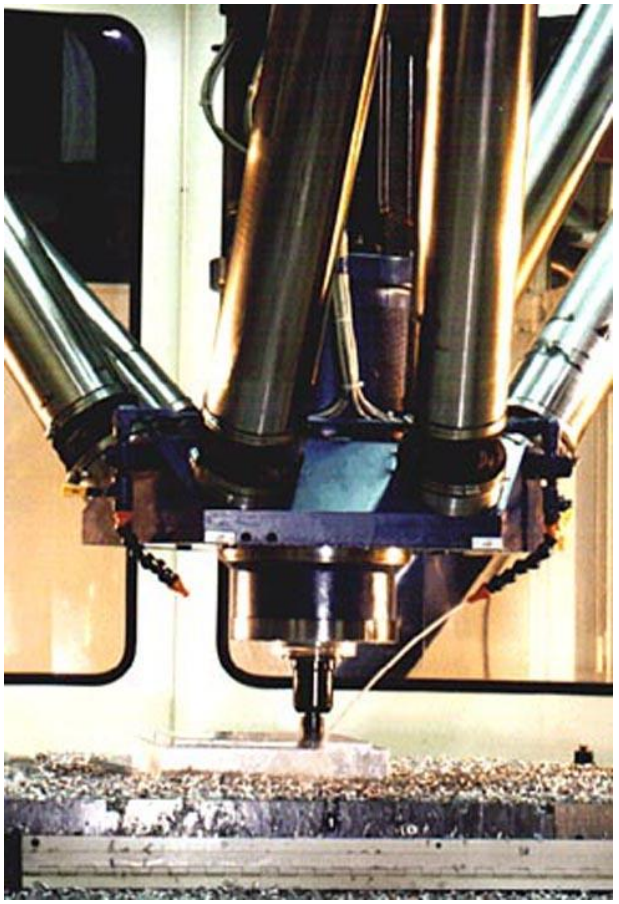
4-Axis Machining Center (HMC)

Classification – Based on no. of axis



5-Axis Machining Center

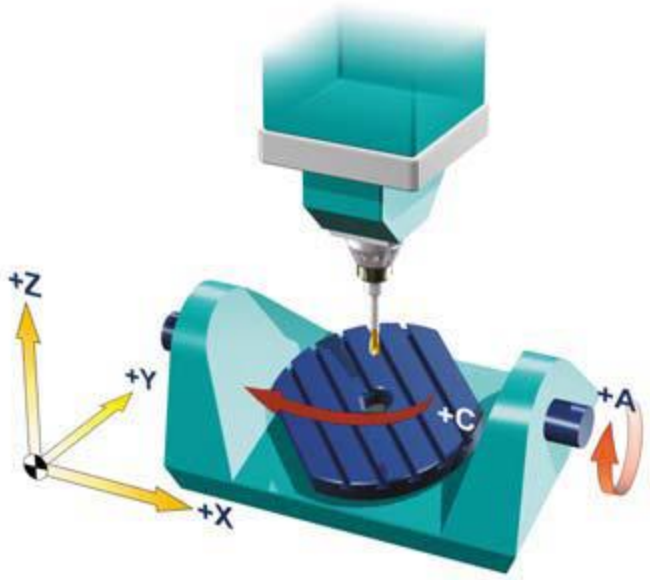
Classification – Based on no. of axis



Hexapod Machining Center

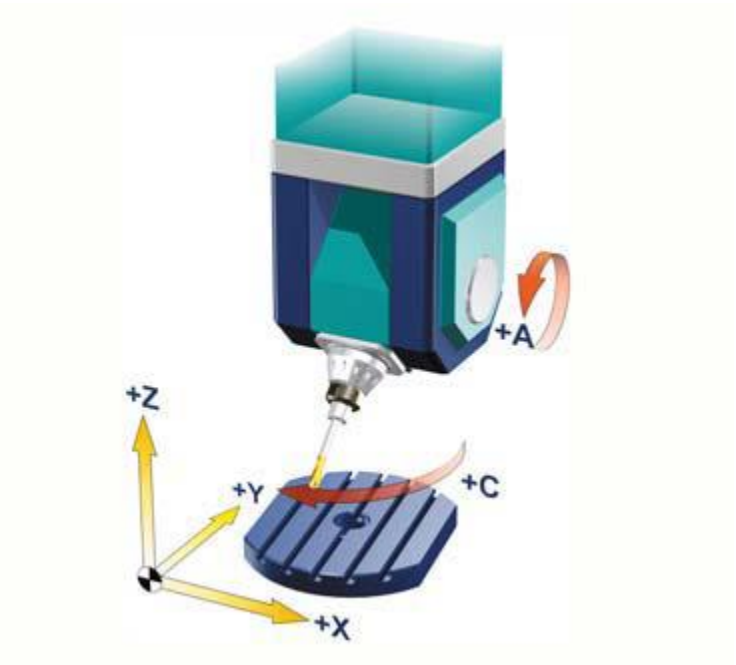
Classification – Based on no. of axis

Two rotary axis in head



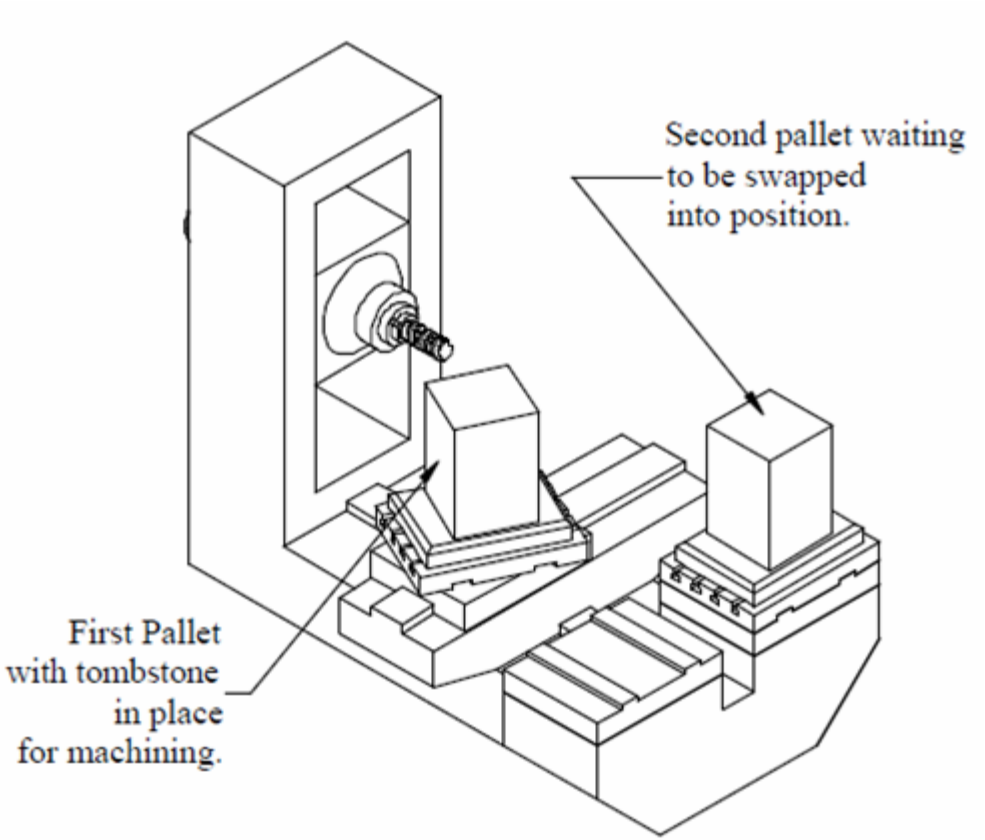
Two rotary axis in table

Classification – Based on no. of axis



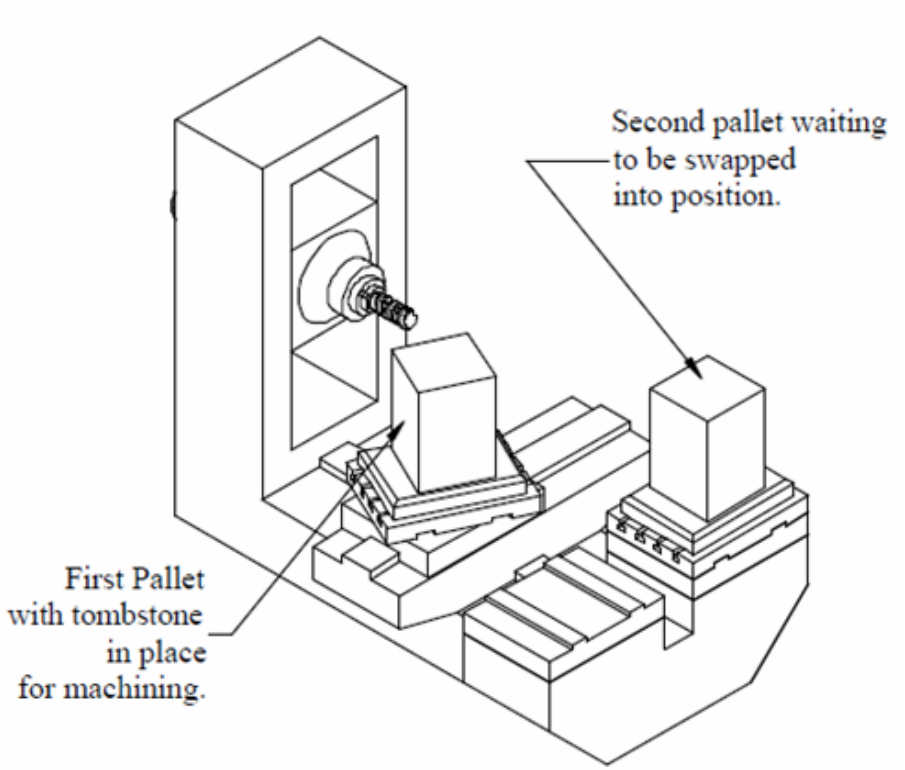
One rotary axis in head / one rotary axis in table

Classification – based on pallet changer



Machining Center with Pallet changer

Classification – based on pallet changer



Machining Center with Pallet changer

Types of Machining Center

DIFFERENCE BETWEEN VMC & HMC

Criteria	Vertical Machining Center	Horizontal Machining Center
Work piece produced	Flat Workpiece Single surface machining 3-axis machining	Box type workpiece, Multiple side machining in one setup
Cost	Less costly	More costly
Tool deflection	No problem of tool deflection	Heavy tools deflects
Cutting zone visibility	Difficult to look at	Easy cut area visibility
Chip recutting	Extensive recutting of chip	Chip drop out of the cut are
Flexibility	Less	More
Thrust force	Absorbed directly by machine table	Absorbed by tombstone and fixtures

Tooling for Machining Center

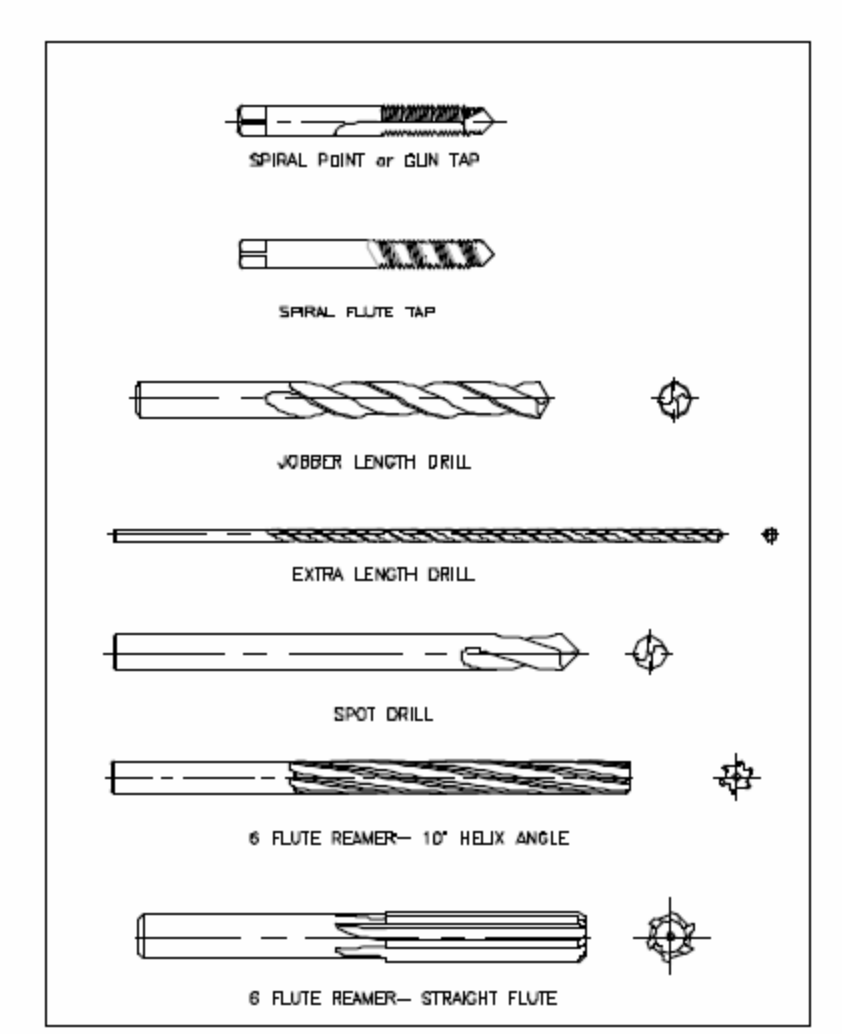
End Mills

Face Mills

Ball End Mills

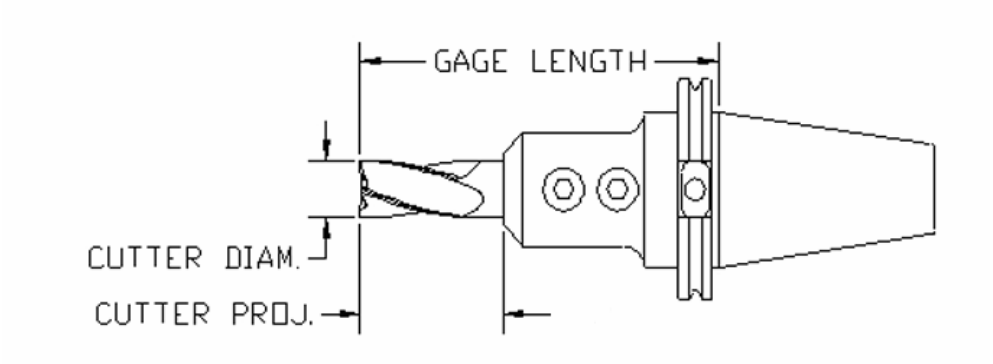
Slitting and side cutters

Tooling for Machining Center



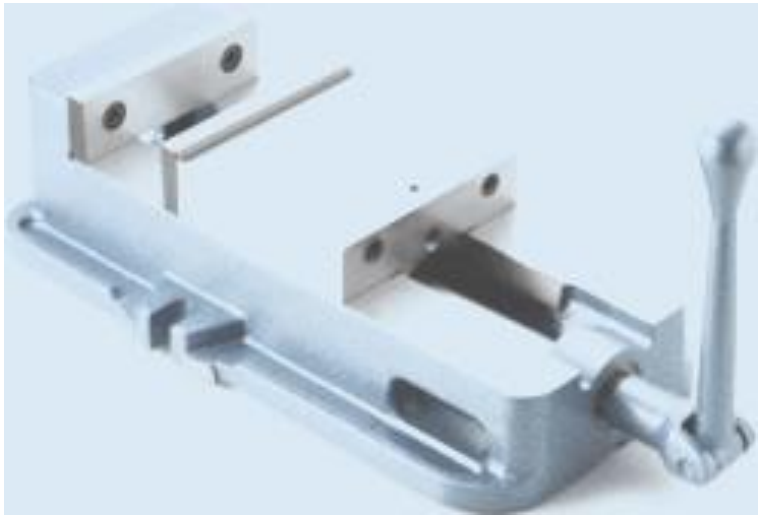
Drills, Taps and Reamers

Tooling for Machining Center



Tool Holder

Tooling for Machining Center



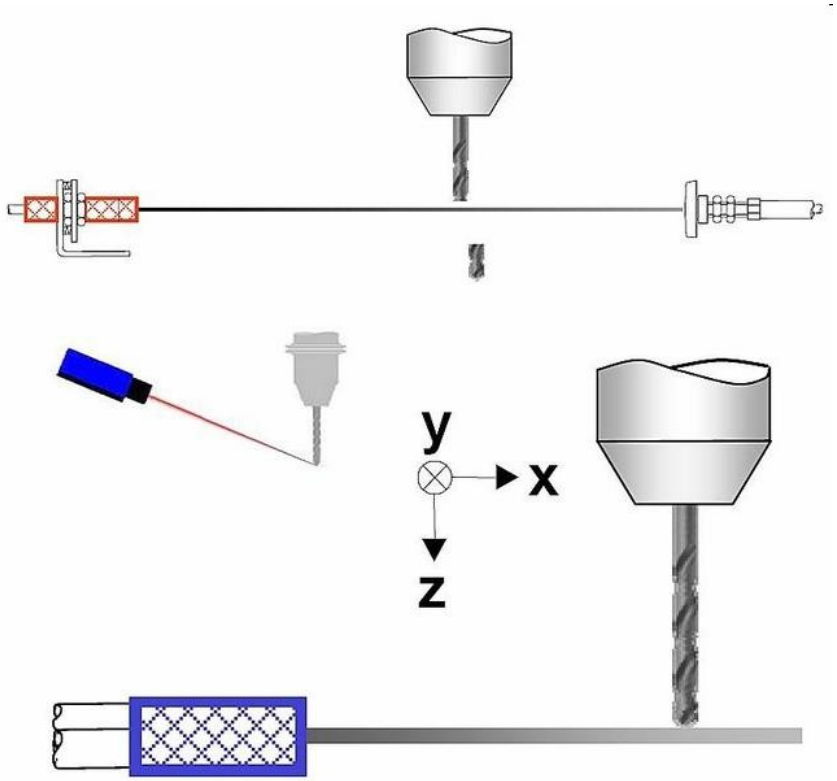
Machine Vice

Tombstone Fixture

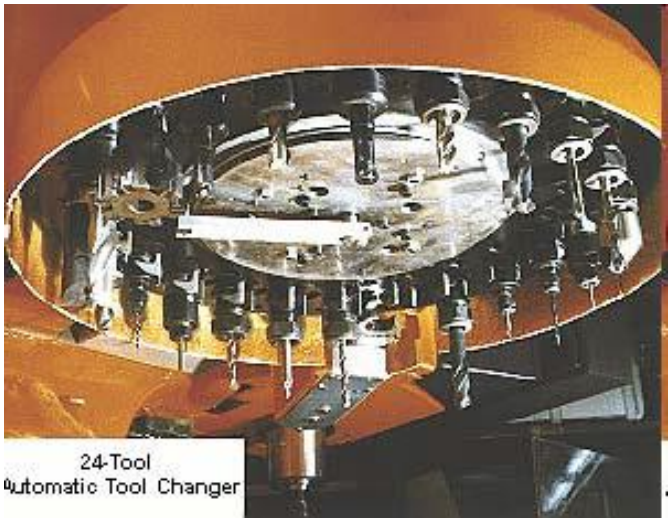
Automated features and capabilities

- Torque control machining
  - ✓ Torque, heat and vibration sensors
- Surface sensing probe
  - ✓ Multidirectional precision electronic switch
- Automated tool delivery
- Multiple and angled spindle heads
- Broken tool detection

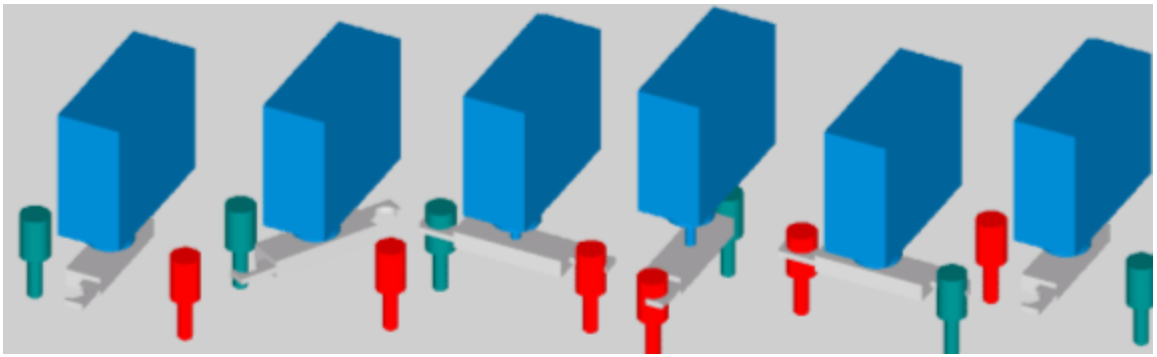
Broken tool detection

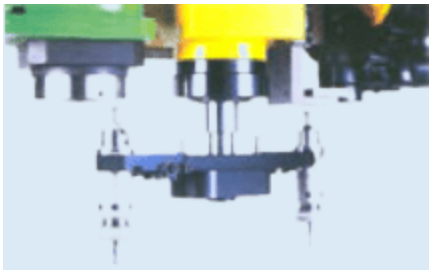


Automated tool delivery



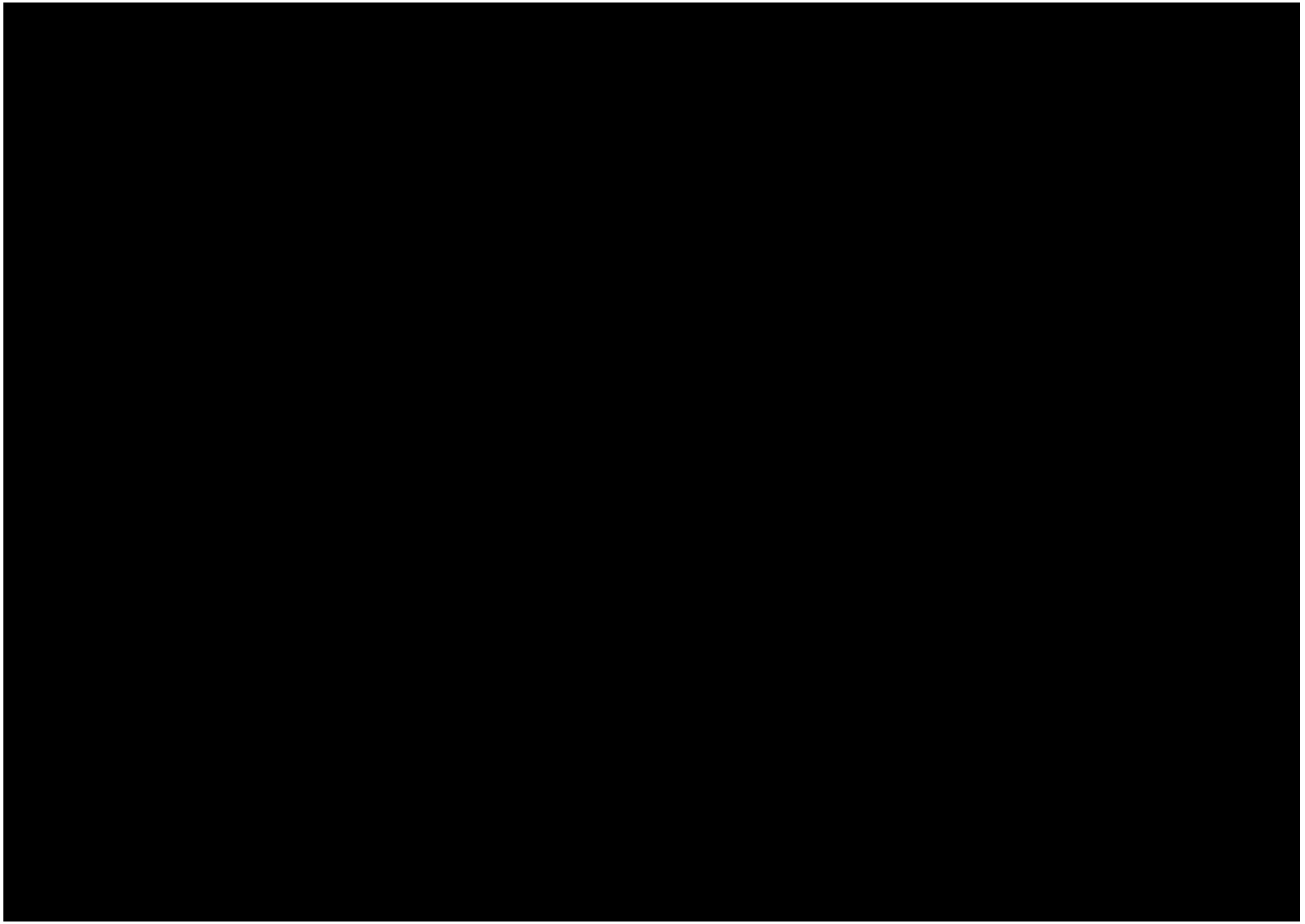
Automated tool delivery



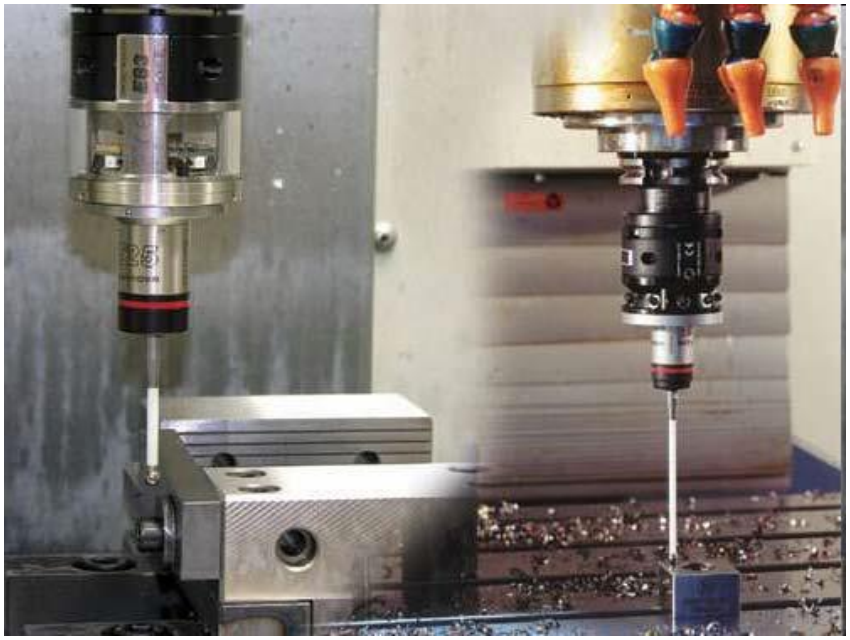


Source : NPTEL

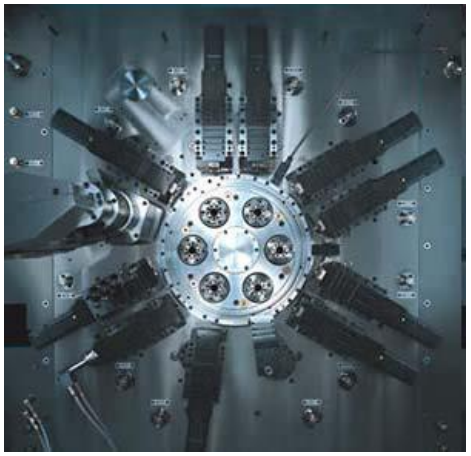
Automated tool delivery



Surface sensing probe



Multiple and angled spindle heads



Chip removal system

TURNING CENTER

CONTENT

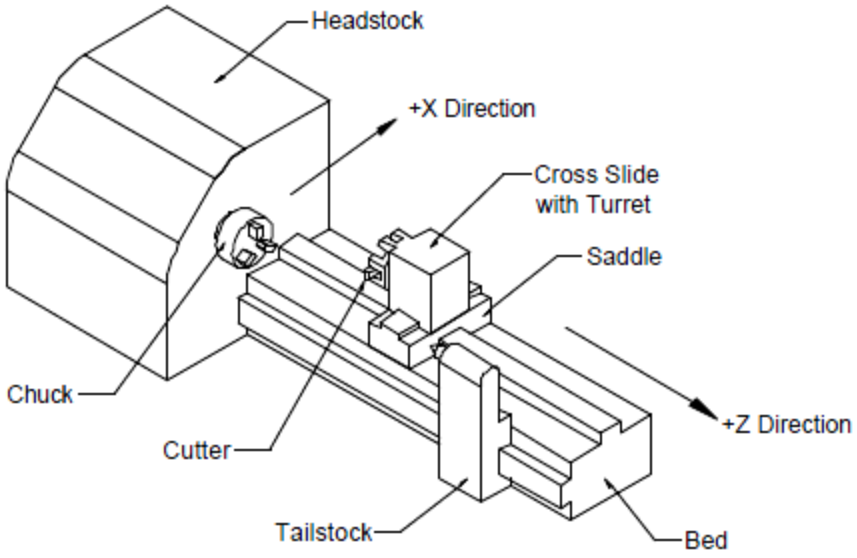
- Types of Turning Center
- Tooling for turning center
- Machine zero and Workpiece zero
- Automated features and capabilities

Types of Turning Center

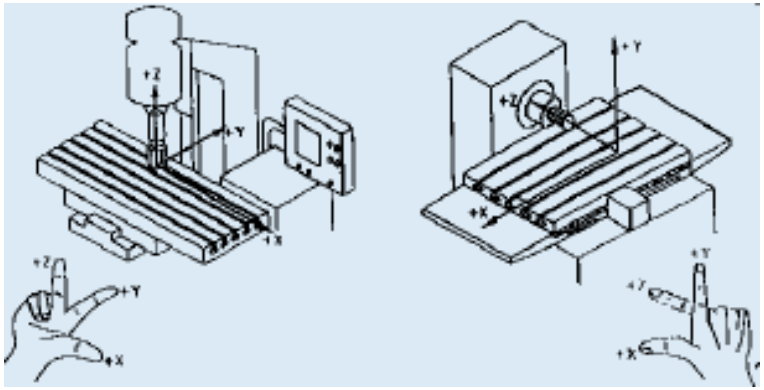
Based on

- Types of design
  - ✓ Horizontal
    - FRONT lathe (Engine lathe type)
    - REAR lathe (Slant bed design)
  - ✓ Vertical
- Number of axis
    - Two, Three, Four, Six etc.

Types of Turning Center

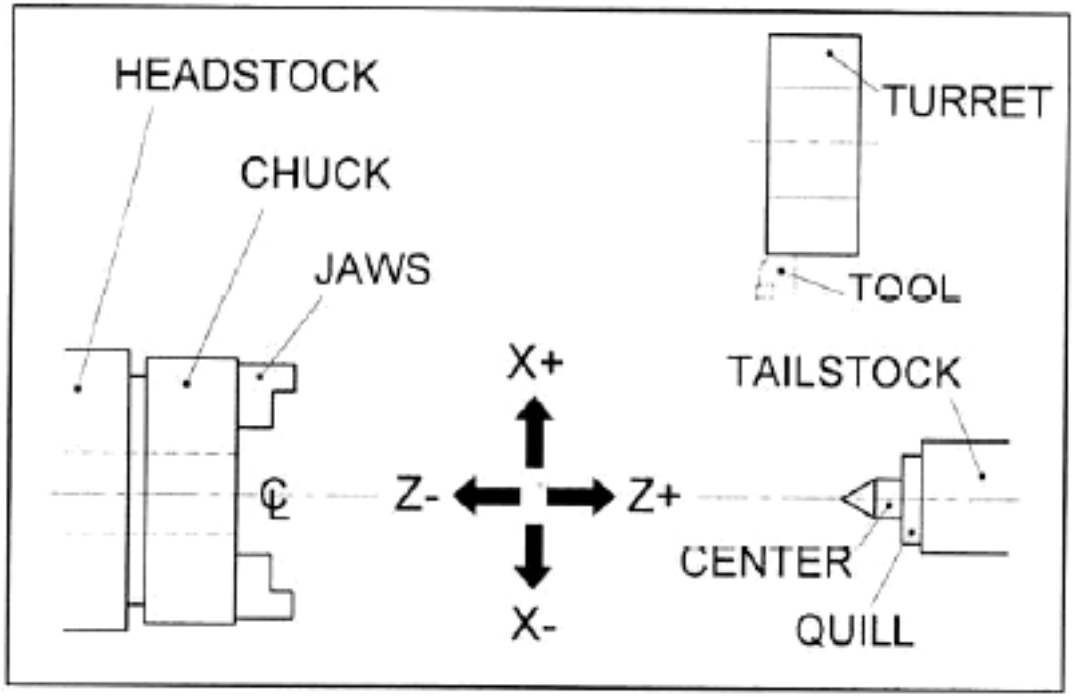


2-Axis Turning Center



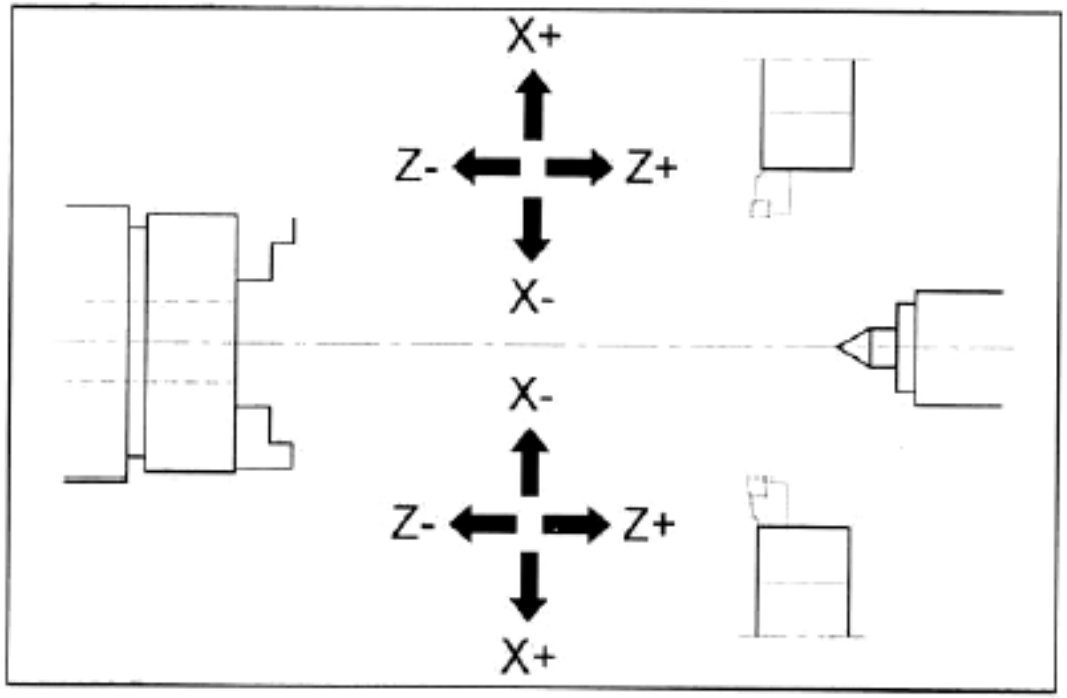
Right hand rule of
axis designation

Types of Turning Center



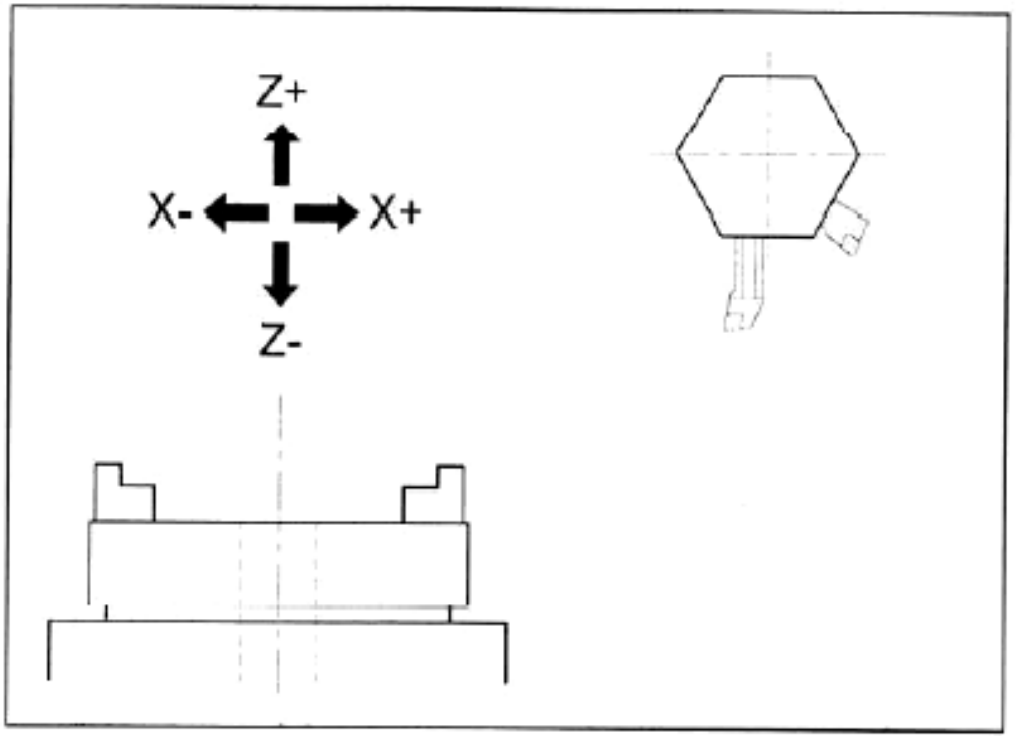
2-Axis Turning Center

Types of Turning Center



4-Axis Turning Center
(Two Turrets)

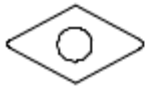
Types of Turning Center



Vertical Turning Center

Tooling for Turning Center

V – 35° diamond



D – 55° diamond

T – triangle

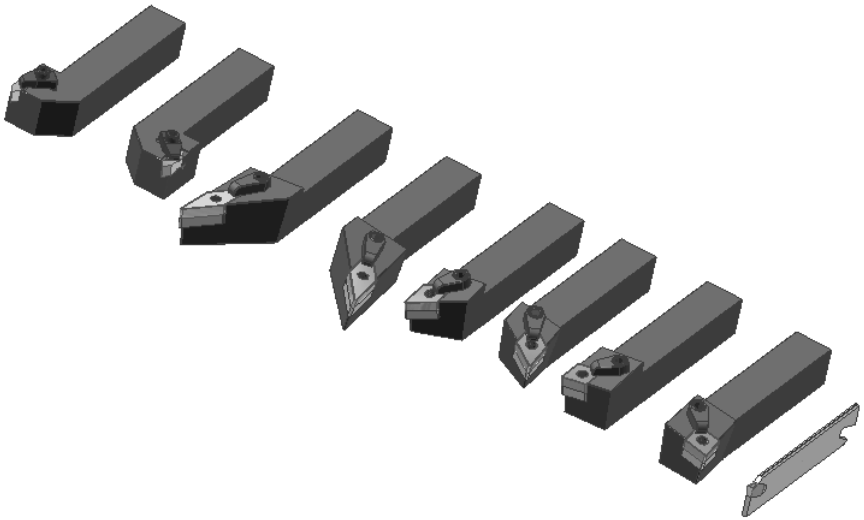
C – 80° diamond

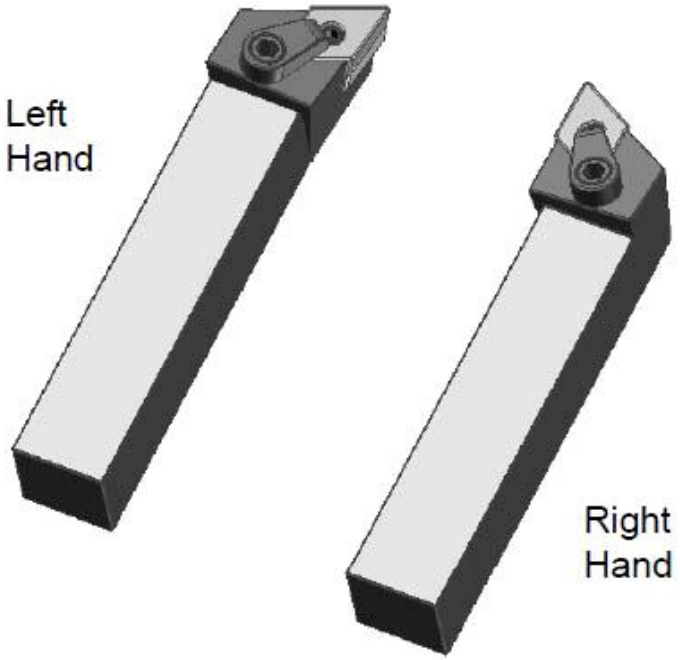
W – 80° trigon

S – square

R – round

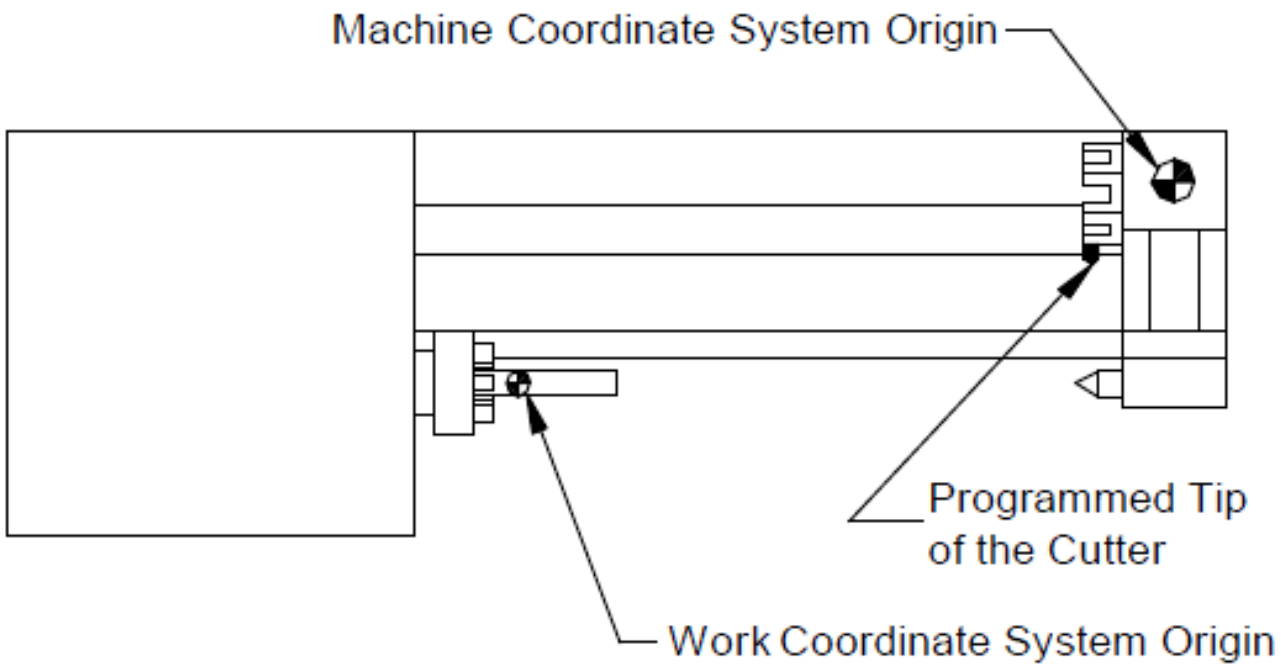
Tooling for Turning Center





Single Point Indexable Insert Holders

Machine zero and Workpiece zero



Top View of the Turning Center

Automated features and capabilities

- Automatic gauging
  - ✓ In-process gauging
  - ✓ Post-process gauging
    - Off-machine gauging
    - On-machine gauging
- Probing
- Live spindle tooling
- Tool change systems
- Tool monitoring and sensing

COORDINATE MEASURING MACHINE (CMM)

CONTENT

- Introduction
- Mechanical Structure
- CMM controls
- CMM programming
- CMM applications
- CMM benefits
- Operation cycle description
- Importance to FMS

Introduction

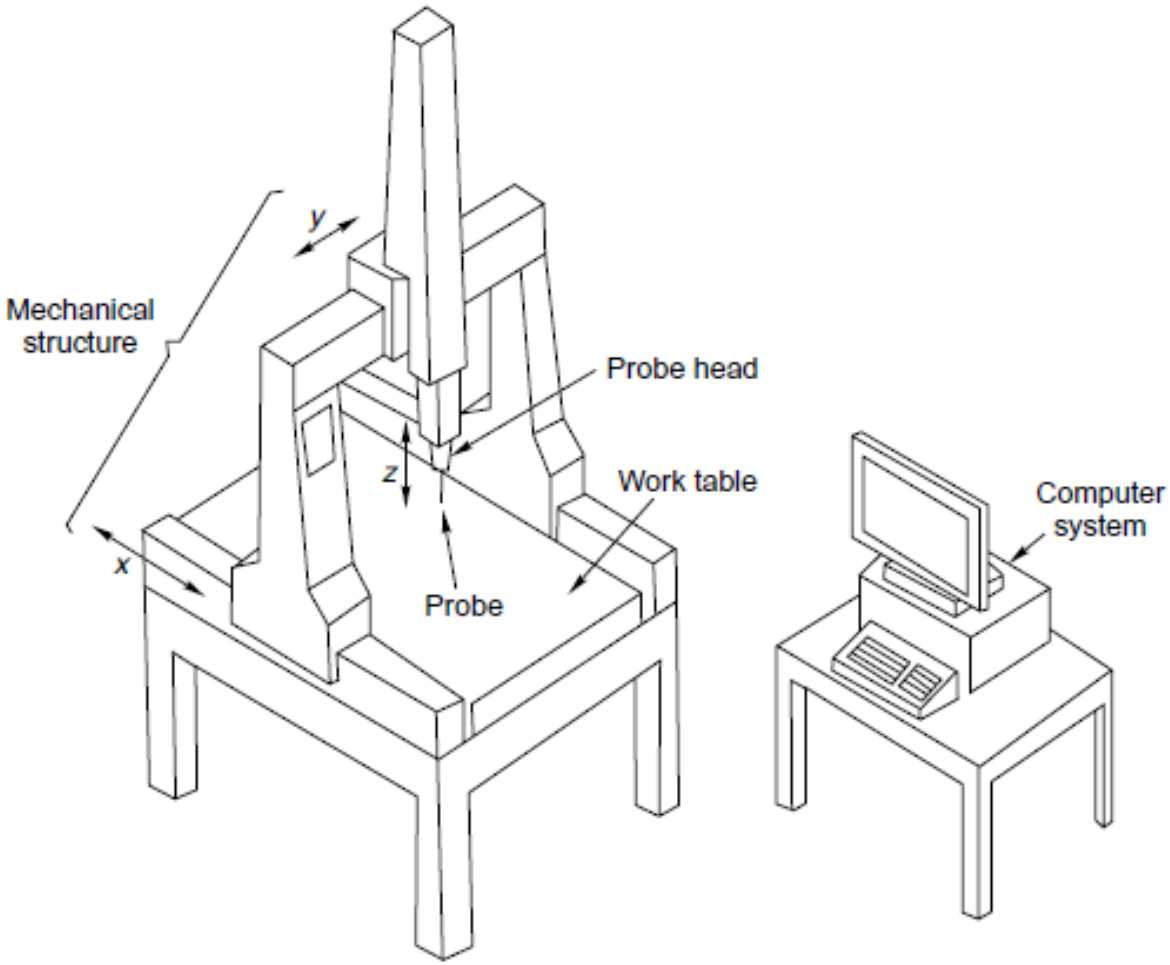
➢ Coordinate Metrology

- It is concerned with measurement of the actual shape and dimensions of an object and comparing these with the desired shape and dimensions.

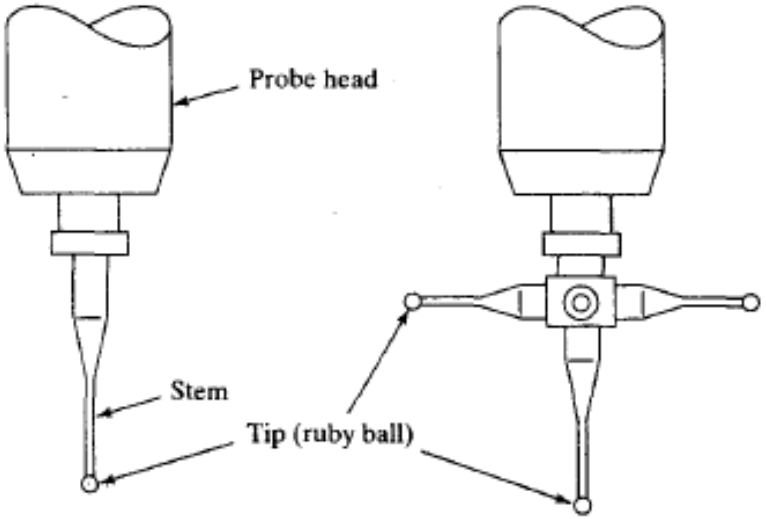
➢ Coordinate Measuring Machine (CMM)

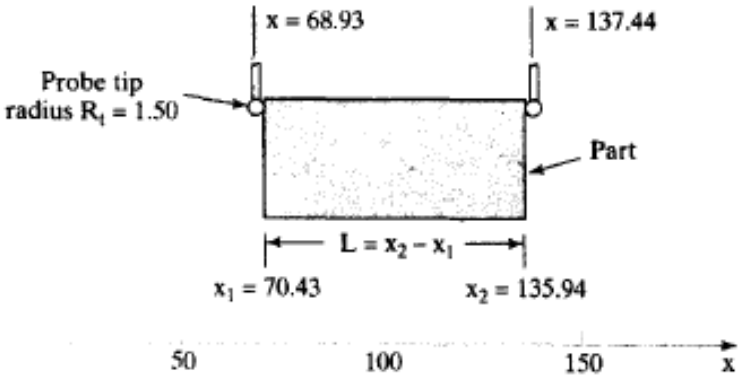
- CMM is electromechanical system to perform coordinate metrology.

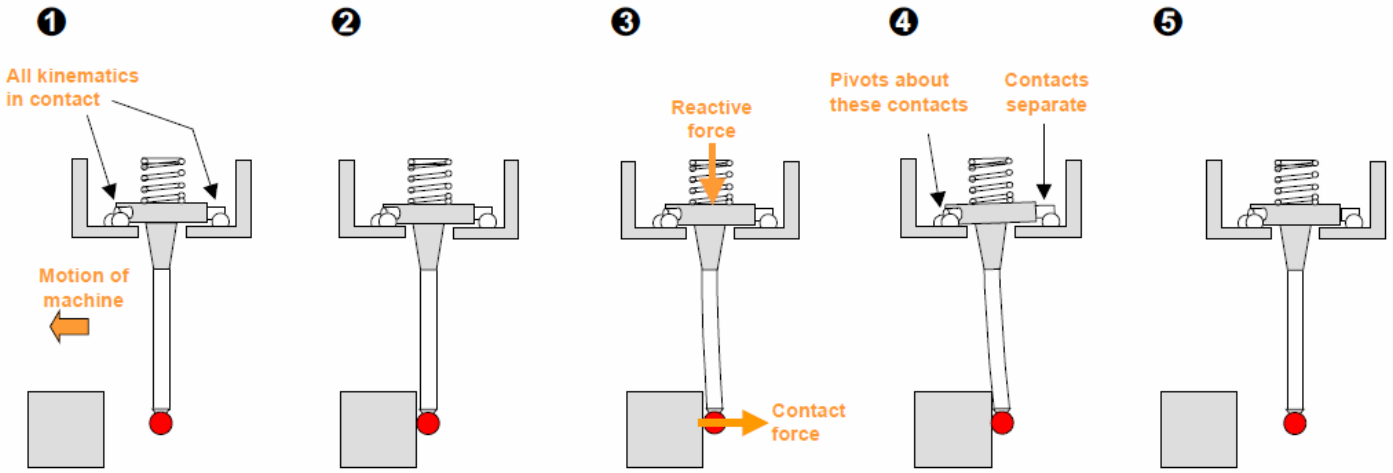
Introduction



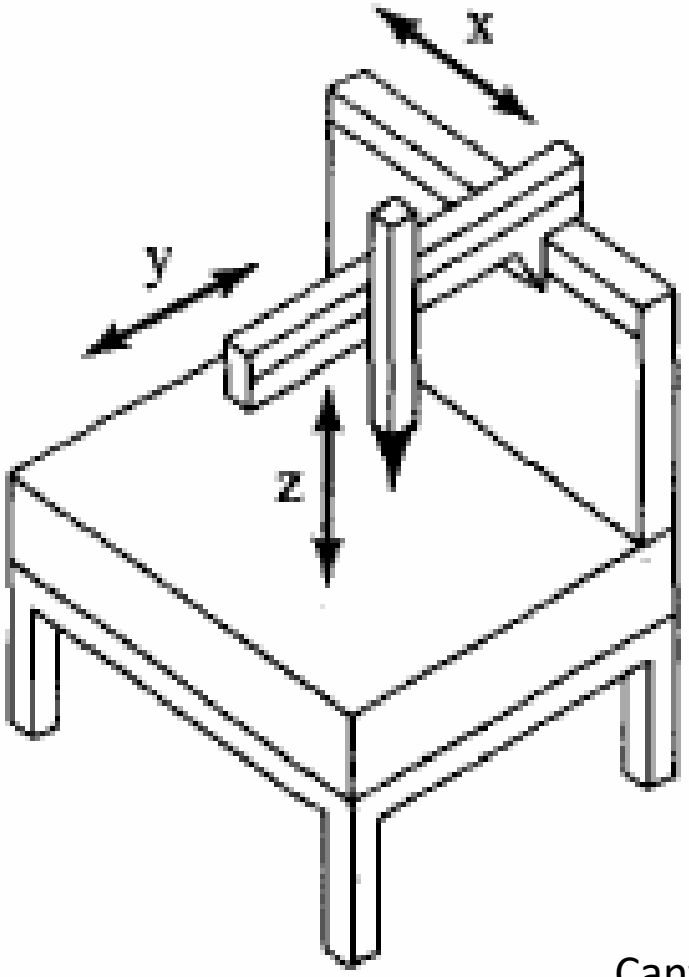
Probe


Probe head
Stem
Tip (ruby ball)


x = 68.93
x = 137.44
Probe tip
radius R_t = 1.50
Part
L = $x_2 - x_1$
x_1 = 70.43
x_2 = 135.94
50
100
150
x

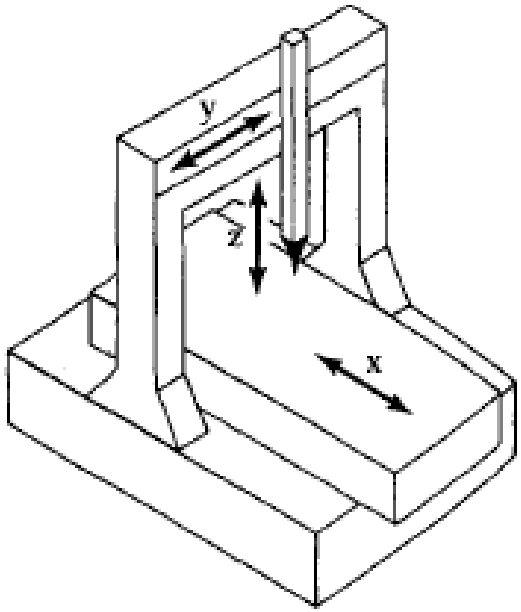

1
2
3
4
5
All kinematics in contact
Motion of machine
Reactive force
Contact force
Pivots about these contacts
Contacts separate

Mechanical Structure



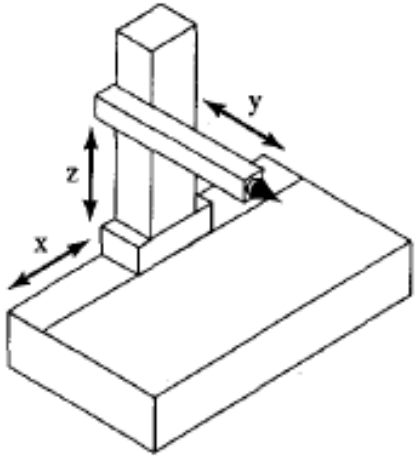
Cantilever

Mechanical Structure



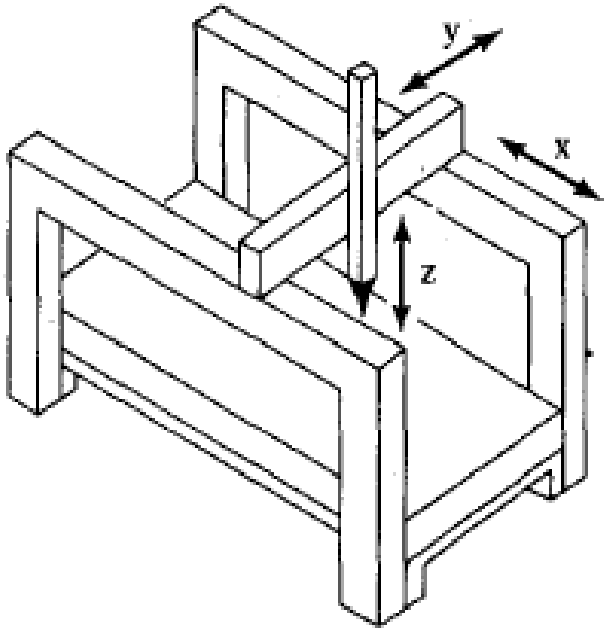
Fixed bridge

Mechanical Structure



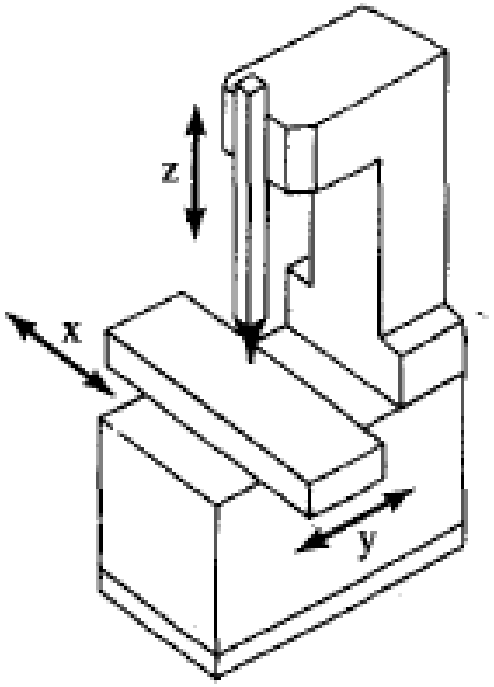
Horizontal arm

Mechanical Structure



Gantry

Mechanical Structure



Column

CMM controls

- Manual drive
- Manual drive and computer-assisted data processing
- Motor-driven CMM with computer-assisted data processing
- CMM with direct computer control

CMM programming

- Manual lead through
- Off-line programming
  - ✓ Motion commands
  - ✓ Measurement commands
  - ✓ Report formatting commands
  - ✓ CAD programming
    - Dimensional Measuring Interface Standard (DMIS)
- Other software

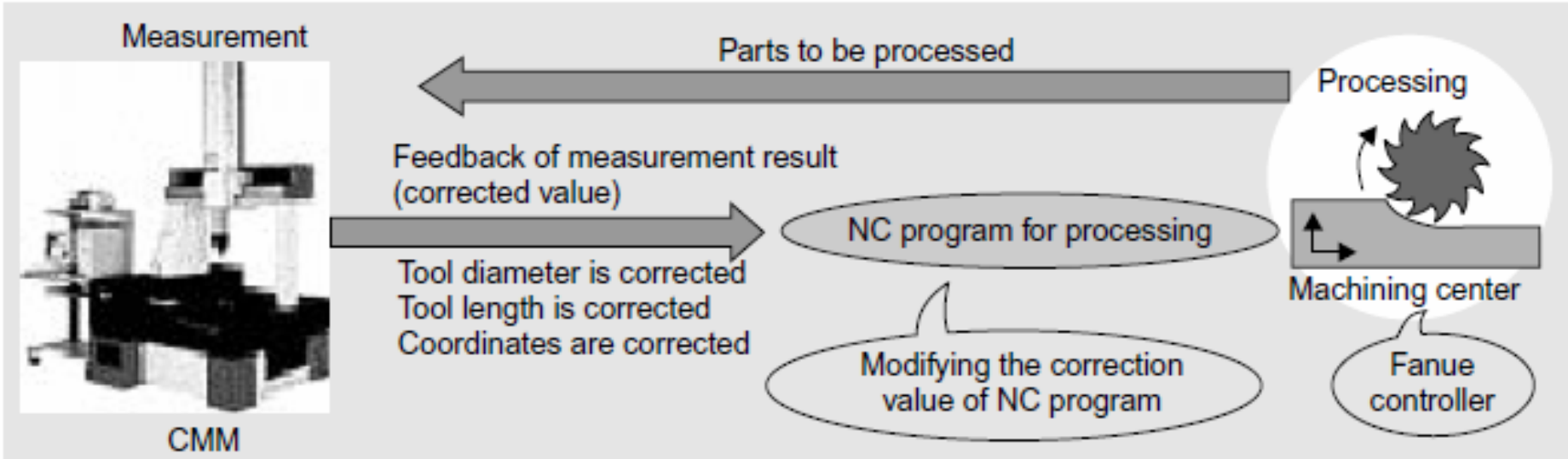
CMM applications

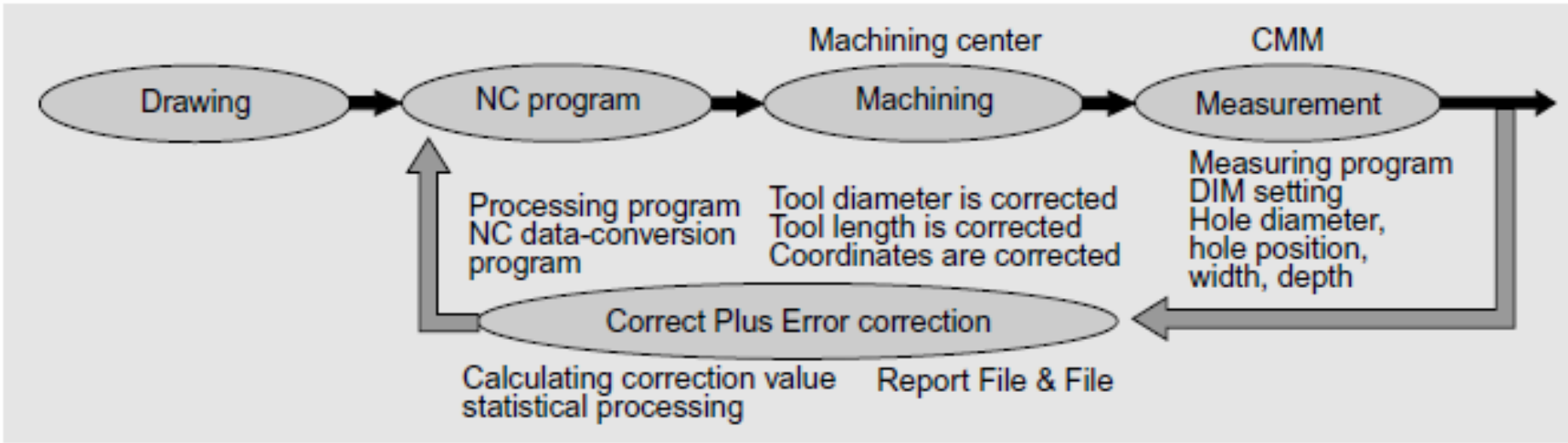
- Many inspectors performing repetitive manual inspection operations
- Post-process inspection
- Measurements of geometric features requiring multiple contact points
- Multiple setups are required if parts are manually Inspected
- Complex part geometry
- High variety of parts to be inspected
- Repeat orders

CMM benefits

- Reduced inspection cycle time
- Flexibility
- Reduced operator error
- Greater accuracy and precision
- Avoidance of multiple setups

Importance to FMS



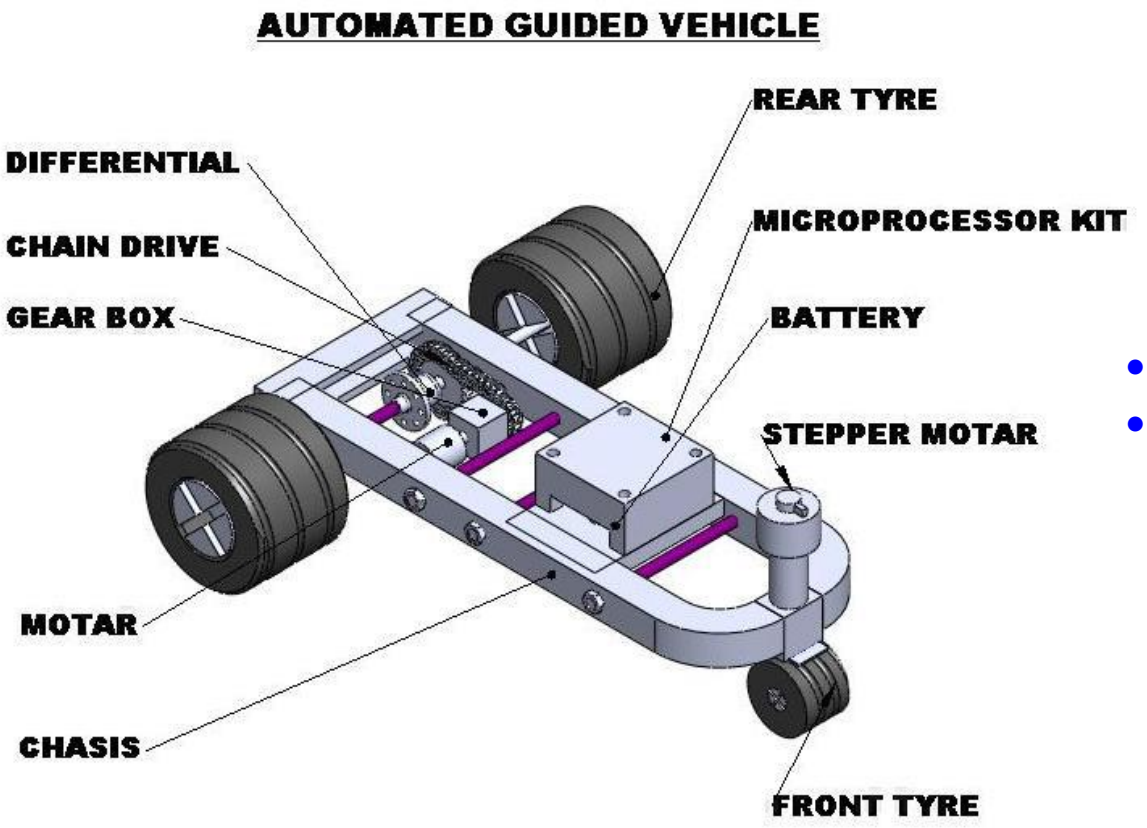


AUTOMATED GUIDED VEHICLE (AGV)

CONTENT

- Introduction
- Types of AGVS
- AGV Guidepaths
- Navigation system of AGVS
- Path decisions in AGVS
- AGV applications

Introduction



- Differential speed control
- Steered wheel control

Types of AGVS

Towing AGV

Unit load AGV

Fork truck AGV

Pallet truck AGV

Towing/Tug AGVS

- Most Productive, can have multiple trailers
- Limitation: Do not have reverse
- Advantages: First AGV technology, good for continued use in changing environments, can have different hitches
- Possible use: hauling bins of materials to a station

- (Tuggers & Tow Vehicles-Automated Guided Vehicles (AGV) Type)

Unit Load AGVS

- Most traditional, also called top carrier
- Interact with cranes, stands, and conveyors
- Can maneuver well in small spaces
- Carries loads such as racks, drums, or racks

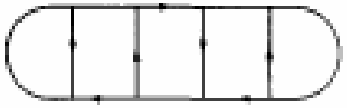
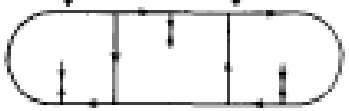
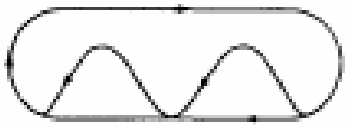
(Unit Load Automatic Guided Vehicles)

Forklift Truck AGVS

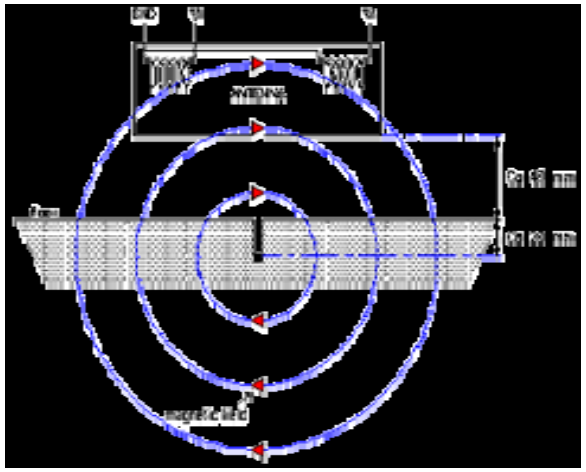
- Disadvantages: new technology
- Advantages: Designed for rugged conditions
- Can stack things in levels

(Forklift AGVs)

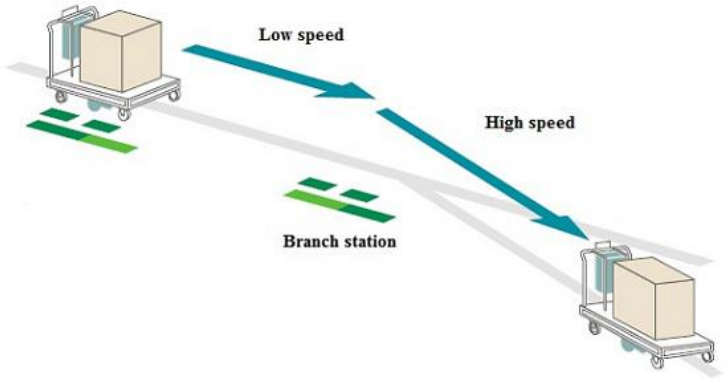
AGV Guidepaths

Guidepath Pattern	Type	Functional Layout
Open in-line	Single	
	Multiple	
	Intersecting	
Open branched	Simple	
	Complex	
Closed loop	Continuous	
	Joined continuous	
	Intersecting continuous	
	Intersecting and joined continuous	
Webbed	Free form	

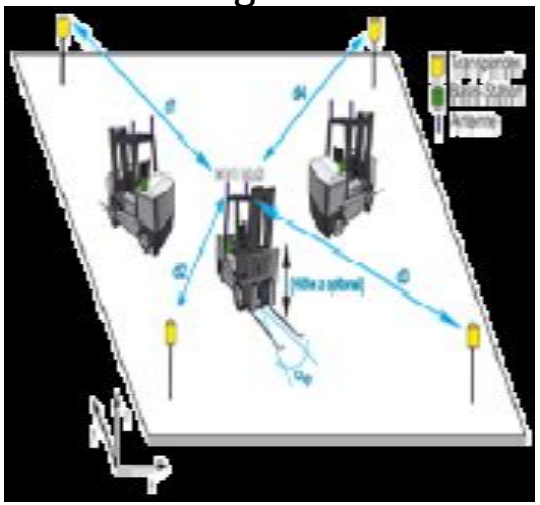
Navigation system of AGVS



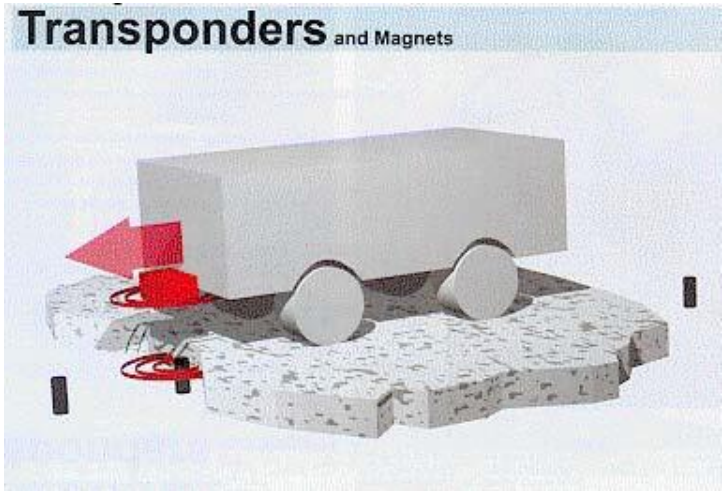
Wire guidance



Tape guidance



Laser guidance



Gyroscope guidance

Path decisions in AGVS

- Frequency select mode
- Path select mode
- Magnetic tape mode

AGV applications

- Repetitive movement of materials
- Regular delivery
- Medium throughput
- On-time delivery is required
- Material tracking is important

Applications

Major Industries that use AGVS

- Aerospace
- Apparel
- Automotive
- Beauty Products
- Books and Library Systems
- Dairy
- Food and Beverage
- Mail Order Fulfillment
- Office and Computer Equipment
- Pharmaceuticals and Health Care
- Refrigerator and Freezer Applications
- Retail
- Sporting Goods
- Textiles

Applications that Utilize AGVS

- Archive Systems
- Cross Docking
- Distribution
- High Density Storage
- High Speed Sortation
- Material Flow and Transport
- Production and Manufacturing Delivery Systems
- Production and Manufacturing Support Systems
- Warehouse Management and Control
- Work-In-Process Buffers

Standards

- Specialized AGVS are Modified Standard Models
  - Light Load AGVS
    - Designed to carry light loads
  - Assembly Line AGVS
    - Designed to be used in a serial manufacturing process

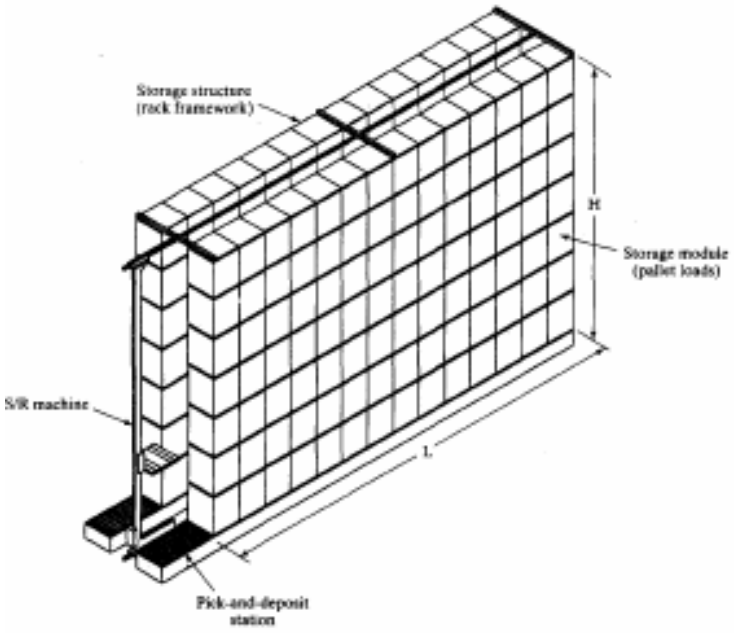
AUTOMATED STORAGE & RETRIEVAL SYSTEM (AS/RS)

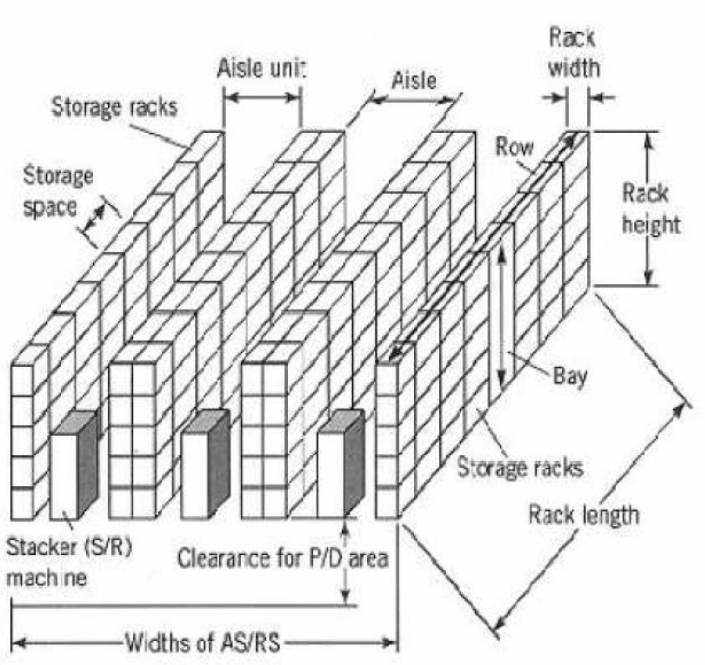
CONTENT

- Introduction
- Objectives of AS/RS
- Types of AS/RS
- Components of an AS/RS
- AS/RS rack size

Introduction

- An automated storage/retrieval system (AS/RS) can be defined as storage system that performs storage and retrieval operations with speed and accuracy under a defined degree of automation.

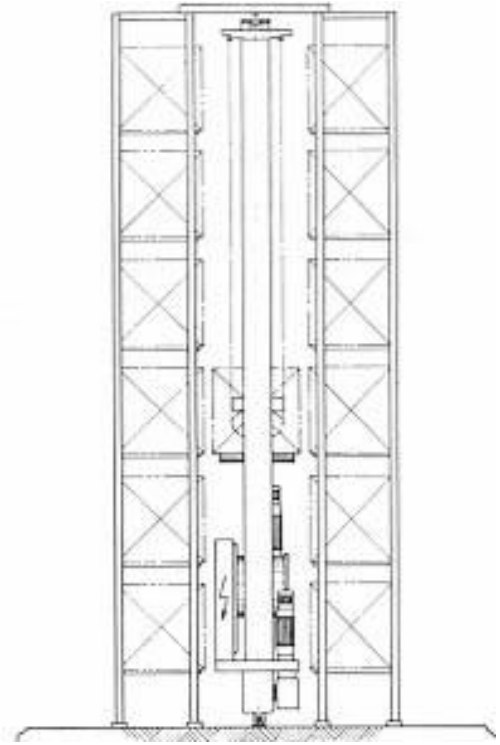


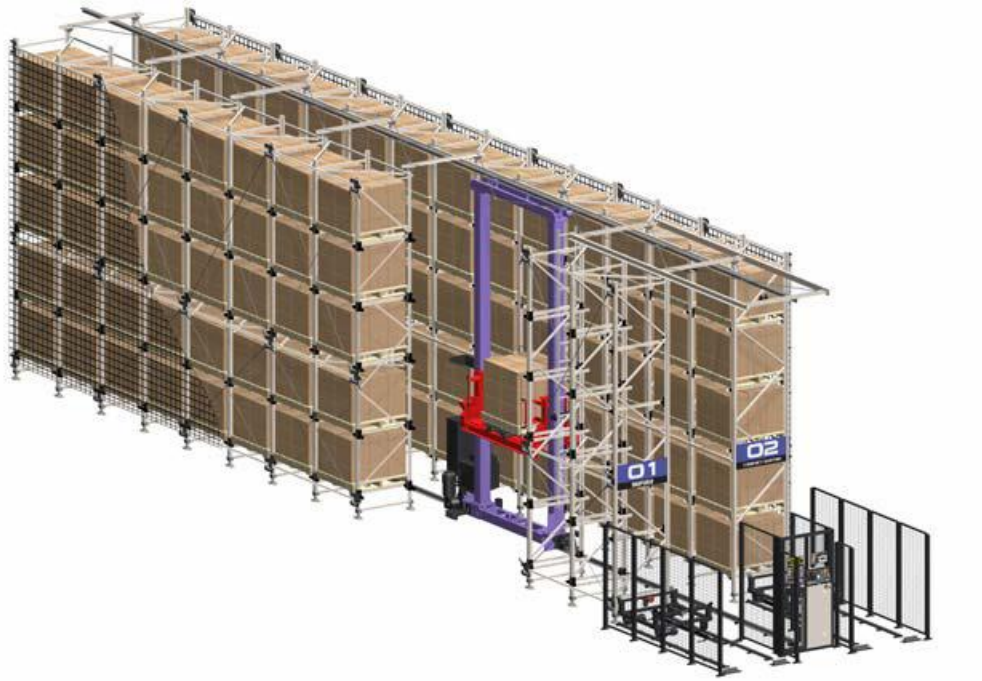


Objectives of AS/RS

- Improving control of material
- Reducing inventory
- Eliminating excessive & repetitive handling of material
- Increasing utilization of space
- Reducing product losses
- Improving safety, security & work environment

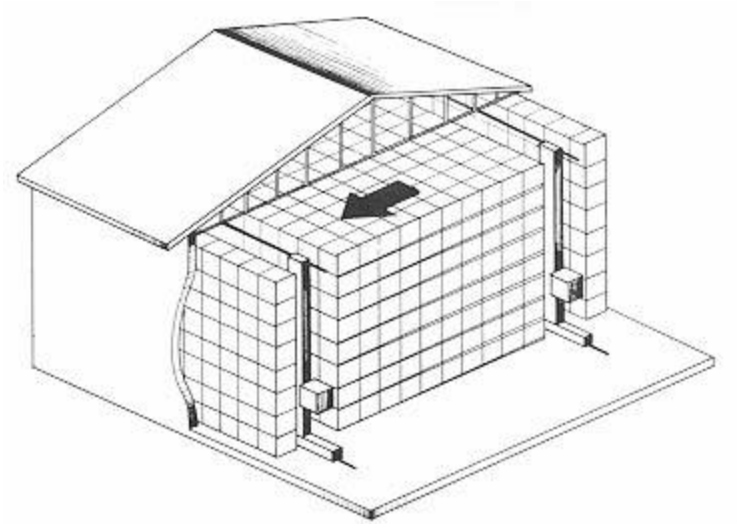
Types of AS/RS

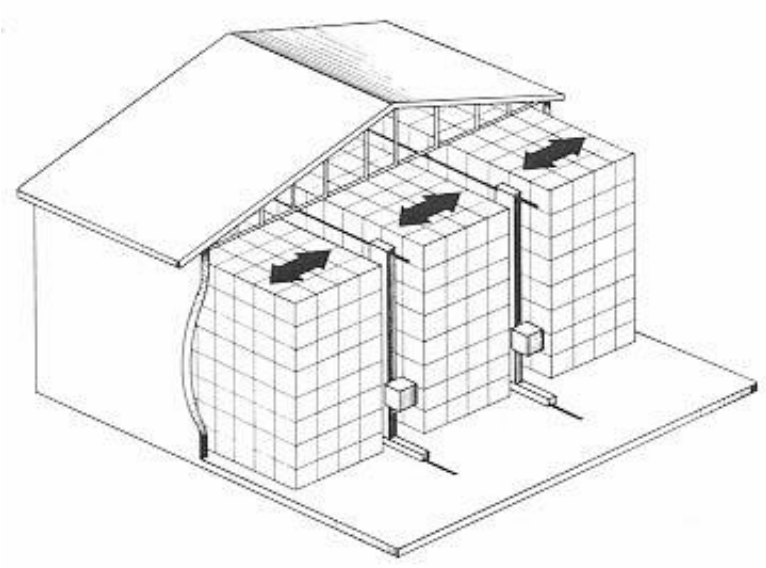




Unit load AS/RS

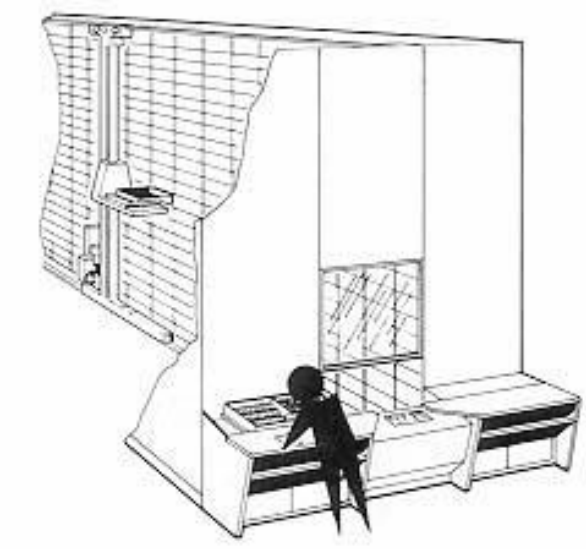
Types of AS/RS





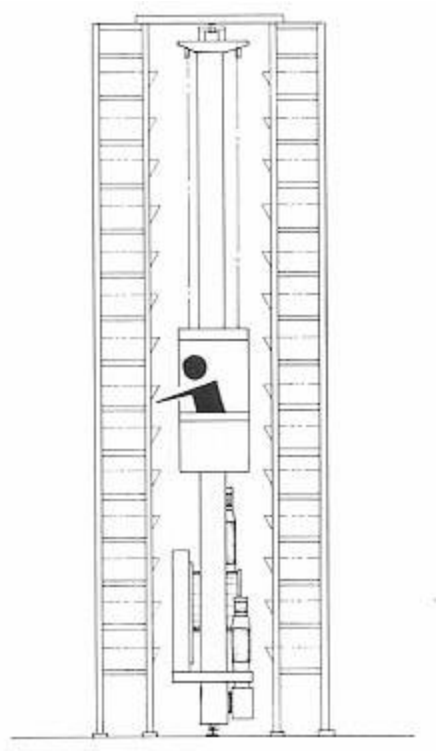
Deep lane AS/RS

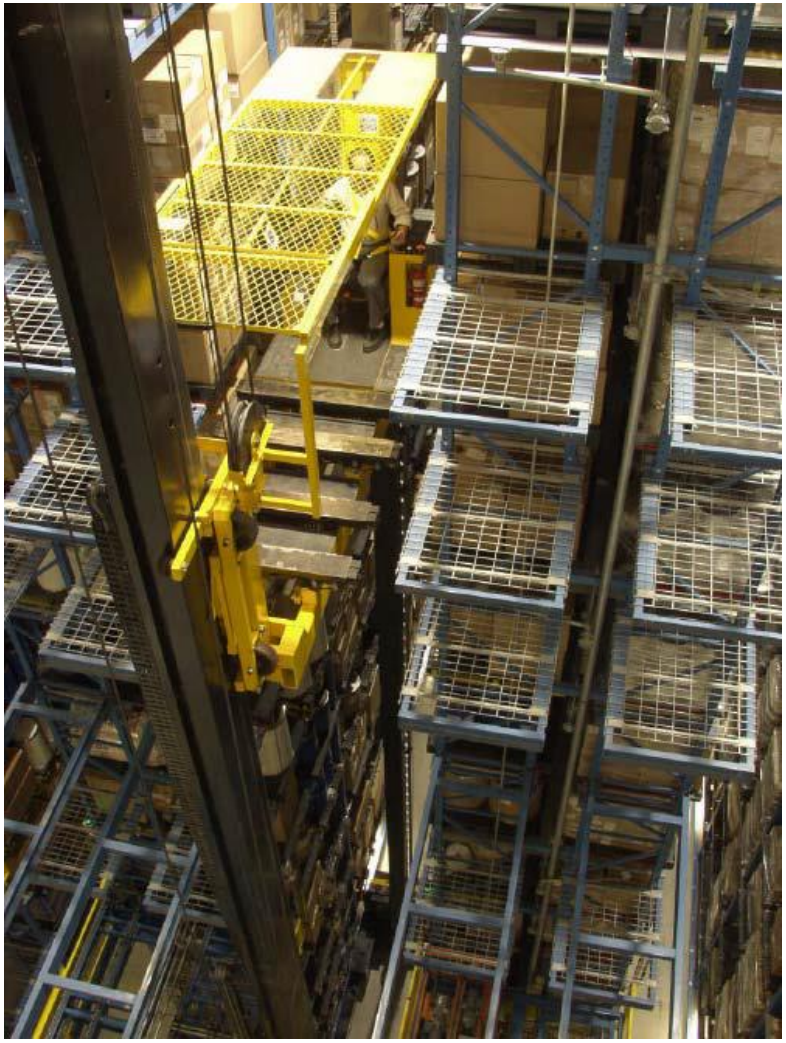
Types of AS/RS



Mini load AS/RS

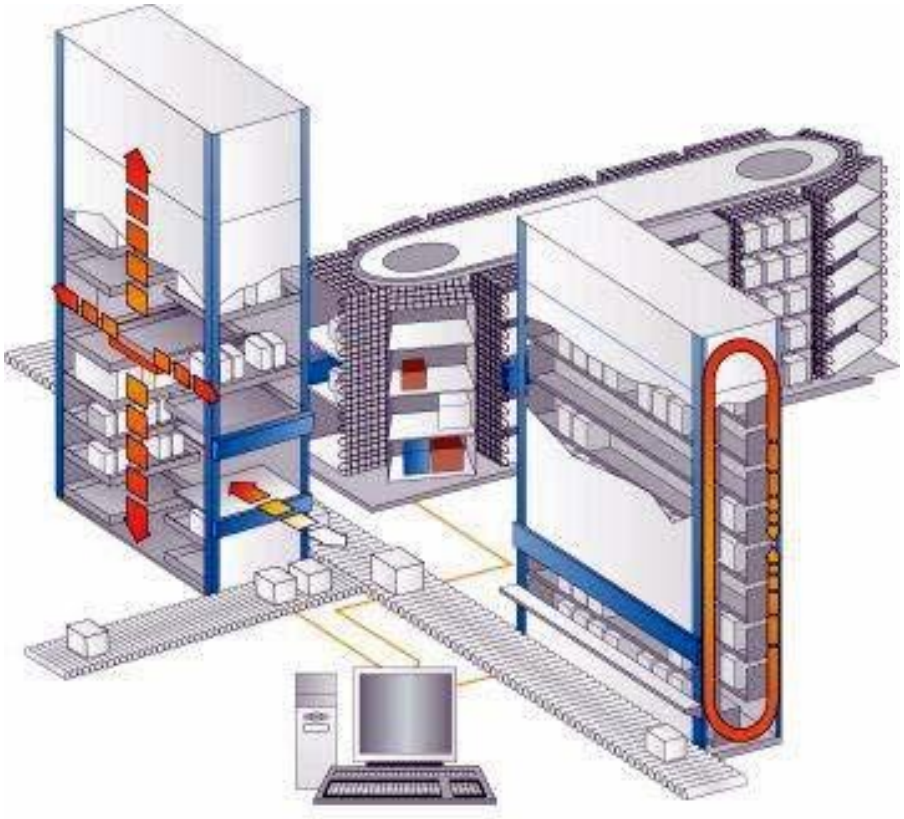
Types of AS/RS





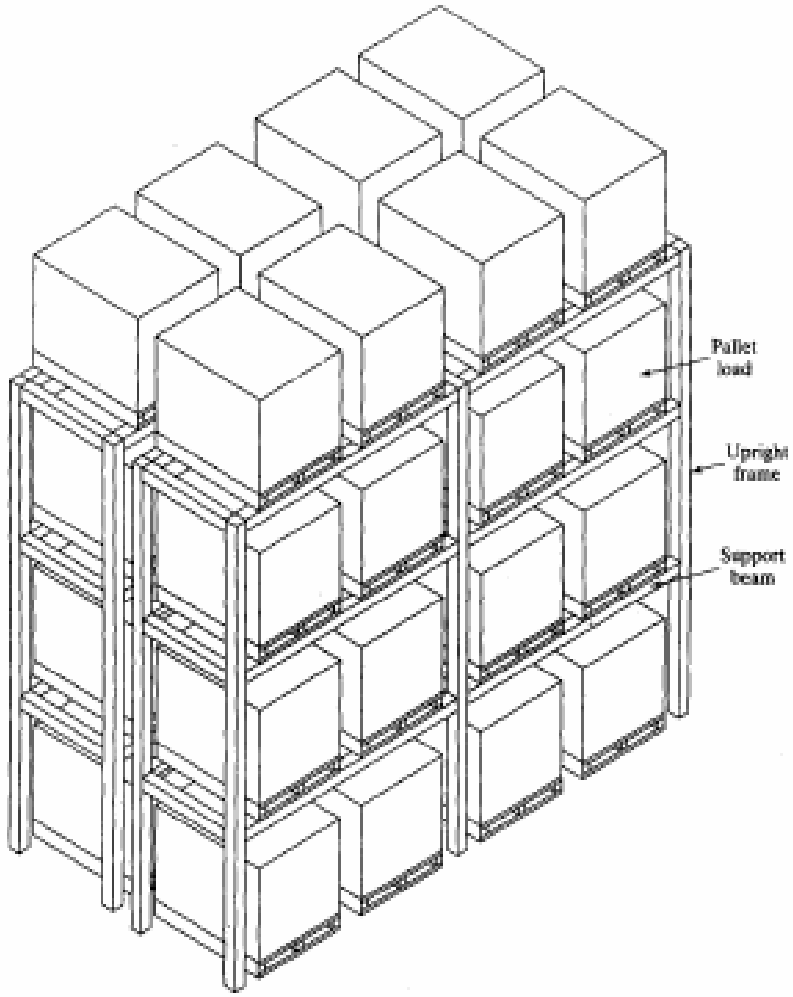
Man-on-board AS/RS

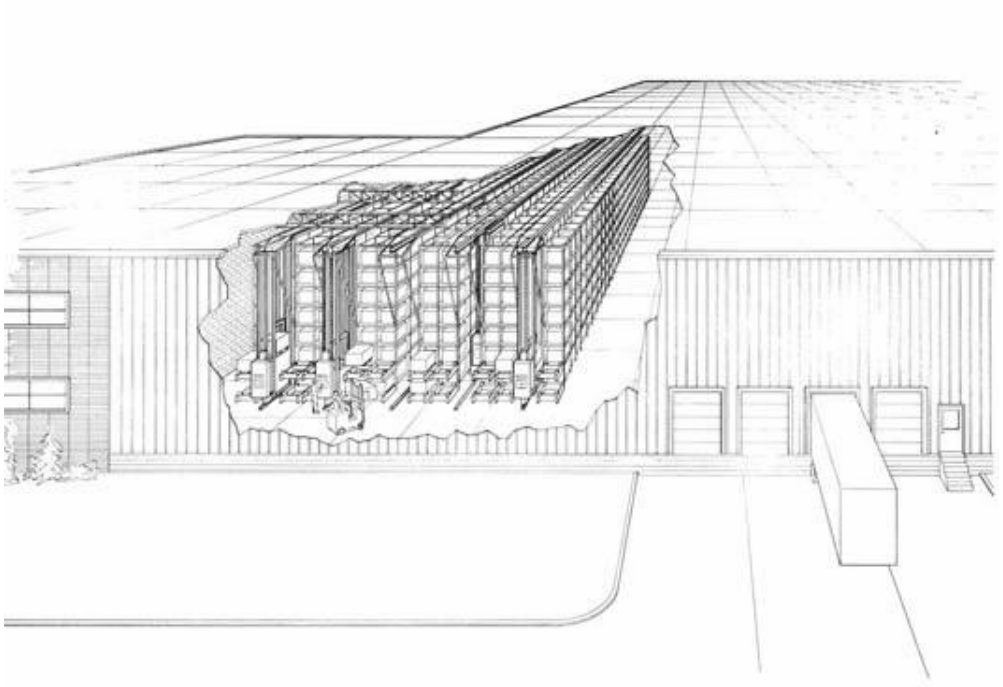
Types of AS/RS



Vertical lift AS/RS

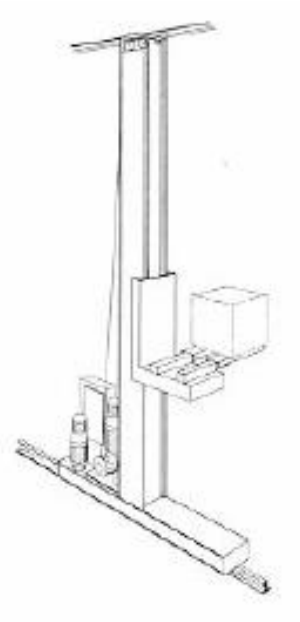
Components of an AS/RS



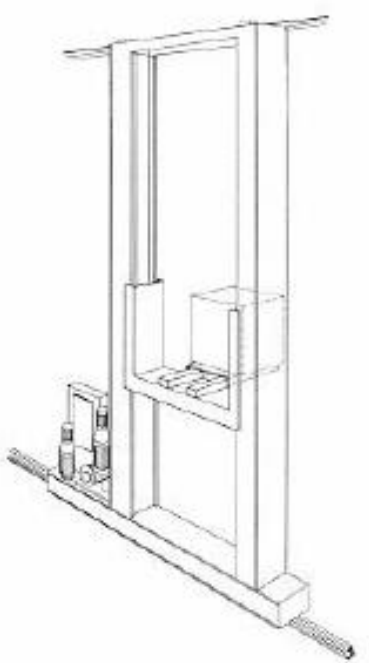


Storage structure

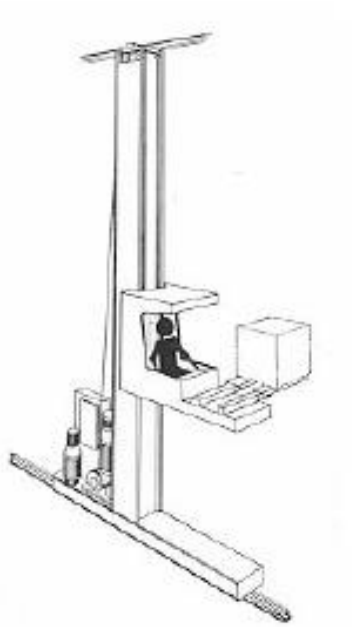
Components of an AS/RS



Single mast



Double mast



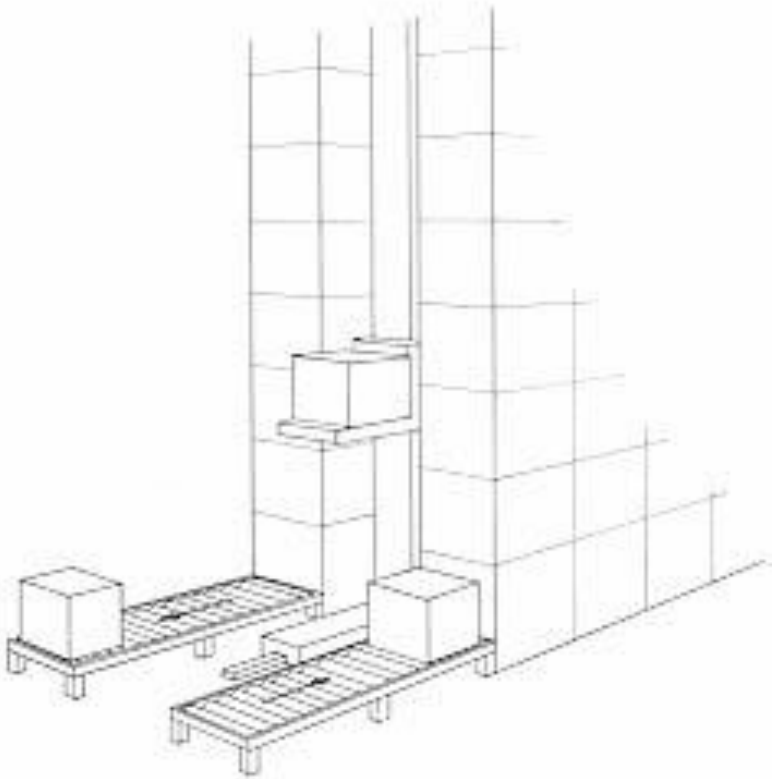
Man-on-board

Storage / Retrieval machine

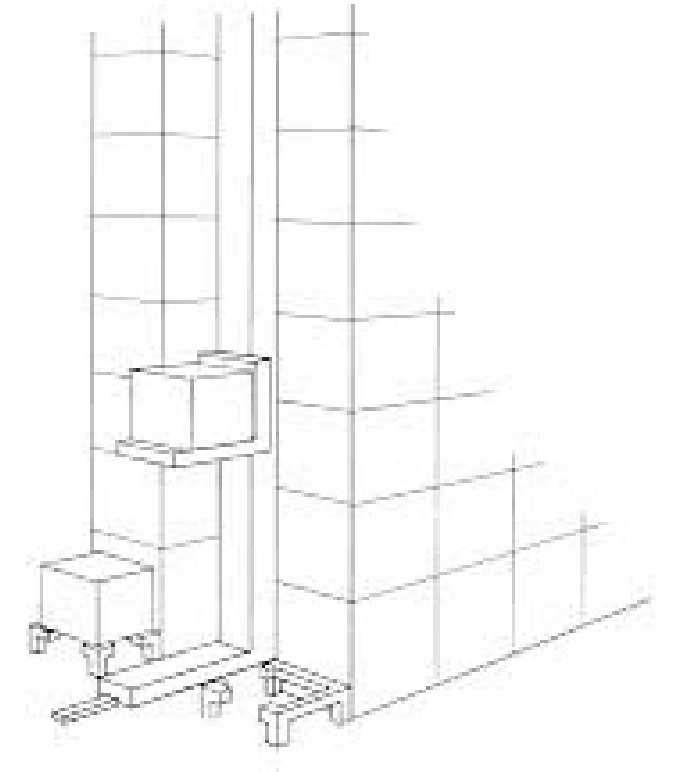
Components of an AS/RS

Storage modules

Components of an AS/RS



Conveyor



Fixed

Pick and deposit station