A seminar on

“AUTOMATED GUIDED VEHICLES”

ATHIPALAYAM COIMBATORE

REVOLUTION THROUGH TECHNOLOGY

764 - SRIPC

CONTENTS

- Introduction
- History of AGV'S
- What is AGV?
- Types of AGV's
- Why consider AGV's
- Types of navigations in AGV's
- Applications of AGV's

Introduction

AGVs increase **efficiency** and **reduce costs** by helping to automate a manufacturing facility or warehouse.

AGVs can **carry loads or tow objects** behind them in **trailers**. The trailers can be used to move raw materials or finished product. The AGV can also store objects on a bed. some AGVs use fork lifts to lift objects for storage. AGVs are employed in nearly every industry, including, **paper, metals, newspaper and general manufacturing**.

Continued…

An AGV can also be called a **laser guided vehicle(LGV**) or self-guided vehicle (SGV). In Germany the technology is also called **Fahrerlose** Transport system (FTS) and in Sweden Forarlosa trucker.

AGVs are available in a variety of models and can be used to move products on an assembly line, transport goods throughout a plant or warehouse.

History of AGV'S

The first AGV was brought to market in the **1950s**, by **Barrett Electronics of Northbrook**, and at the time it was simply a tow truck that followed a wire in the floor instead of a rail. over the years the technology has become more sophisticated and today automated vehicles are mainly **Laser navigated** ex: LGV.

In an automated process, LGVs are programmed to communicate with other robots to ensure product is moved smoothly through the warehouse, whether it is being stored for future use or sent directly to shipping areas. Today the AGV plays an important role in the design of new **factories** and **warehouses.**

What is AGV?

AGV is a material handling system that uses independently operated, self-propelled vehicles guided along defined pathways.

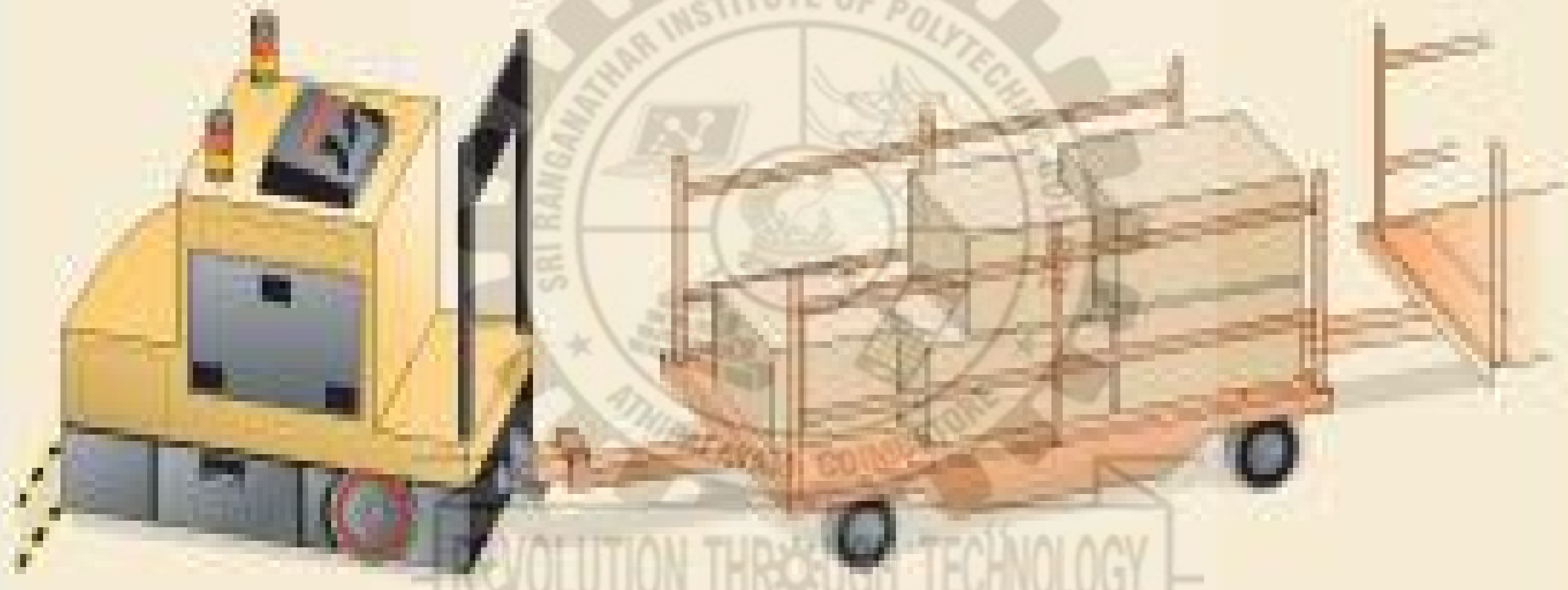
Types of AGV'S

- Driverless trains
- AGV'S pallet trucks
- Unit load carriers

Driverless trains:-

- It consists of a **towing vehicle** that pulls one or more trailers to form a train.
- This type is applicable in moving **heavy pay loads** over **large distance** in **warehouses or factories** with or without intermediate pickup and drop off points along the route.
- It consists of **5-10 trailers** and is an **efficient** transport system.
- The towing capacity is up to **60,000** pounds

Tugger



Driverless train

Like a locomotive pulling rail cars, a tugger pulls trailers through a facility to pick up and deliver products.

Driverless train

AGV Pallet Trucks:-

- Pallet trucks are used to move palletized loads along predetermined routes.
- The capacity of an AGV pallet truck ranges up to several thousand kilograms and some are capable of handling two pallets.
- It is achieved for vertical movement to reach loads on racks and shelves.

AGV Pallet Truck

AGV Pallet Truck

Unit load carriers:-

- These are used to move **unit loads** from one station to another.
- It is also used for **automatic loading** and **unloading** of pallets by means of rollers.
- Load capacity ranges up to **250 kg** or less.
- Especially these vehicles are designed to move **small** loads.

Unit load

Unit load carrier

Typically used in totally-automated processes, unit load AGV's carry pallets, slipsheets or cartons on their decks. Unit load vehicles are designed to interface with automated equipment, like conveyors.

Unit load carrier

Why consider AGVs?

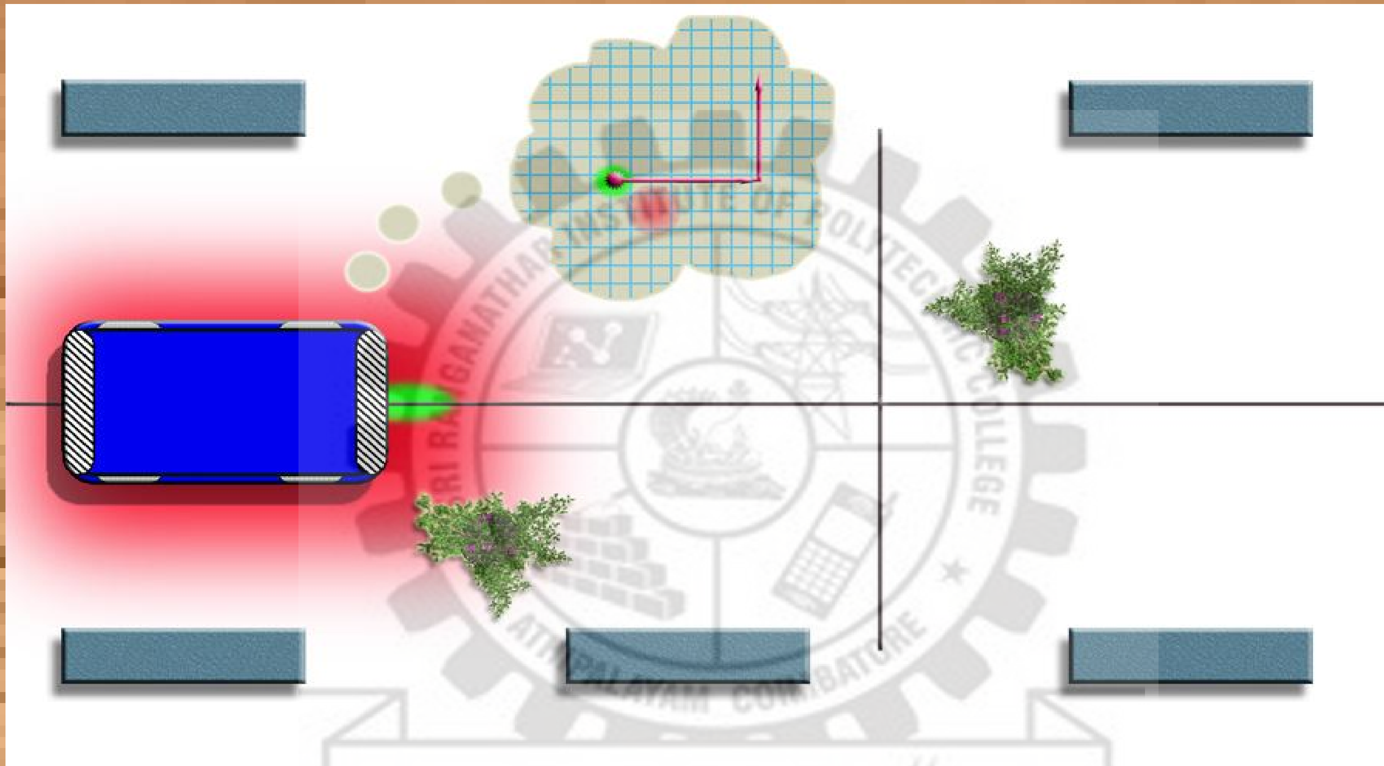
- Reduces the labor cost.
- Flexible.
- Intelligent.
- Time consuming.
- Can significantly reduce production & warehouse costs.
- Transforming the materials handling industry.

Types of navigation in AGV'S

- Wired navigation
- Guide tape navigation
- Laser target navigation

Wired navigation

- The wired sensor is placed on **bottom** of the AGV'S and is placed facing the **ground**.
- A **slot** is cut in the **ground** and a wire is placed approximately **1 inch** below the **ground**.
- The **sensors** detects the **radio frequency** being transmitted from the **wire** and follows it.



wired navigation AGV’S

Guide tape navigation

- The AGV'S(some known as automated guided carts or AGC'S) use **magnetic tape** for the guide path.
- The AGC'S is fitted with the appropriate **guide sensors** to follow the **path** of the **tape**.
- It is considered a "**passive**" system since it does not require the guide medium to be energized as wire does.

Guide tape navigation AGV'S

Laser target navigation

- The AGV'S carry's a **laser** transmitter and **receiver** on a rotating **turret**.
- The **laser** is sent off then received again the **angle** and **distances** are **automatically** calculated and stored into AGV'S **memory**.
- The AGV'S has **reflector map** stored in **memory** and can correct its position based on **errors** between the expected and received measurements.

Continued…

- It can then **navigate** to a destination target using the constantly updating position.

Laser target navigation AGV'S

Common AGV Applications

Automated Guided Vehicles can be used in a wide variety of applications to **transport** many different types of material including **pallets, rolls, racks, carts, and containers.**

Raw Material Handling:-

AGVs are commonly used to transport **raw materials** such as **paper, steel, rubber, metal, and plastic.** This includes transporting materials from receiving to the **warehouse**, and **delivering** materials directly to production lines.

Work-in-Process Movement:-

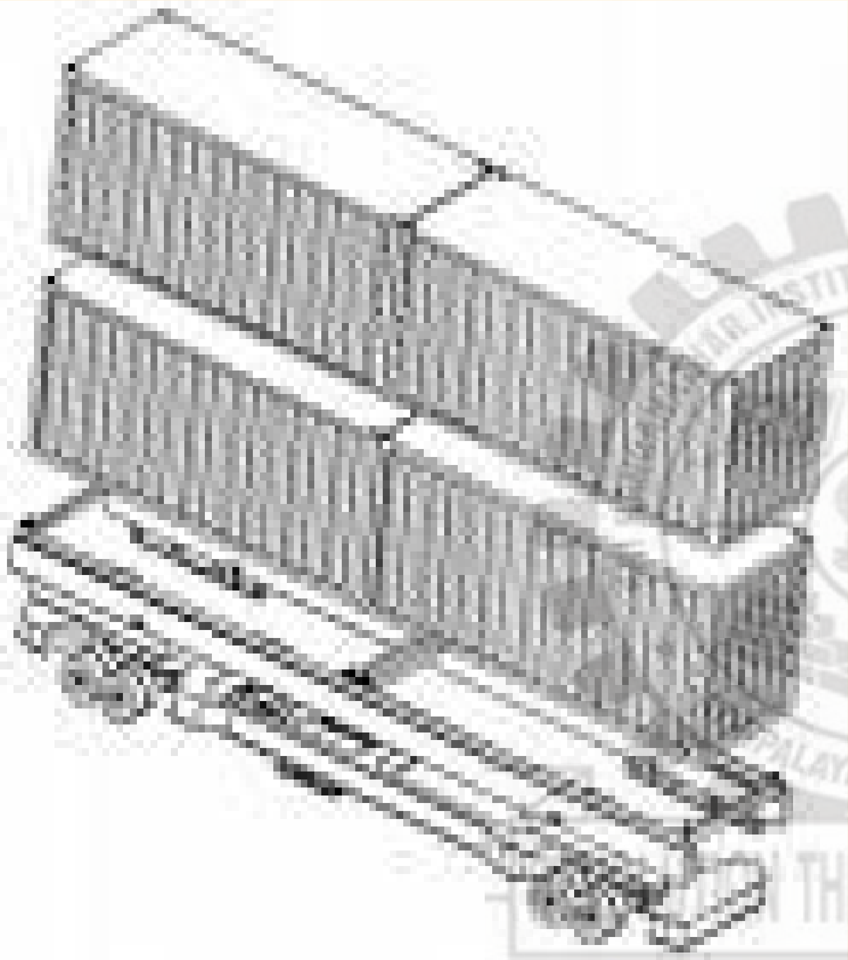
Work-in-Process movement is one of the first applications where automated guided vehicles were used, and includes the repetitive **movement** of **materials** throughout the manufacturing process.

Pallet Handling:-

Pallet handling is an extremely popular application for AGVs as repetitive movement of pallets is very common in manufacturing and distribution facilities.

Finished Product Handling:-

Moving **finished** goods from **manufacturing** to **storage** or shipping is the final movement of materials before they are delivered to customers. These movements often require the gentlest material handling because the products are complete and subject to damage from rough handling.



Pallet handling

Finished goods handling

Thank you

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CONCURRENT ENGINEERING

Basic Tenets of Concurrent Engineering

- -Doing things simultaneously
- -Focusing on the Process
- -Converting hierarchical organizations into teams

Concurrent Engineering

- Concurrent Engineering = Teamwork
- -The more communication exists, the better the product
- Balancing of Needs
- -Customer, Supplier, Engineers, Marketing,and Manufacturing needs
- Management

  -Good mgmt is vitally important

  -Encourage communication

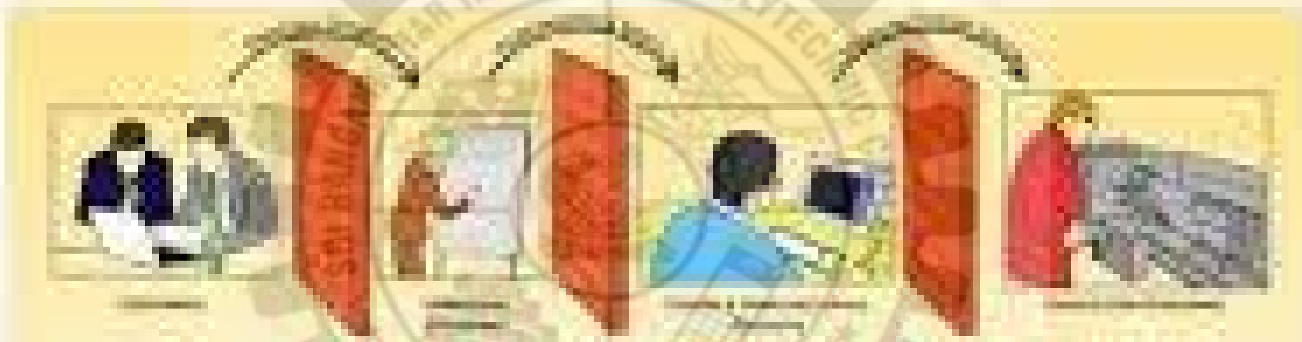
  -Strong mgmt support

Need for Concurrent Engineering

In today's business world, corporations must be able to

- react to the changing market needs rapidly, effectively, and responsively.
- to reduce their time to market and adapt to the changing environments.
- decisions must be made quickly and they must be done right the first time out.
- concurrent engineering is a process th at must be reviewed and adjusted for continuous improvements of engineering and business operations.

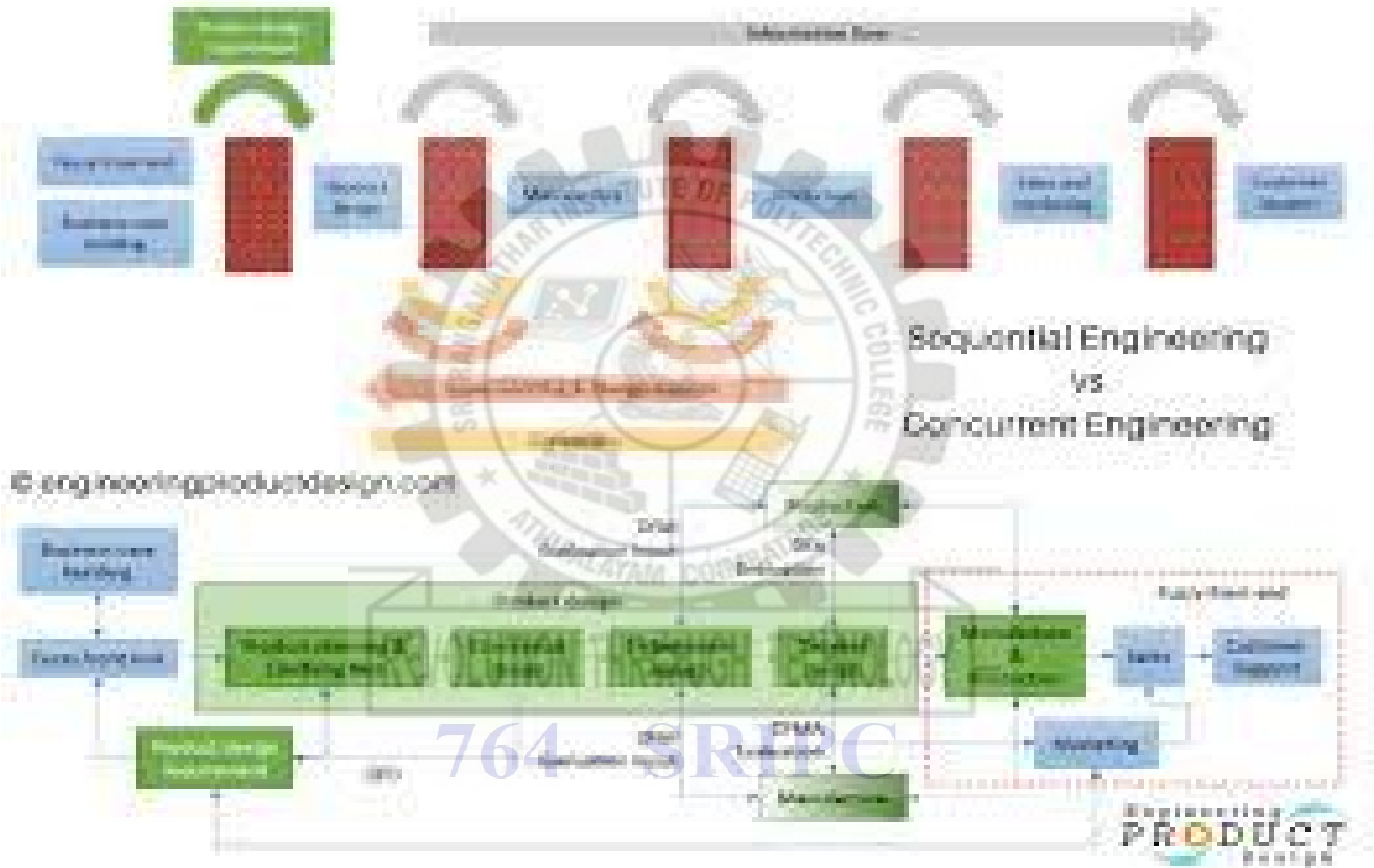
Concurrent Engineering



Traditional Process = Linear

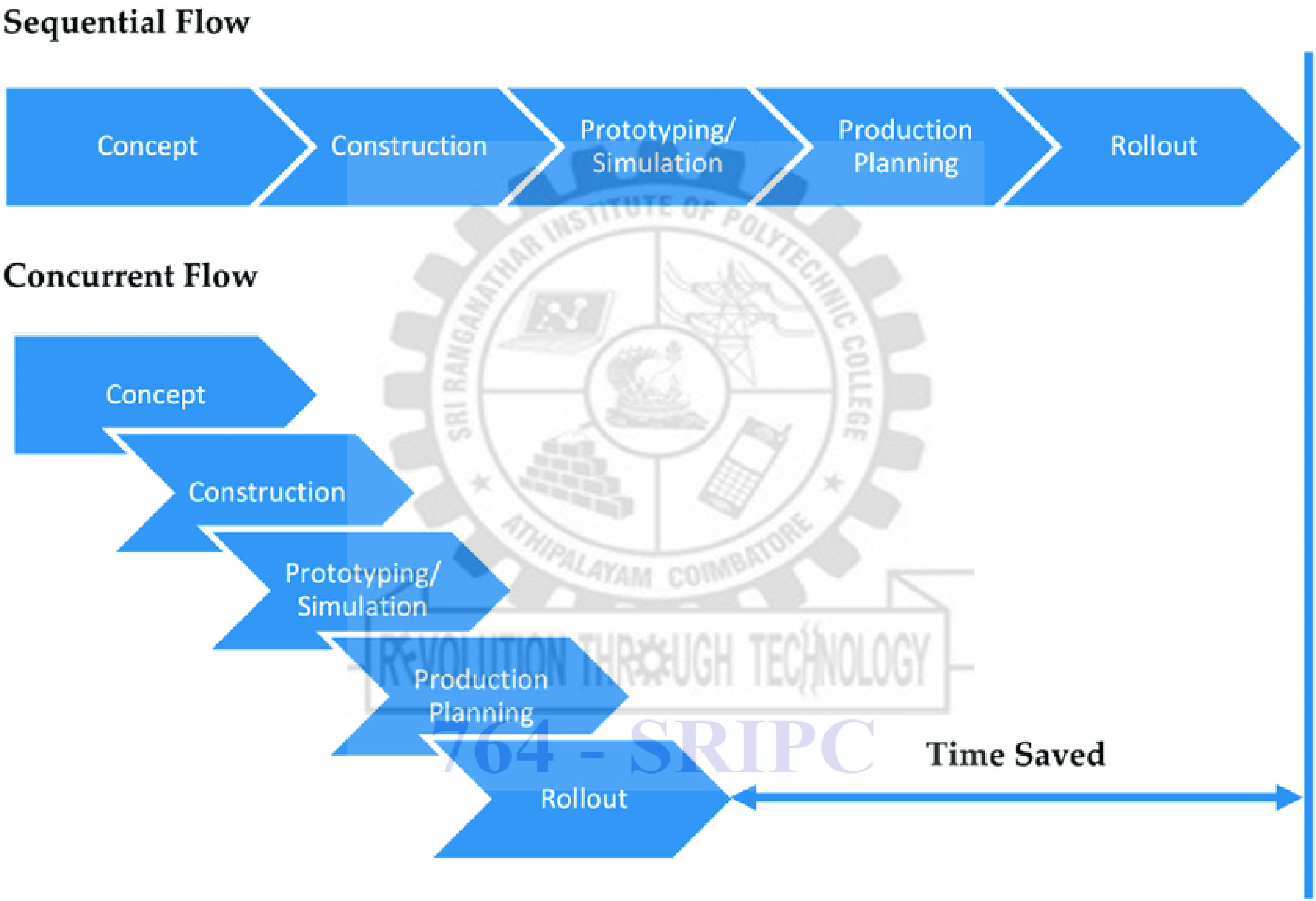
Vs

Concurrent Engineering = Team collaboration


Sequential Engineering
vs
Concurrent Engineering
© engineeringproductdesign.com

Concurrent engineering

Tech Design


Sequential Flow
Concept
Construction
Prototyping/
Simulation
Production
Planning
Rollout
Concurrent Flow
Concept
Construction
Prototyping/
Simulation
Production
Planning
Rollout
Time Saved

SEQUENTIAL ENGG vs CONCURRENT ENGG

SEQUENTIAL ENGG — CONCURRENT ENGG

- Across the wall method - team work
- Increased product development lead time - reduced
- No integration between departments - close integration between the dept
- increased production cost -decreased
- No control - greater control design
- Quick optimization of design - backtracking method
- Quality with increased lead time - improved quality
- Cost of product design changes is more -less
- No special systems are followed - application of DFMA &FMEA is possible
- Less profit - profit increases

3 Main Areas to Concurrent Engineering

- 1) People
- 2) Process
- 3) Technology

1: People

- -Formation of teams
- -Training

    computer aided drafting

    problem-solving and conflict resolution

2: Process

- -Changes in your processes
- -Be open to change

3: Technology

- -CAD/CAM
- -Software, Hardware, and Networking

DESIGN SUPPORT TOOLS IN CONCURRENTENGINEERING

- Quality Function Deployment
- History…
- •1972
- •Japan
- •Mitsubishi Heavy Industries Ltd
- .•Total Quality Managemen
- •Valuable tool
- •Underused
- •Fundamental to successt

QFD - Defined

- A quality assurance tool for profit and non-profit organizations aimed at locating customer needs and transcending those needs into product/service production stages, ensuring that customer needs are delivered in the end

FLEXIBLE MANUFACTURING SYSTEMS

FLEXIBLE MANUFACTURING SYSTEMS

MODELING AND ANALYSIS OF MANUFACTURING SYSTEMS

DEFINITION

A FLEXIBLE MANUFACTURING SYSTEM (**FMS**) IS A SET OF ***NUMERICALLY CONTROLLED MACHINE TOOLS*** AND ***SUPPORTING WORKSTATIONS*** CONNECTED BY AN ***AUTOMATED MATERIAL HANDLING SYSTEM*** AND CONTROLLED BY A ***CENTRAL COMPUTER***

ELEMENTS OF FMS

- AUTOMATICALLY REPROGRAMMABLE MACHINES.
- AUTOMATED TOOL DELIVERY AND CHANGING
- AUTOMATED MATERIAL HANDLING
- COORDINATED CONTROL

FMS FEATURES

- MANY PART TYPES CAN BE LOADED
- PARTS CAN ARRIVE AT MACHINES IN ANY SEQUENCE
- PARTS IDENTIFIED BY CODES
- MANY MACHINES CAN BE INCLUDED
- SMALL FMS LEAD TO FLEXIBLE CELLS

- EXPENSIVE TO IMPLEMENT BUT SAVINGS CAN BE SIGNIFICANT
- FLOOR SPACE REDUCIBLE BY 1/3
- EQUIPMENT UTILIZATION UP TO 85% OR MORE
- DETAILED PRODUCTION SEQUENCE NOT NEEDED WELL IN ADVANCE

MANUFACTURING FLEXIBILITY

- BASIC
  - ***MACHINE*** (VARIETY OF OPERATIONS)
  - ***MATERIAL HANDLING*** (PART MOBILITY AND PLACEMENT)
  - ***OPERATION*** (VARIETY OF OPERATIONS PRODUCING SAME PART FEATURES)

- SYSTEM
  - ***PROCESS*** (VARIETY OF PARTS PRODUCIBLE WITH SAME SETUP)
  - ***ROUTING*** (ABILITY TO USE DIFFERENT MACHINES UNDER SAME SETUP)
  - ***PRODUCT*** (CHANGEOVER)
  - ***VOLUME*** (PRODUCTION LEVEL)
  - ***EXPANSION*** (ADDED CAPACITY)

- AGGREGATED
  - ***PROGRAM*** (UNATTENDED RUNNING)
  - ***PRODUCTION*** (RANGES OF PARTS, PRODUCTS, PROCESSES, VOLUME, EXPANSION)
  - ***MARKET*** (COMBINATION OF PRODUCT, PROCESS, VOLUME AND EXPANSION)

COMMENTS

THE PART TYPES ASSIGNED TO THE FMS SHOULD HAVE SUFFICIENT PRODUCTION VOLUMES TO MAKE AUTOMATION ATTRACTIVE BUT INSUFFICIENT TO JUSTIFY DEDICATED PRODUCTION LINES

ORIGINS OF FMS

- LINK LINES (1960'S)
- NC MACHINES AND CONVEYORS
- BATCH PROCESSING

FMS PRIORITIES

- MEETING DUE DATES
- MAXIMIZING MACHINE UTILIZATION
- MINIMIZE THROUGHPUT TIMES
- MINIMIZE ***WIP*** LEVELS

FMS COMPONENTS

- MACHINES
- PART MOVEMENT SYSTEMS
- SUPPORTING WORKSTATIONS
- SYSTEM CONTROLLER

MACHINES

- PRISMATIC VS ROTATIONAL PARTS
- HORIZONTAL MACHINING CENTERS (HMC) AND HEAD INDEXERS (HI)
- TOOL MAGAZINES AND AUTOMATIC TOOL CHANGERS

PART MOVEMENT

- CONVEYORS
- TOW CARTS
- RAIL CARTS

SUPPORTING WORKSTATIONS

- LOAD/UNLOAD STATIONS
- AUTOMATIC PART WASHERS
- COORDINATE MEASURING MACHINES

CONTROLLER

- COMPUTER
- WORKER (ATTENDANT)
- TRACKING SYSTEM FOR
  - PARTS
  - MACHINES

COMPONENTS OF THE MANUFACTURING FACILITY

- FACILITY
- SHOP
- CELL
- WORKSTATION
- EQUIPMENT

BASIC STEPS IN DECISION HIERARCHY

- ***LONG TERM PLANNING OR SYSTEM DESIGN*** (PART TYPES & EQUIPMENT SELECTION)
- ***MEDIUM RANGE PLANNING OR SETUP*** (DAILY DECISIONS ABOUT PARTS & TOOLING)
- ***SHORT TERM OPERATION*** (SCHEDULING & CONTROL)

SYSTEM DESIGN

- PROBLEM: SELECTING SYSTEM SIZE, HARDWARE, SOFTWARE AND PARTS FOR THE ***FMS***
- SIZE & SCOPE ARE SELECTED ACCORDING TO CORPORATE STRATEGY
- HARDWARE & SOFTWARE SELECTED TO FIT SCOPE

SCHEDULING AND CONTROL

- BASIC PROBLEM AREAS
  - **SEQUENCING AND TIMING OF PART RELEASES TO THE SYSTEM**
  - **SETTING OF INTERNAL PRIORITIES IN THE SYSTEM**
  - **ABILITY OF SYSTEM TO TAKE CORRECTIVE ACTION WHEN COMPONENTS FAIL**

Flexible Assembly Systems

- For the combination of raw materials and components into products with functional characteristics.
- Automated vs manned systems
- Example: Vibratory bowl feeders and vision systems
- Role of Design for Assembly

FLEXIBLE MANUFACTURING SYSTEMS

...Thank you...

Content

- Introduction
- What is Rapid Prototyping?
- Why Rapid Prototyping?
- How does Rapid Prototyping Work?
- Applications of Rapid Prototyping
- Basic Process
- Advantages of Rapid Prototyping
- Disadvantage of Rapid Prototyping
- Conclusion
- References

Introduction

- Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data.
- What is commonly considered to be the first RP technique, Stereolithography, was developed by 3D Systems of Valencia, CA, USA. The company was founded in 1986, and since then, a number of different RP techniques have become available.

What is Rapid Prototyping?

- Rapid Prototyping is the "process of quickly building and evaluating a series of prototypes" early and often throughout the design process.
- Prototypes are usually incomplete examples of what a final product may look like.

Why Rapid Prototyping?

The reasons of Rapid Prototyping are

- To increase effective communication.
- To decrease development time.
- To decrease costly mistakes.
- To minimize sustaining engineering changes.

How does Rapid Prototyping Work?

- Rapid Prototyping, also known as 3D printing, is an additive manufacturing technology.
- The process begins with taking a virtual design from modeling or computer aided design (CAD) software.
- The 3D printing machine reads the data from the CAD drawing and lays down successive layers of liquid, powder, or sheet material — building up the physical model from a series of cross sections.
- These layers, which correspond to the virtual cross section from the CAD model, are automatically joined together to create the final shape.

Applications of Rapid Prototyping

RAPID TOOLING

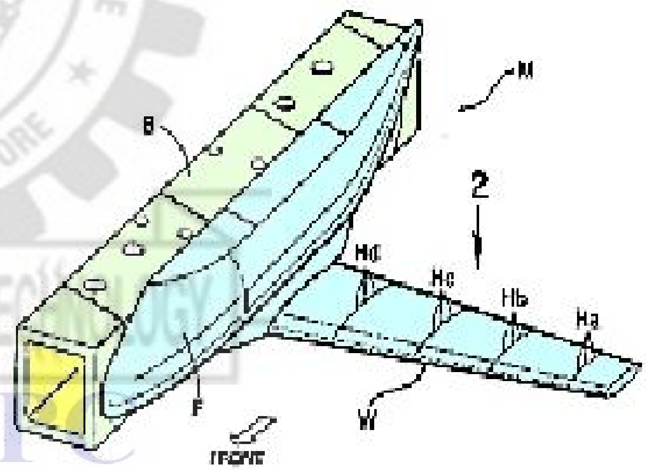
- Patterns for Sand Casting
- Patterns for Investment Casting
- Pattern for Injection moldings

RAPID MANUFACTURING

- Short productions runs
- Custom made parts
- On-Demand Manufacturing
- Manufacturing of very complex shapes

AEROSPACE & MARINE

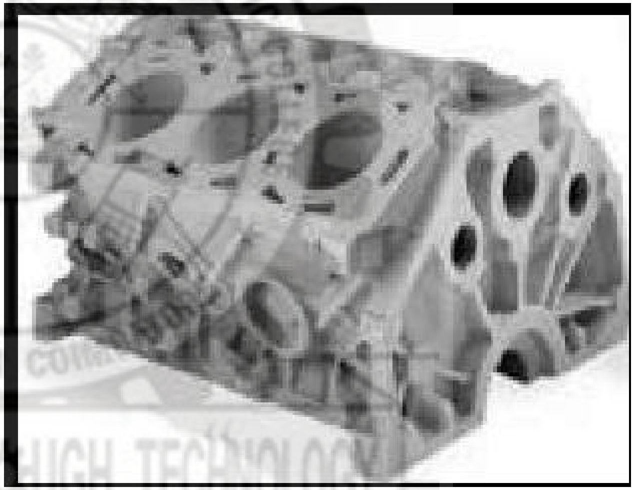
- Wind tunnel models
- Functional prototypes
- Boeing’s On-Demand-Manufacturing



Wind tunnel model by additive fabrication.

AUTOMOTIVE RP SERVICES

- Needed from concept to production level
- Reduced time to market
- Functional testing
- Dies & Molds



BIOMEDICAL APPLICATIONS - I

- Prosthetic parts
- Presurgical planning models
- Use of data from MRI and CT scan to build 3D parts
- 3D visualization for education and training

BIOMEDICAL APPLICATIONS - II

- Customized surgical implants
- Mechanical bone replicas
- Anthropology
- Forensics

ARCHITECTURE

- 3D visualization of design space
- Iterations of shape
- Sectioned models

FASHION & JEWELRY

- Shoe Design
- Jewelry
- Pattern for lost wax
- Other castings

Basic Process

- Although several rapid prototyping techniques exist, all employ the same basic five-step process. The steps are:
- 1. Create a CAD model of the design
- 2. Convert the CAD model to STL format
- 3. Slice the STL file into thin cross-sectional layers
- 4. Construct the model one layer atop another
- 5. Clean and finish the model

Advantages of Rapid Prototyping

- · Today's automated, toolless, patternless RP systems can directly produce functional parts in small production quantities.
- · Parts produced in this way usually have an accuracy and surface finish inferior to those
made by machining.
- · However, some advanced systems are able to
produce near tooling quality parts that are close to or are the final shape.
- · The parts produced, with appropriate post processing, will have material qualities and properties close to the final product.
· More fundamentally, the time to produce any part --- once the design data are available --- will be fast, and can be in a matter of hours.

Disadvantage of Rapid Prototyping

- One more disadvantage of rapid prototyping is that it may not be suitable for large sized applications.

  The producer may produce an inadequate system that is unable to meet the overall demands of the organization. Too much involvement of the user might hamper the optimization of the program.
  The producer may be too attached to the program of rapid prototyping, thus it may lead to legal involvement.

Conclusion

- Finally, the rise of rapid prototyping has spurred progress in traditional subtractive methods as well.
- Advances in computerized path planning, numeric control, and machine dynamics are increasing the speed and accuracy of machining.
- Modern CNC machining centers can have spindle speeds of up to 100,000 RPM, with correspondingly fast feed rates.
- 34 Such high material removal rates translate into short build times.

References

- www.google.com
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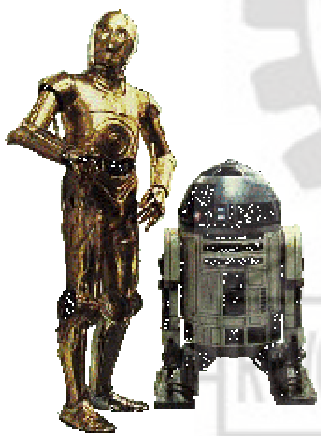
Thanks

Introduction to Robotics

A common view : Robots as Humanoids



We will be studying Industrial manipulator type Robots.

Agenda

- Introduction to Robotics
- Classification of Robots
- Robot accessories
- Robot coordinates
- Work volumes and Reference Frames
- Robot Programming
- Robot Applications in Lean Mfg.

Robotics Timeline

- **1922 Czech author Karel Capek wrote a story called Rossum’s Universal Robots and introduced the word “Rabota”(meaning worker)**
- **1954 George Devol developed the first programmable Robot.**
- **1955 Denavit and Hartenberg developed the homogenous transformation matrices**
- **1962 Unimation was formed, first industrial Robots appeared.**
- **1973 Cincinnati Milacron introduced the T3 model robot, which became very popular in industry.**
- **1990 Cincinnati Milacron was acquired by ABB**

Robot Classification

The following is the classification of Robots according to the Robotics Institute of America

- Variable-Sequence Robot : A device that performs the successive stages of a task according to a predetermined method easy to modify
- Playback Robot :A human operator performs the task manually by leading the Robot
- Numerical Control Robot : The operator supplies the movement program rather than teaching it the task manually.
- Intelligent Robot : A robot with the means to understand its environment and the ability to successfully complete a task despite changes to the environment.

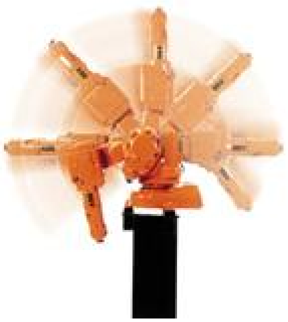
ROBOT

- Defined by Robotics Industry Association (RIA) as
  - a re-programmable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motion for a variety of tasks
- possess certain anthropomorphic characteristics
  - mechanical arm
  - sensors to respond to input
  - Intelligence to make decisions

Robot Accessories

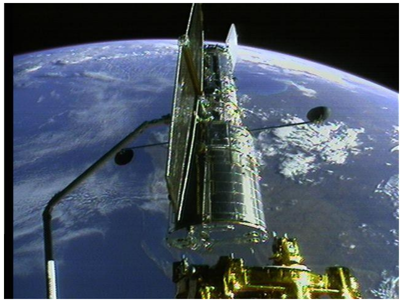
A Robot is a system, consists of the following elements, which are integrated to form a whole:

- Manipulator / Rover : This is the main body of the Robot and consists of links, joints and structural elements of the Robot.



- End Effector : This is the part that generally handles objects, makes connection to other machines, or performs the required tasks.

It can vary in size and complexity from a endeffector on the space shuttle to a small gripper



Accessories

- **Acutators : Actuators are the muscles of the manipulators. Common types of actuators are servomotors, stepper motors, pneumatic cylinders etc.**

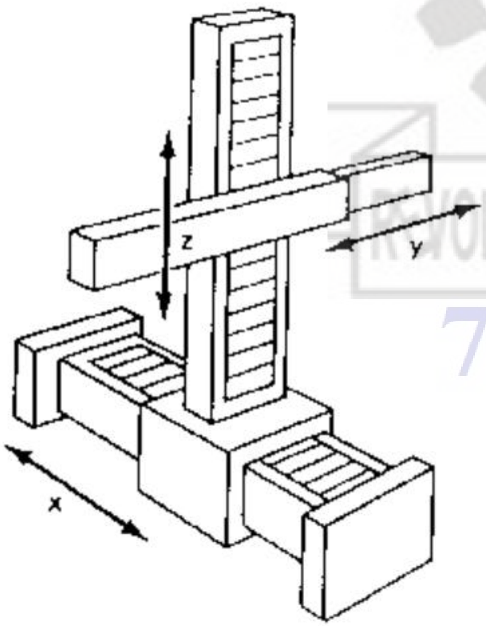
- **Sensors : Sensors are used to collect information about the internal state of the robot or to communicate with the outside environment. Robots are often equipped with external sensory devices such as a vision system, touch and tactile sensors etc which help to communicate with the environment**

- **Controller : The controller receives data from the computer, controls the motions of the actuator and coordinates these motions with the sensory feedback information.**

Robot Configurations

Some of the commonly used configurations in Robotics are

- **Cartesian/Rectangular Gantry(3P) :** These Robots are made of 3 Linear joints that orient the end effector, which are usually followed by additional revolute joints.



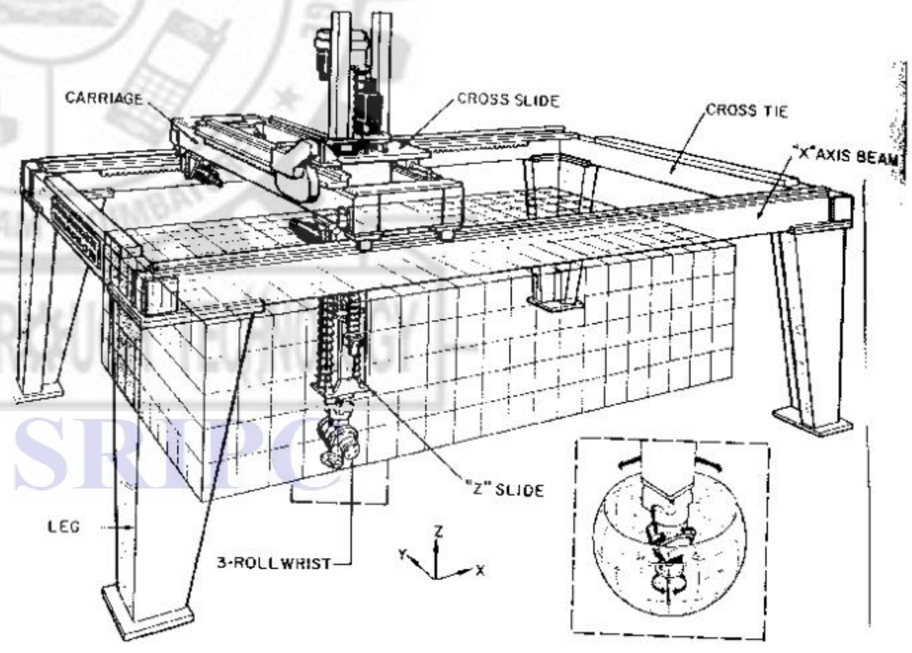
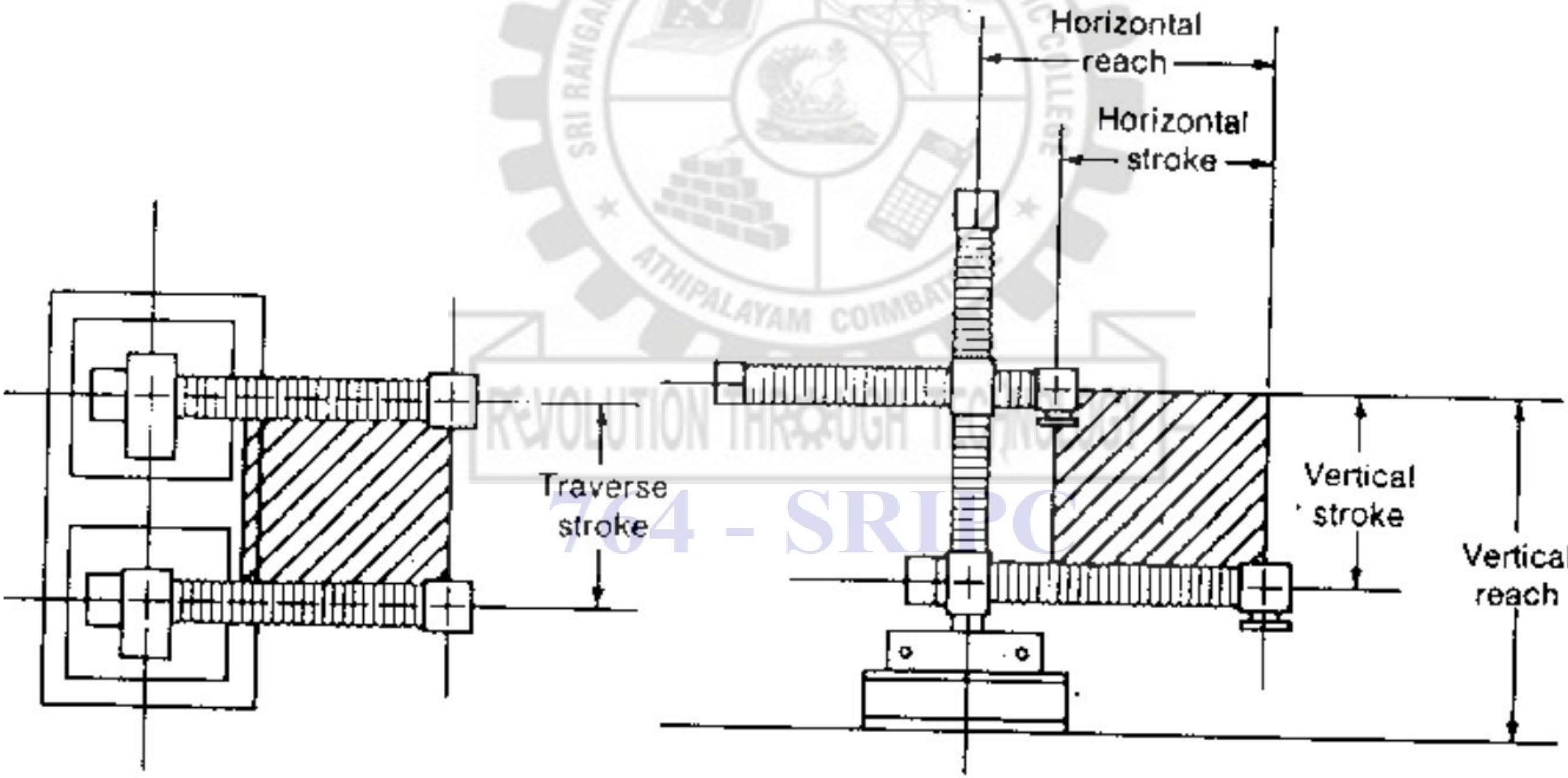


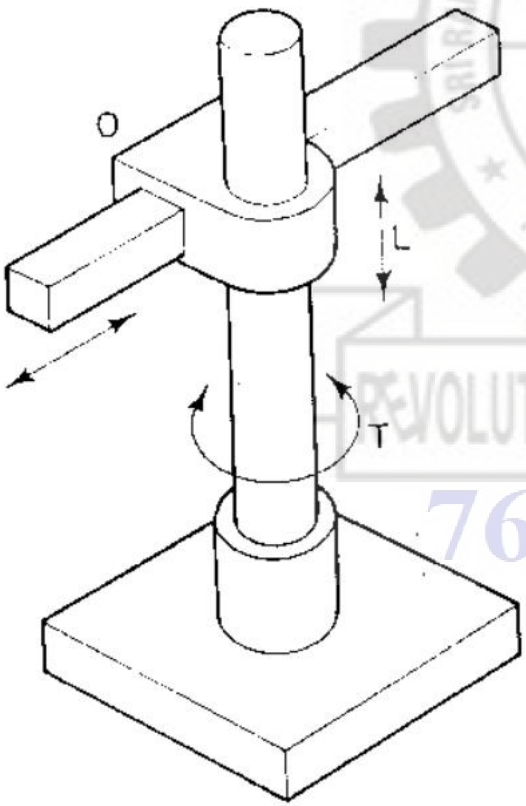
Figure 9.3. Gantry configuration robot. (Courtesy of Cincinnati Milacron.)

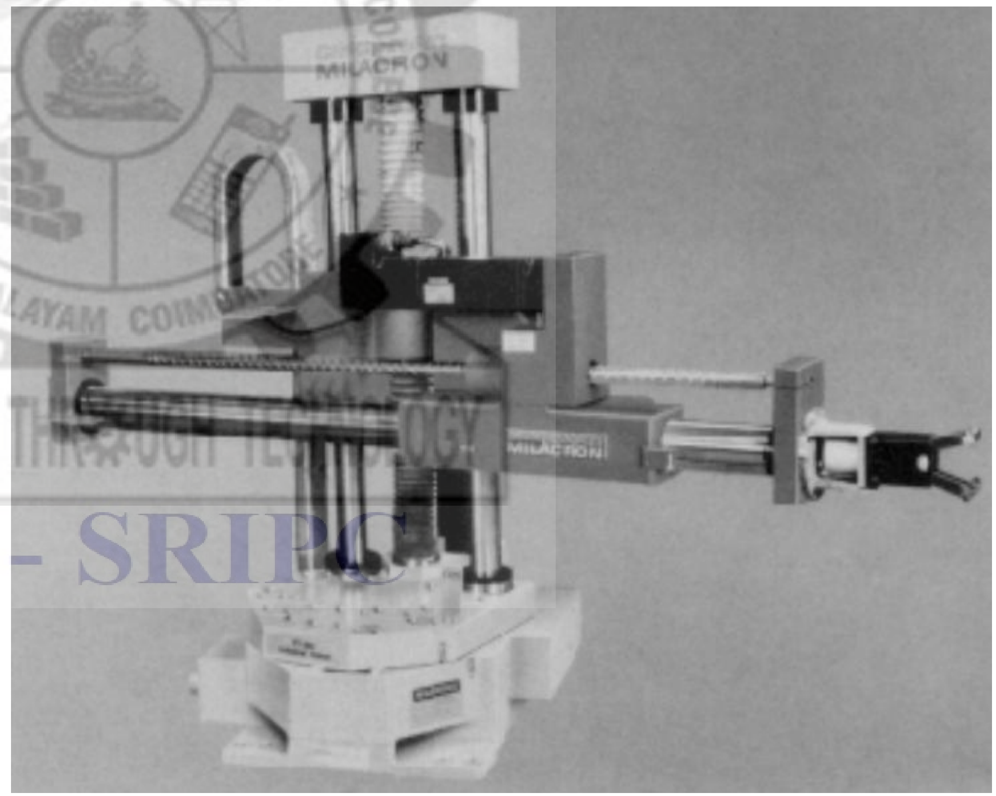
Cartesian Robot - Work Envelope



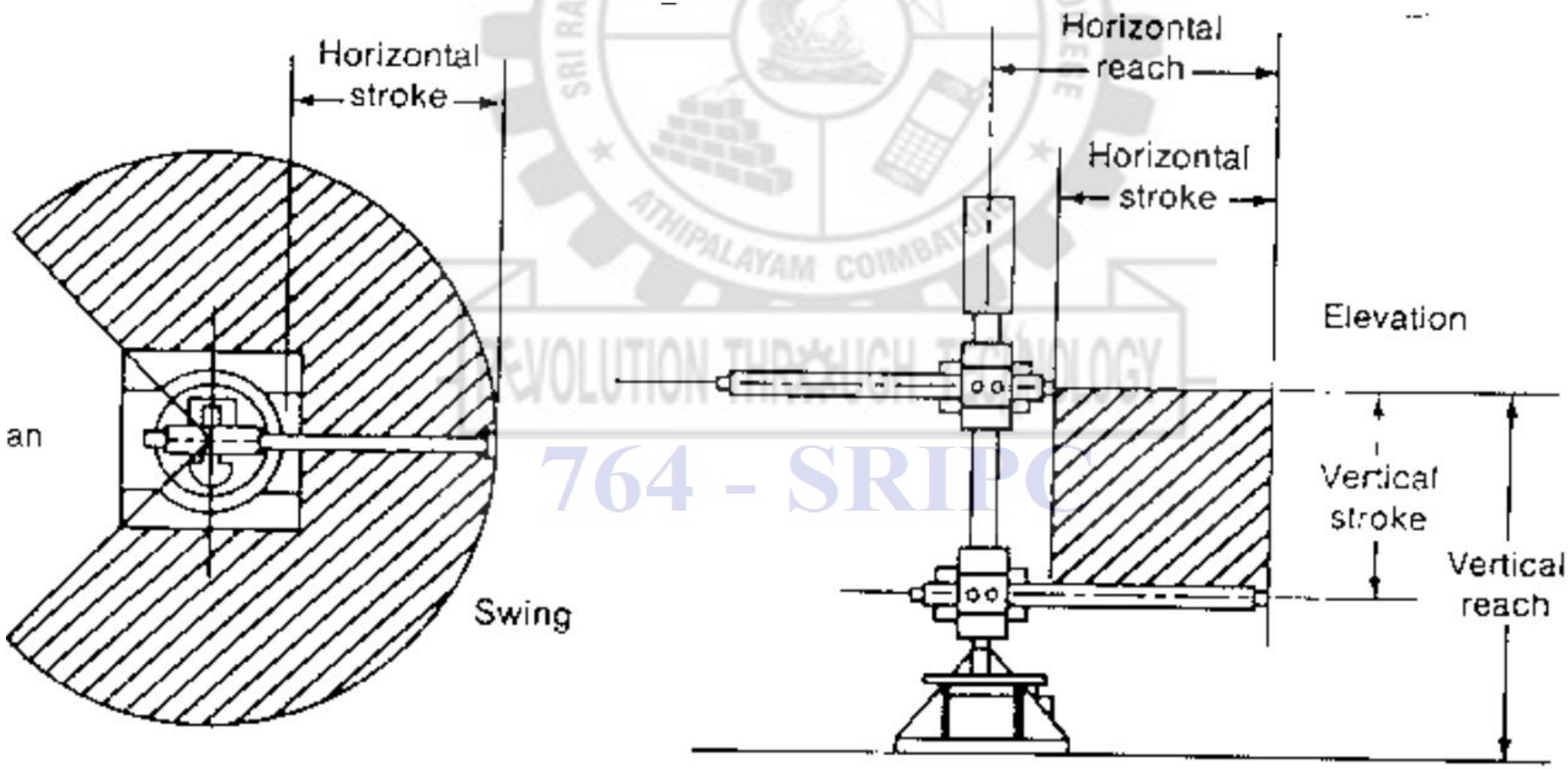
Robot Configurations (cont'd)

- **Cylindrical (R2P):** Cylindrical coordinate Robots have 2 prismatic joints and one revolute joint.



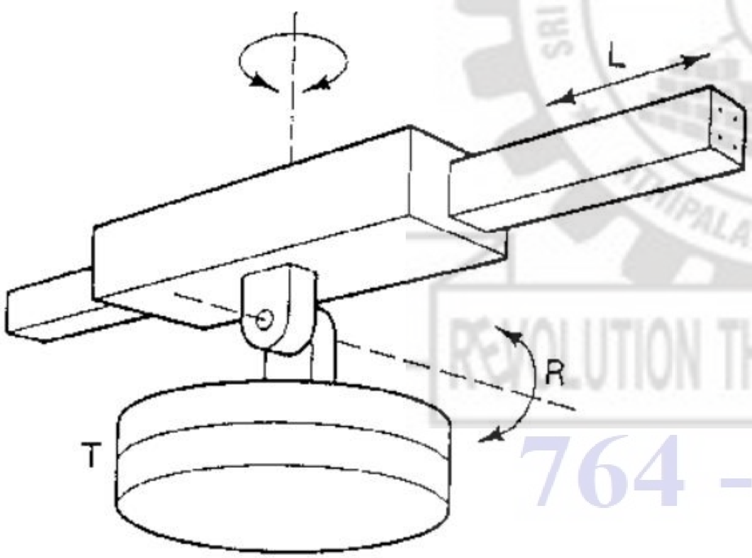


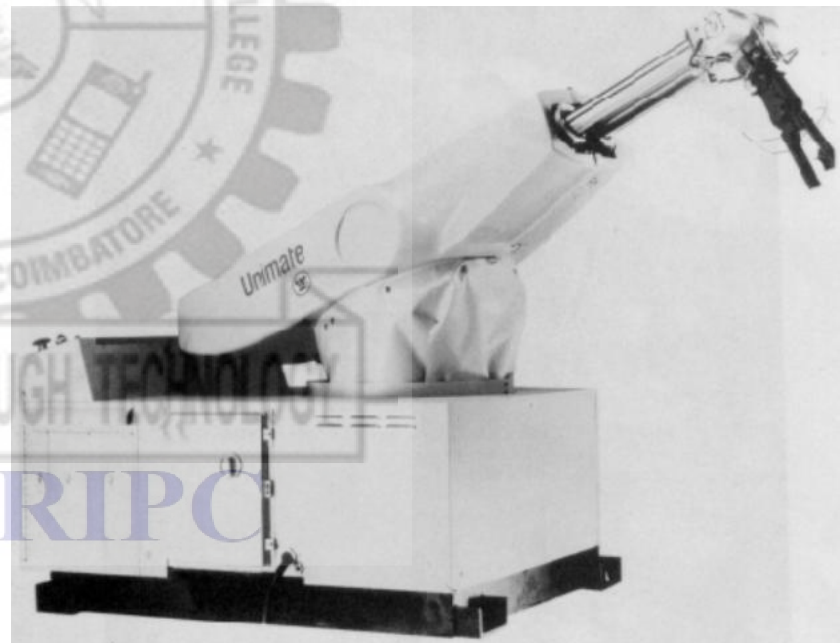
Cylindrical Robot - Work Envelope



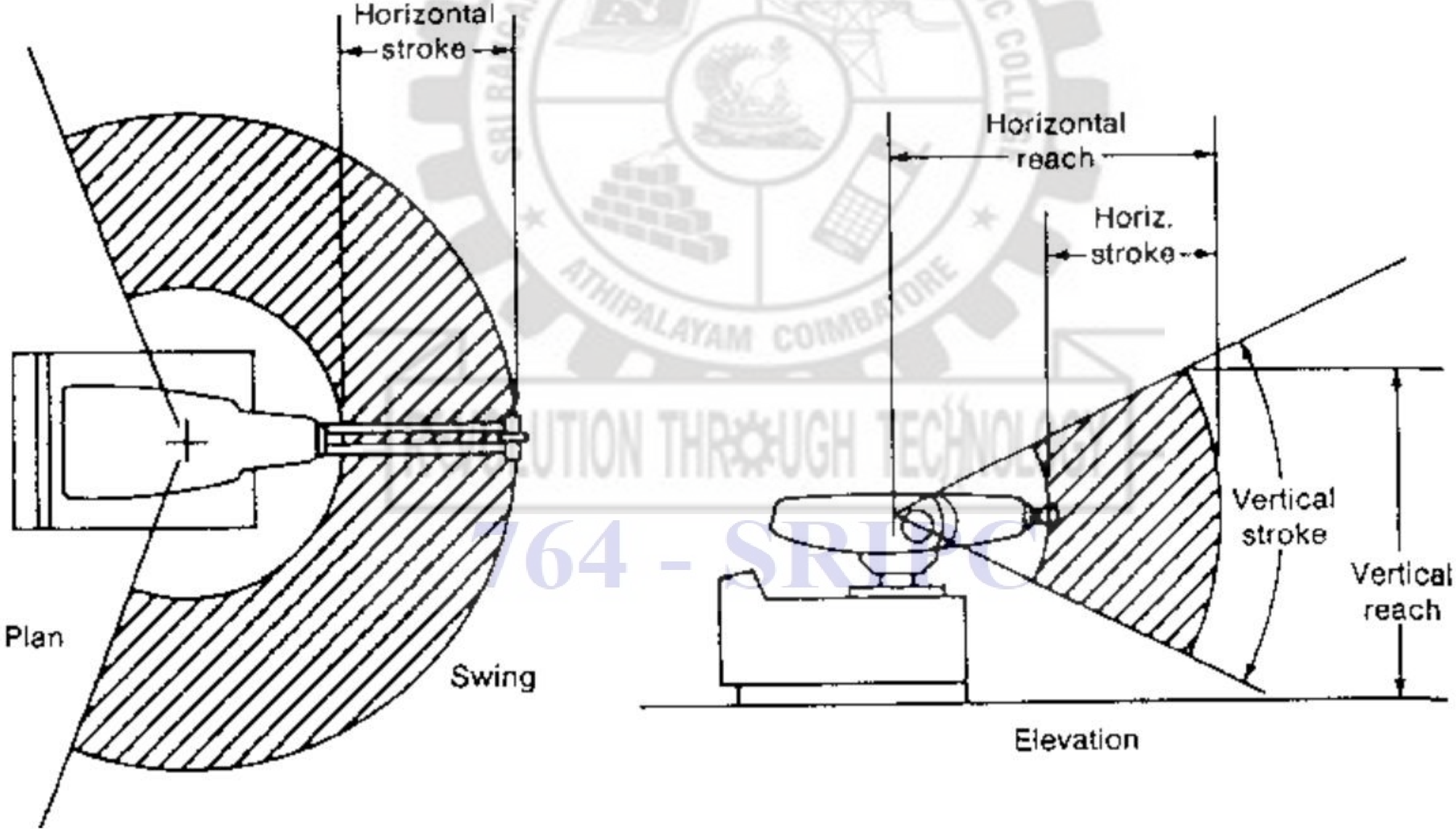
Robot Configurations (cont'd)

- **Spherical joint (2RP):** They follow a spherical coordinate system, which has one



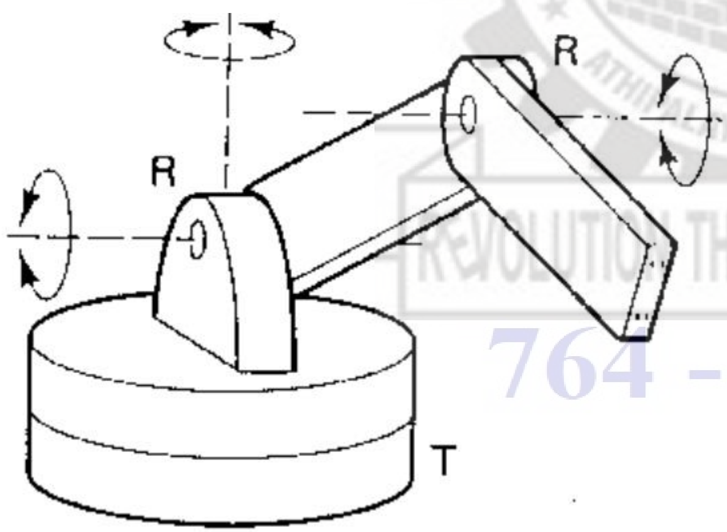


Spherical Robot - Work Envelope



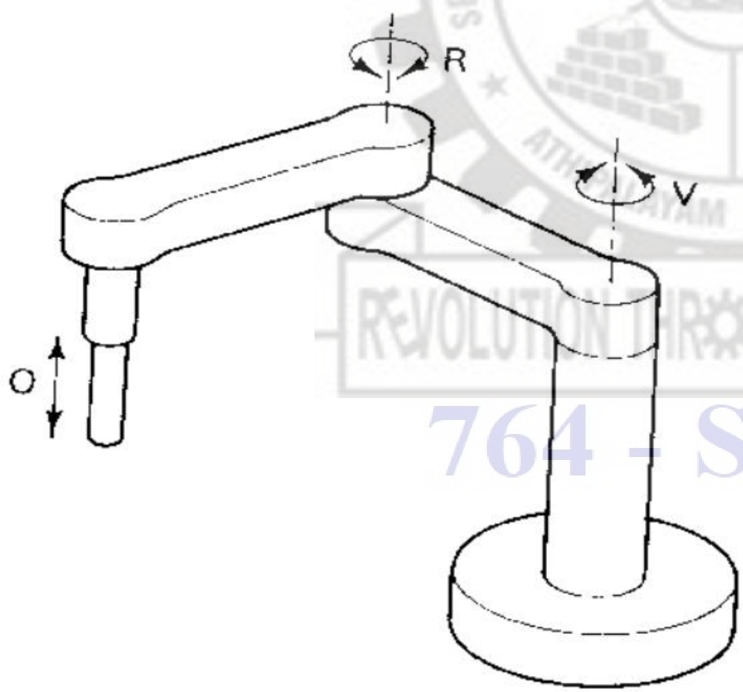
Robot Configurations (cont'd)

- **Articulated/anthropomorphic(3R) :**An articulated robot's joints are all revolute, similar to a human's arm.

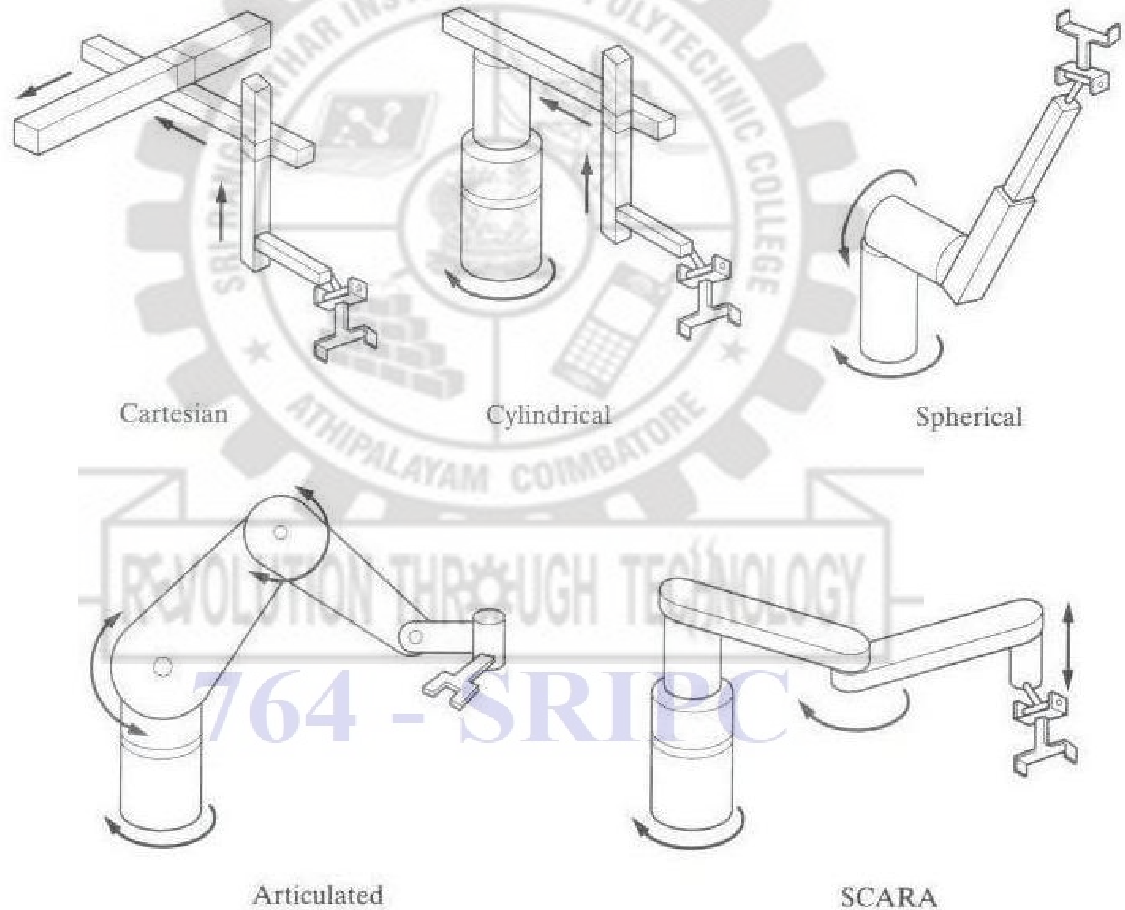


Robot Configurations (cont’d)

- **Selective Compliance Assembly Robot Arm (SCARA) (2R1P):** They have two revolute joints that are parallel and allow the Robot to move in a horizontal plane, plus an additional prismatic joint that moves vertically



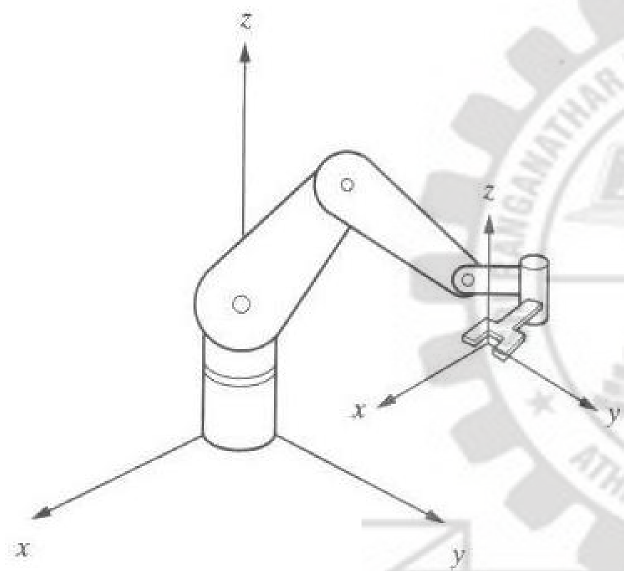
Robot Configurations



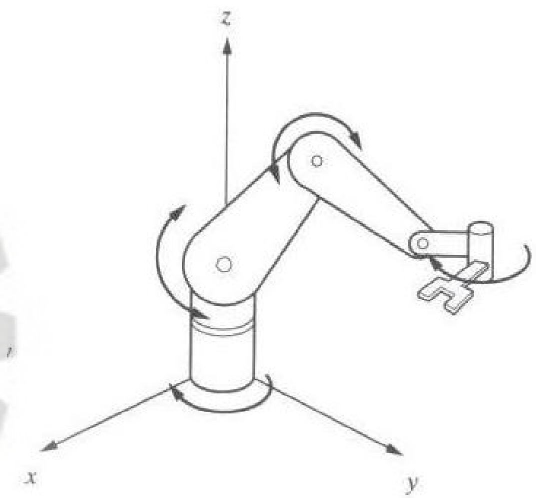
Reference Frames

- World Reference Frame which is a universal coordinate frame, as defined by the x-y-z axes. In this case the joints of the robot move simultaneously so as to create motions along the three major axes.
- Joint Reference Frame which is used to specify movements of each individual joint of the Robot. In this case each joint may be accessed individually and thus only one joint moves at a time.
- Tool Reference Frame which specifies the movements of the Robots hand relative to the frame attached to the hand. The x’,y’and z’ axes attached to the hand define the motions of the hand relative to this local frame. All joints of the Robot move simultaneously to create coordinated motions about the Tool frame.

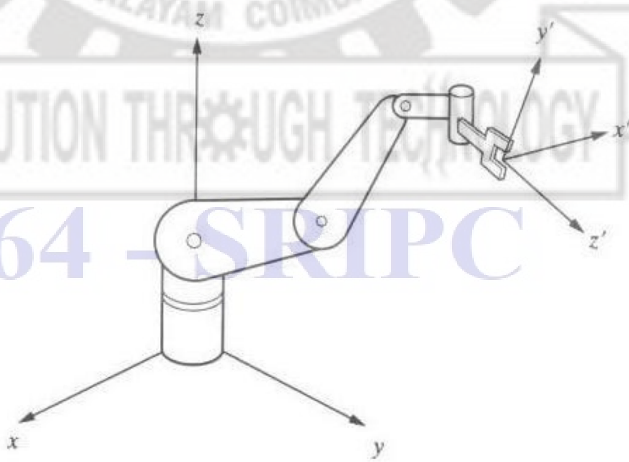
Robot Reference Frames



World reference frame



Joint reference frame



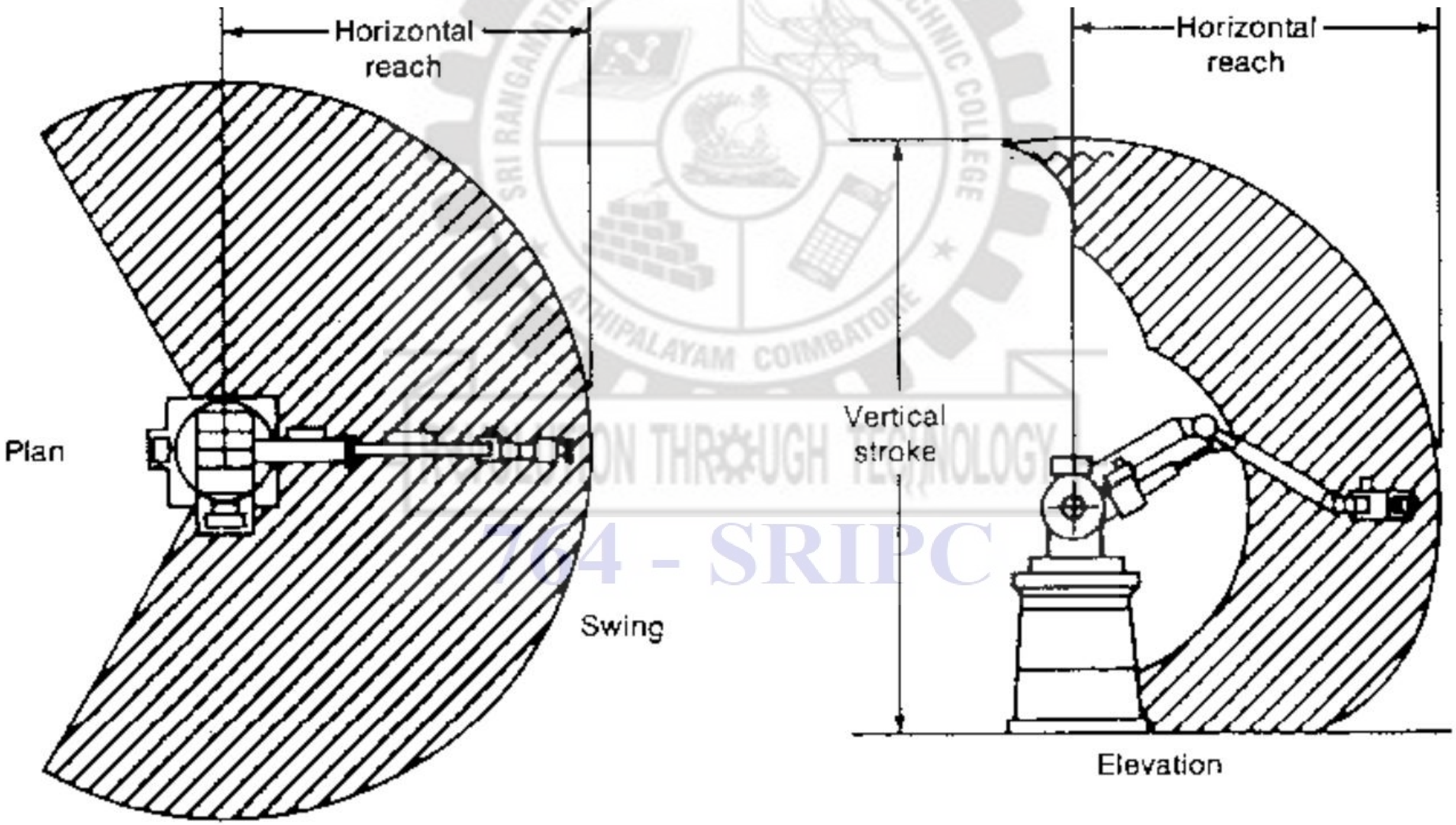
Tool reference frame

Work Envelope concept

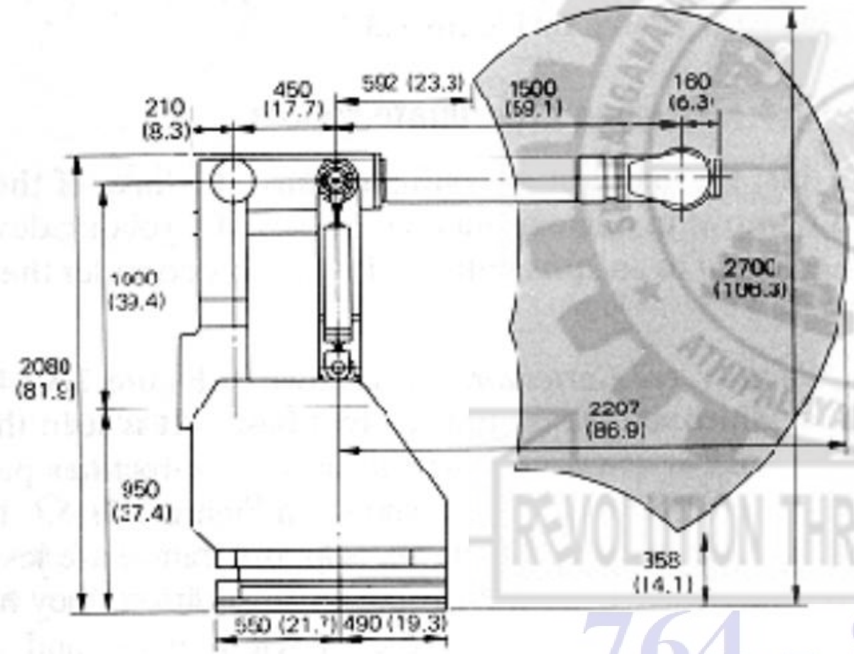
- Depending on the configuration and size of the links and wrist joints, robots can reach a collection of points called a **Workspace**.

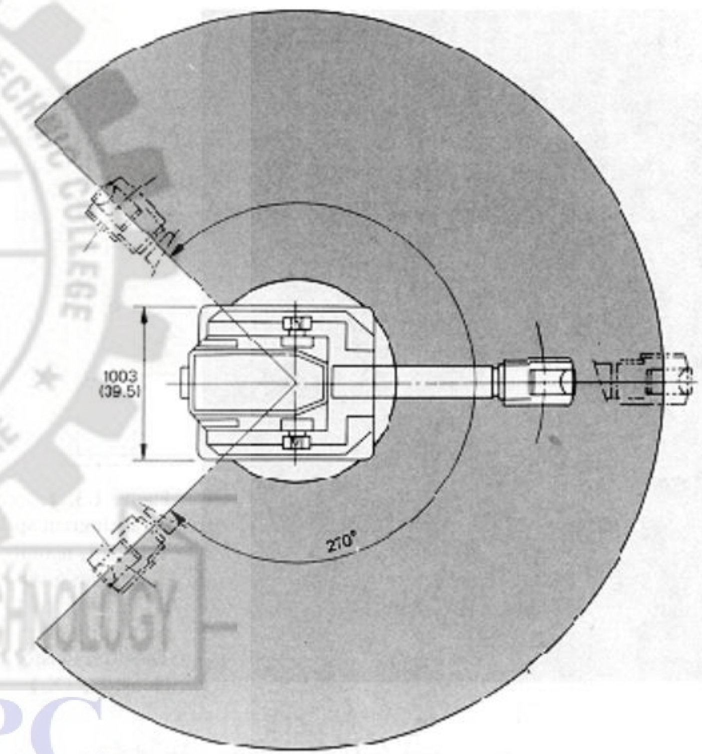
- Alternately Workspace may be found empirically, by moving each joint through its range of motions and combining all space it can reach and subtracting what space it cannot reach

Pure Spherical Jointed Arm - Work envelope



2) Parallelogram Jointed





Exercise

Readiness Assessment Test A.K.A. RAT

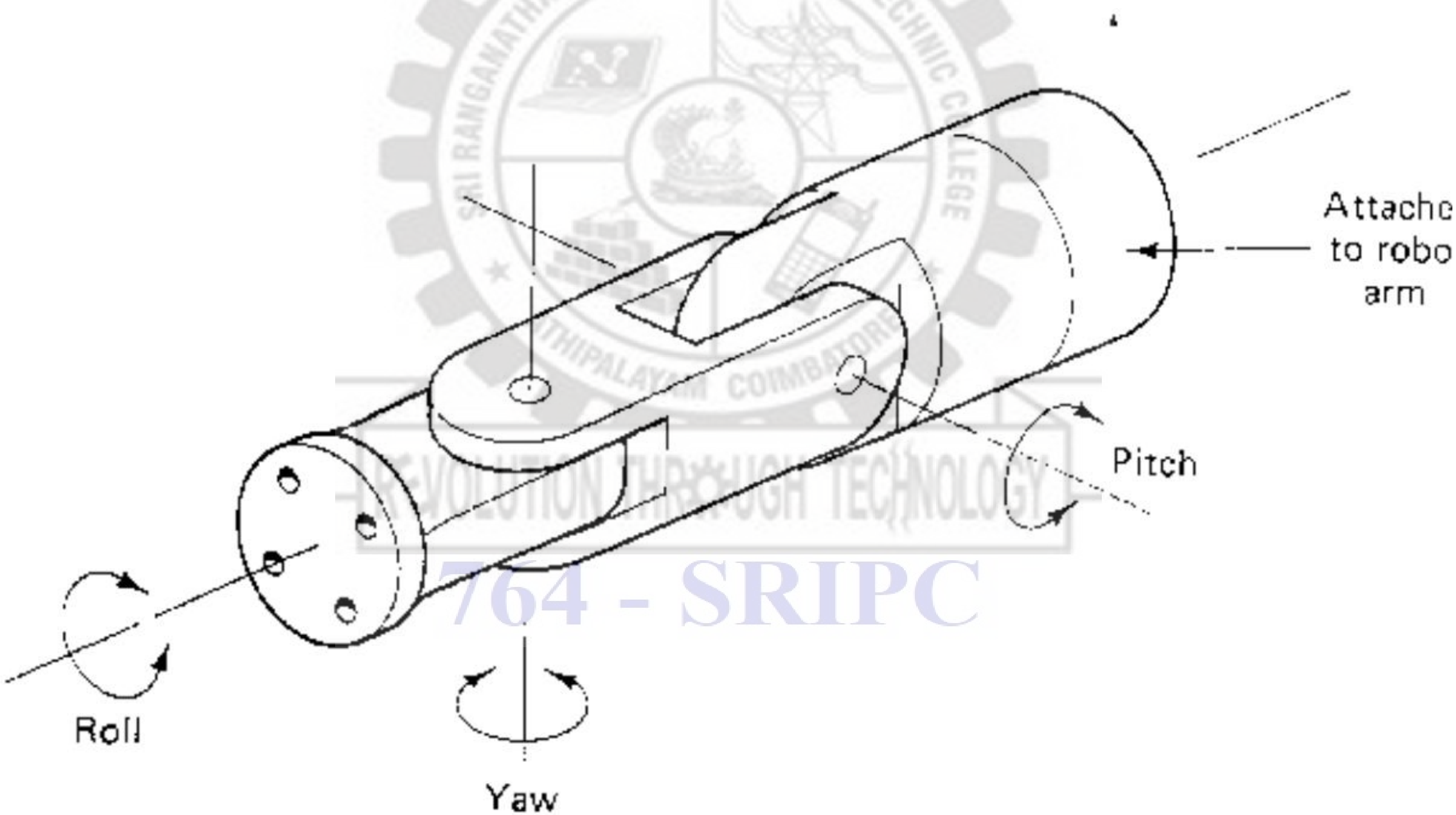
AS A INDIVIDUAL, prepare a detailed response for the following Readiness Assessment test

What type of Robot Configuration does the ABB 140 Robot have?
Can you find out its Work Space?

WRIST

- typically has 3 degrees of freedom
  - ***Roll*** involves rotating the wrist about the arm axis
  - ***Pitch*** up-down rotation of the wrist
  - ***Yaw*** left-right rotation of the wrist
- End effector is mounted on the wrist

WRIST MOTIONS



CONTROL METHODS

- ***Non Servo Control***
  - implemented by setting limits or mechanical stops for each joint and sequencing the actuation of each joint to accomplish the cycle
  - end point robot, limited sequence robot, bang-bang robot
  - No control over the motion at the intermediate points, only end points are known

- Programming accomplished by
  - setting desired sequence of moves
  - adjusting end stops for each axis accordingly
  - the sequence of moves is controlled by a “squencer”, which uses feedback received from the end stops to index to next step in the program
- Low cost and easy to maintain, reliable
- relatively high speed
- repeatability of up to 0.01 inch
- limited flexibility
- typically hydraulic, pneumatic drives

- ***Servo Control***
  - Point to point Control
  - Continuous Path Control
- Closed Loop control used to monitor position, velocity (other variables) of each joint

Point-to-Point Control

- Only the end points are programmed, the path used to connect the end points are computed by the controller
- user can control velocity, and may permit linear or piece wise linear motion
- Feedback control is used during motion to ascertain that individual joints have achieved desired location

- Often used hydraulic drives, recent trend towards servomotors
- loads up to 500lb and large reach
- Applications
  - pick and place type operations
  - palletizing
  - machine loading

Continuous Path Controlled

- in addition to the control over the endpoints, the path taken by the end effector can be controlled
- Path is controlled by manipulating the joints throughout the entire motion, via closed loop control
- Applications:
  - spray painting, polishing, grinding, arc welding

ROBOT PROGRAMMING

- Typically performed using one of the following
  - On line
    - teach pendant
    - lead through programming
  - Off line
    - robot programming languages
    - task level programming

Use of Teach Pendant

- hand held device with switches used to control the robot motions
- End points are recorded in controller memory
- sequentially played back to execute robot actions
- trajectory determined by robot controller
- suited for point to point control applications

- Easy to use, no special programming skills required
- Useful when programming robots for wide range of repetitive tasks for long production runs
- RAPID

Lead Through Programming

- lead the robot physically through the required sequence of motions
- trajectory and endpoints are recorded, using a sampling routine which records points at 60-80 times a second
- when played back results in a smooth continuous motion
- large memory requirements

Programming Languages

- Motivation
  - need to interface robot control system to external sensors, to provide “real time” changes based on sensory equipment
  - computing based on geometry of environment
  - ability to interface with CAD/CAM systems
  - meaningful task descriptions
  - off-line programming capability

- Large number of robot languages available
  - AML, VAL, AL, RAIL, RobotStudio, etc. (200+)
- Each robot manufacturer has their own robot programming language
- No standards exist
- Portability of programs virtually non-existent