# Flexible manufacturing systems

# Components of a FMS

# Computer Numerical Control

- Computer Numerical Control (CNC) means that a local computer directly controls machine functioning.
- Numerical control allows the transmission of information to the machine tool, and thus all the subsequent actions implemented by the machine itself.
- *Numerical control means exploiting information technology and electronics in order to improve machine tools performances and flexibility*

# Computer Numerical Control

- Compared to traditional machines, CNC machines require totally different manpower operations.
- First CNC machines were built in the mid-’50s but their large-scale diffusion started in the ‘70s.
- The very first CNC machine was built in 1947 in USA for the aeronautic industry, in order to meet the need to provide complex surfaces in reasonable times.

# Technological evolution

- Traditional Machine
  - Considerable passive times (air cutting and machine stoppage)
  - Higher error possibility
  - Productivity also depends on operator skills
- CNC Machine
  - Strongly reduced passive times, also related to machine equipment
  - Error possibility only during the programming phase
  - Production results do not depend on operator skills
  - Productivity strongly depends on the technological level of the machine

# Human-machine interface

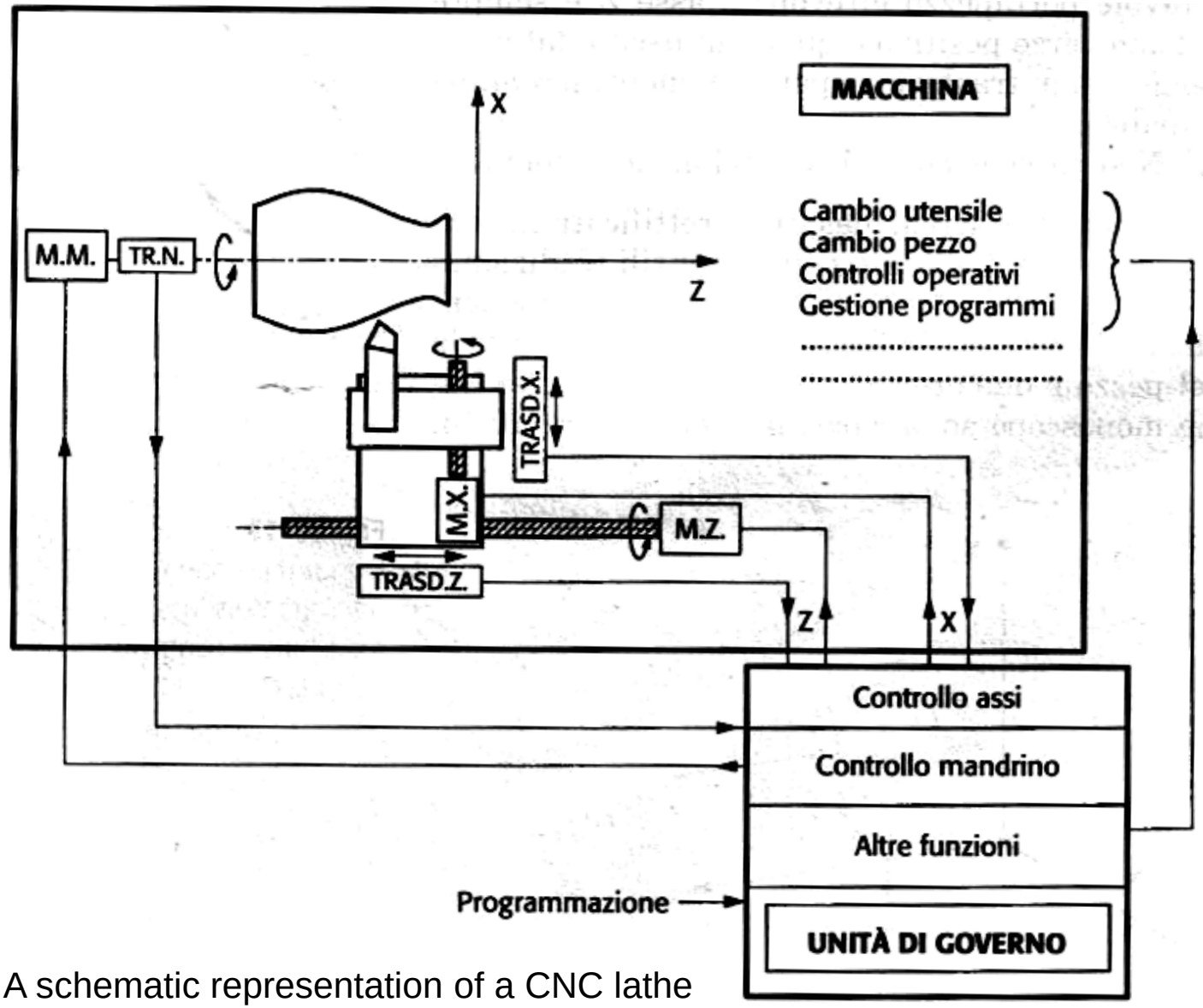
- Traditional Machine
  - Design analysis
  - Mnemonic activities to identify operations sequences
  - Parts fixing
  - Tools fixing
  - Working parameters settings
  - Operations execution
- CNC Machine
  - Off-line computer programming
  - Transferring of the program to the machine
  - Parts fixing
  - Tools loading
  - Operations starting
  - Operations supervision

# Opportunities and Problems

- Opportunities
  - High automation
  - High flexibility
  - Passive time reduction
  - Productivity increase
  - Quality improvement
  - Waste reduction
  - Manpower reduction
  - Versatility increase
- Problems
  - High costs related to:
    - Acquisition investment
    - Maintenance
    - Assistance
    - Programming of processing cycles

# CNC machines characteristics

- One engine for each controlled axis (synchronized and simultaneous movements)
- Moving elements provided with transductors that continuously recognize axis positions
- High installed power
- High speed of positioning movements
- Mechanisms to quickly change tools
- Tools to hold and move pallets,  for the rapid replacement of finished products with WIP products
- Conveyors facilitating the gathering and disposal of shavings
- Sliding barriers delimiting working areas in order to ensure operators security



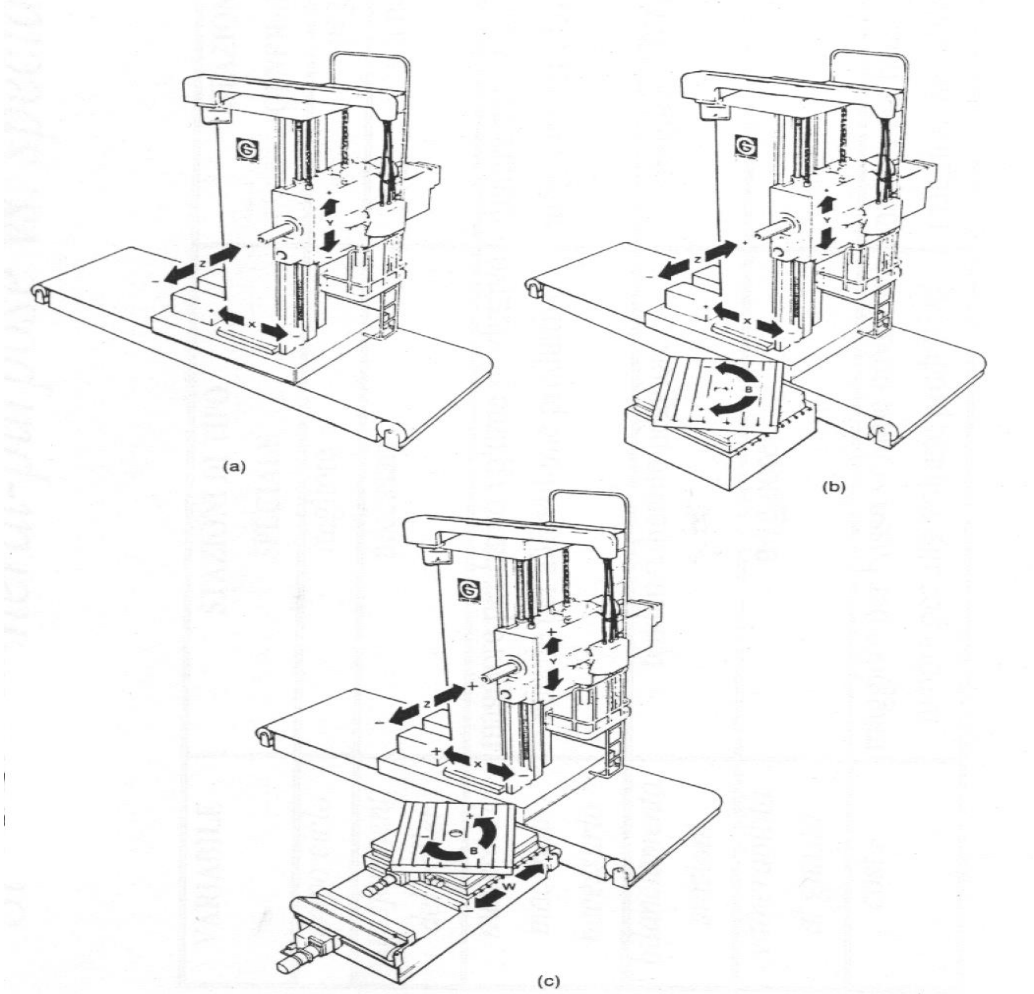

MM: spindle engine
TRN: transductor angular speed
MZ: engine Z axis
TRSDZ: transductor Z axis
MX: engine X axis
TRASDX: transductor X axis

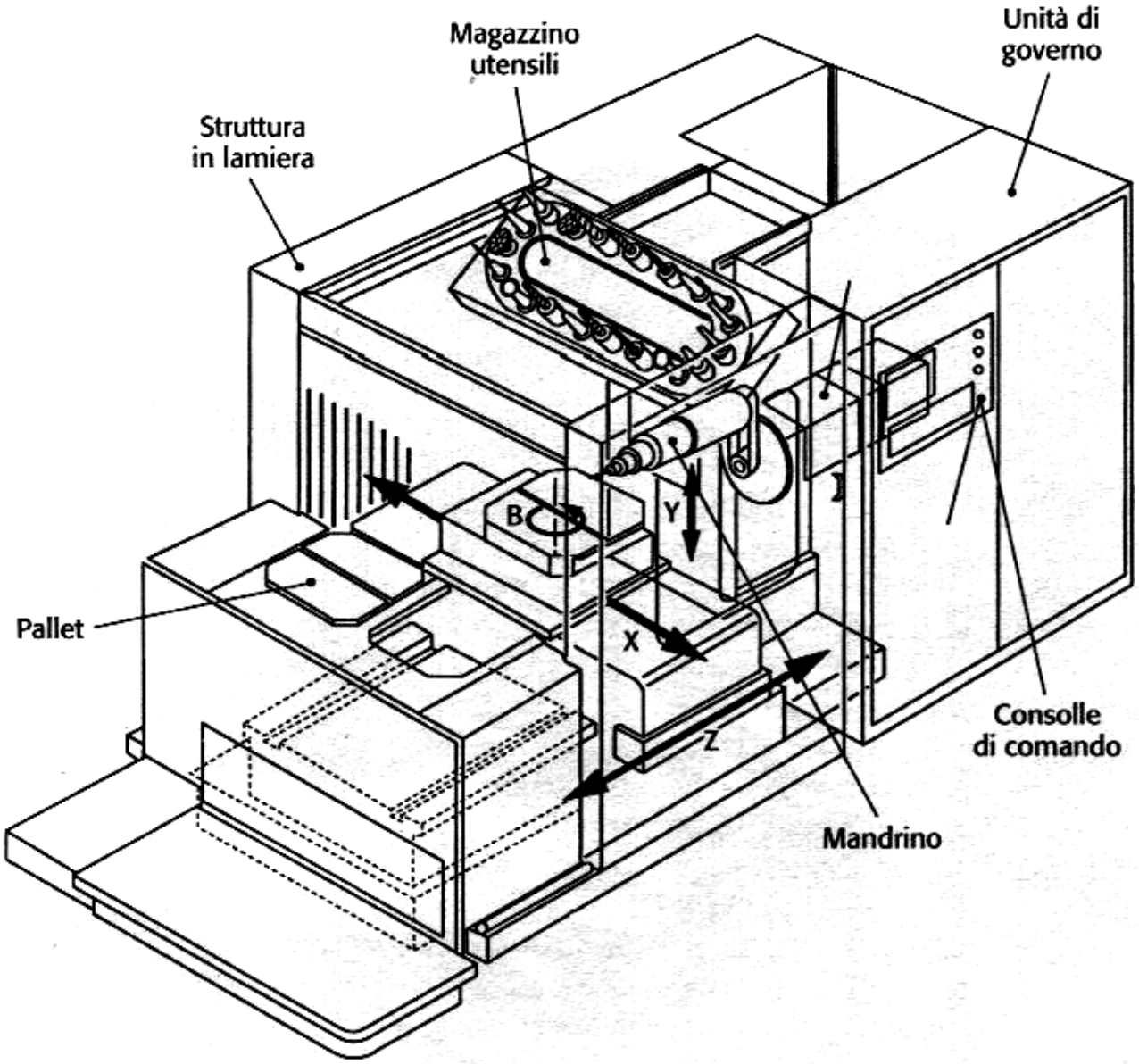
A schematic representation of a CNC lathe

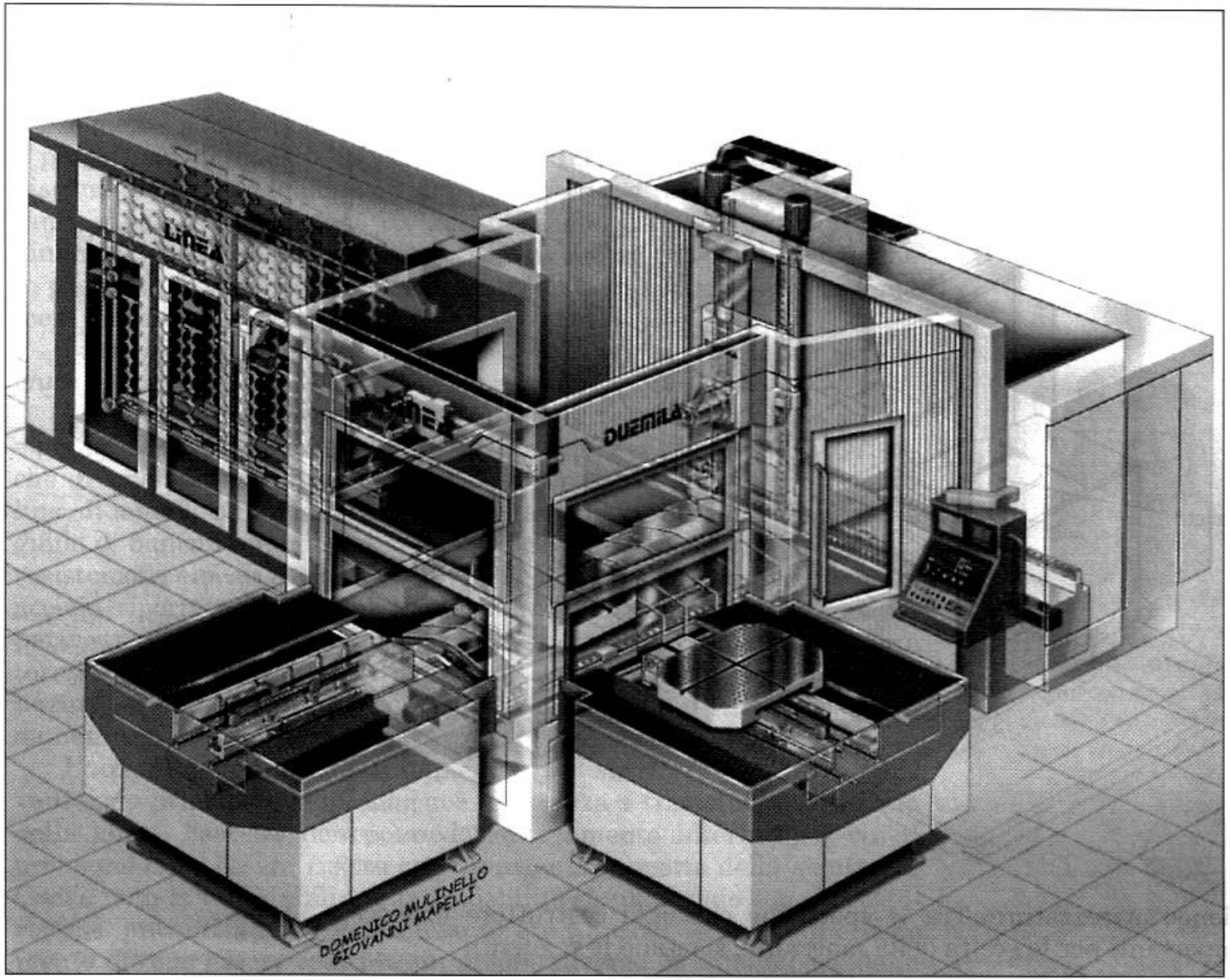
# M*achining centre*

- It is a machine with multiple scope of work, highly flexible where it is possible to make a high number of operations (drilling, milling, ….)
- Main technical characteristics:
  - Operating field (workable volume)
  - Orientation of the rotational axis of the spindle (p.e.: horizontal)
  - Number of controlled axes
  - Max rotational speed of the spindle
  - Max translation speed of the axes (passive move)
  - Installed power / avaiilable power

# 3,4 and 5-axis machining centers



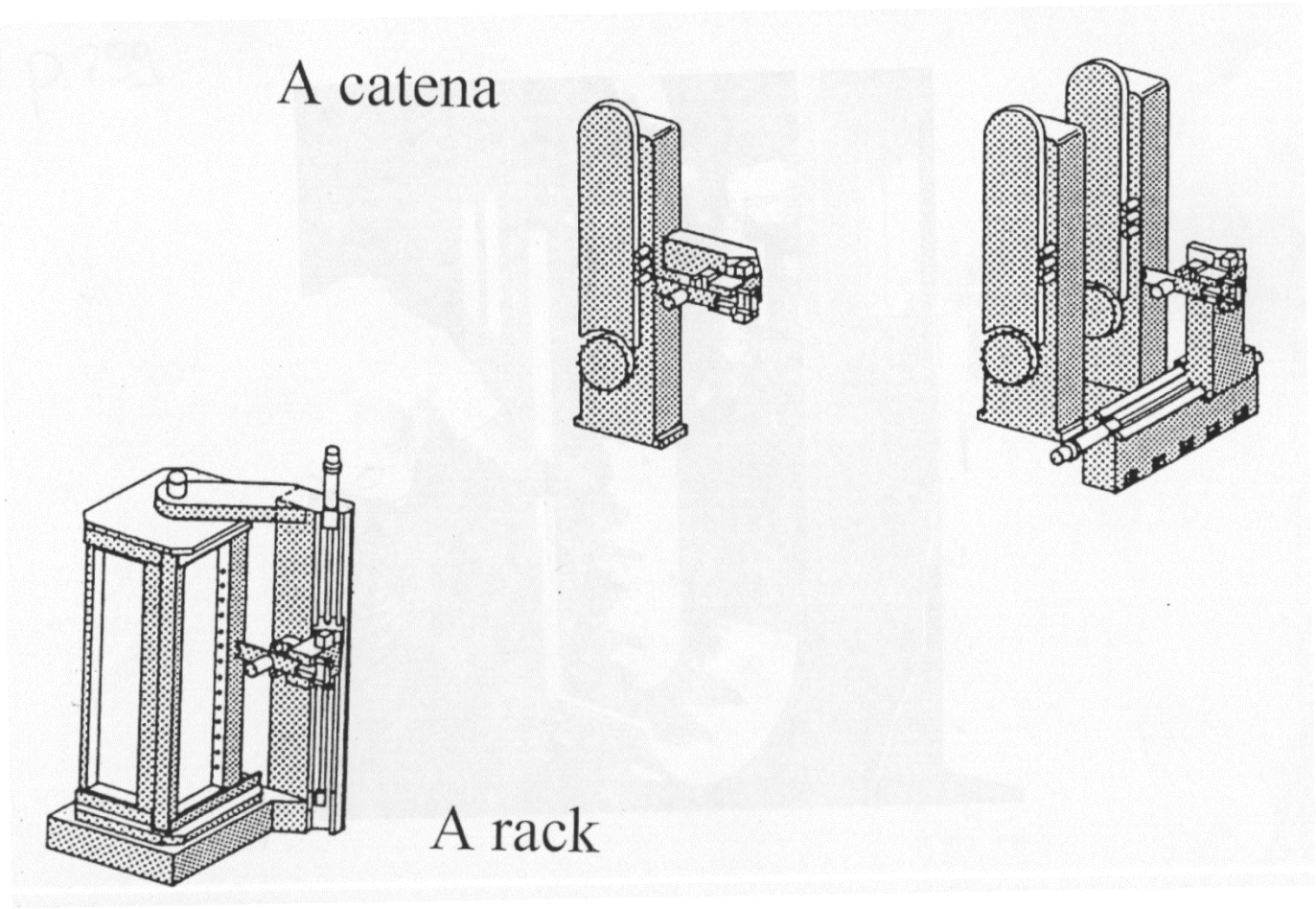

Magazzino utensili
Unità di governo
Struttura in lamiera
B
Y
Pallet
X
Z
Consolle di comando
Mandrino


LINEA
DUEMILA
DOMENICO MULINELLO
GIOVANNI MAPELLI

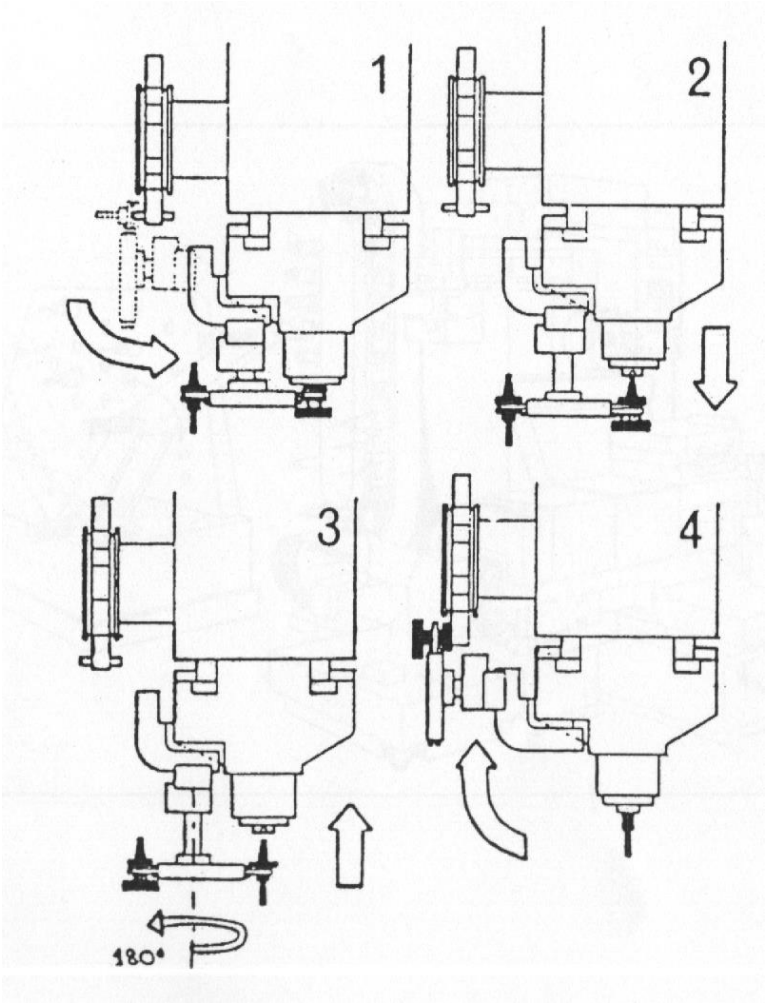
# Warehouse for tools

- Tools required for producing a part and/or a set of parts need to be located in a warehouse for tools dedicated to the machine tool before the start of the machining phase
- Before their positioning, tools undergo a off-line presetting (they are dimensioned considering a fixed point of reference). Presetting-data need to be memorized within the governing units so that ensuring the correct execution of the machining.
- Warehouse for tools can hold up to hundreds tools simultaneously

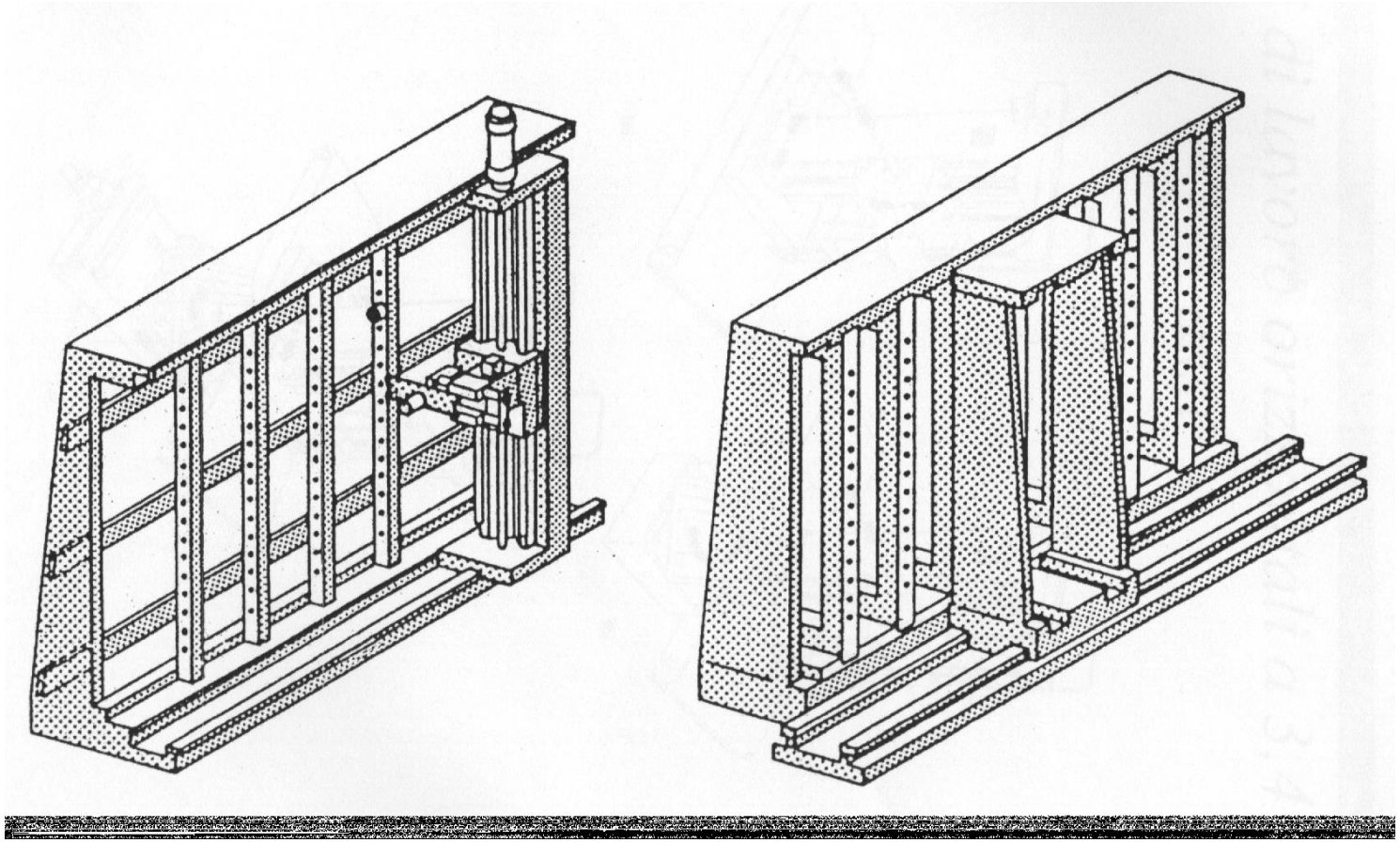
# Wareohouse for tools of a machine



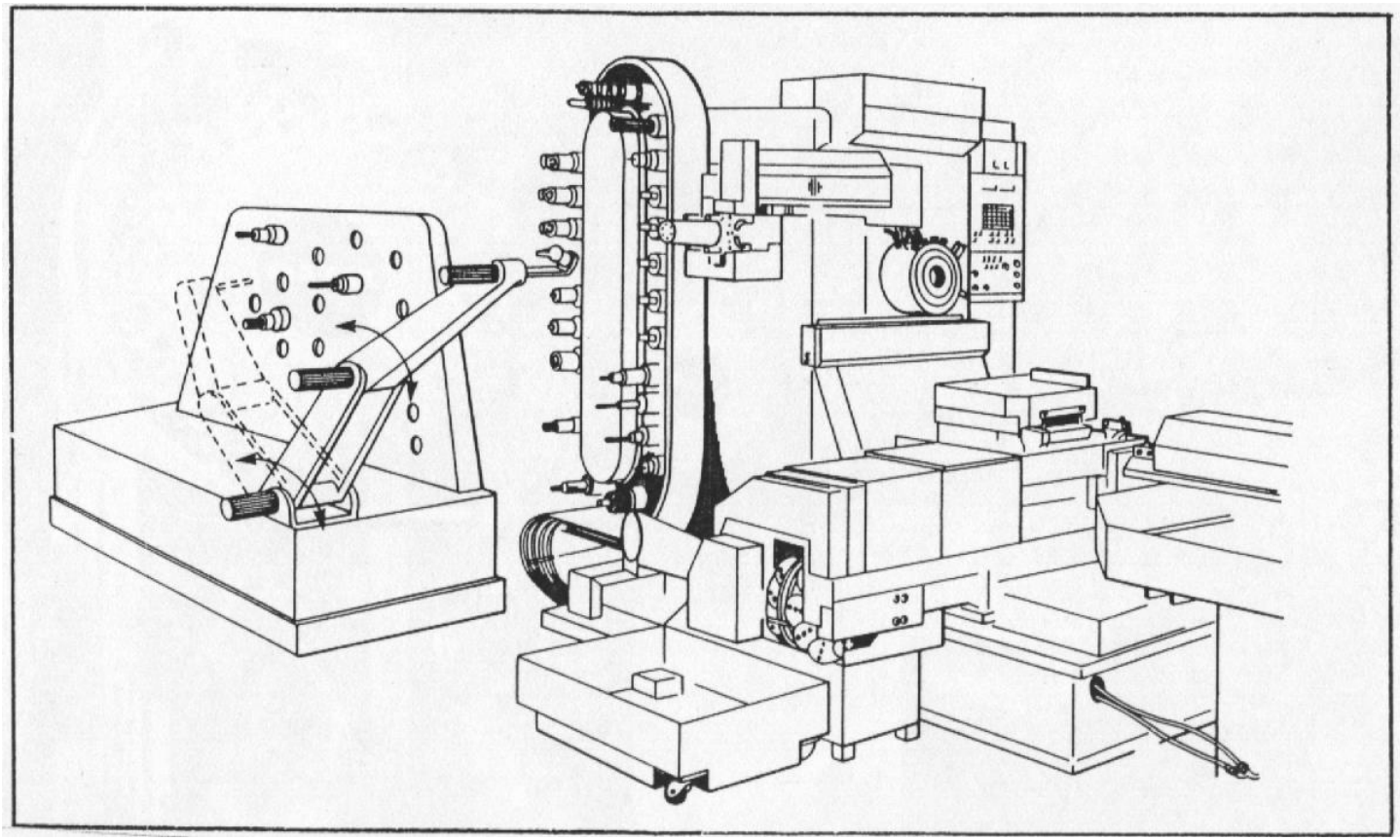
# Automatic change of the tool



# Wareohouse for tools of the system



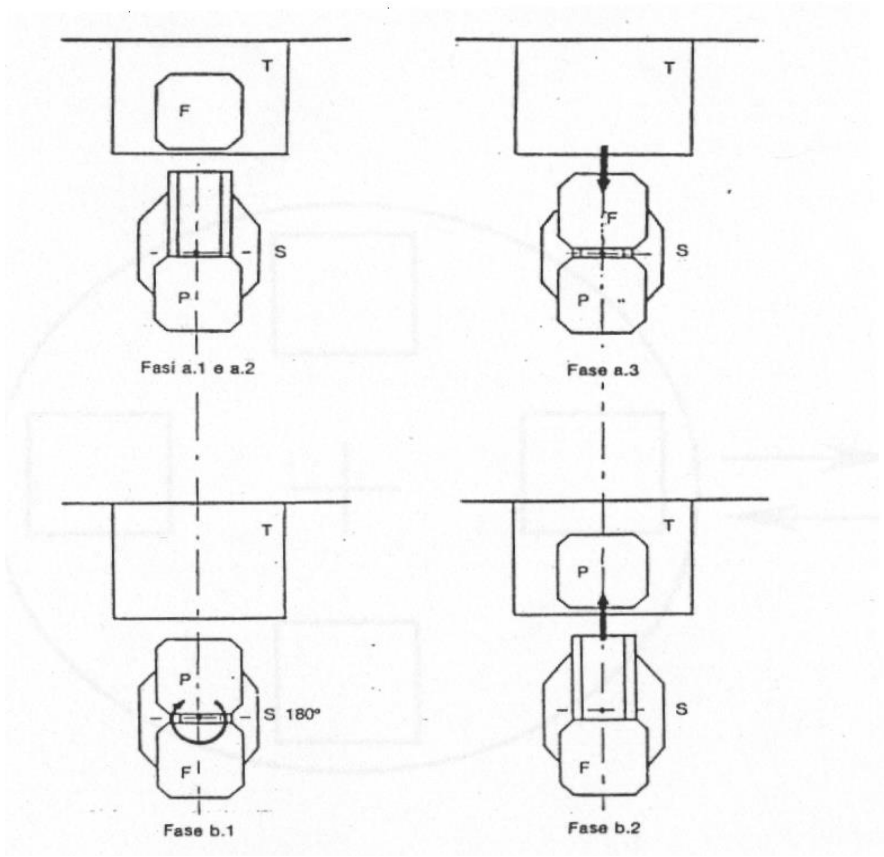
# System for changing tools with AGV



# Systems for changing parts

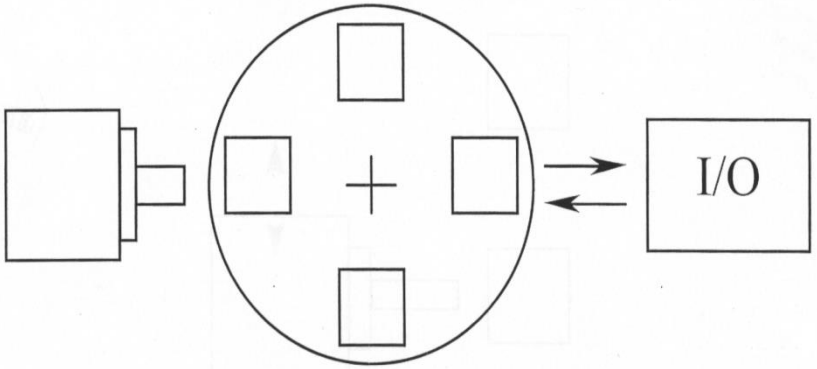
- Changing the part should be as quick as possible so that avoiding wasting time during the machining phase.
- In order to hold and handle parts (or pallets) a table is exploited, its movements are allowed by an automatic system.
- Different CNC centers can be linked with each others and presuppose the presence of systems moving pallets from one center to another

# Pallet exchangers: rotating with two compartments

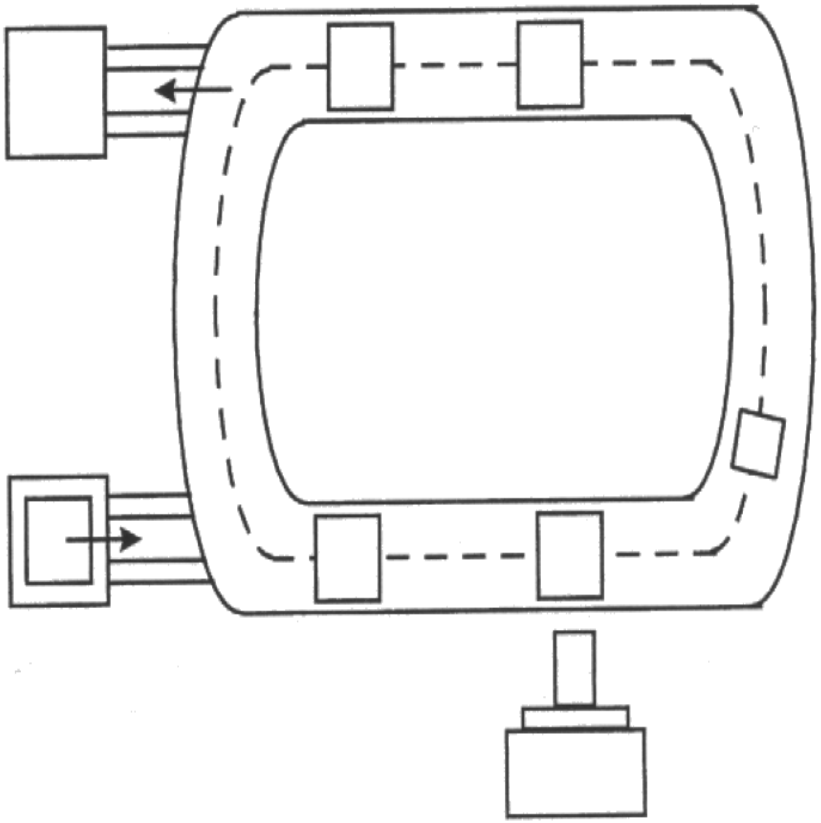



T, holding-pallet table
F, pallet with finished product
P, pallet with the part to be processed
S, system for pallet exchange

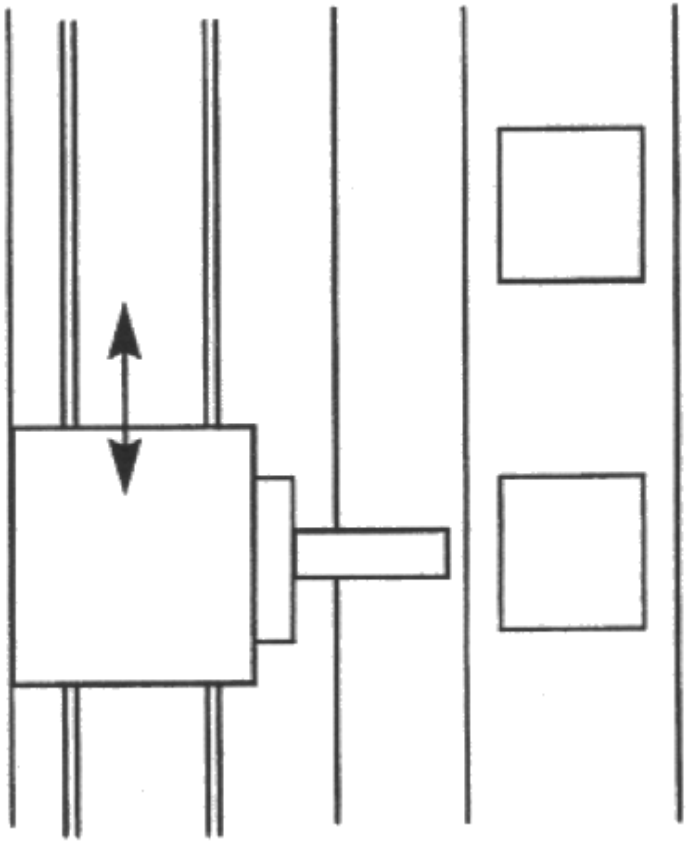
# Rotating table



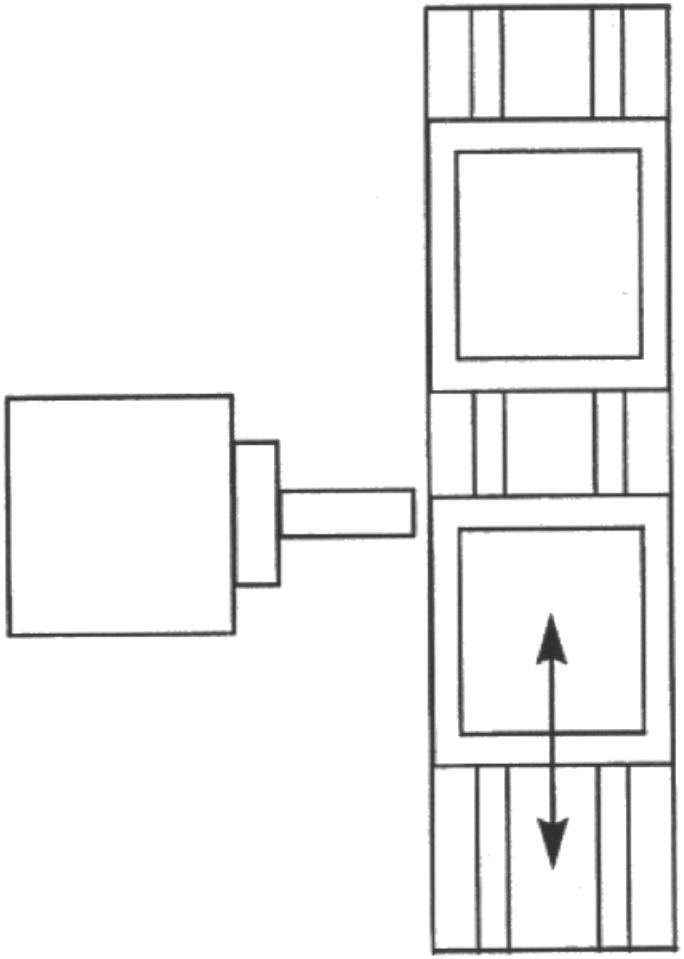

# Pallet carousel



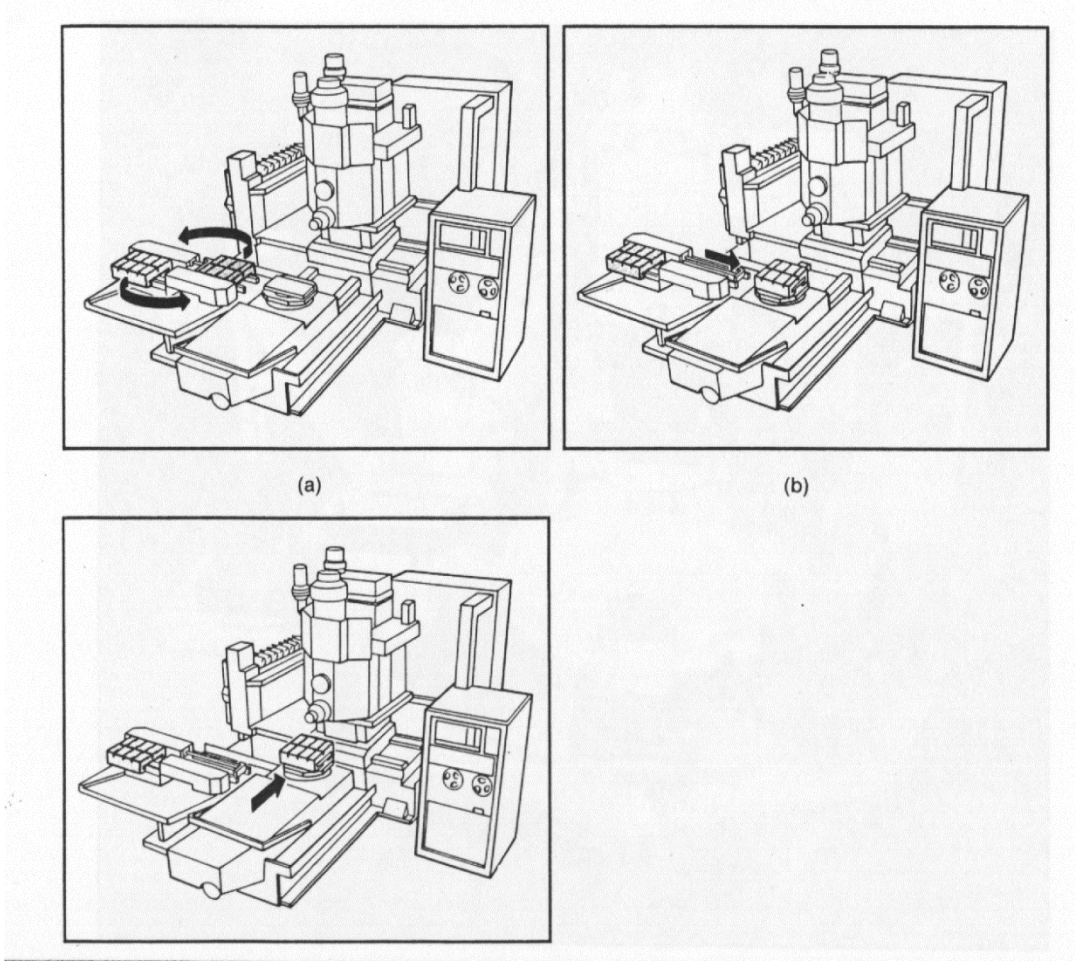
# Mobile head



# Commuting table

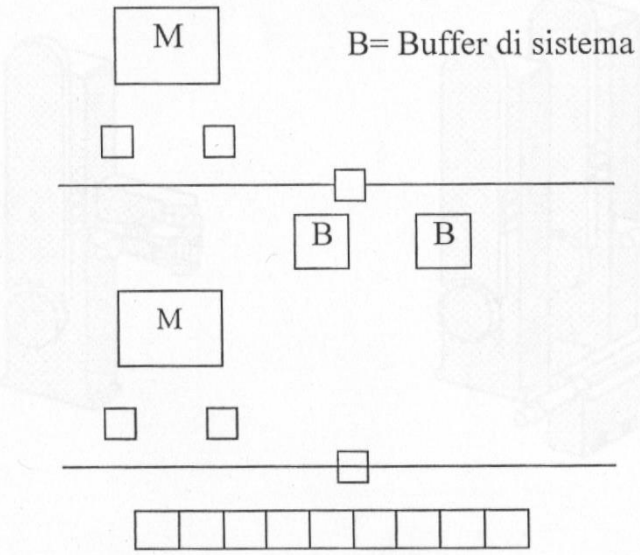


# Shuttle

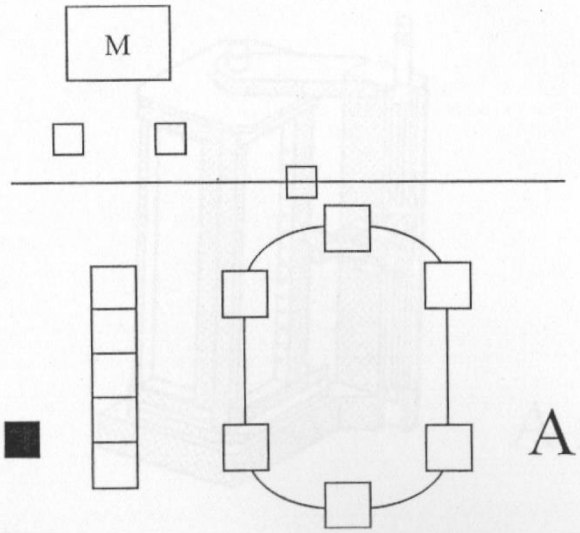


# System buffers and inter-operational buffers

- A posizioni singole

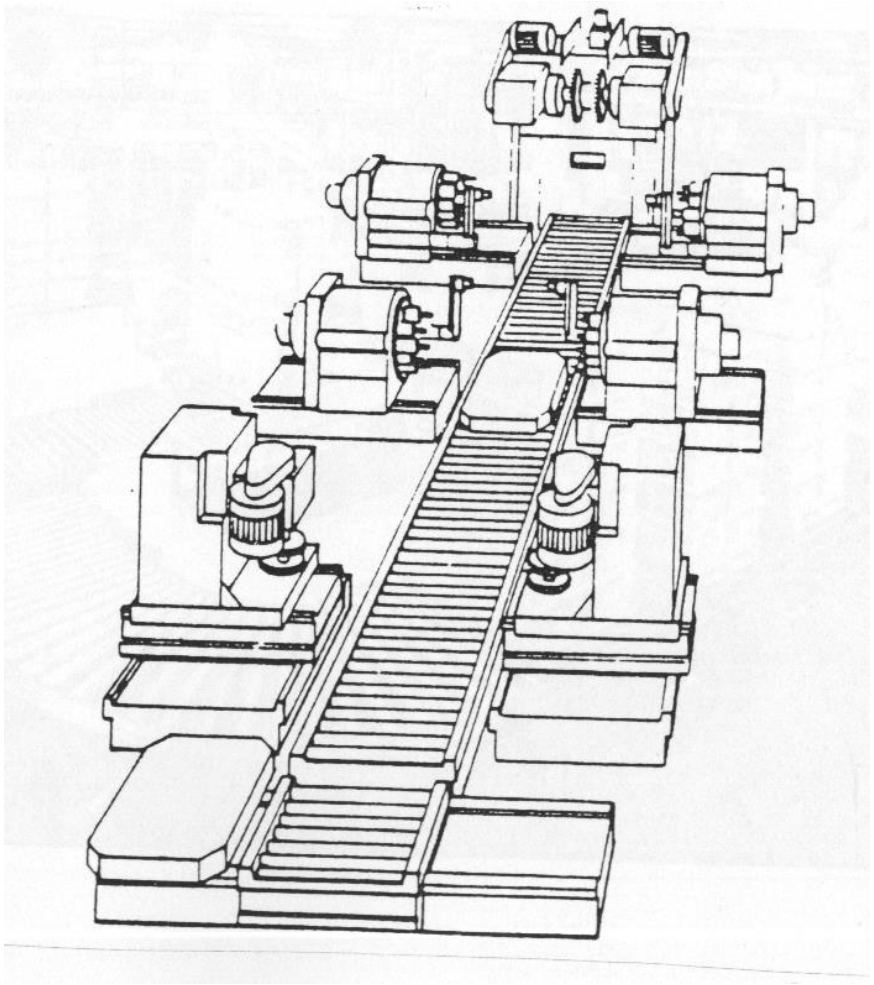



- A scaffalatura

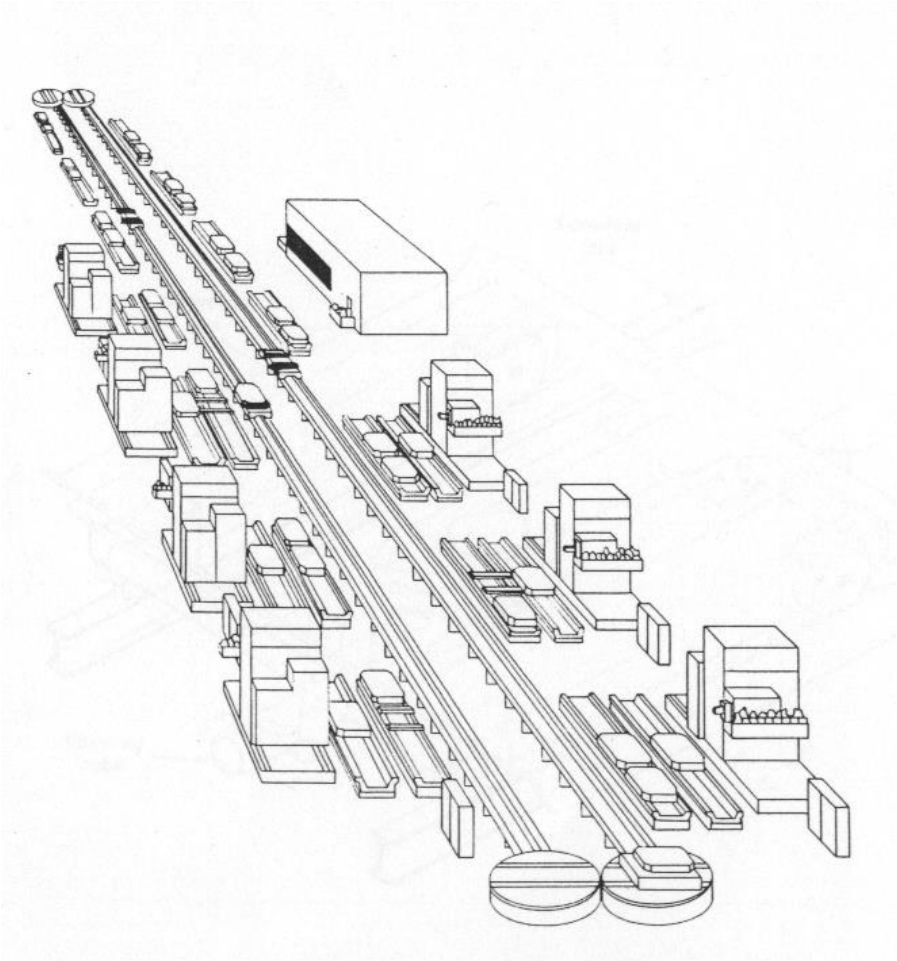



- A carosello rotante

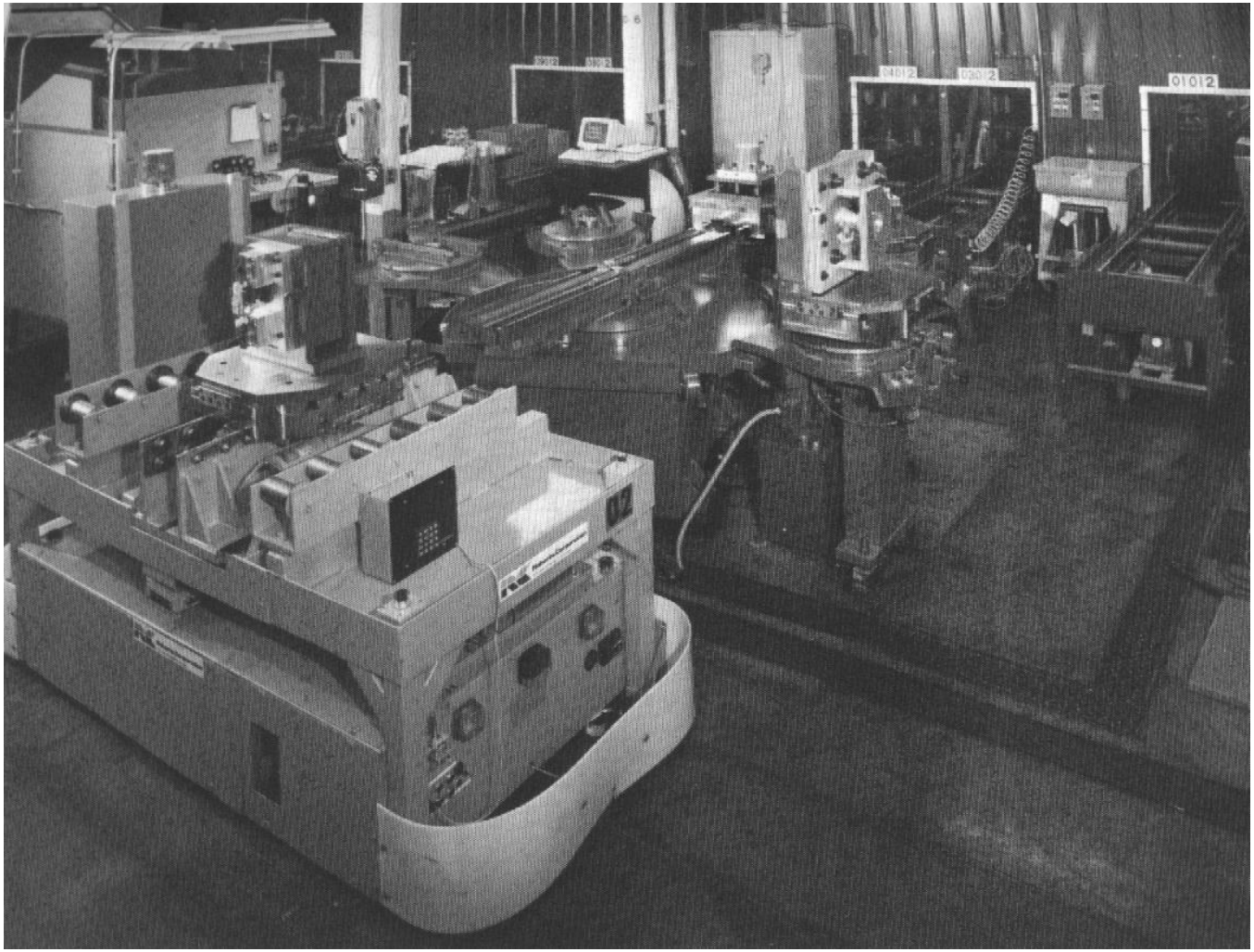
# Roller conveyor



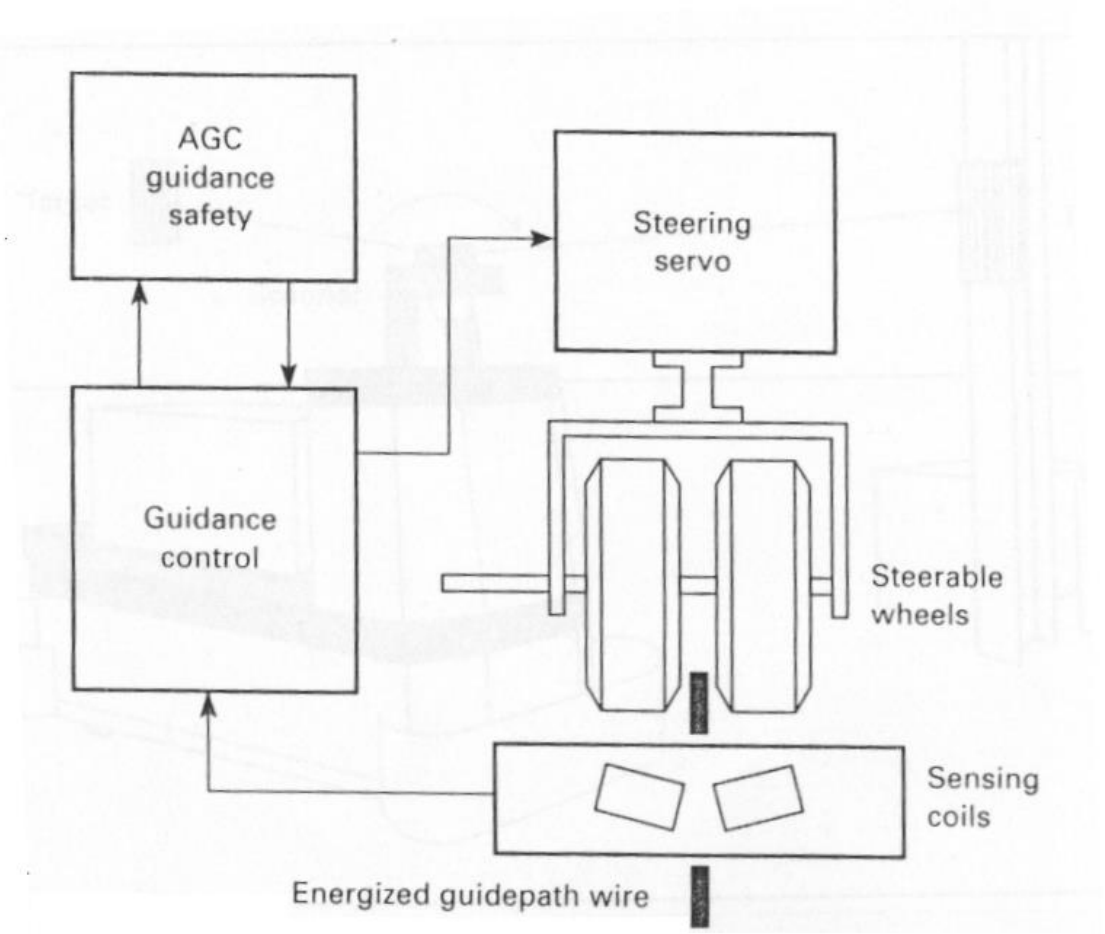
# Rail transport



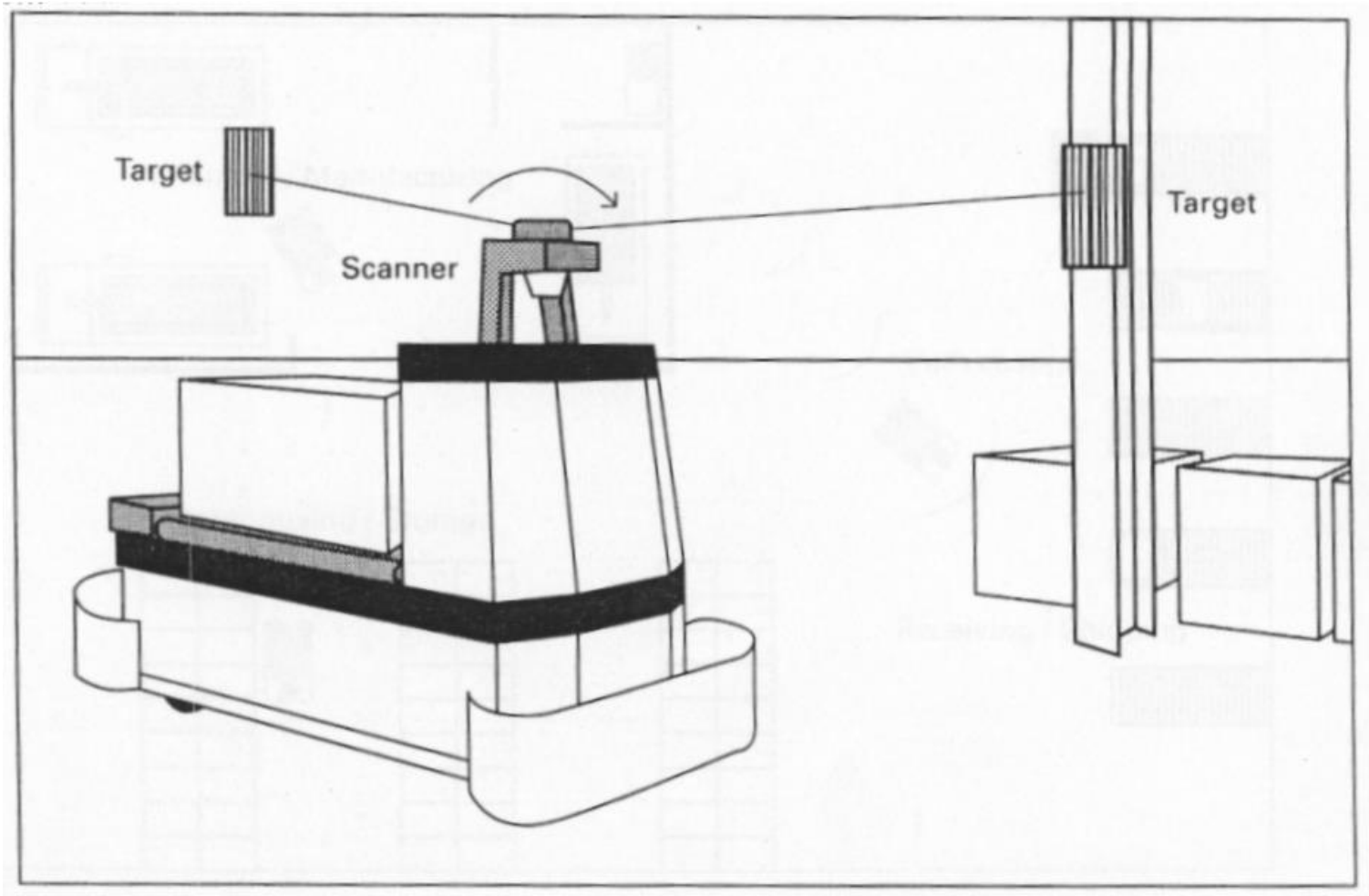
# Automated Guided Vehicle (AGV)



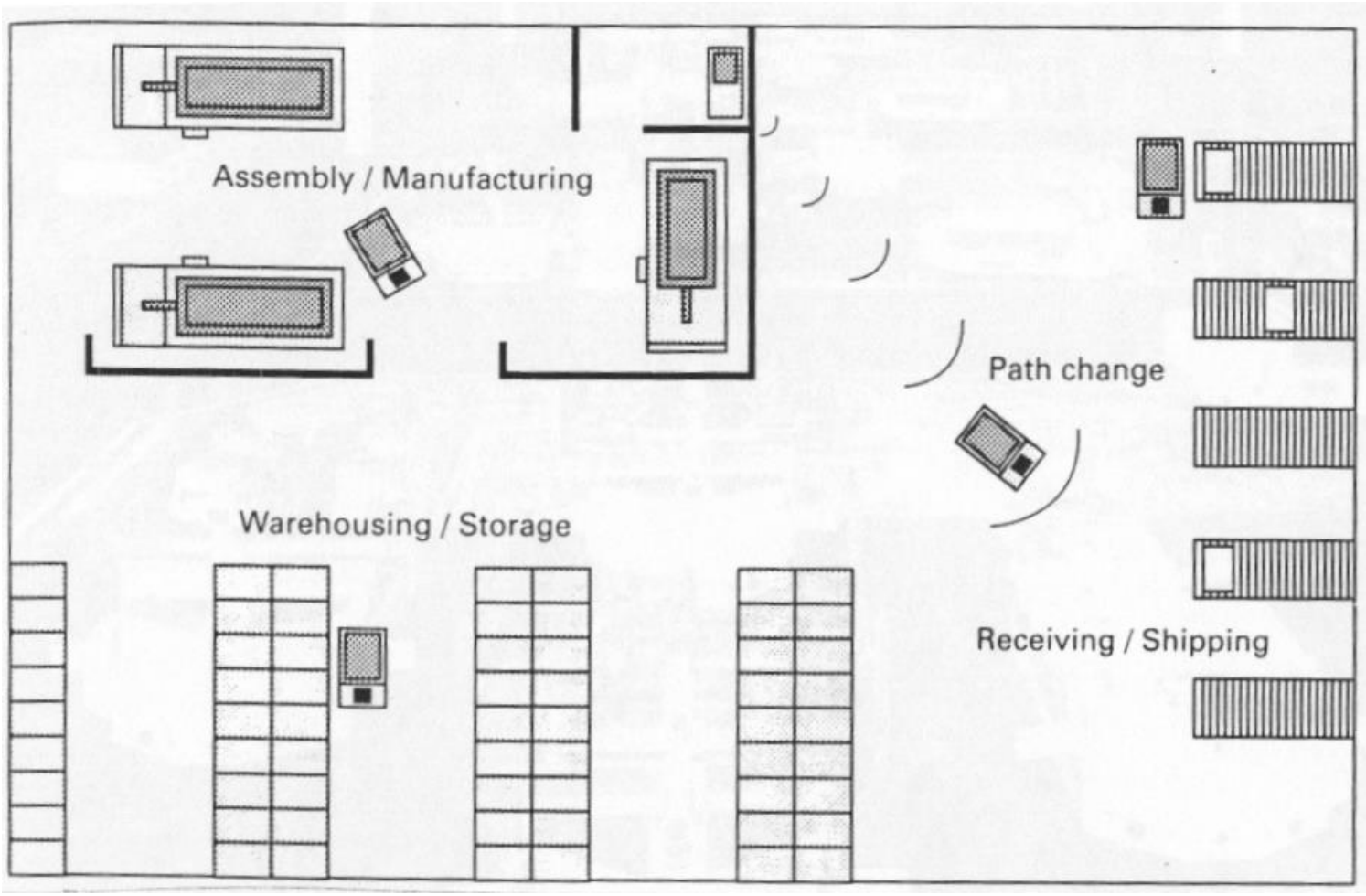
# Guiding system of an AGV (1)



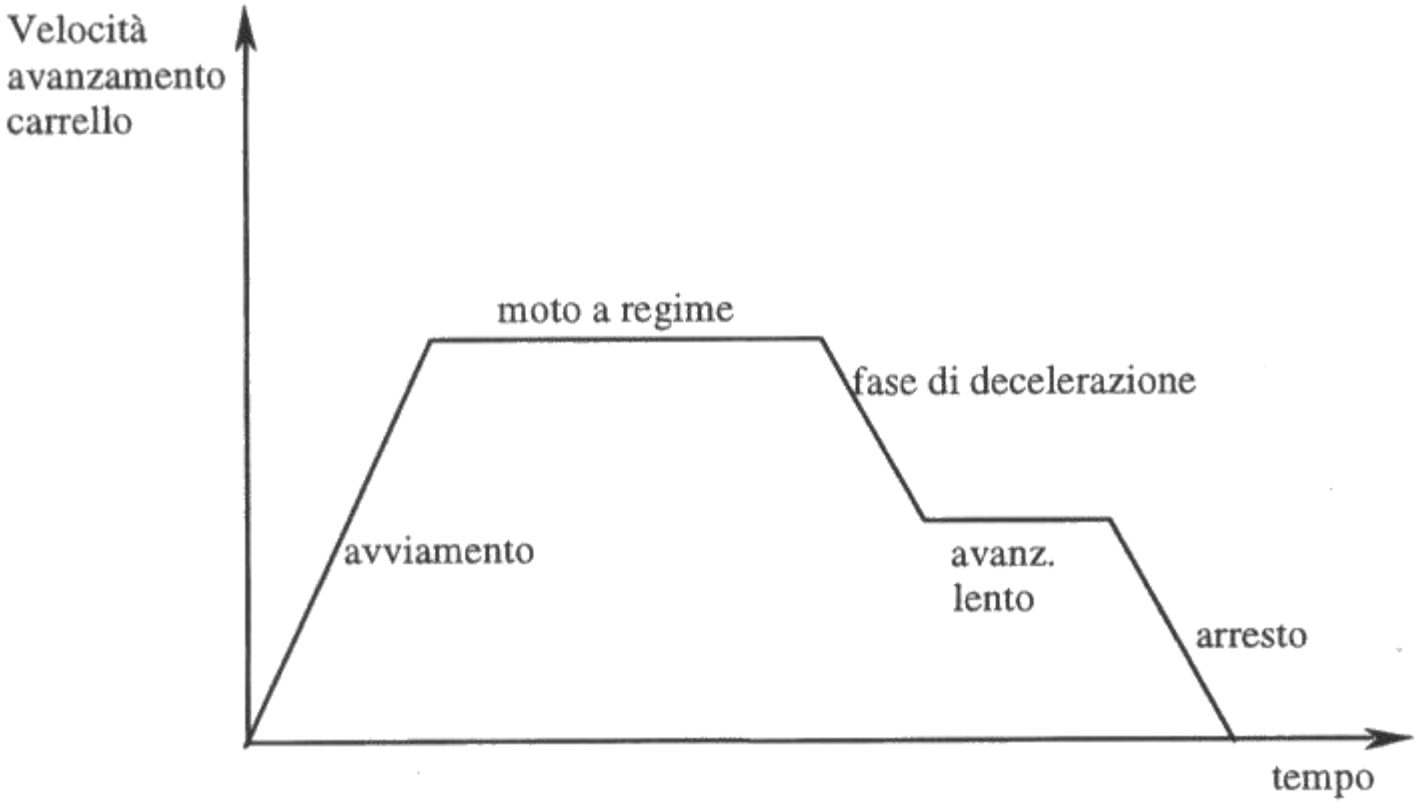
# Guiding system of an AGV (2)



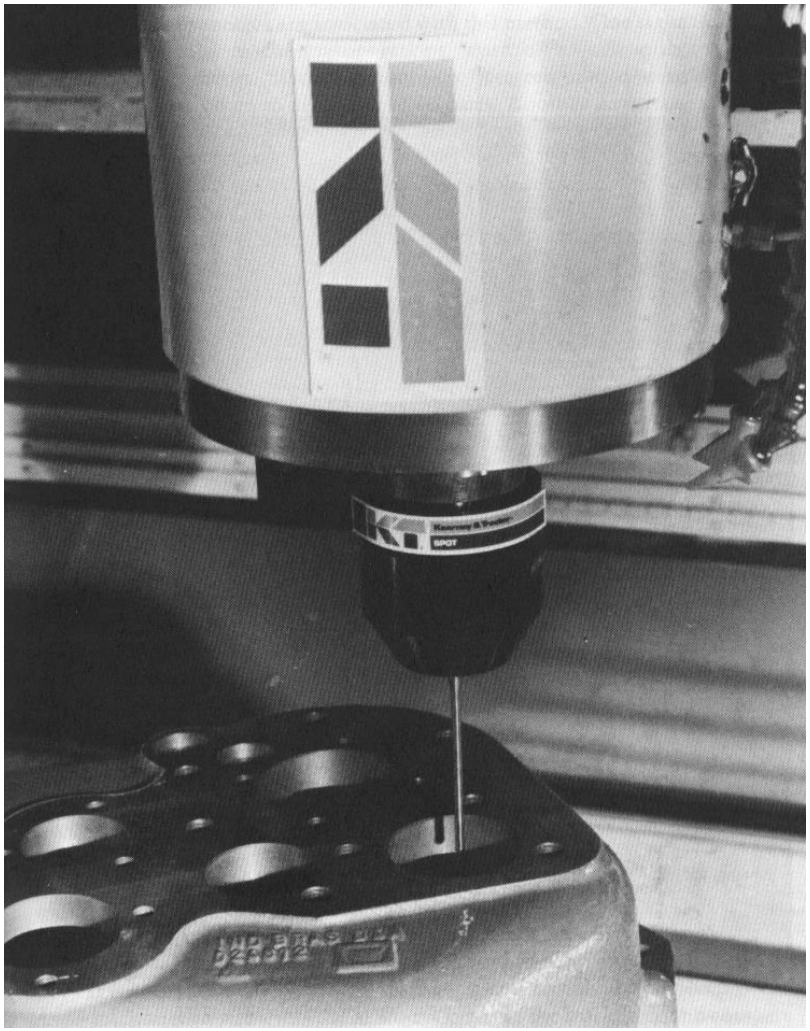
# Guiding system of an AGV (3)



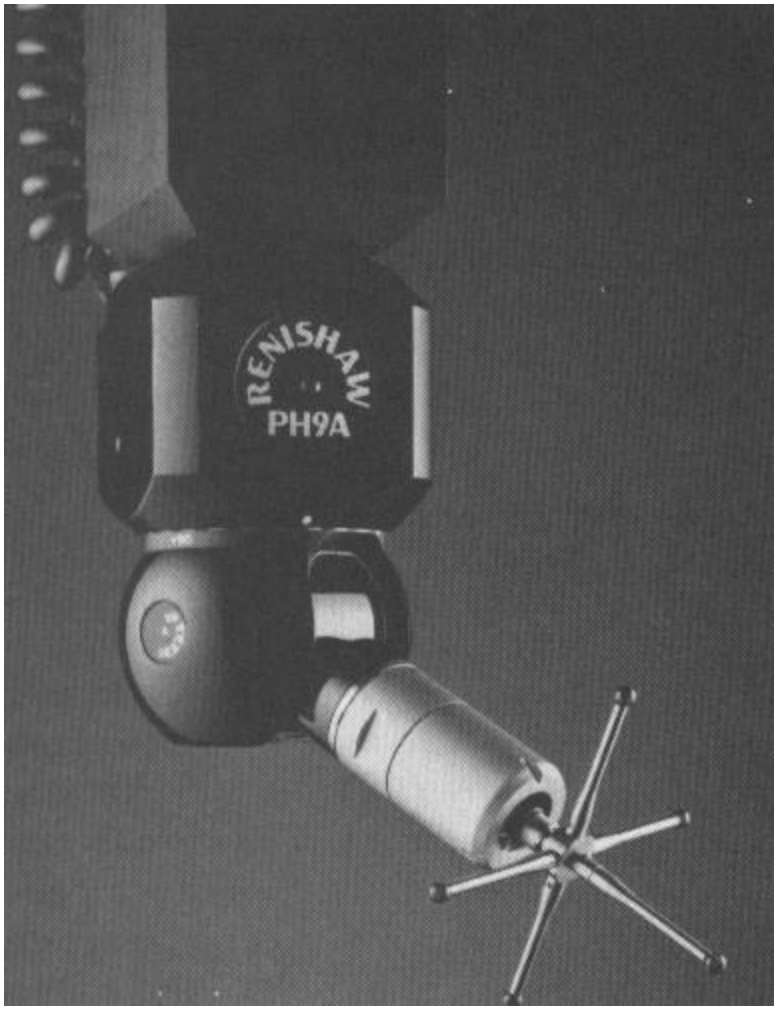
# Speed profile of an AGV



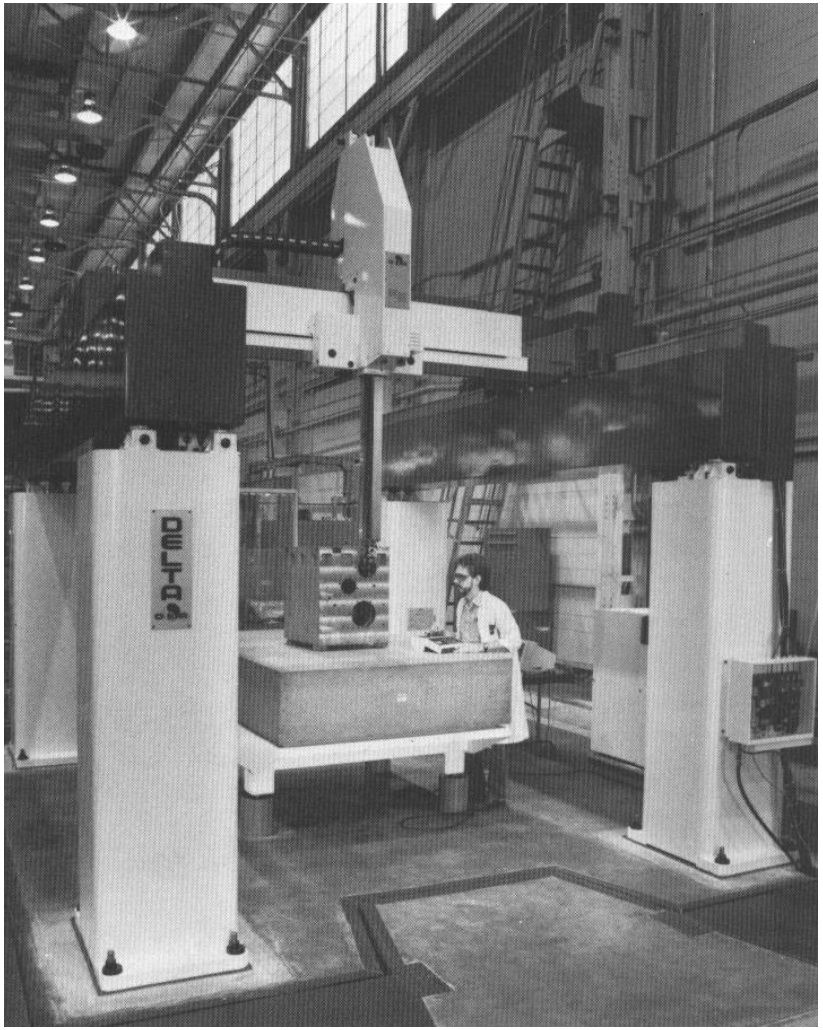
# Dimension check



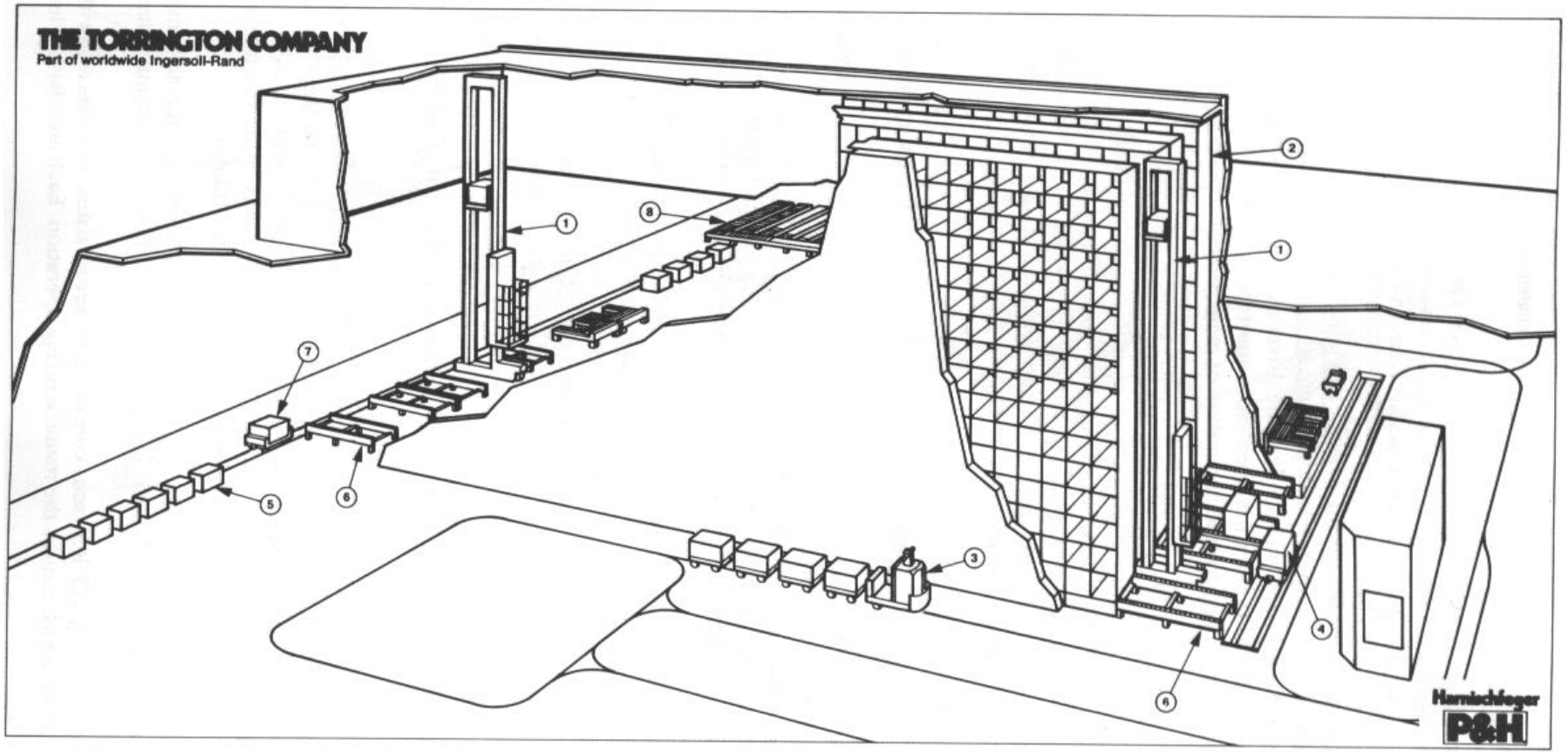
# Multi-headed tester



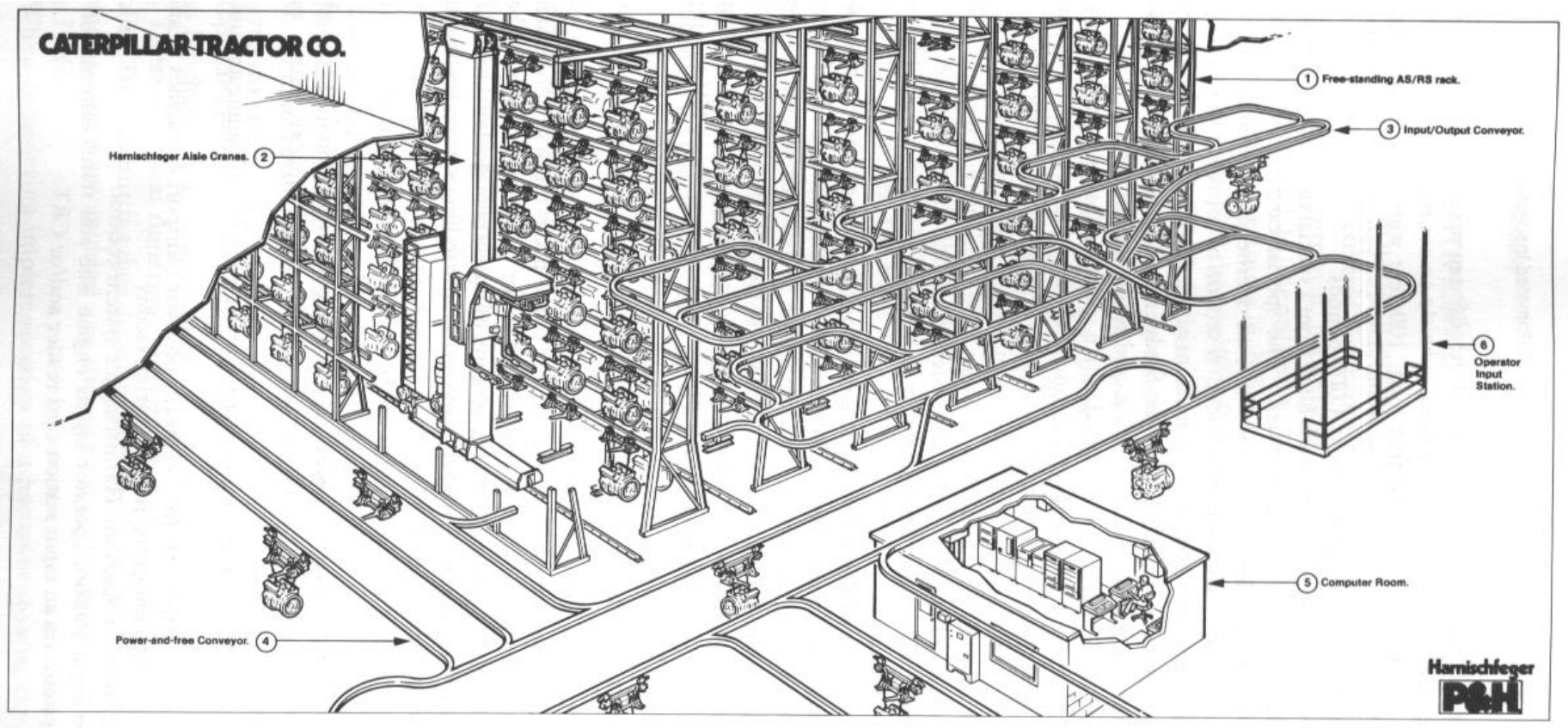
# *Gantry system for the dimension check*



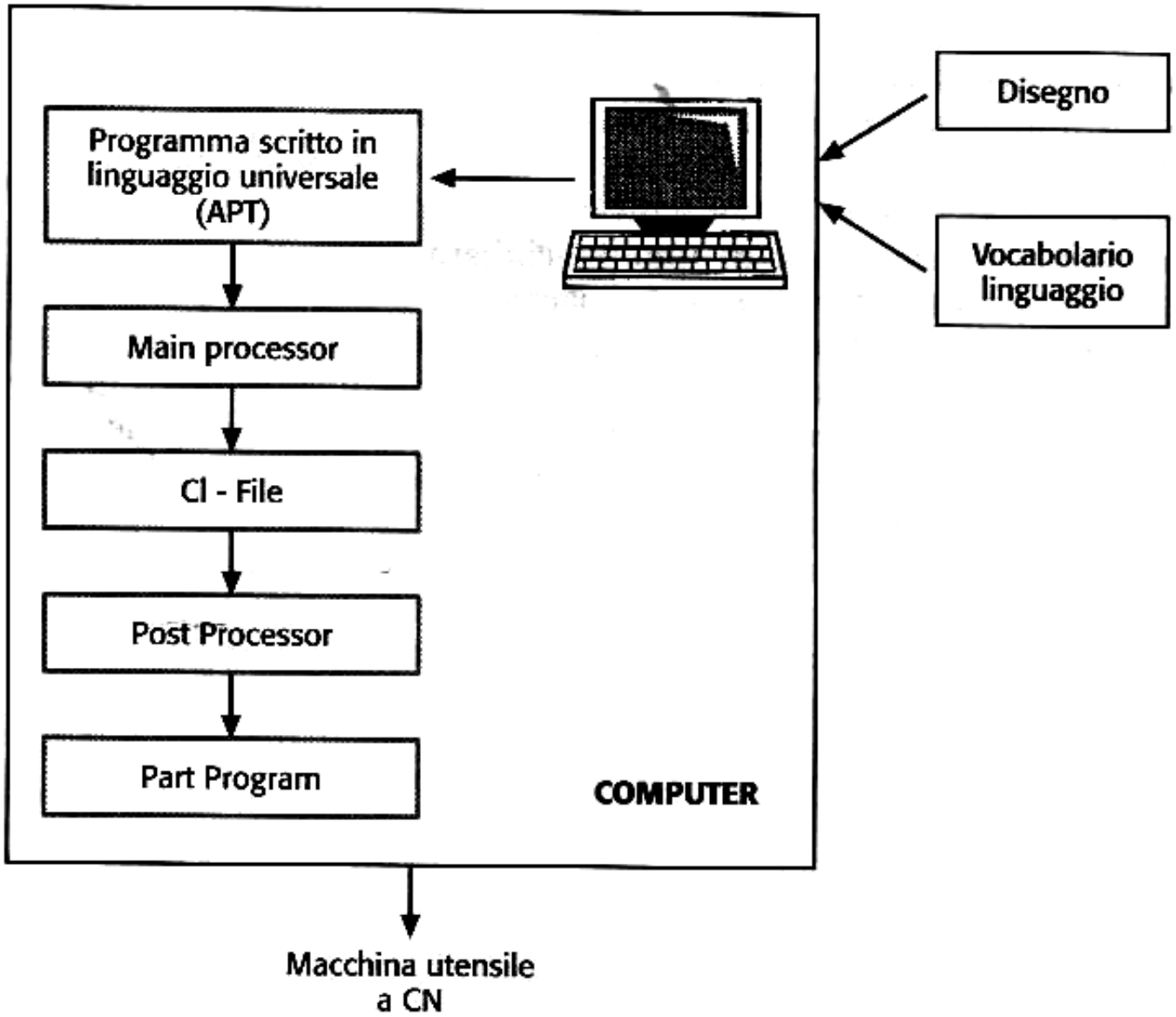
# Automated Storage/Retrieval System - ASRS - (Ingersol-Rand)



# Automated Storage/Retrieval System - ASRS - (Caterpillar)

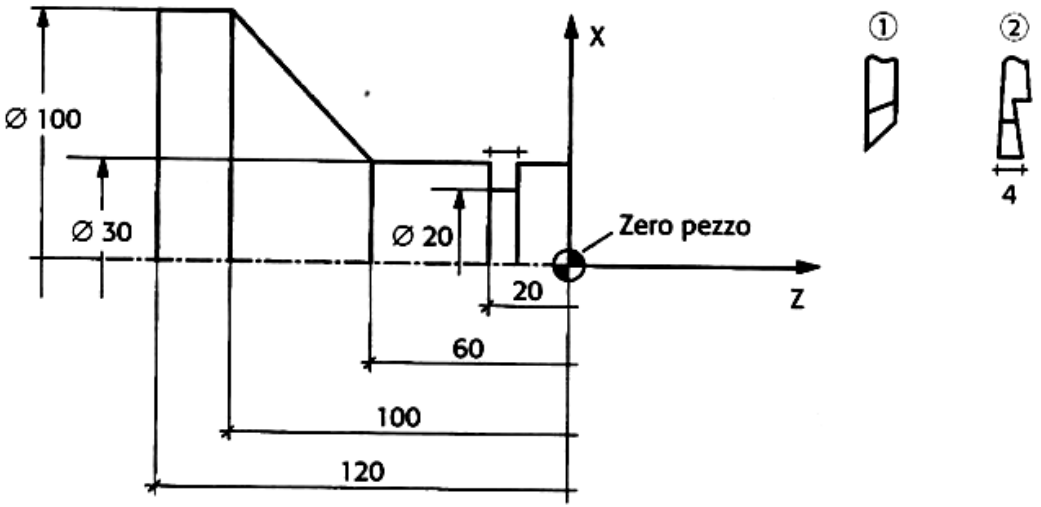


# Focus on CNC machines


Programma scritto in linguaggio universale (APT)
Main processor
Cl - File
Post Processor
Part Program
COMPUTER
Disegno
Vocabolario linguaggio
Macchina utensile a CN

# Programming elements

- The *part program* provides all information required to execute the machining phases:
  - Regarding the tool trajectory from the part, both related to the geometry and to the moving modes (of advancement, cutting, positioning, …)
  - Regarding the chosen technological parameters (speed, advancement, …)
  - Regarding other auxiliary information, such as:
    - Tool selection
    - Use of cutting fluids
    - Load/unload of pallets
    - …




```
T 101 M 6                          Chiamata utensile 1
G 96 S 100 M4 F2                   Impostazione parametri di taglio
G 0 X Z 1                          Avvicinamento rapido
G 1 Z                              Tornitura profilo
X 30
Z - 60
X 100 Z - 100
Z - 120
G 0 X 150 Z 150                    Allontanamento rapido
T 202 M 6                          Chiamata utensile 2
G 97 S 300 M 4 F.08 M 08           Impostazioni parametri di taglio
                                   e apertura refrigerante
G 0 X 31 Z - 20                    Avvicinamento rapido
G 1 X 20                           Esecuzione gola
G 0 X 31                           Allontanamento rapido
Z 150 M 09                         e stop refrigerante
M 30                               Stop programma e reset
```

An easy program in the language of CNC machines

# Machining

- The machining program is loaded in the memory of the governing unit
- The machining program is selected at the moment the parts need to be processed
- Before starting each machining phase, the «zero machine» has to be identified, it is the reference for all handling instructions
- A setup programming cycle (complete or partial) has to be executed in order to verify the presence of any programming error
- Parts have to be positioned
- The program is launched

# CAM systems – *Computer Aided Manufacturing*

- CAD systems can be integrated with the related CAM package. They allow to create, starting from the design, the part program. The part program provides all paths of tools to be given directly to the CNC machine to execute machining operations

# Numerical Control: conclusions

- The two fundamental and characterizing parameters of a production system are (they are in a trade-off relationship):
  - Productivity: the capacity to process a high quantity of parts in a given time, given defined levels of quality and cost
  - Flexibility: the capacity to quickly adapt to process an high number of parts that have different and changeable characteristics
- CNC machines optimally provide both the aforementioned characteristics, indeed they ensure:
  - Reduced execution times (productivity)
  - Minimal passive times (flexibility)

# Numerical Control: conclusions

- It is particularly advantageous for the machining of:
  - Parts with complex shape
  - Parts requiring an high number of tools
  - Continuous control of the cutting speed
  - Exploitation of not highly skilled operators

- Further applications of CNC (in addition to the shaving removal) can be:
  - Robots
  - Measuring machines
  - Centers for the machining of sheet metal
  - Centraper la lavorazione della lamiera
  - Laser cutting systems, *water jet*, …. flat parts systems

- The set of CNC machines constitute a FMS – *Flexible Manufacturing System,* based on the electronic link of single units with a central PC, which manages the allocation of processing activities required on the different machines

# Robot

# Rossum universal robots (K. Capek), 1920

- In this theatrical drama, for the first time the term *robota* = forced or heavy labor was used

# Robotics laws (I. Asimov), 1942

- *A robot may not injure a human being or, through inaction, allow a human being to come to harm*
- *A robot must obey any orders given to it by human beings, except where such orders will conflict with the First Law*
- *A robot must protect ist own existence as long as such protection does not conflict with the First or Second Law*

# Main typologies of robots

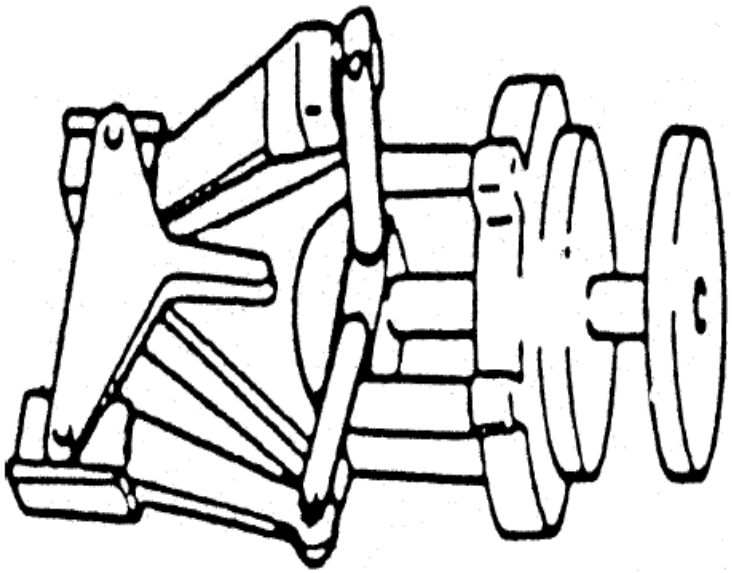
Cartesian


Anthropomorphic

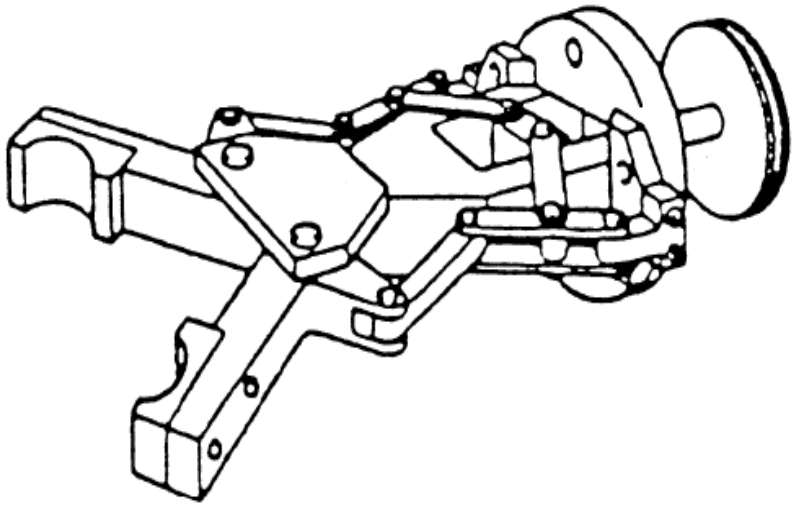

SCARA

# Constituent elements of robots: the hand

The hand can execute *gripper functions or end effector functions*



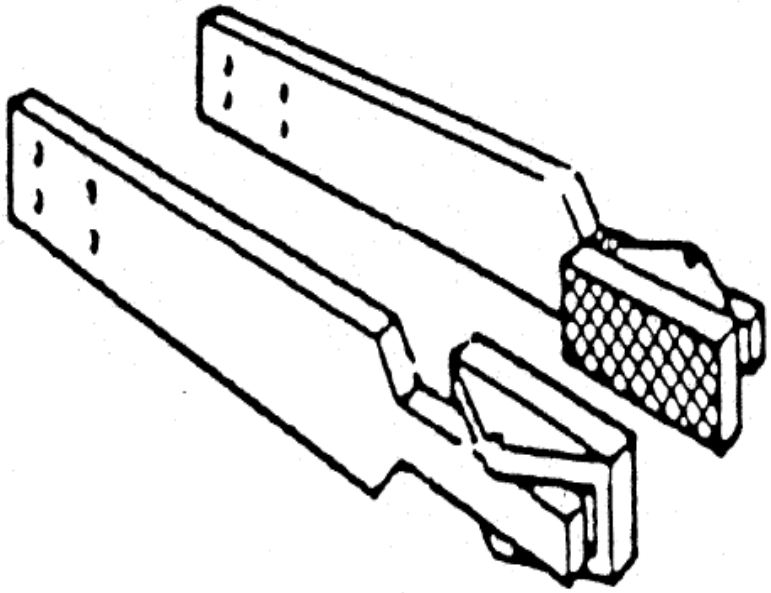
Standard hand



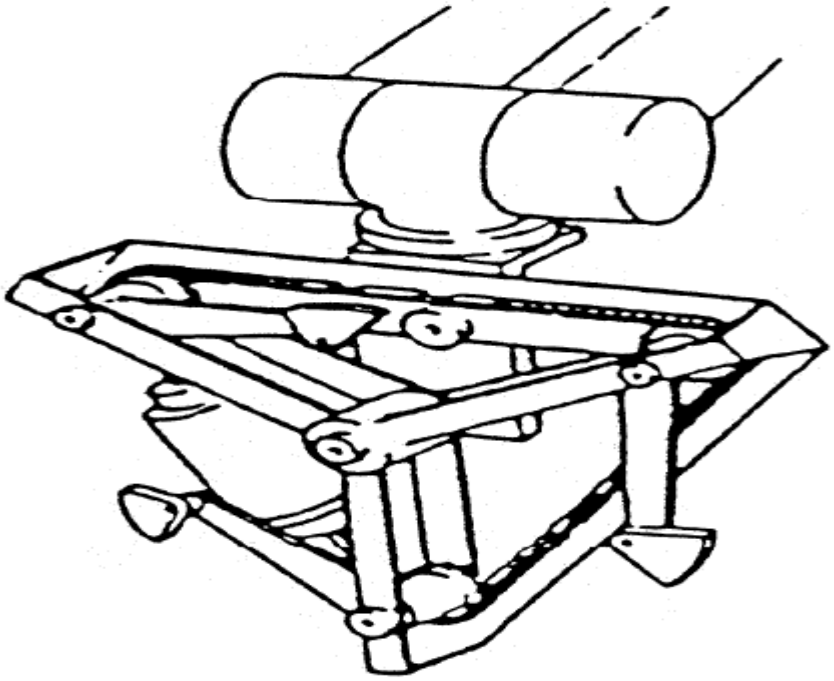
Hand with high opening

# Constituent elements of robots: the hand

The hand can execute *gripper functions or end effector functions*



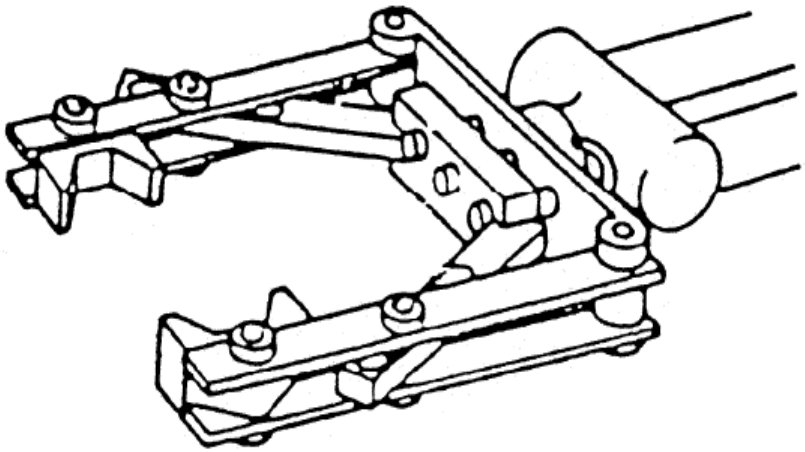
Hand with aligned fingers



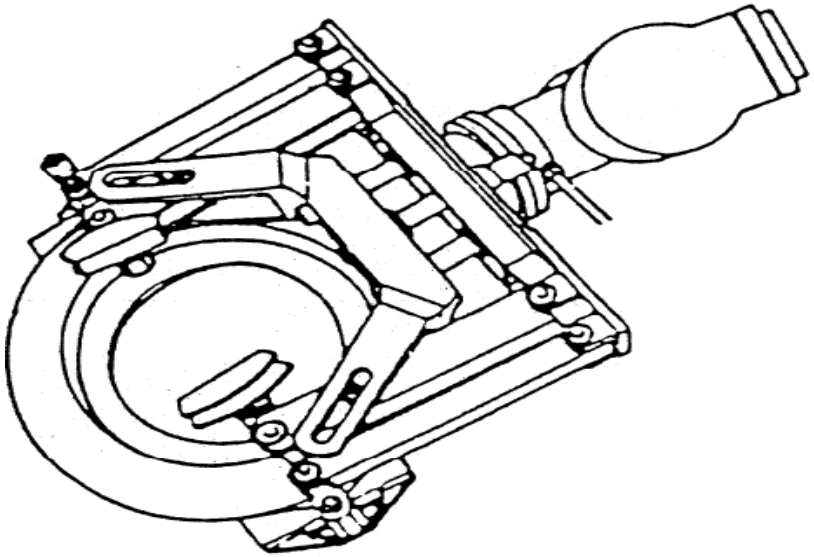
Self-centering hand

# Constituent elements of robots: the hand

The hand can execute *gripper functions or end effector functions*



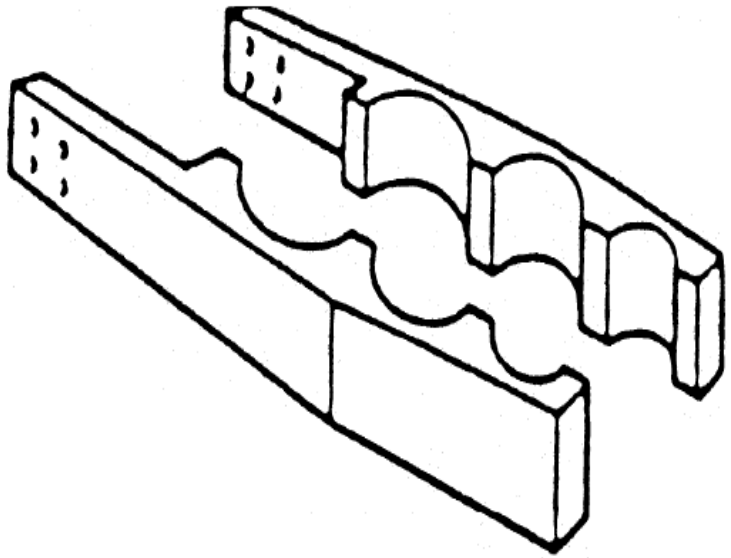
Hand with cams



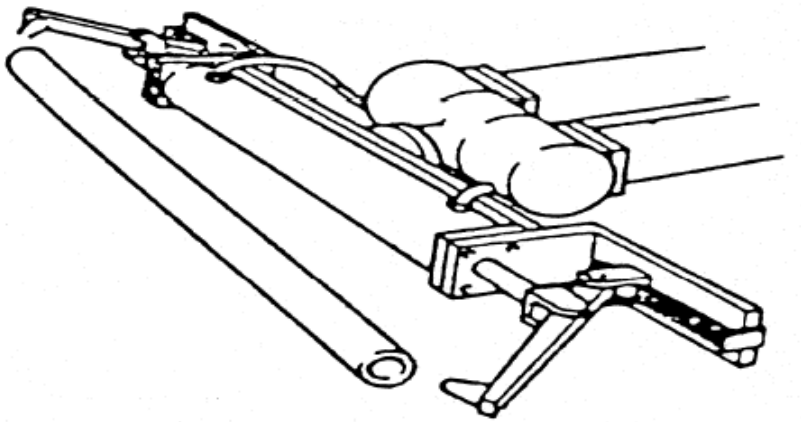
Hand with cams with internal and external jaws

# Constituent elements of robots: the hand

The hand can execute *gripper functions or end effector functions*



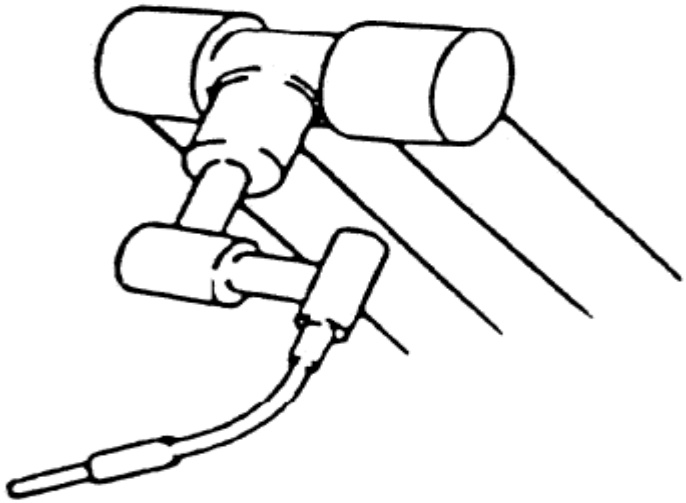
Hand for parts with different sizes



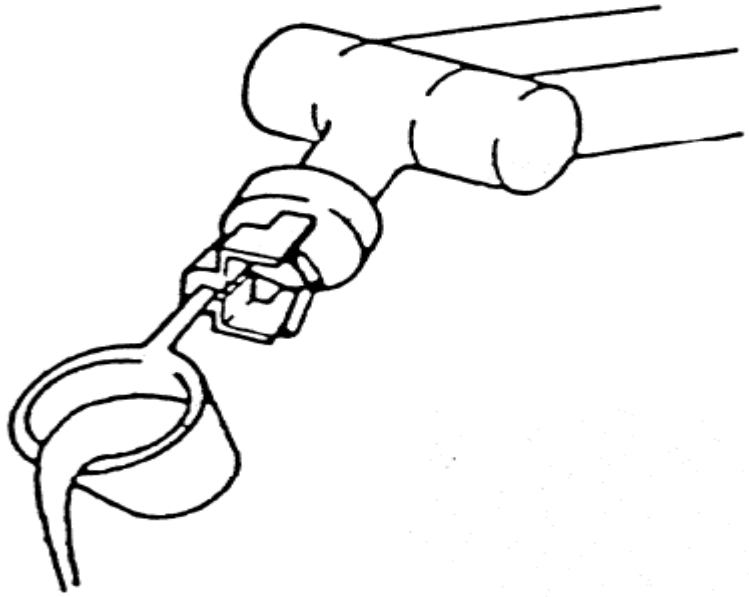
Special hand for glass tubes

# Constituent elements of robots: the hand

The hand can execute *gripper functions or end effector functions*



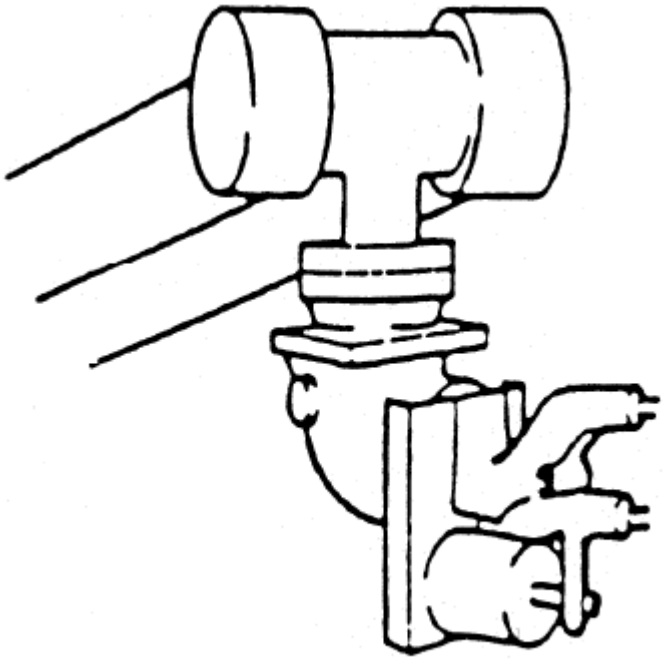
Flashlight for arc welding



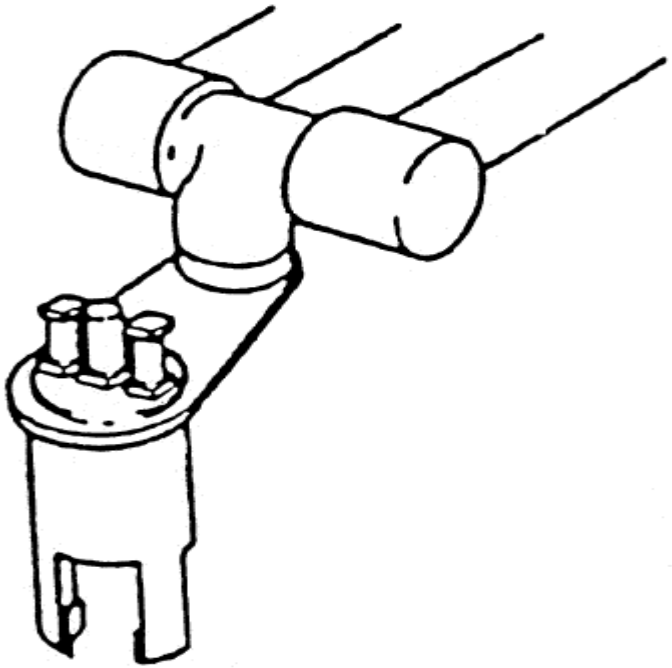
Hand with ladle

# Constituent elements of robots: the hand

The hand can execute *gripper functions or end effector functions*



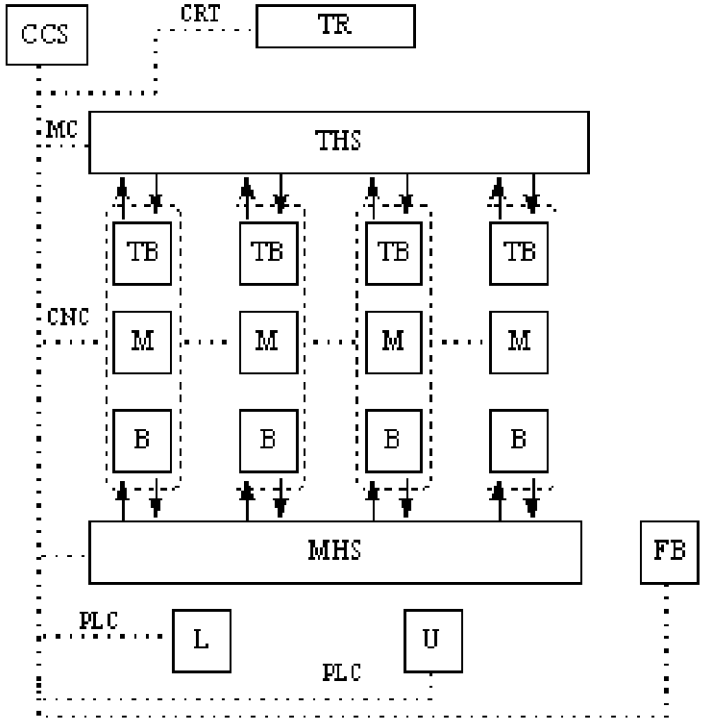
Gun for points welding



Pneumatic iron

# FMS – Conceptual schema and examples

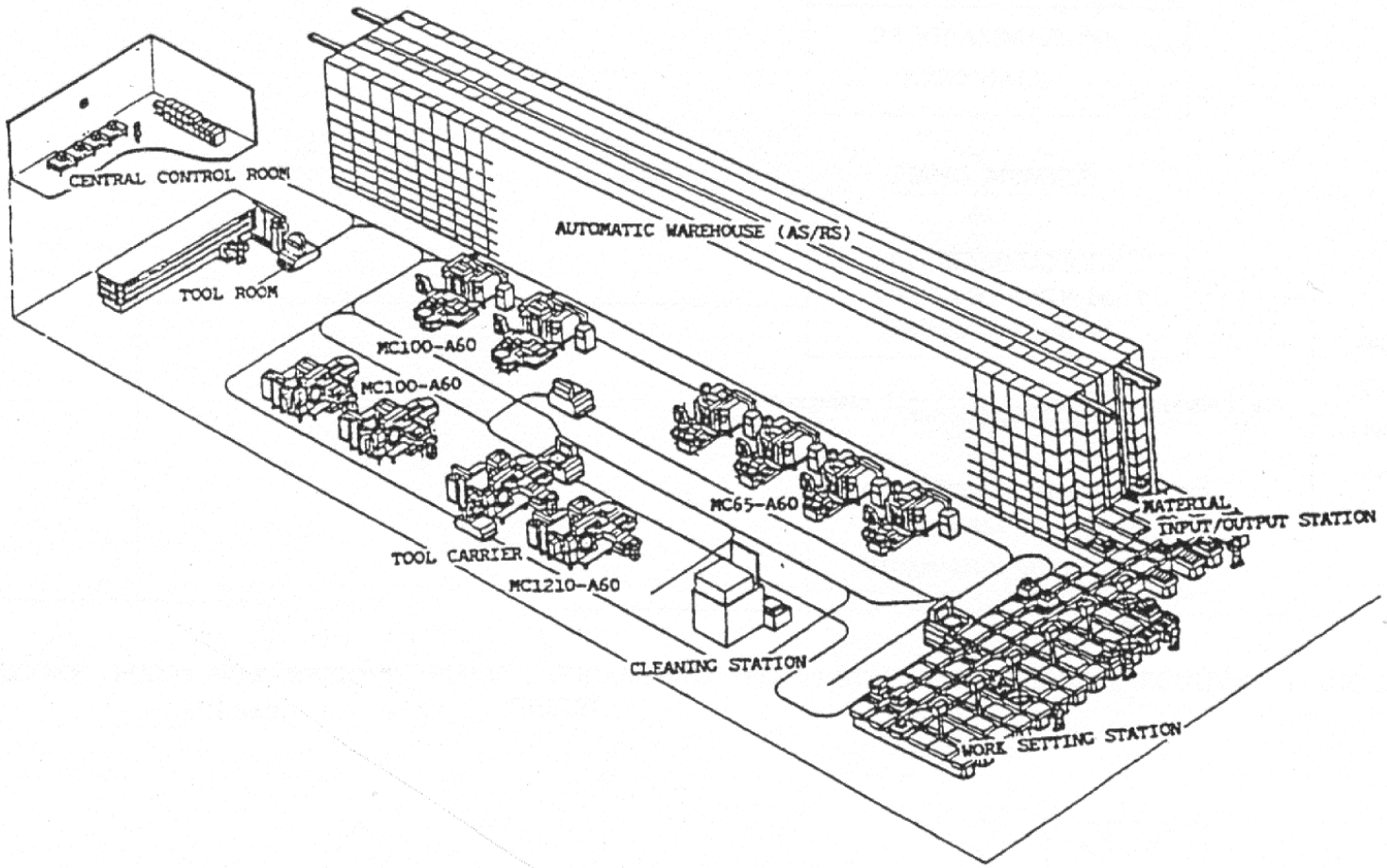
# LOGIC SYSTEM OF A FMS



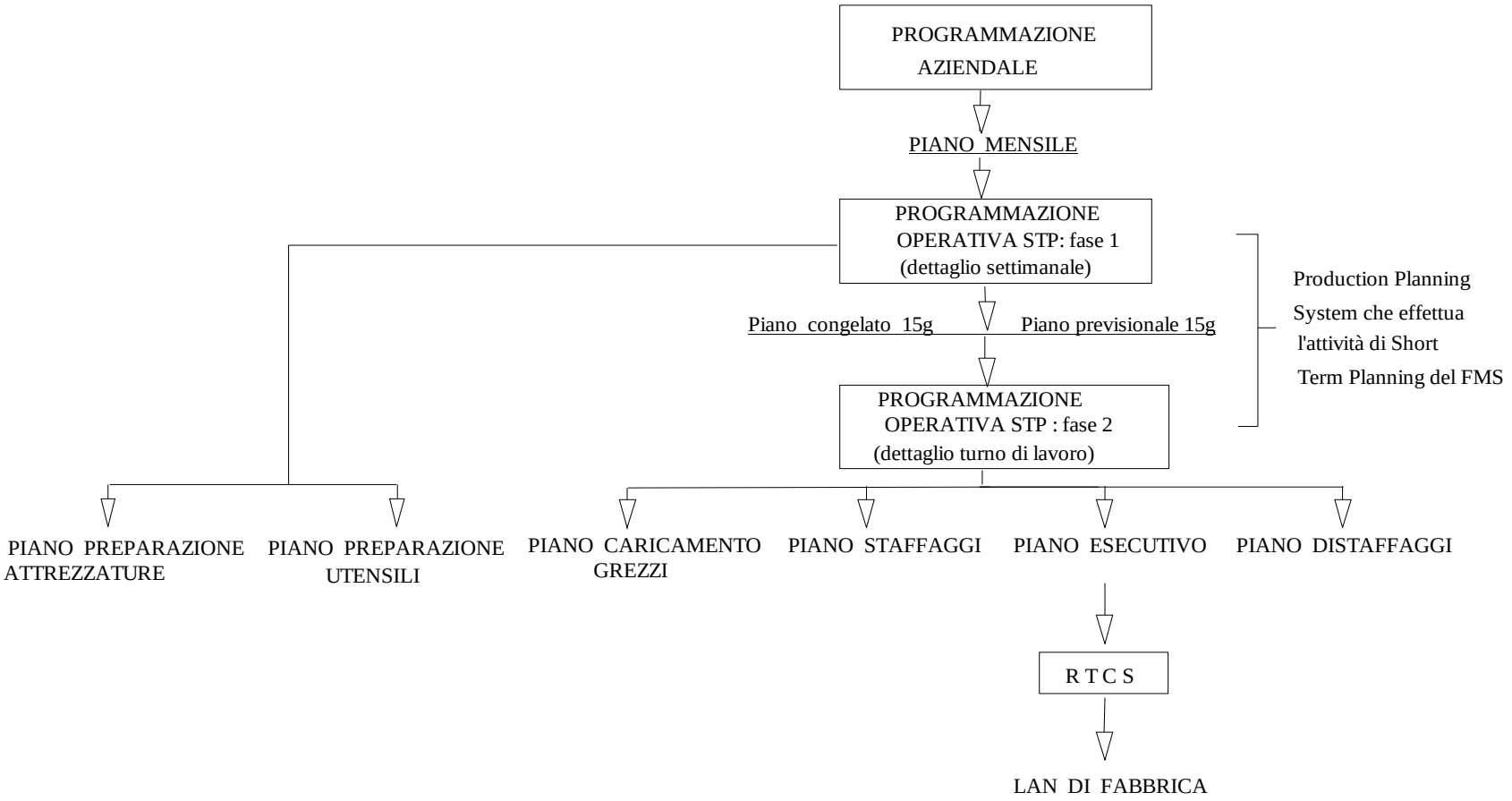

*Legenda*

| | | | |
|---|---|---|---|
| M | = NC Machine | TB | = Tool Buffer |
| MHS | = Material Handling System | L | = Load |
| B | = Buffer storage | U | = Unload |
| WS | = Work Station | FB | = Fixture Buffer |
| TR | = Tool Room | CCS | = Computer Control System |
| THS | = Tool Handling System | ..... | = Data Network |

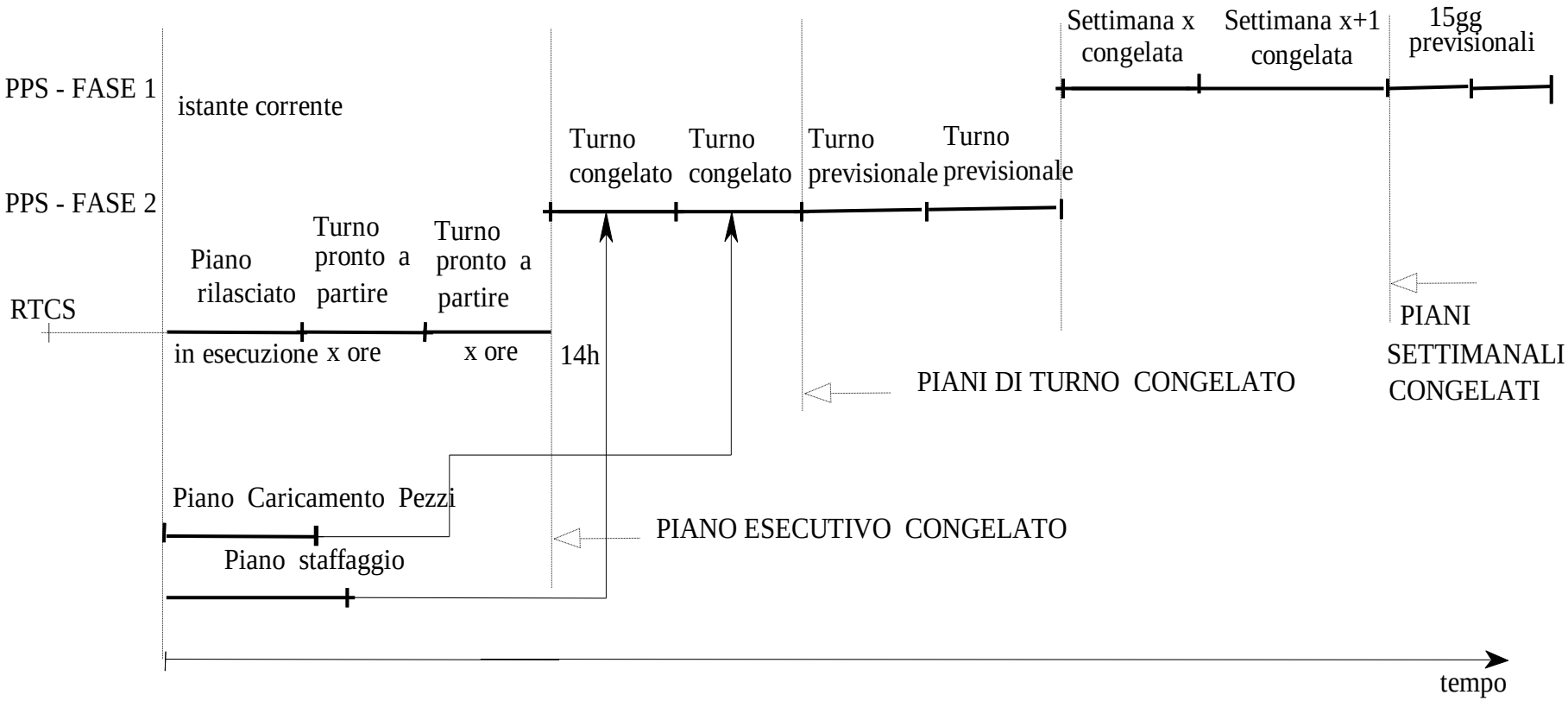
# MAX MAKINO SYSTEM



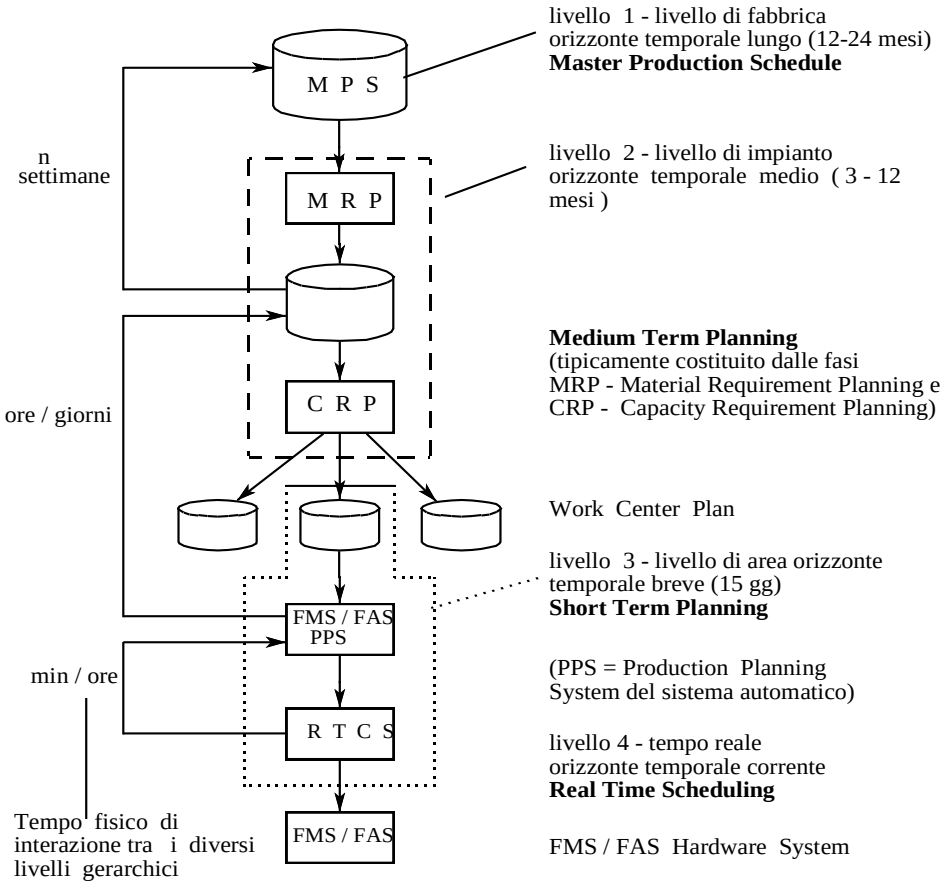
# SHORT-TERM PROGRAMMING ACTIVITY



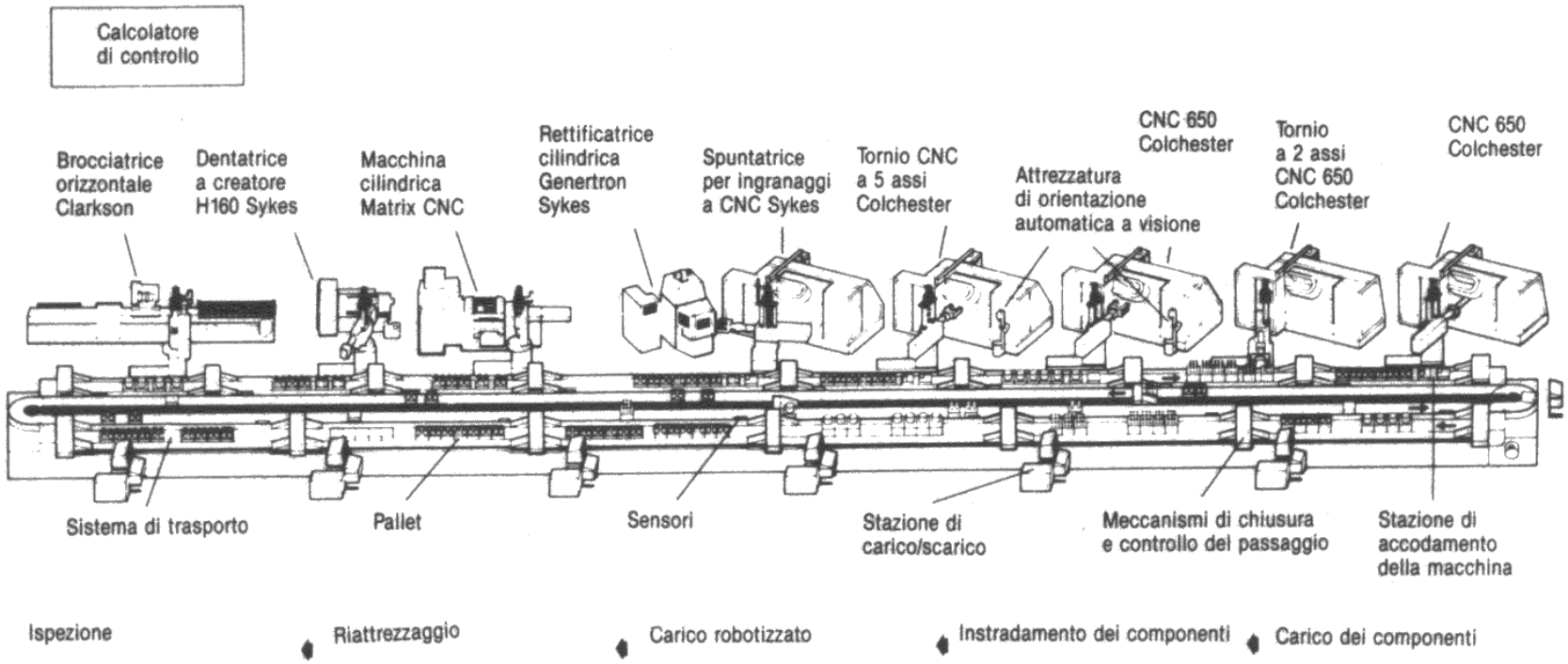
# PLANNED TEMPORAL HORIZONT



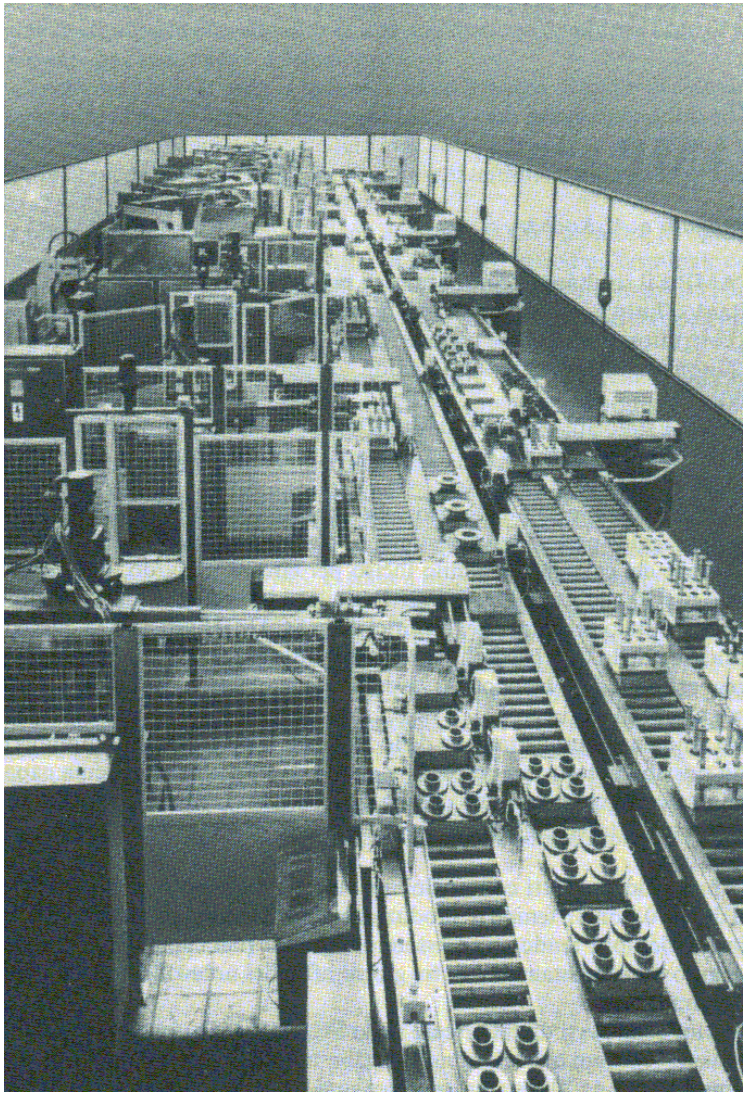
# Architecture of the management system



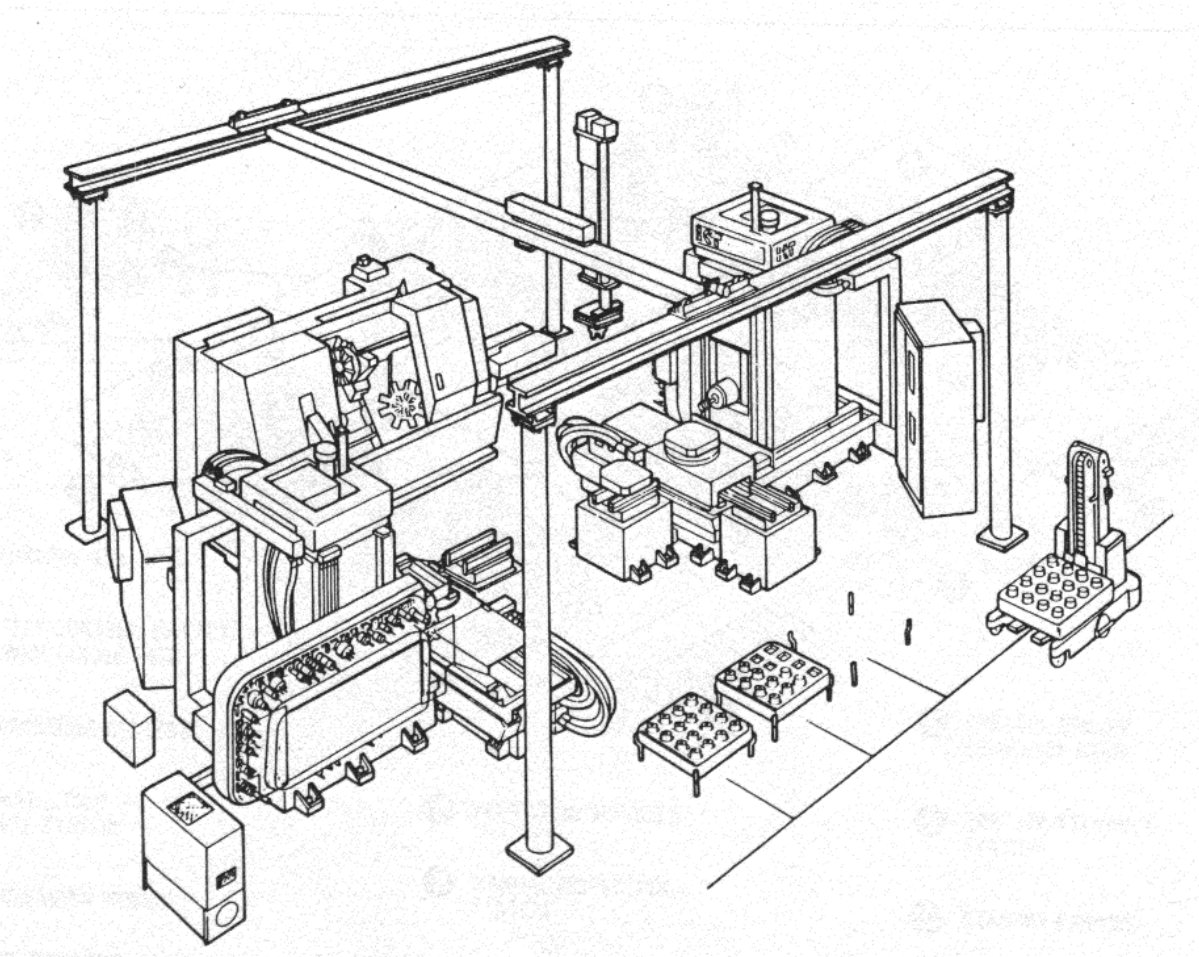
# SCAMP system



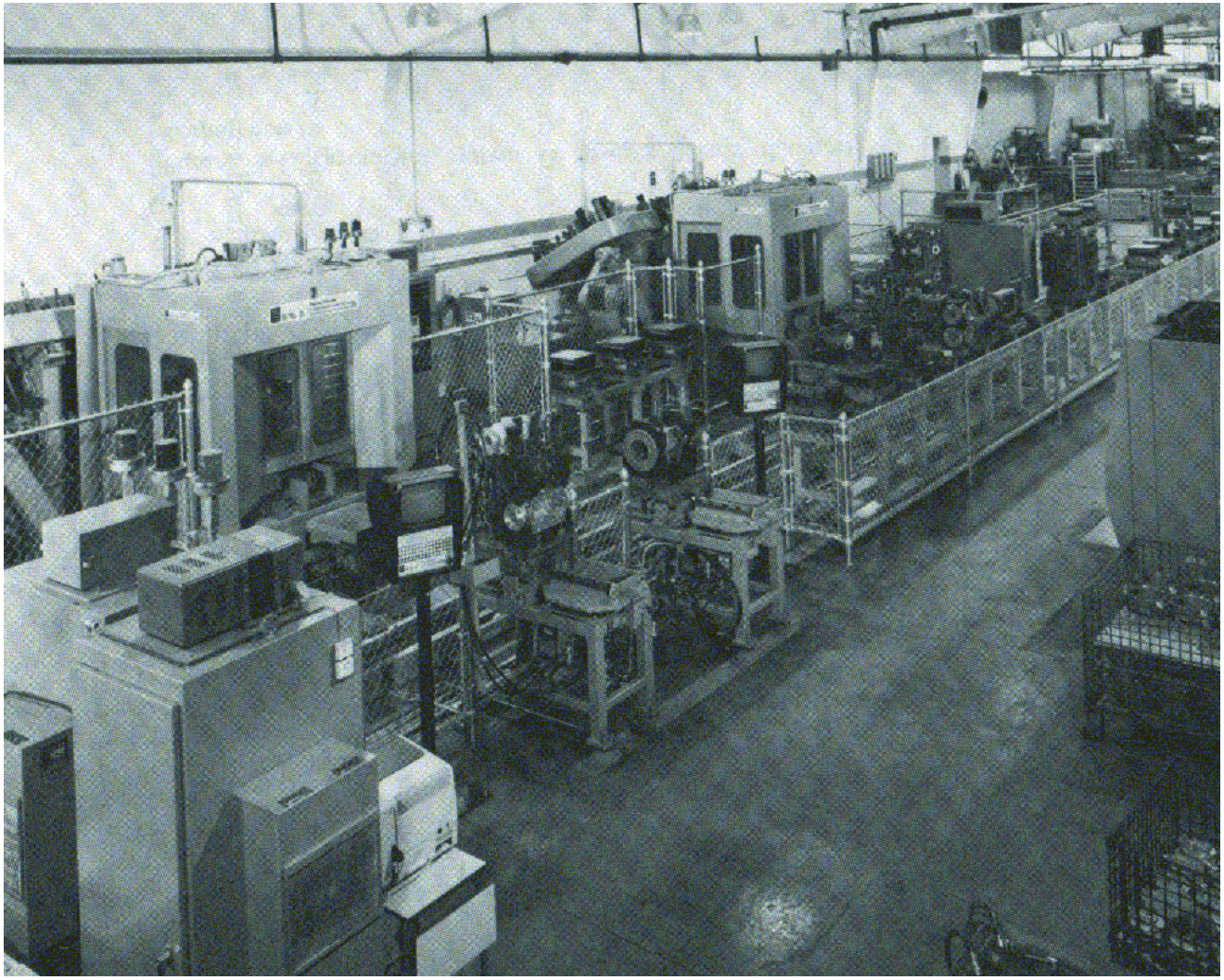
# SCAMP system



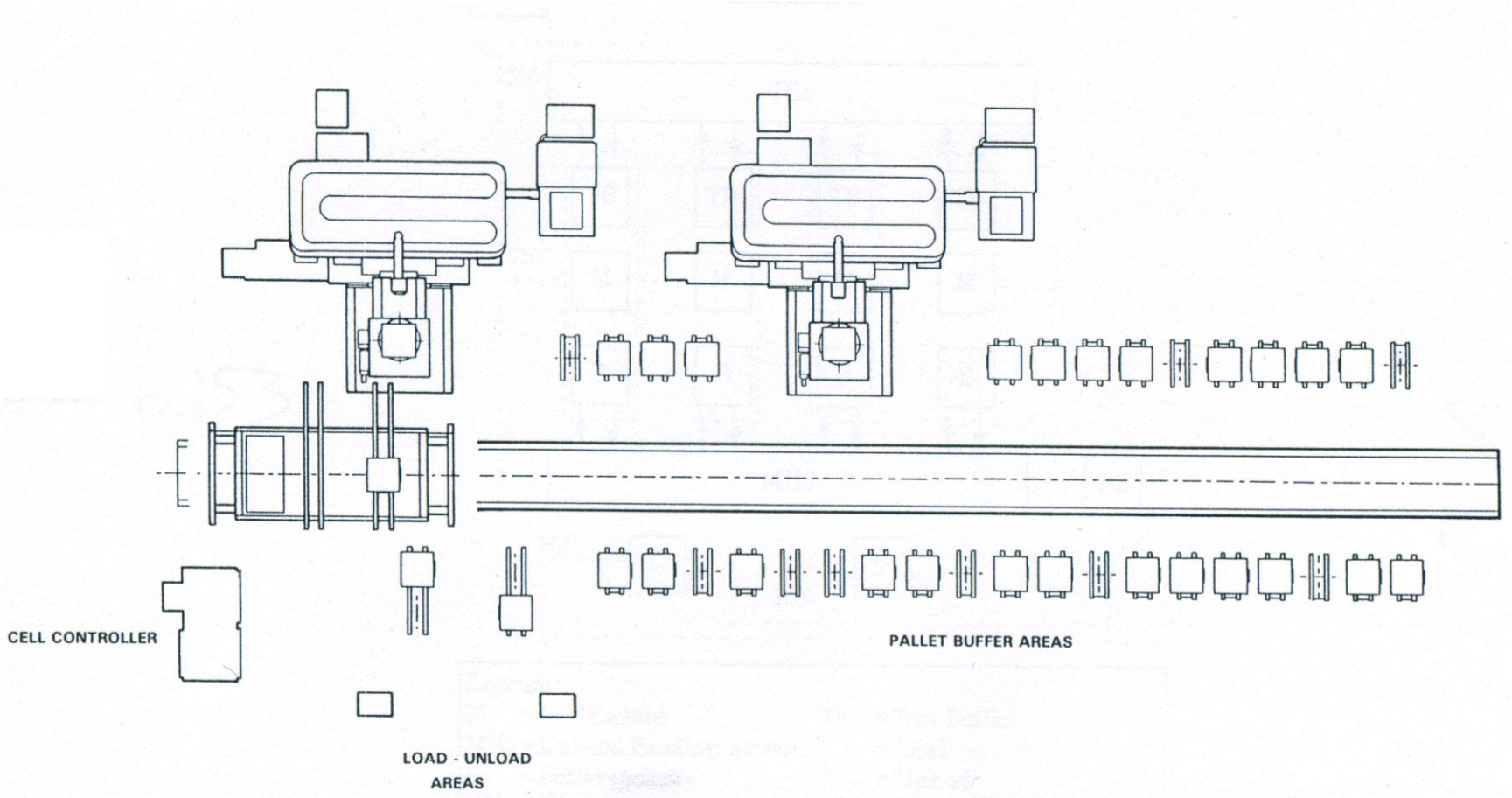
# AN EXAMPLE OF MANUFACTURING CELL



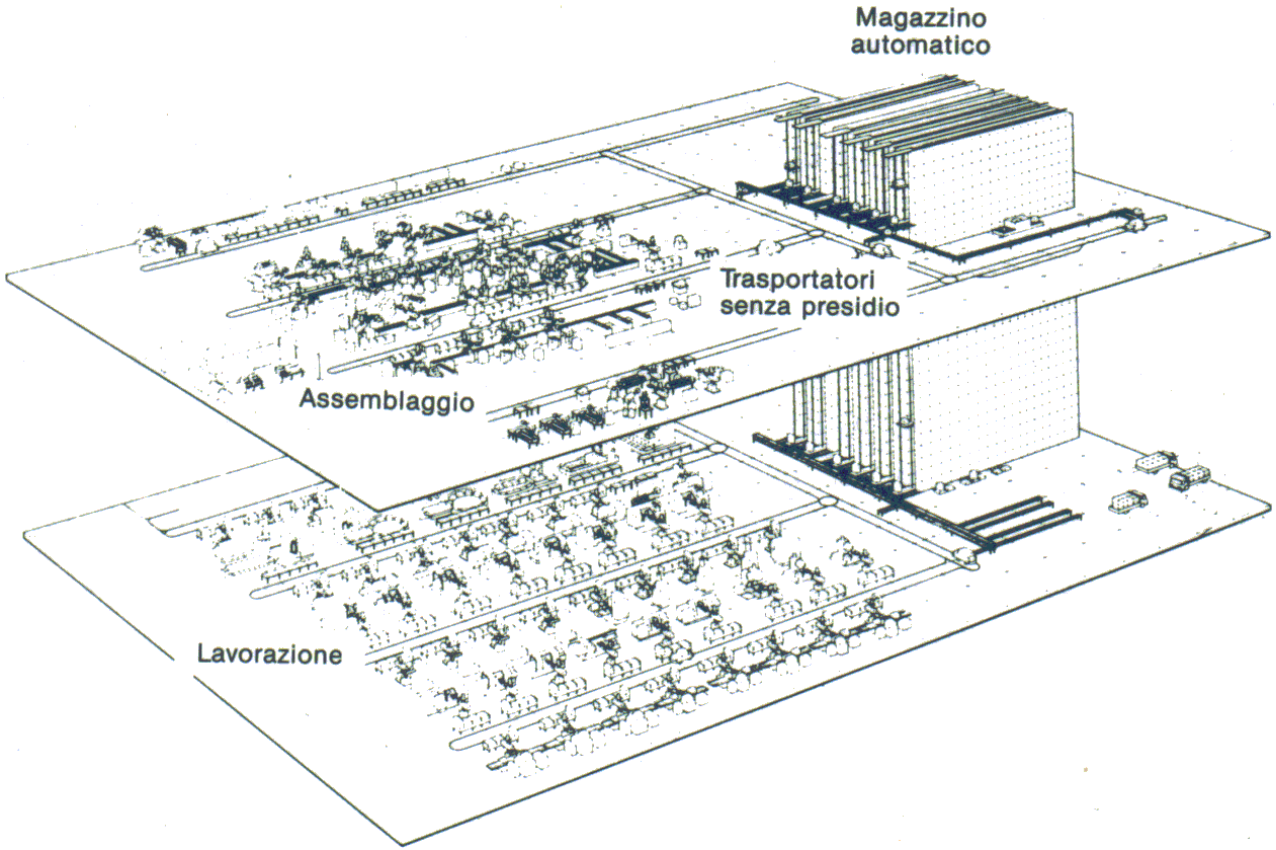
# Badger Meter CELL



# Badger Meter CELL



# FANUC FMS


Magazzino
automatico
Trasportatori
senza presidio
Assemblaggio
Lavorazione