Robotization in transport systems

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Foundation of the course

The course of the „Robotization in transport systems” includes:

- 15 hours of the lecture per semester,
- 15 hours of the project.

Assessment of the course:

- presence and positive assessment of project and preparation of the printed version of the final report,
- passing the test from the lecture (colloquium on the last class in the summer semester).

Literature (1)

1. **BlochH. P., Geitner F. K.: Practical Machinery Management for Process Plants– Machinery Component Maintenance and Repair (vol. 3),** Elsevier Linacre House, USA, 2005.
2. **Bloom N. B.: Reliability Centered Maintenance (RCM) Implementation Made Simple**, McGraw-Hill, USA, 2006.
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4. **Gross J. M.: Fundamentals of Preventive Maintenance**, AMACOM, USA, 2002.
5. **Lechner G., Naunheimer H.: Automotive transmissions. Fundamentals, Selection, Design and Application**, Springer-Verlag, Germany, 1999.
6. **Mobley R. K., Higgins L. R., Wikoff D. R.: Maintenance Engineering Handbook**, McGraw-Hill, USA, 2008.
7. **Nakagawa T.: Maintenance Theory of Reliability**, Springer-Verlag, London, 2005.
8. **Palmer D.: Maintenance planning and scheduling handbook**, McGraw-Hill, USA, 1999.

Literature (2)

9. **Ryabinin I.: Reliability of engineering systems**, MIR Publishers, Moscow, 1976.
10. **Scheffer C., Girdhar P.: Machinery Vibration Analysis & Predictive Maintenance**, Elsevier Linacre House, London, 2004.
11. **Smith R., Mobley R. K.: Industrial Machinery Repair. Best Maintenance Practices Pocket Guide**, Butterworth-Heinemann, USA, 2003.
12. **Fraden J.: Handbook of modern sensors –physics, design, applications, Springer, 2004.**
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14. **Bell J. L.: Set Theory Boolean - Valued Models and Independence Proofs, Clarendon Press, Oxford, 2005.**
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16. **Boyer S.: SCADA: Supervisory Control and Data Acquisition, ISA, USA, 2004.**
17. **Buse D.P., Wu Q.H.: IP Network-based Multi-agent Systems for Industrial Automation – Information Management, Condition Monitoring and Control of Power Systems, Springer - Verlag, London, 2007.**

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1. Kasprzyk J.: Programowanie sterowników przemysłowych. WNT, Warszawa 2010.
2. Świder J., Michalski P.: Systemy wspomagania diagnostyki sieci przemysłowych AS-interface. Wydawnictwo Politechniki Śląskiej, Gliwice, 2008.
3. Nawrocki W.: Rozproszone systemy pomiarowe. WKiŁ, 2006
4. Kasprzyk J.: Identyfikacja procesów. Wydawnictwo Politechniki Śląskiej, Gliwice 2002.
5. Zielińska T.: Maszyny kroczące: podstawy, projektowanie, sterowanie i wzorce biologiczne. WNT, Warszawa, 2003.
6. Broel-Plater B.: Sterowniki programowalne. Właściwości i zasady stosowania, Wydział Elektryczny Politechniki Szczecińskiej, Szczecin, 2003.
7. Gawrysiak M.: Mechatronika i projektowanie mechatroniczne, Dział Wydawnictw i Poligrafii Politechniki Białostockiej, 1997.
8. Heimann B., Gerth W., Popp K.: Mechatronika: komponenty, metody, przykłady, Wydawnictwa Naukowe PWN, Warszawa, 2001.

Literature (in Polish, 2)

1. Piątkiewicz A., Sobolski R.: Dźwignice. Tom I i II. WNT. Warszawa 1978.
2. Brach I i inni: Poradnik techniczny. Mechanik. Tom IV cz. 3. WNT. Warszawa 1982
3. Goździecki M., Świątkiewicz H.: Przenośniki. WNT. Warszawa 1985
4. Korzeń Z.: Logistyczne systemy transportu i magazynowania. Tom I i II. Wyd. IliM. Poznań 1989
5. Woźniak H. i inni: Podstawy logistyki. Wyd. Mangala Pres, Gdańsk 1999
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7. Zdanowicz R: Robotyzacja procesów technologicznych. Wydawnictwo Politechniki Śląskiej. Gliwice 1999
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12. Polskie Normy z zakresu obliczania wytrzymałości zbloczy, lin oraz dźwignic i hamulców
13. Zasady doboru napędów elektrycznych - publikacja elektroniczna firmy SEW-Eurodrive

The thematic scope of the lecture

- Basic concepts in the field of transport systems,
- Classification of cranes, crane work intensity group,
- Steel ropes as drive elements,
- Types of brakes used in cranes,
- The calculations associated with the selection of engines for handling,
- Transporters,
- Telescopic and scissor systems (lifts),
- Control of technological systems, integration of robotic systems,
- Robotization, types of technological operations susceptible to robotization,
- Exemplary robotic structures
- Examples of robotic systems in terms of analysis of transport possibilities and completion of the warehouse,
- Examples of robotic storage systems,
- Symbols used in transport analysis.

Transport - the definition and division

Transport - is a set of activities related to the transfer of persons and material goods using appropriate means. The set of activities related to the transfer includes both the mode of transmission as well as all activities that enable carrying, which include: loading, unloading and handling.

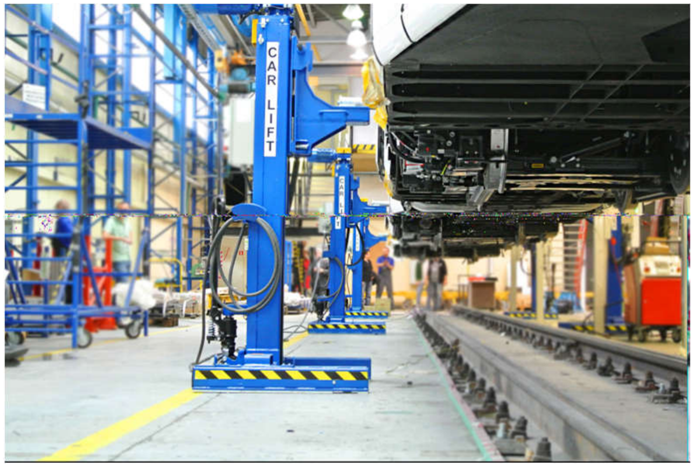
Internal transport - it is transport in the workplace, where the workplace is both a production plant as well as a service plant in which the transport process takes place.

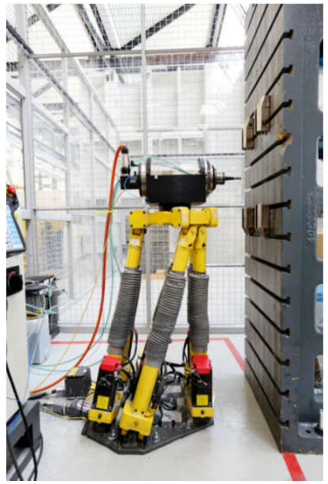
External transport - is transport outside the workplace, but connected by roads or transport lines with the workplace and used to transport people and material goods to the plant and their export outside the workplace.

Transport - the definition and division

Closed transport - transport taking place at the workplace or in its immediate vicinity, using measures of limited scope

Long-distance transport - it is transport that extends over further distances, taking place along transport routes, i.e. railways, airlines or along transport lines, i.e. conveyor or pipeline lines.

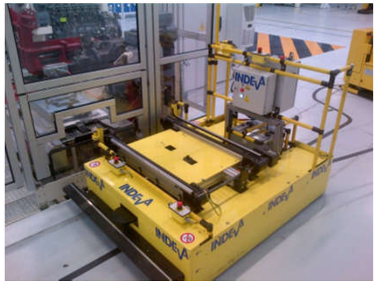




Means of transport. Definition and division.

Vehicles with intermittent traffic - means that interrupt their transport traffic and stop for unloading, loading or other manipulative activities.

Continuous transport means - these are means that are either constantly in motion or the material being conveyed is a continuous stream.



Means of transport

with limited *with unlimited*

range of action

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Means of transport. Definition and division.

Unlimited range means of transport include:

- rolling stock,
- water fleet,
- air transport.

Limited means of transport include:

- means of transport with intermittent traffic (cranes, carts),
- means of continuous transport (conveyor lines, so-called belt conveyors, and pipelines including pneumatic transport),
- means of transport with continuous or intermittent traffic (ropeways, conveyors, loaders).

Definitions

Cranes - these are means of transport with a limited range and intermittent traffic, whose main task is lifting. And lowering loads and their transfer within reach of the hoist.

Conveyors - these are means of transport with a limited range and with continuous or intermittent movement, used to carry the wearer, and in exceptional cases also persons.

Cable railways - are means of transport with limited range, continuous or intermittent movement, whose task is to move people or cargo on a rope track suspended above the terrain.

Conveyor lines (belt conveyors) - these are means of transport - with limited range and continuous movement, used to carry the wearer, at greater distances outside the plants (means of external transport). Most often built in the form of cascaded connected transmission lines supplying large industrial plants with raw materials (e.g. providing coal-fired power plants).

Cranes (1)

Cranes - these are means of transport with limited and intermittent traffic, the main task of which is lifting and lowering of loads and their transfer within reach of the hoist.

Due to the type of drive, we distinguish:

- manually operated cranes,
- steam-powered cranes,
- gas-powered cranes,
- electric powered cranes,
- cranes with diesel and electric drive,
- hydraulic lift cranes,
- lift with pneumatic drive,
- hybrids with hybrid drives, which combine more than one type of drive (for example, combustion drives driving a compressor or a hydraulic pump, which is the source of the operating medium for a pneumatic-hydraulic drive)

Cranes (2)

Due to the type of work, the cranes are divided into:

- jacks,
- overhead travelling cranes,
- rigid and self-propelled cranes,
- lifts and elevators,
- shifters, turntables and tipplers,
- supports and landings,
- cranes,
- special cranes (e.g. stacker cranes).

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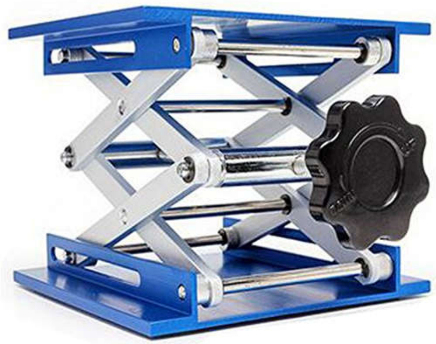
Definitions

Lifting jack - is a simple hoist used to carry loads vertically through an element that is not a pull (e.g. piston, screw, sprocket). A typical example may be a hydraulic or screw jack both in a classic system and with a knee or scissor mechanism.





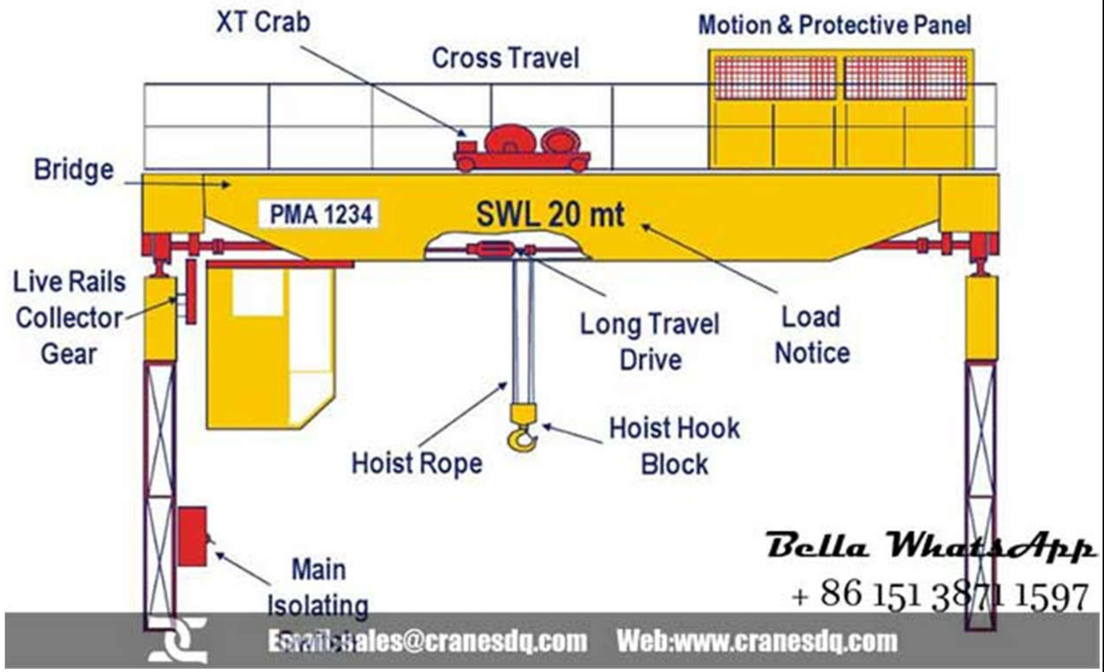


Definitions

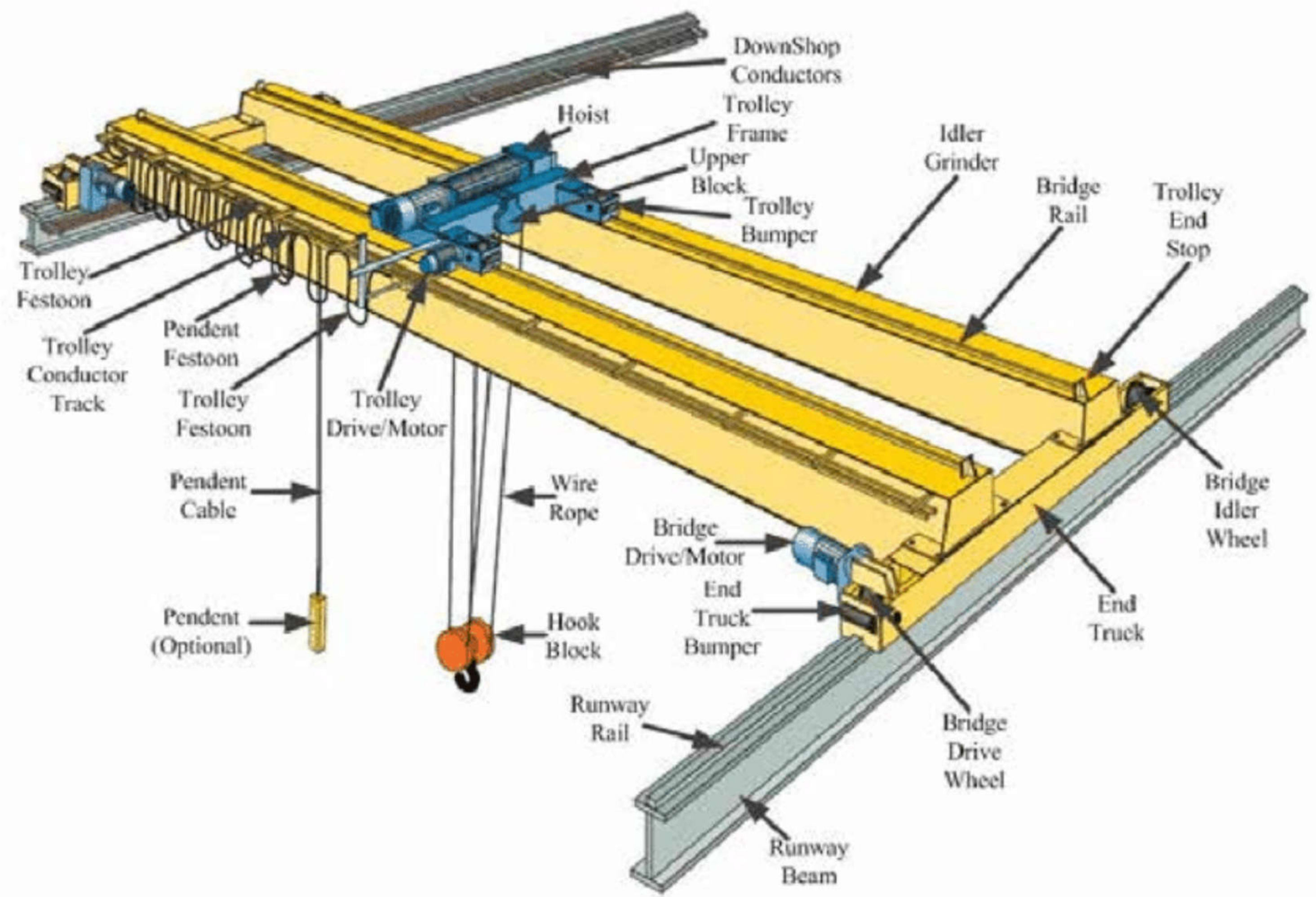
Overhead crane - it is a crane consisting of a sliding load carrying system and a strut or trolley moving on it. It is the most common means of internal transport. It is used in the operation of production halls, warehouses and open landfills. It is used to support loading, unloading and unloading processes, and sometimes also technological operations are carried out on it.

We can distinguish:

- one or two-crane bridge cranes,
- overhead gantry cranes,
- gantry cranes,
- half gantry cranes,
- overhead cranes - bridges,
- gantry cranes - semi-bridges,
- tower cranes,
- special container cranes.



Definitions

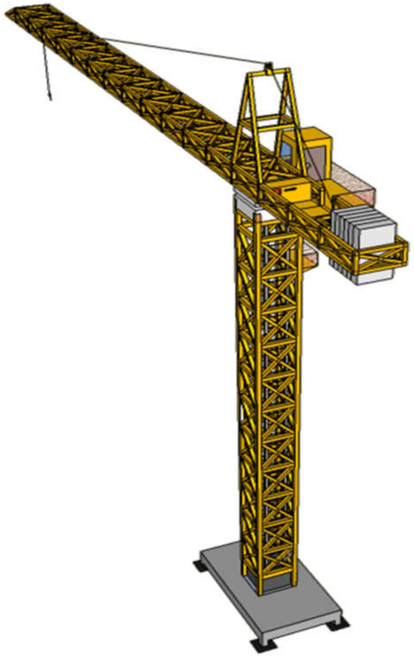


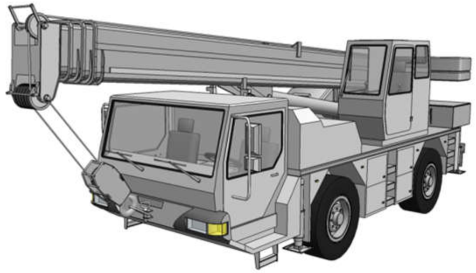
Definitions

Crane - it is a device whose part of the support system called a boom can perform rotational movements in a vertical or horizontal plane or in both planes at the same time.

Typical cranes with permanent foundation:

- crane overhang on a fixed pole,
- crane overhang on the pillar,
- crane suspended on a pillar,
- boom crane on a pillar,
- derrick platform crane,
- boom platform crane.





Typical mobile cranes:

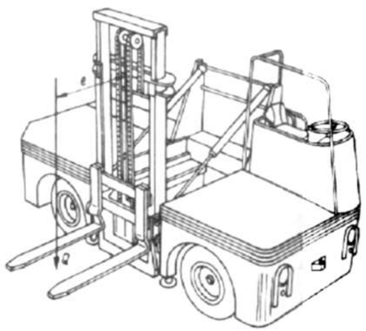
- rail crane,
- crane on the running gear,
- self-propelled crane,
- a railway crane for removing breakdowns in rail traffic.

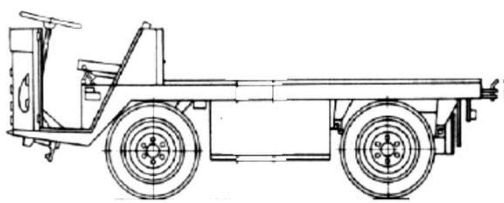
Definitions

Carriages - these are road or rail transport vehicles with intermittent traffic used for horizontal or vertical transport of loads. These devices have a driving mechanism that may have a limited range of operation (e.g. through the length of the track) or not have such restrictions. They usually have their own power supply (generators, internal combustion engines).

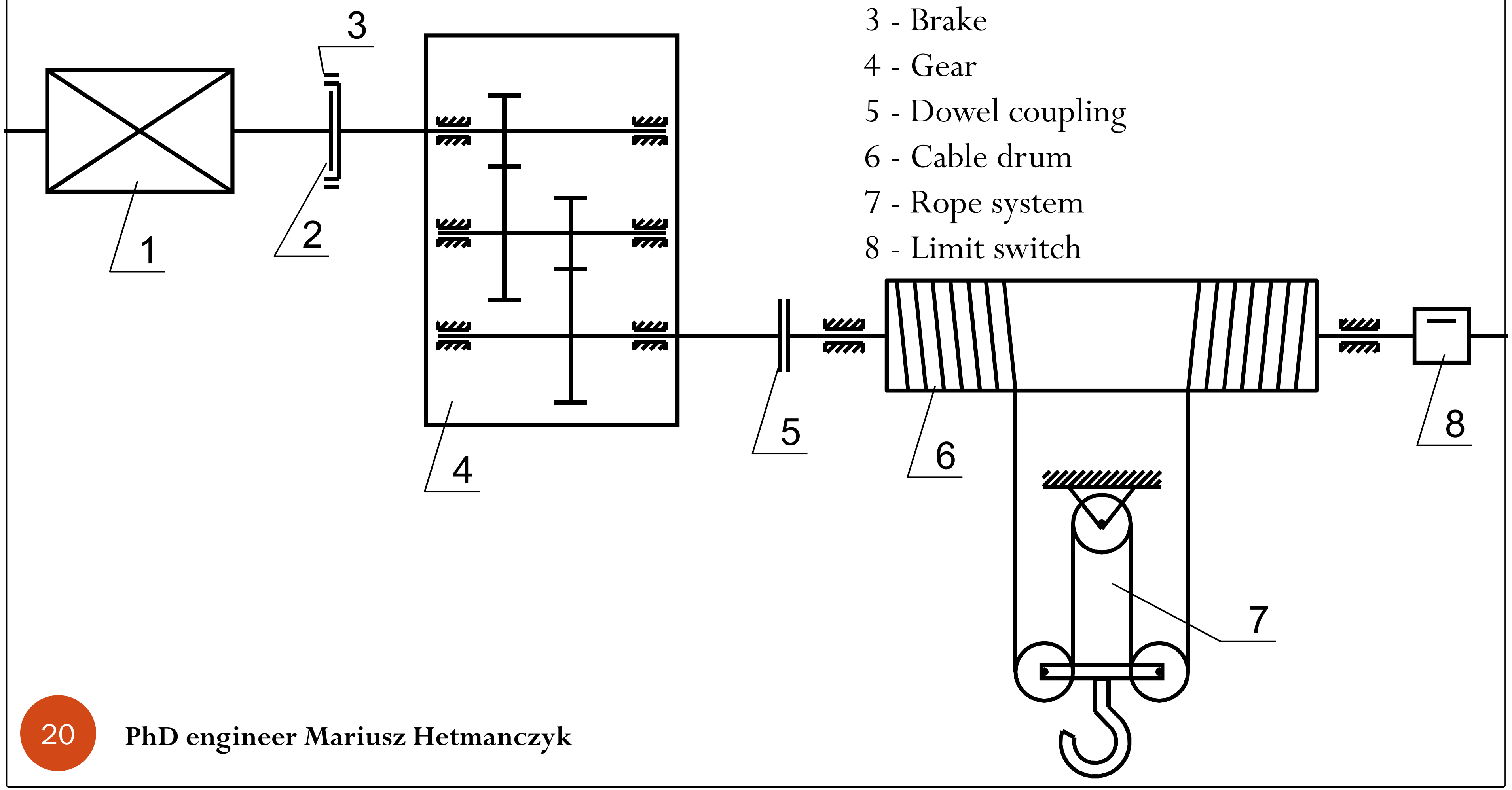
This crane group includes:

- track trucks,
- hand car pole,
- platform track trucks,
- tracked trolleys,
- car chassis (wheeled),
- tracked undercarriage,
- railway chassis,
- forklifts (platform, front and side forklifts),
- stringing systems.





Cranes - lifting mechanism

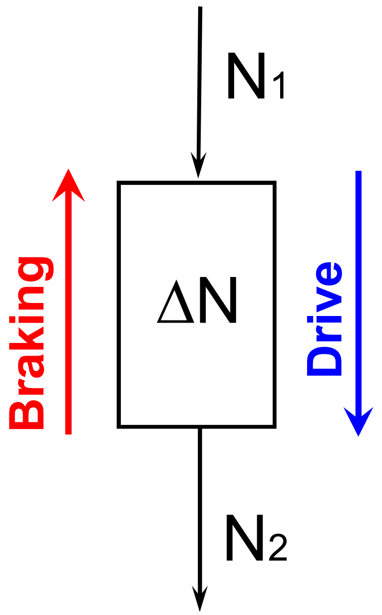


1 - Electric engine
2 - Flexible coupling with brake disc
3 - Brake
4 - Gear
5 - Dowel coupling
6 - Cable drum
7 - Rope system
8 - Limit switch

Cranes - lifting mechanism

The ratio of the mechanism - is the ratio of the number of revolutions of the first shaft (engine shaft) to the number of revolutions of the last shaft in the mechanism. (the ratio is always greater than zero)

The efficiency of the mechanism - it is the ratio of the power given by the mechanism to the power absorbed by the mechanism (efficiency is a number less than one)



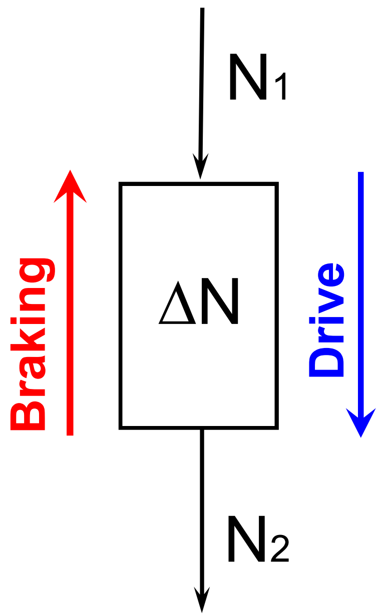
$$N_2 = N_1 - \Delta N$$

ΔN – losses in the mechanism

N_1 – power on the drive side

N_2 – power at the output of the mechanism

The efficiency of the mechanism when braking



$$N_2 = N_1 - \Delta N \quad \Rightarrow \quad N_1 = N_2 + \Delta N$$

$$\eta_m = \frac{N_2}{N_1} = \frac{N_2}{N_2 + \Delta N}$$

$$\frac{1}{\eta_m} = \frac{N_2 + \Delta N}{N_2} = 1 + \frac{\Delta N}{N_2}$$

$$\eta_{mh} = \frac{N_2 - \Delta N}{N_2} = 1 - \frac{\Delta N}{N_2}$$

substituting : $\frac{\Delta N}{N_2} = \frac{1}{\eta_m} - 1$ *we obtain:*

$$\eta_{mh} = 2 - \frac{1}{\eta_m}$$

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The condition of self-locking

$$\eta_m \leq 0{,}5$$

$$\eta_{mh} = 2 - \frac{1}{\eta_m}$$

therefore $\eta_m = \frac{1}{2}$ *we obtain:*

$$\eta_{mh} = 2 - \frac{1}{\frac{1}{2}} = 2 - 2 = 0$$

$$\eta_{mh} \leq 0$$

In isolated or low external environment systems, there must be an external element of energy dissipation (power) called the brake

Industrial robots

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AUTOMATION AND ROBOTS

There are three types of automation:

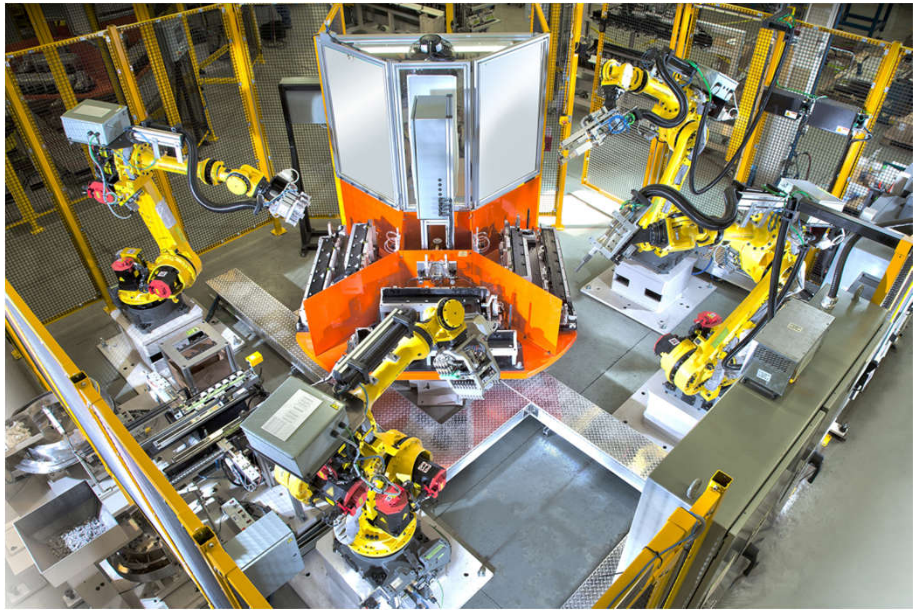
- **Fixed automation**: is used for high production volume and utilizes expensive special equipment to process only one product.

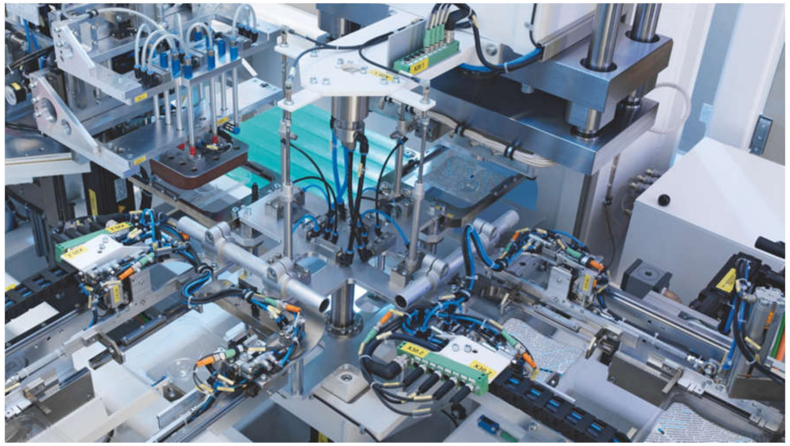
  Ex: a good example of this automation can be found in the automobile industry, where highly integrated transfer lines are used to perform machining operations on engine and transmission components.

- **Flexible automation**: is used for medium production volume and utilizes a central computer to control the process of different products at same time.

  Flexible automation consists typically consists of a series of workstations that are interconnected by material handling and storage equipment to process different product configurations at the same time on the same manufacturing system.

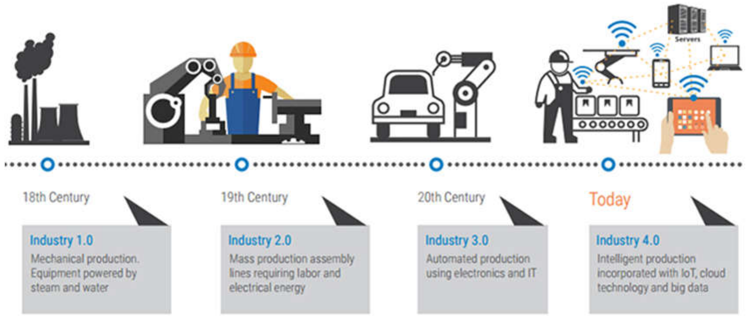
- **Programmable automation:** is used for low production volume operated under control of a program. It processes one batch of similar products at a time.

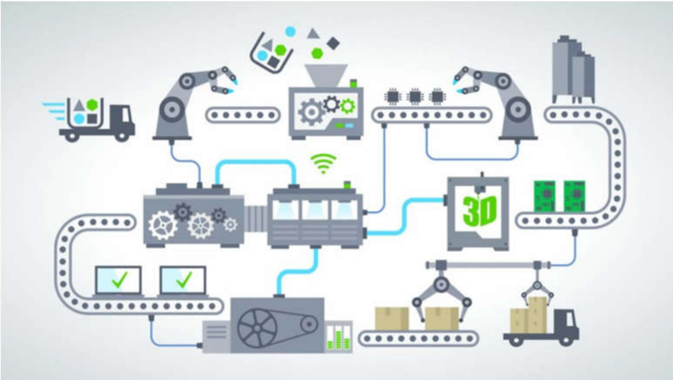




INDUSTRIAL ROBOTS

- Definitions:
  - An industrial robot is a reprogrammable, multifunction; manipulator designed to move materials, parts, tools, or special devices through variable programmed motions for the performance of variety of tasks.
  - A machine formed by a mechanism, including several degree of freedom, often having the appearance of one or several arms ending in a wrist capable of holding a tool, a work piece, or an inspection device. In particular its control unit must use a memorizing device and it may sometimes use sensing or adaptation applications to take into account environment and circumstances.
  - A machine constructed as an assemblage of joined links so that they can be articulated into desired positions by a programmable controller and precision actuators to perform variety of tasks.





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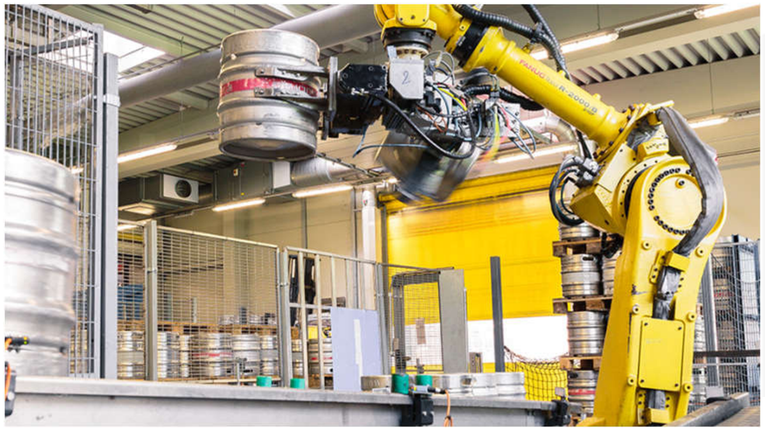
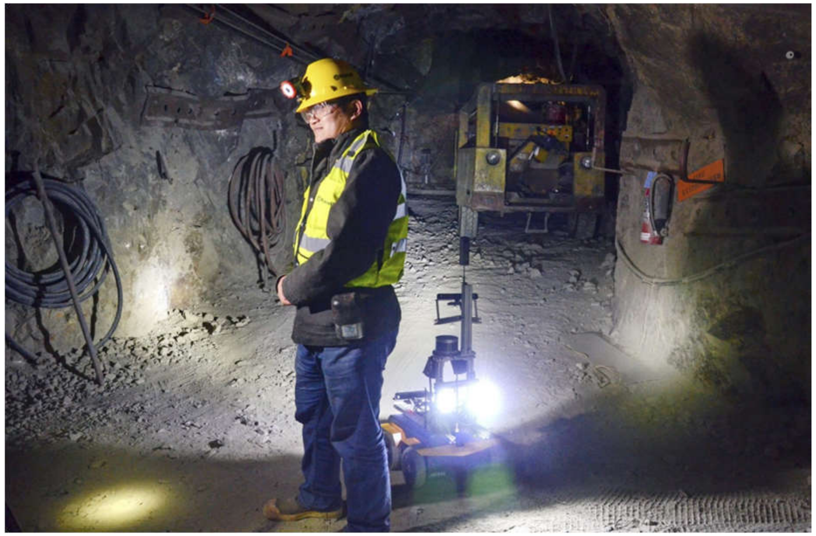
Definition of an industrial robot

An industrial robot is defined by ISO as an automatically controlled, programmable, multi purpose manipulator programmable in three or more axes.



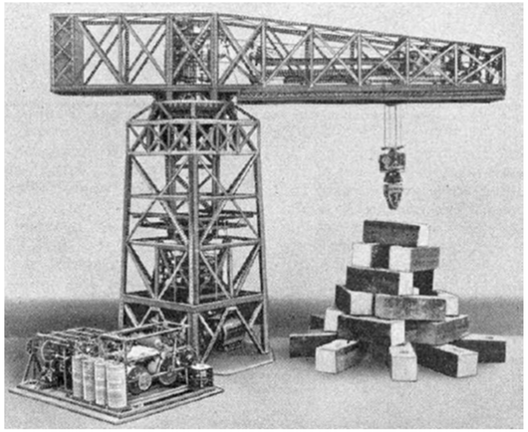
REASONS FOR USING ROBOTS IN INDUSTRY

- REDUCE LABOR COST
- ELIMINATE DANGEROUS JOBS
- INCREASE OUTPUT RATE
- IMPROVE PRODUCT QUALITY
- INCREASE PRODUCT FLEXIBILITY
- REDUCE MATERIAL WASTE
- COMPLY WITH OSHA
- REDUCE LABOR TURNOVER
- REDUCE CAPITAL COST

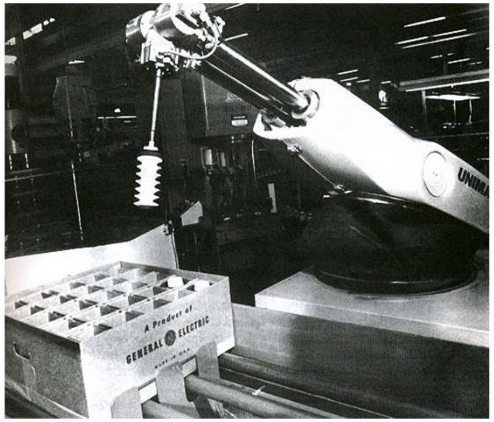


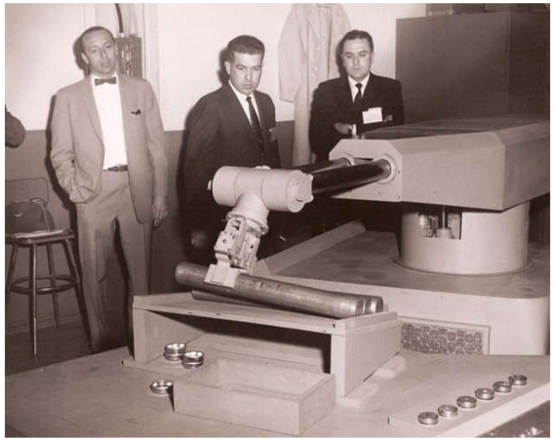
History of industrial robots

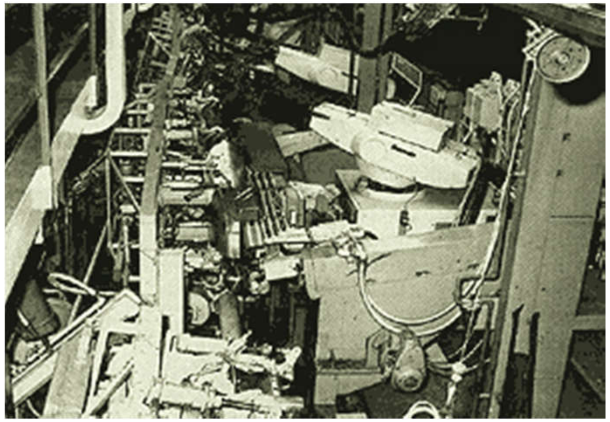
- The first industrial robot, conforming to the ISO definition was completed by “Bill” Griffith Taylor in 1937.



- Technical specifications:
  - constructed as a crane
  - powered by a single electric motor
  - automation was achieved using punched paper tape.

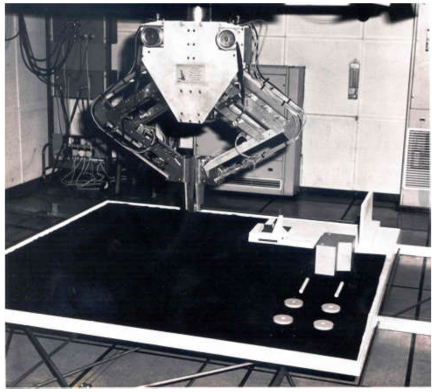


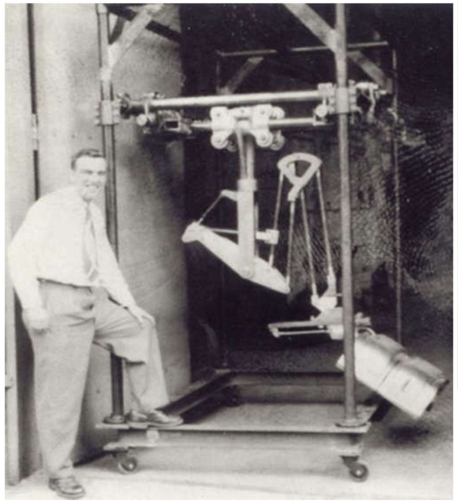




History of industrial robots

- George Devol applied for the first robotics patents in 1954.
- The first company to produce a robot was Unimation, founded by Devol in 1956, and was based on Devol's original patents.
- Their robots used hydraulic actuators and were programmed in joint coordinates.

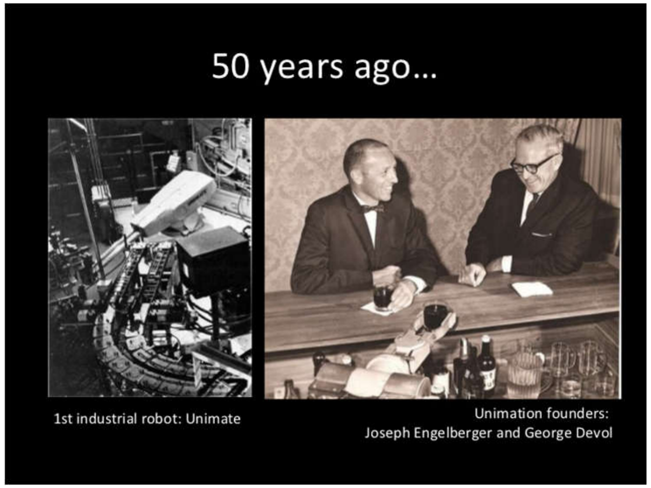





First Robot in history is said to be this soldier with an automatic bellows blowing a trumpet. It was made in 1910 by Friedrich Kaufman of Dresden, Germany, and is on display at present in the Munich Museum. Clockwork spring drives it.

History of industrial robots

- In 1969 Victor Scheinman at Stanford University invented the Stanford arm.
- It was all-electric, 6-axis articulated robot designed to permit an arm solution,
- In 1973 ABB Robotics and KUKA Robotics bringing robots to the market.
- KUKA Robotics built the first robot, known as FAMULUS also one of the first articulated robots to have six electromechanically driven axes.



History of industrial robots

- In 1984 is introduced the AdeptOne, first direct-drive SCARA Robot.
- KUKA, Germany, introduces a new Z-shaped robot arm whose design ignores the traditional parallelogram,
- In 1992 Demaurex, Switzerland, sold its first Delta robot packaging application to Rolan, which was constructed to loading pretzels into blister trays.
- In 1998 ABB, Sweden, developed the FlexPicker, the world's fastest picking robot based on the delta robot.
  - It was able to pick 120 objects a minute

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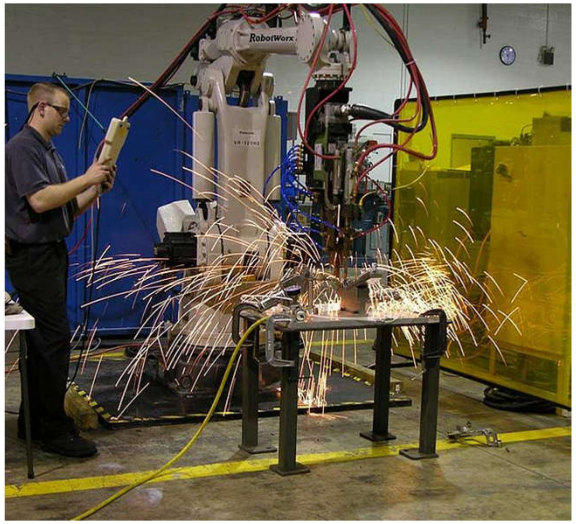
History of industrial robots

- In 1999 Reis Robotics receives patent on the integrated laser beam guiding through the robot arm.
- This technology replaces the need of an external beam guiding device and allow to use laser in combination with a robot at high dynamics.
- In 2004 Motoman, Japan, introduced the improved robot control system which provided the synchronized control of four robots, up to 38 axis,

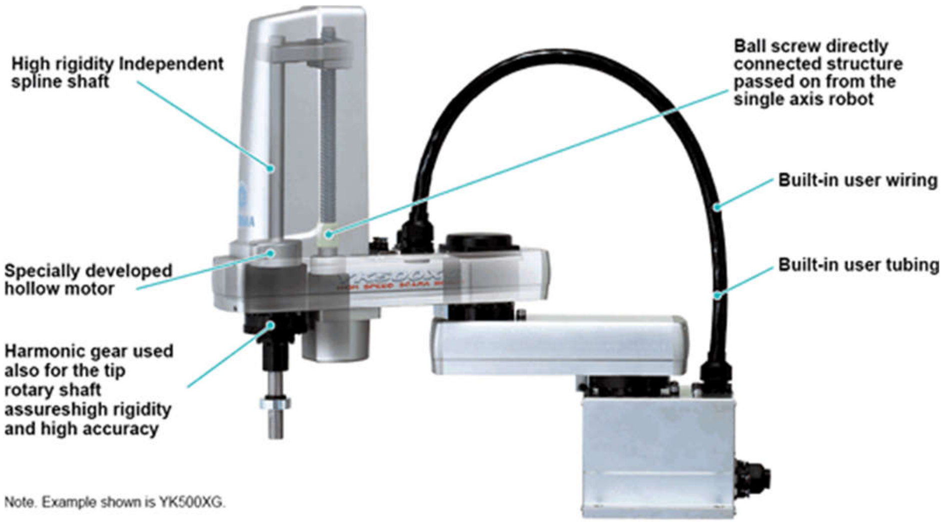
Main types of industrial robots

- An articulated robot is a robot with rotary joints



Main types of industrial robots

- The SCARA acronym stands for **Selective Compliant Assembly Robot Arm.**
- Commonly used in assembly applications.
- This robot is primarily cylindrical in design.



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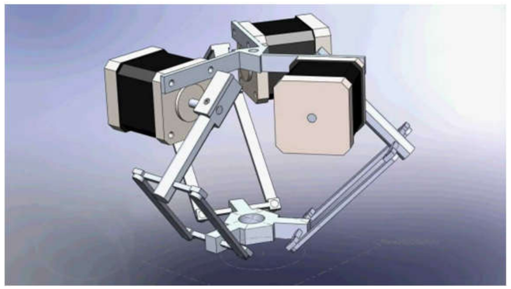
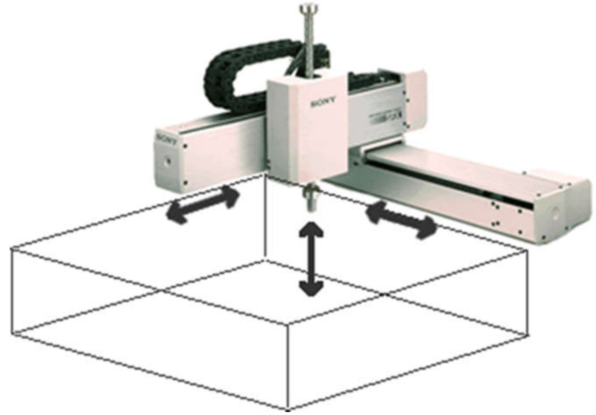
Main types of industrial robots

- A <u>delta robot</u> is a type of parallel robot.
- It consists of three arms connected to universal joints at the base.
- Heavily used in the food, pharmaceutical, and electronic industries, this robot configuration is very accurate.



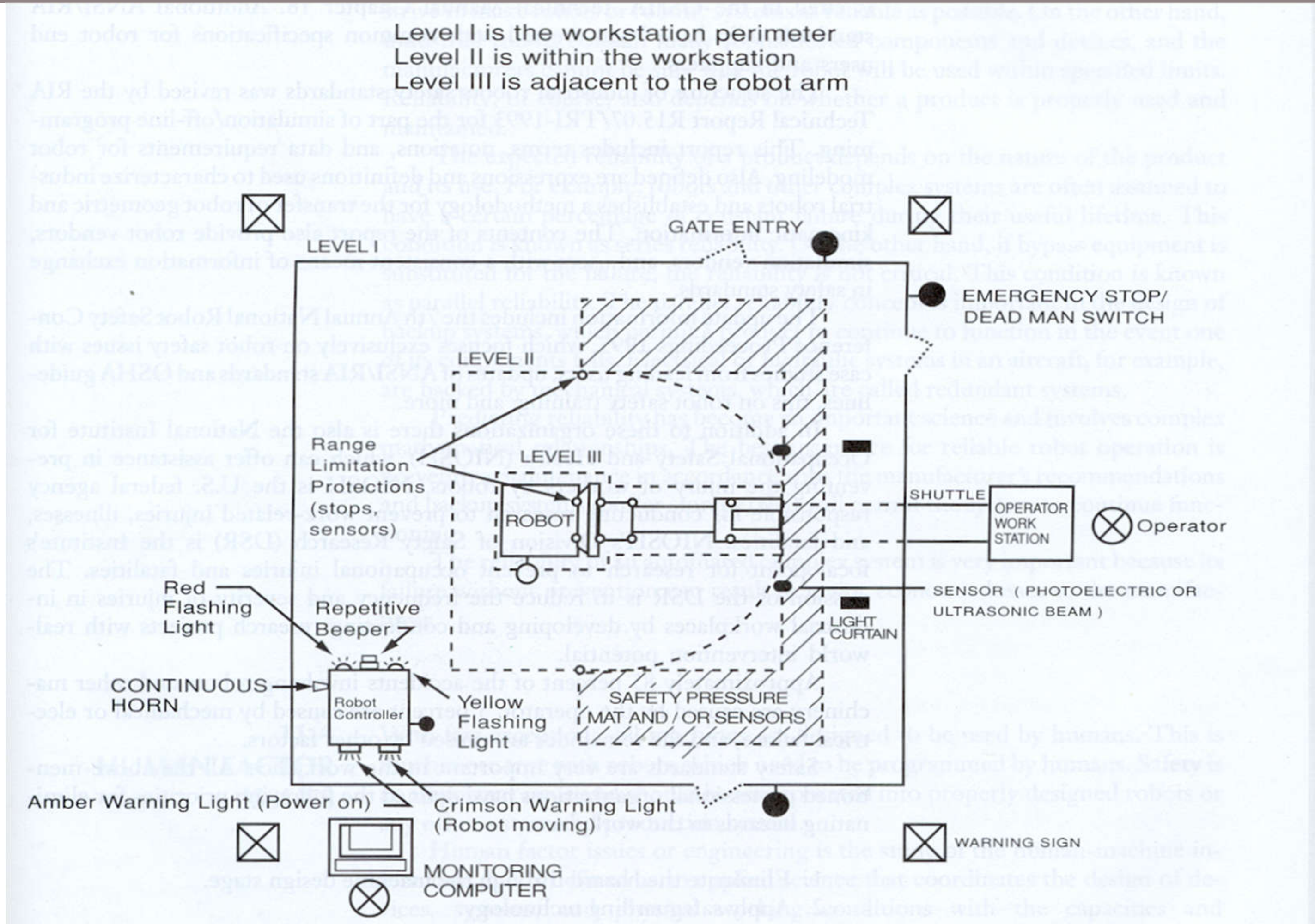
Main types of industrial robots

- Cartesian robots have three linear joints that use the Cartesian coordinate system (X, Y, and Z).
- The three prismatic joints deliver a linear motion along the axis.
- A popular application for this type of robot is a computer numerical control machine (CNC machine).



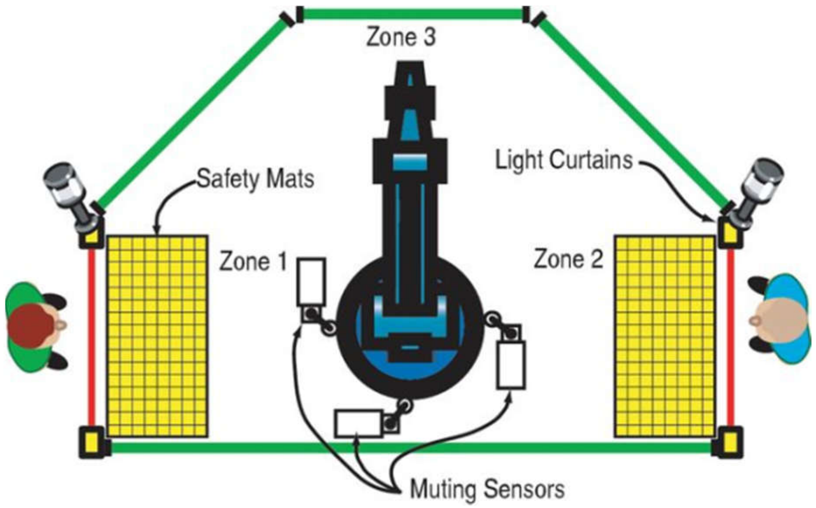
PhD engineer Mariusz Hetmanczyk

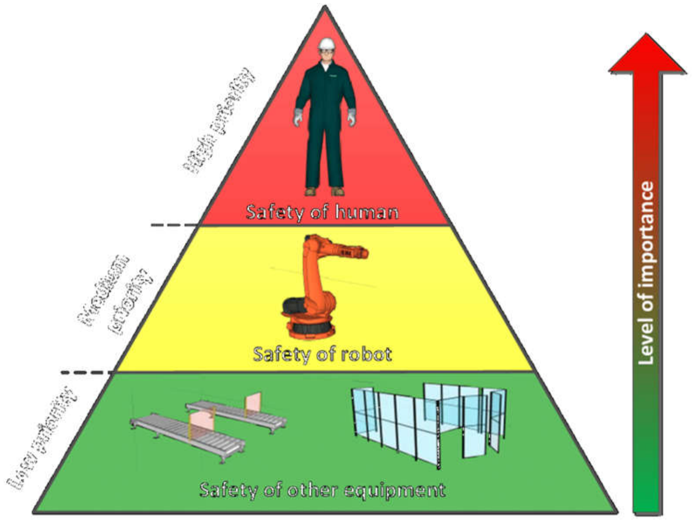
ROBOT SAFETY



SAFETY STANDARDS

- **Safety is an important consideration in installing, programming, operating, and maintaining robot systems.**
- **Safety can also be considered as a judgment of the acceptability of danger, where danger is the combination of hazard and risk.**
- **Hazard is defined as injury producer, and risk is defined as the probability that an injury will occur.**
- **The causes of employee injury in robotic environment includes:**
  - **Parts of the body being caught.**
  - **Being struck by a part or robot gripper.**
  - **Falling from the equipment or structure.**
  - **Slipping or tripping on walking or working surfaces.**
  - **Exposure to dangerous levels of heat or electricity**
  - **Excessive physical strain**

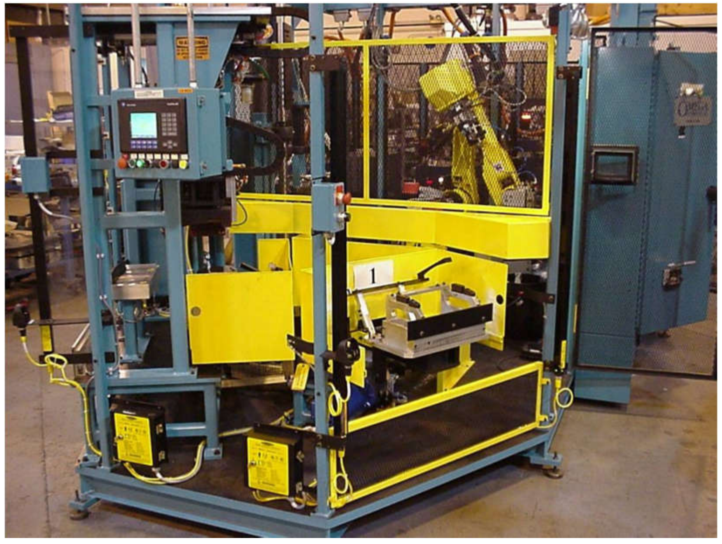


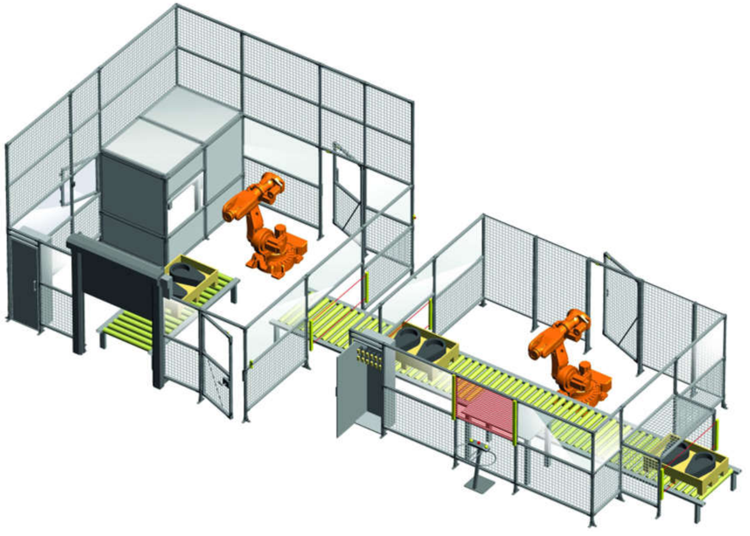


SAFETY SENSORS AND MONITORING

- Safety monitoring involves the use of sensors to indicate conditions or events that are unsafe or potentially unsafe.
- The objective of safety monitoring includes not only the protection of humans who happen to be in the cell, but also the protection of the equipment in the cell.
- The sensors used in the safety monitoring range from the simple limit switches to sophisticated vision system that are able to scan the workplace for intruders and other deviations from the normal operating conditions.
- Great care must be taken in work cell design to anticipate all possible mishaps that might occur during the operation of the cell, and to design safeguards to prevent or limit the damage resulting from these mishaps.

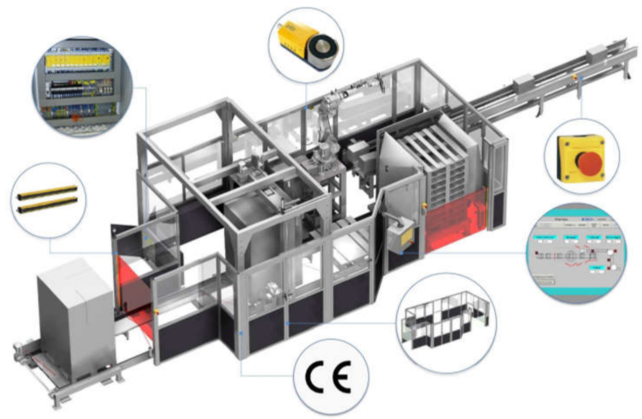
Safety

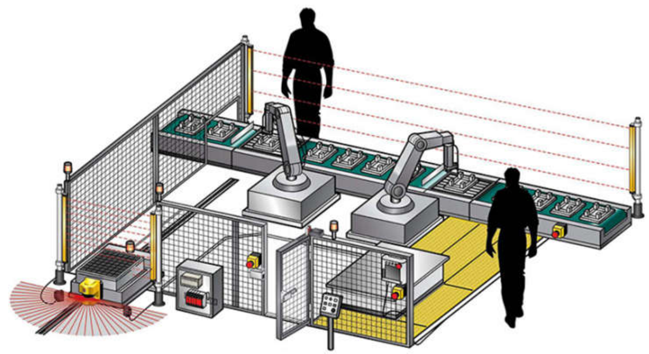




LEVELS OF ROBOT SAFETY

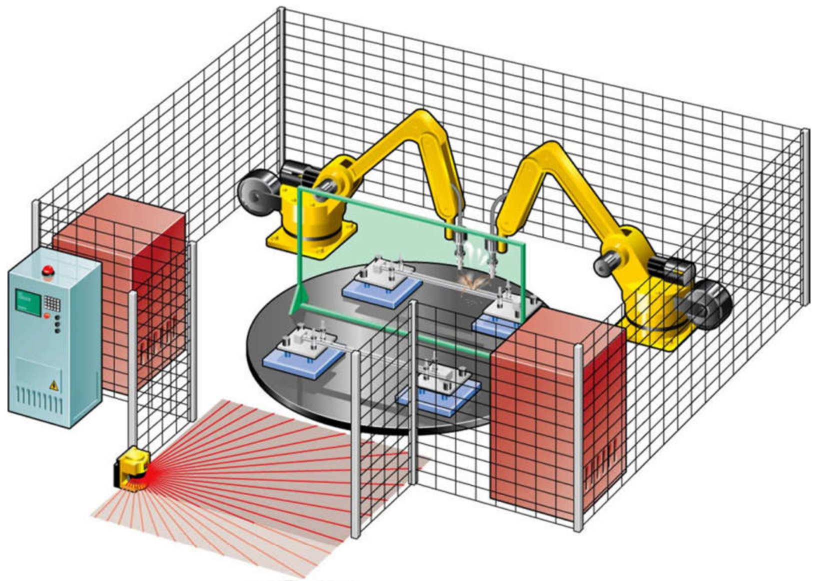
- The national bureau of standards defines three levels of safety sensor systems in robots.
  - Level 1 --- perimeter penetration detection.
  - Level 2 --- intruder detection inside the workcell
  - Level 3 --- intruder detection in the immediate vicinity of the robot.
- Level 1 systems are intended to detect that an intruder has crossed the perimeter boundary of the workcell without regard to the location of the robot.
- Level 2 systems are designed to detect the presence of an intruder in the region between the workcell boundary and the limit of the robot work volume.
- Level 3 systems provide intruder detection inside the work volume of the robot.

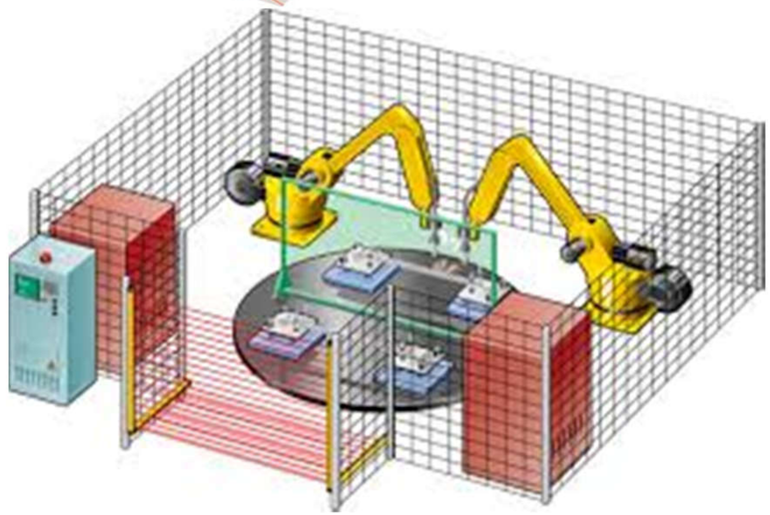




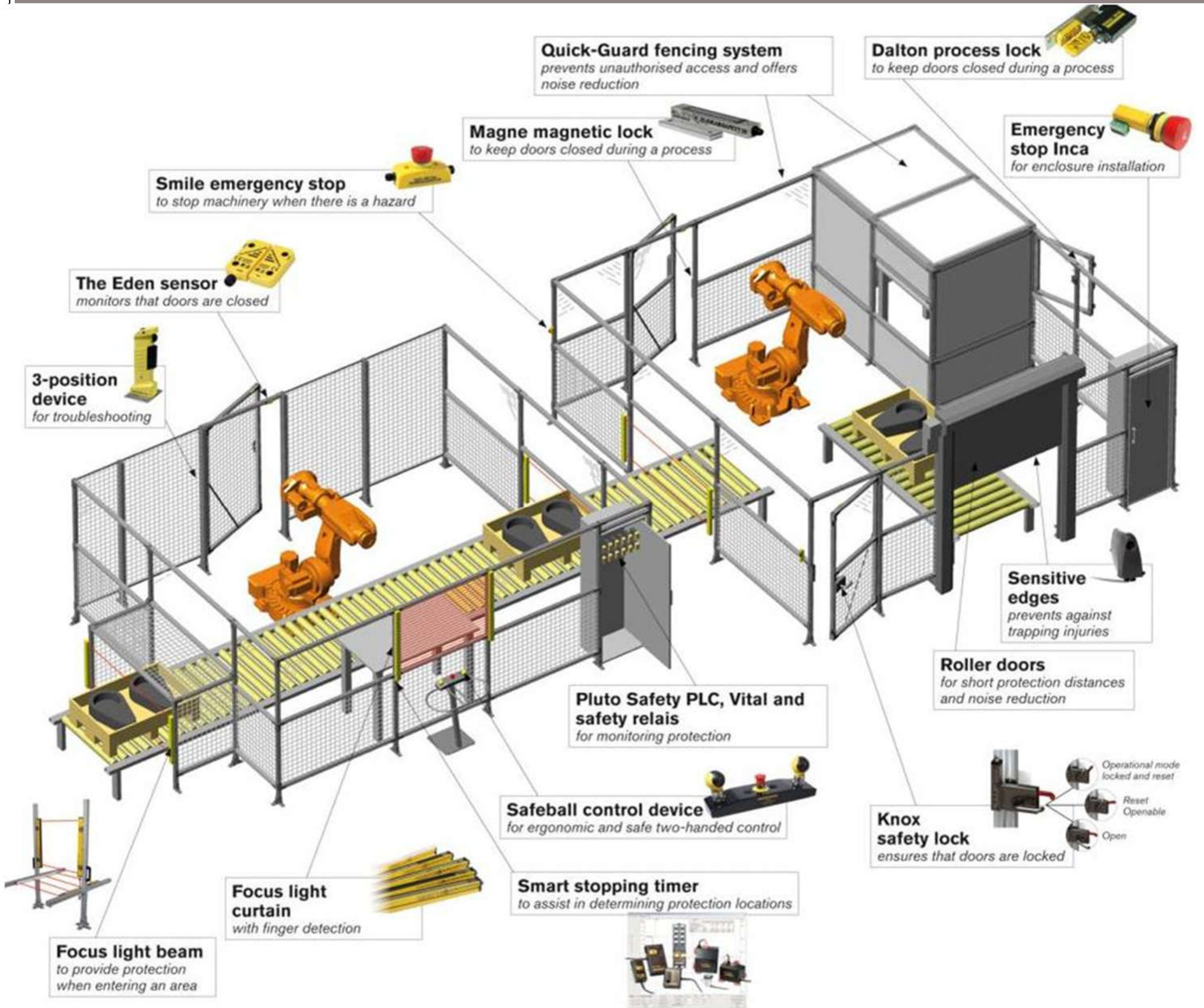
ROBOT SAFETY SENSING SYSTEM

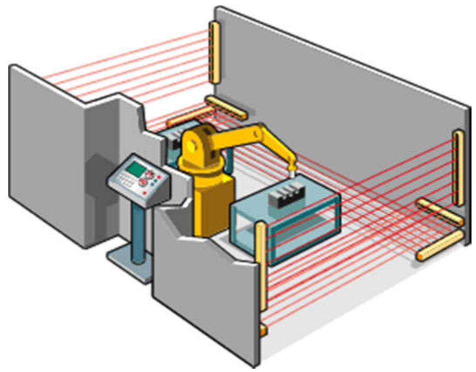
- **There are two common means of implementing a robot safety sensing system**
  1. **Pressure sensitive floor mats --- are area pads placed on the floor around the workcell that sense the weight of someone standing on the mat. These can be used for either level1 or level2 sensing systems.**
  2. **Light curtain --- consists of light beams and photsensitive devices placed around the workcell that sense the presence of an intruder by an intrruption of the light beam. Use of light curtains would be more appropriate as level1 systems.**

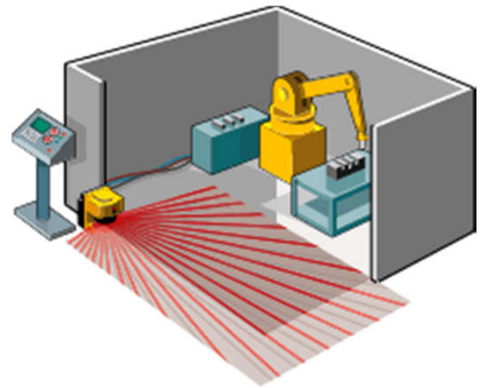


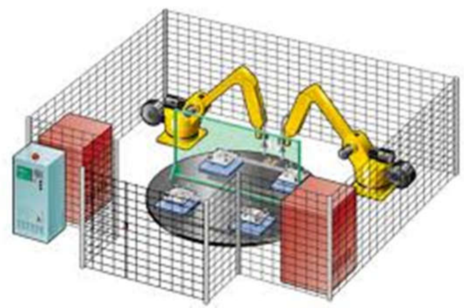


ROBOT SAFETY SENSING SYSTEM



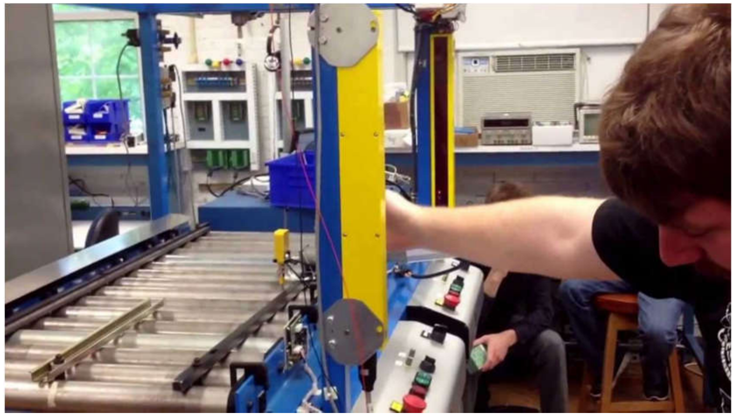


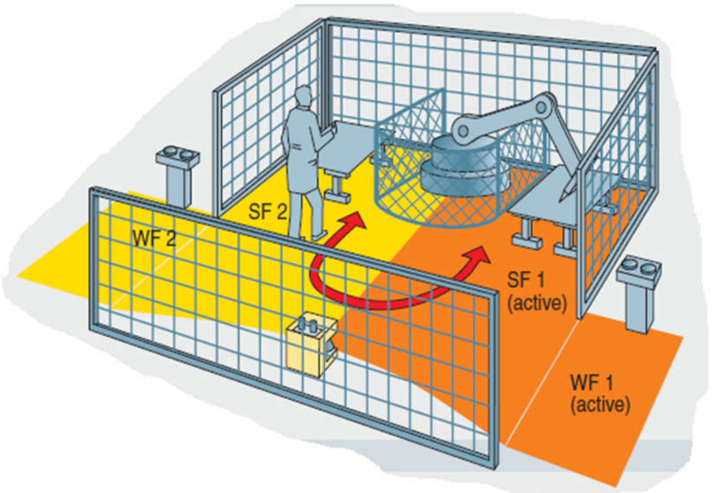




ROBOT SAFETY SENSING SYSTEM

- Proximity sensors located on the robot arm could be utilized as level 3 sensors.
- The safety monitorin strategies that might be followed by the workcell controller would include the following schemes.
  1. Complete shutdown of the robot upon detection of an intruder.
  2. Activation of warning alarms.
  3. Reduction of the speed of the robot to safe level.
  4. Directing the robot to move its arm away from the intruder to avoid collision.
  5. Directing the robot to perform tasks away from the intruder.
- Note: there is another safety monitoring called a "fail-safe hazard detector." The concept of this detector is based on the recognition that some component of basic hazard sensor system might fail and that this failure might not be found out until some safety emergency occurred. The fail-safe hazard detector is designed to overcome this problem.





ROBOT SAFETY SENSING SYSTEM