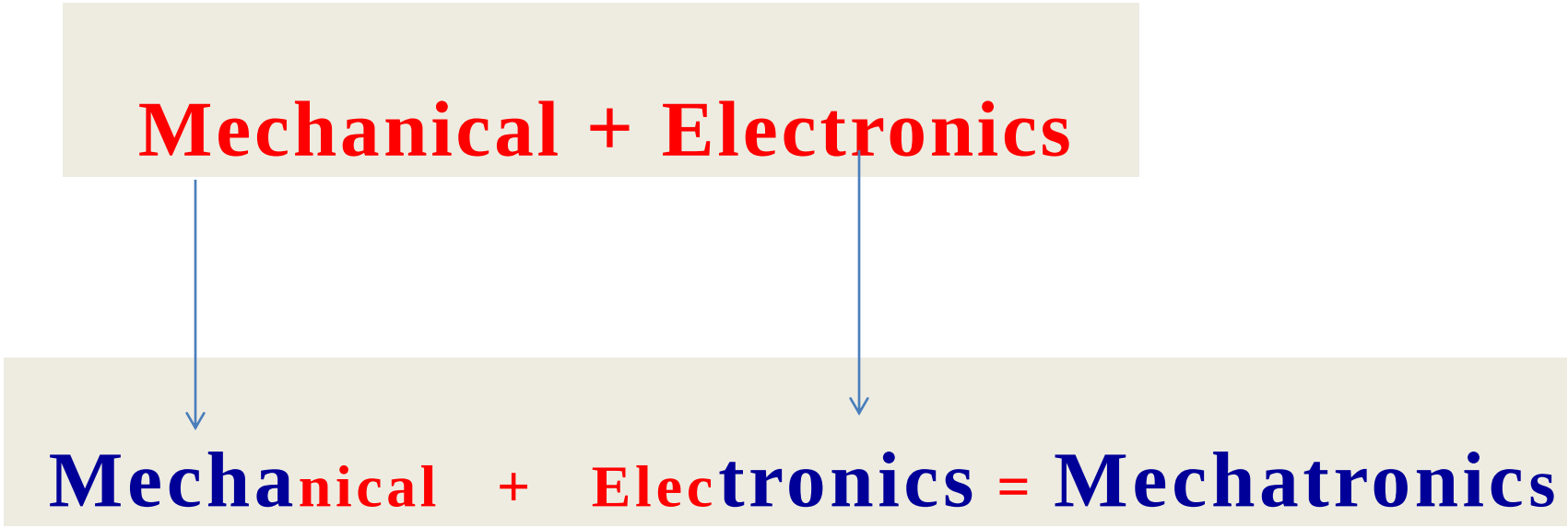
MECHATRONICS

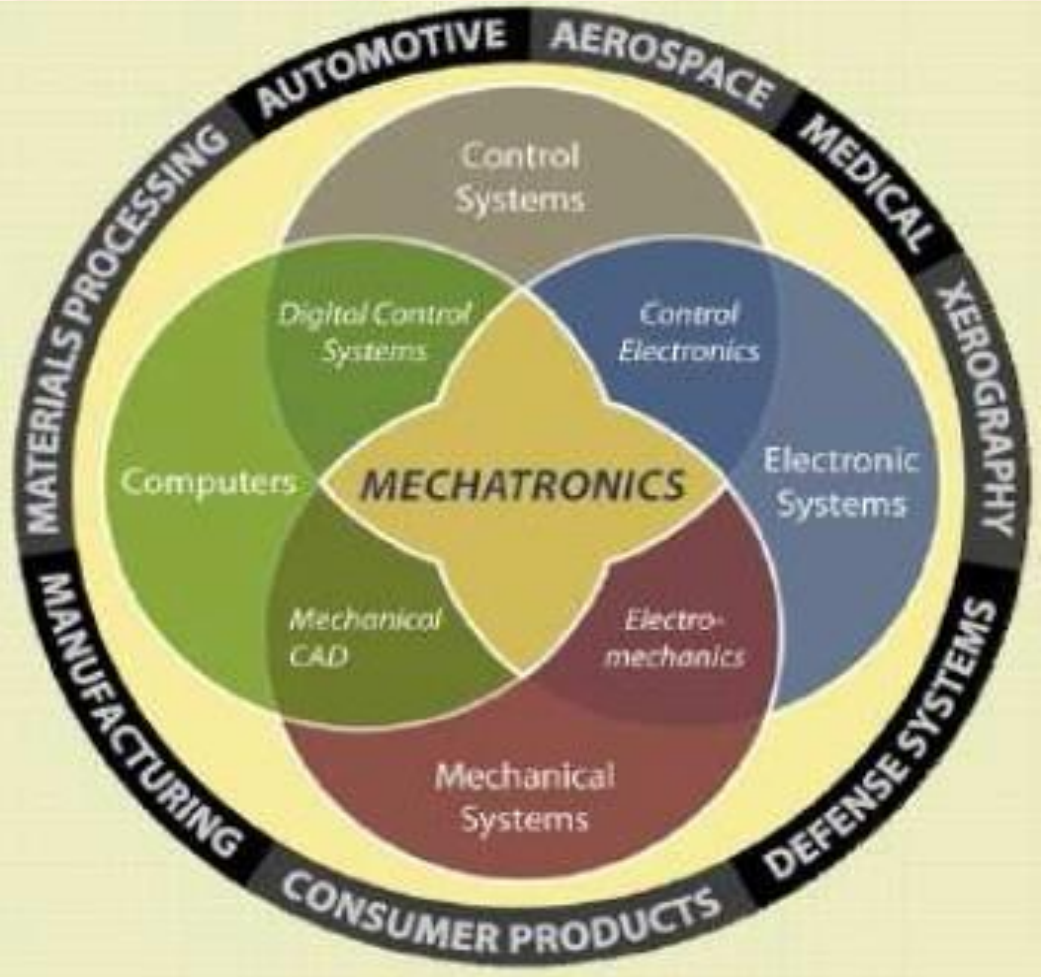
What is “Mechatronics” ?

- Mechatronics is a concept of Japanese origin (1970’s). Gradually, it spread through Europe, and is now commonly used round the Globe.
- It is a multi- disciplinary approach which involves application of Electrical, Mechanical and Computer Engineering to develop Products, Processes and Systems with greater flexibility, ease in re-design and ability of re-programming.



MECHATRONICS

Mechatronics is the integration of sensors, actuators, signal conditioning, power electronics, decision and control algorithms, and computer hardware and software to manage complexity, uncertainty and communication in Engineering Systems.



Graphical Representation of Mechatronics

MECHATRONIC SYSTEM

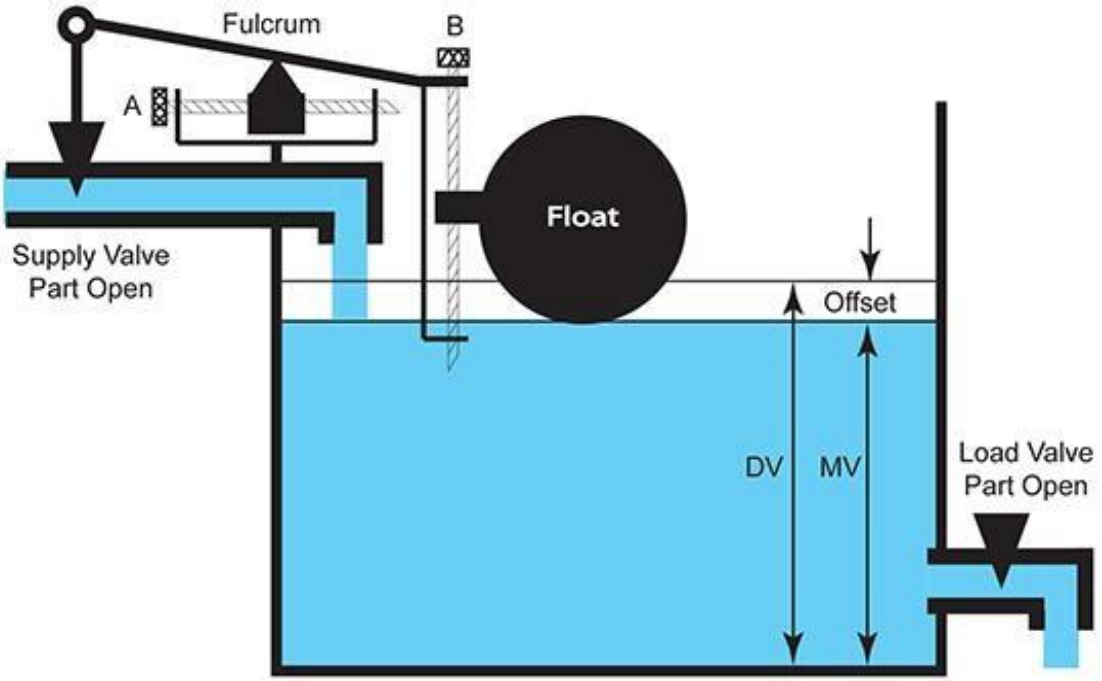
Evolution of Automated Systems:

1. **Completely Mechanical Automated Systems** (before and early 1900s)

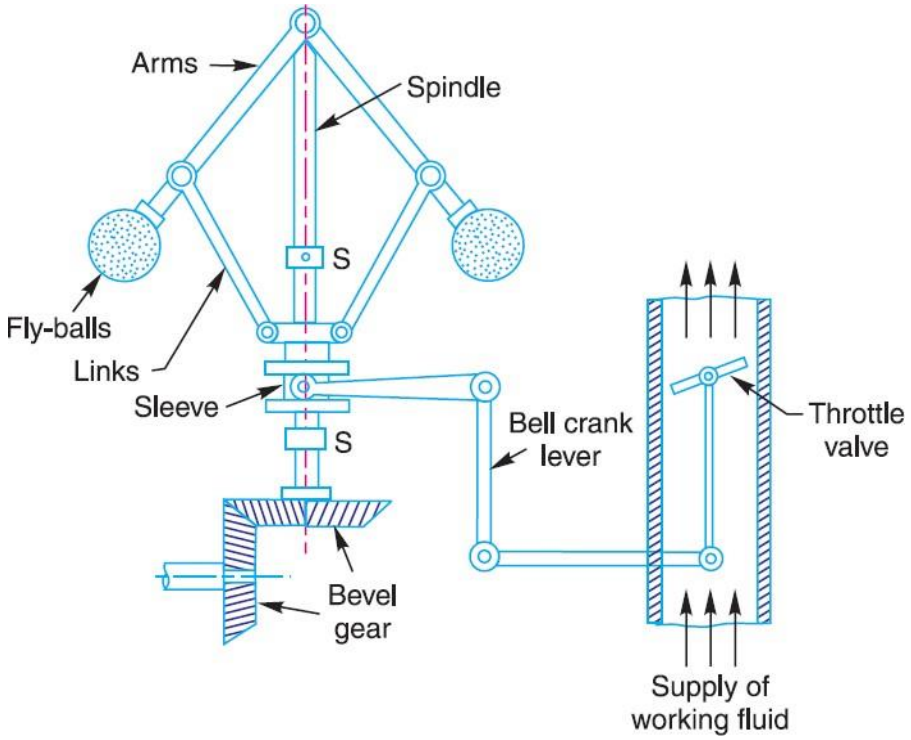
2. **Automatic Devices with electronic components such as relays, transistors etc.** (early 1900s to 1970s)

3. **Computer Controlled Automatic Systems** (1970s – till present)

Mechanical Automated Control System

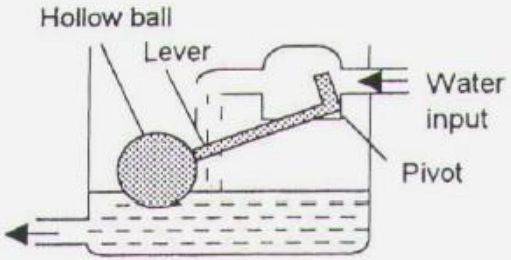


Automatic water lever Controller

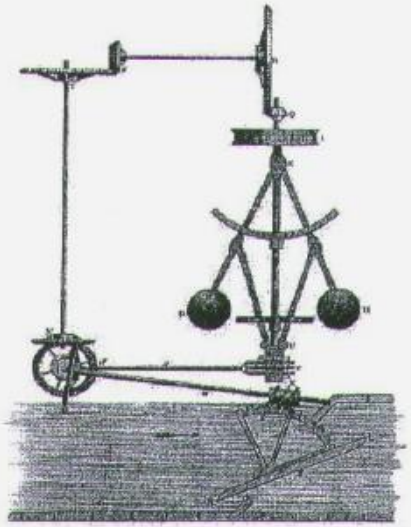


Automatic Engine speed Controller

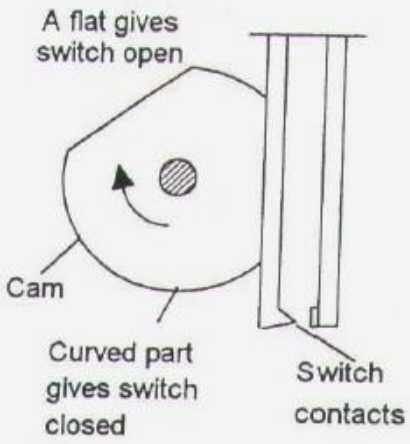
Examples of Predominantly Mechanical Designs

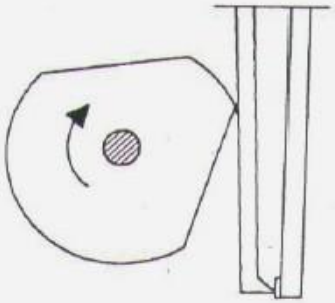


Float Valve



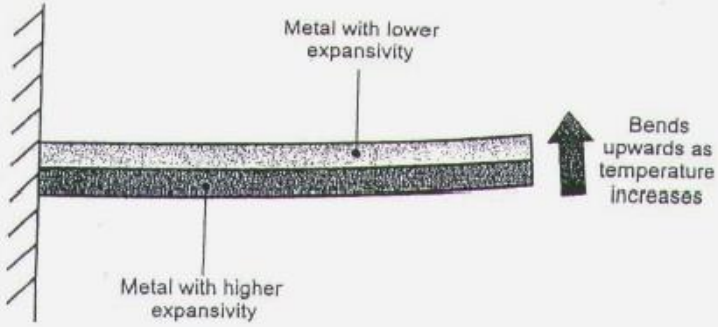
Watt's Governor



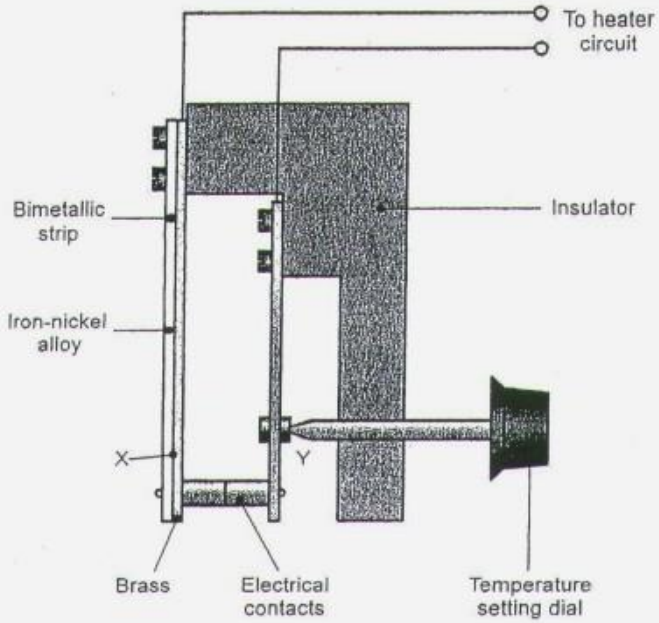


Rotation of the cam closing the switch contacts

Cam Operated Switch



Bi-metallic Strip



Thermostat

Mechatronic System

1. Input/Sensing

I. Push Button/Limit Switches/ON-OFF Switch

II. Through user Program (Man-made)

III. Sensors (Feedback device)- Signal Conditioning, ADC & DAC

2. Controller/Processor

I. Open Loop and Closed Loop Control

3. Output/Action

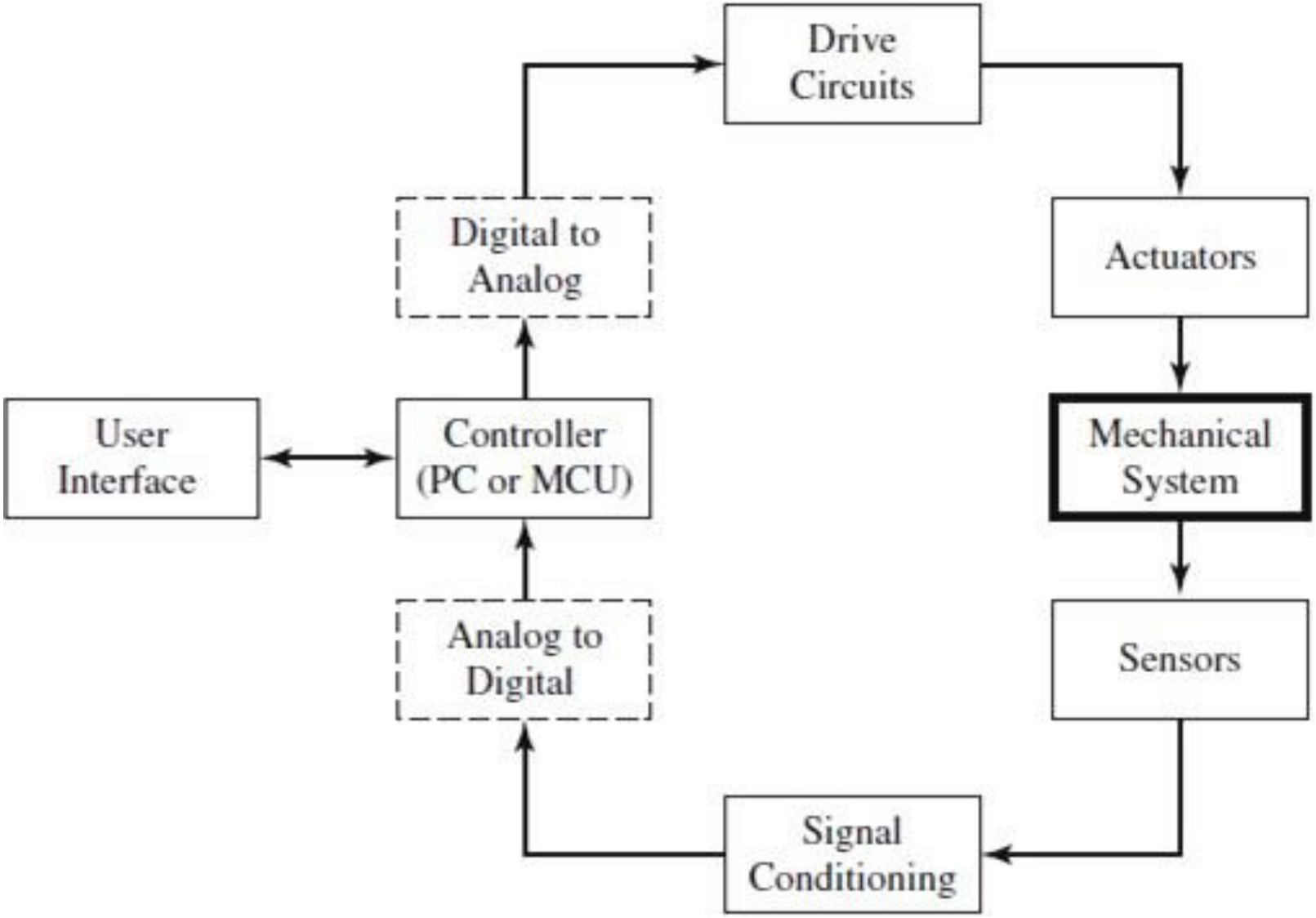
I. Drive Circuits

II. Actuators – Motors, Cylinders, Machines or Systems

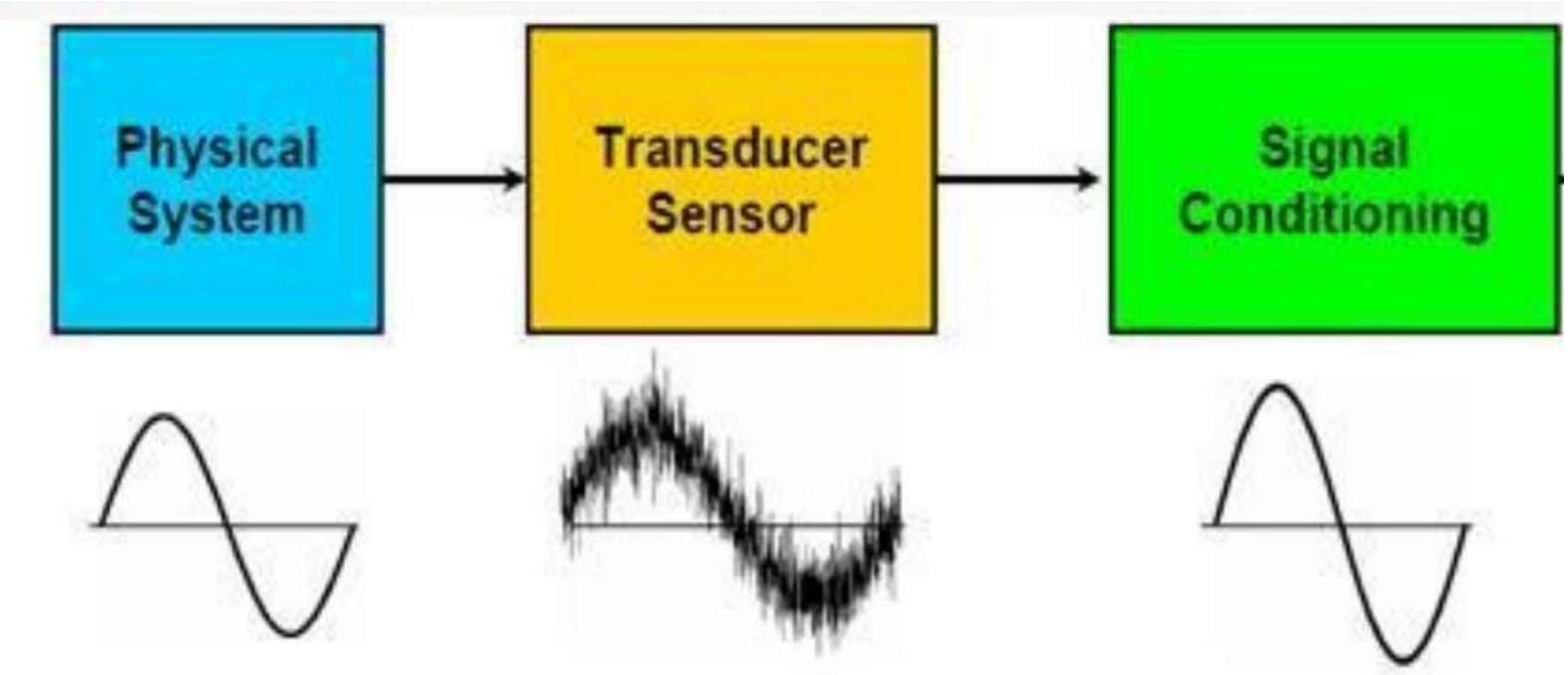
Mechatronic System

- A Mechatronic System has at its core a Mechanical System which needs to be controlled by a Controller.
- The Controller is the 'BRAIN' of the Mechatronic System, which receives input commands from Push button/Limit switches/ON-OF switch or through an user program (man-made) and also receives the feedback signal from Sensors.
- The Controller compares the input signal with the feedback signal and compensates the difference between them (known as error) and finally sends the corrected/compensated signal to the Actuator.
- Actuators are devices that can convert electrical energy to mechanical energy/work.
- The signals produced by the sensors can not be directly read by the Controller and hence they need to be Conditioned (Signal Conditioning).
- After signal conditioning, the signals are converted to a digital form by Analog-to-Digital Convertor (ADC) and then sent to the Controller.

Elements of Mechatronic System

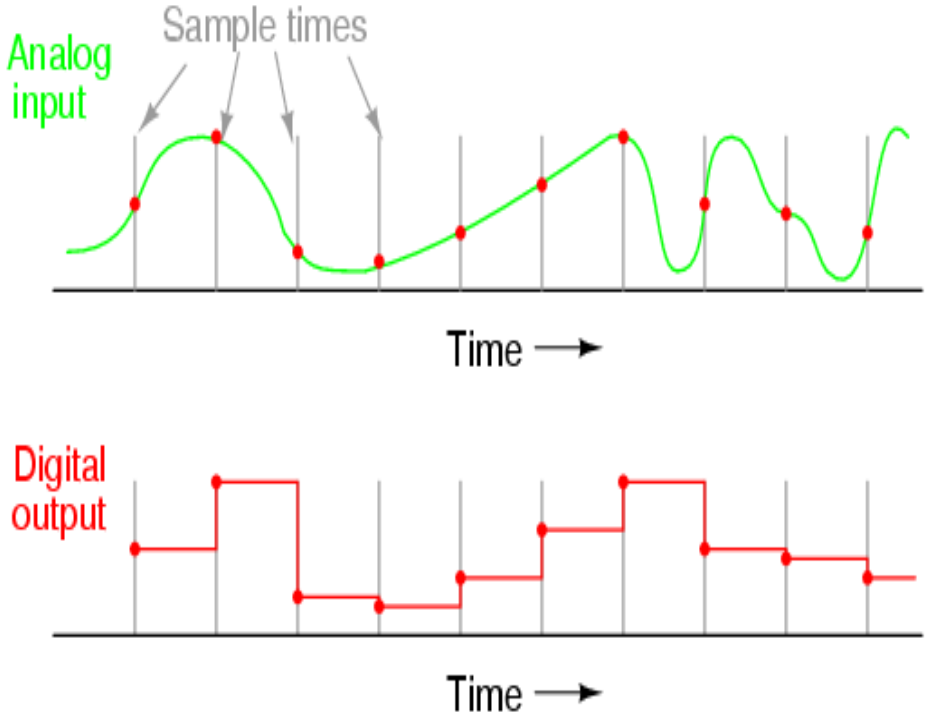


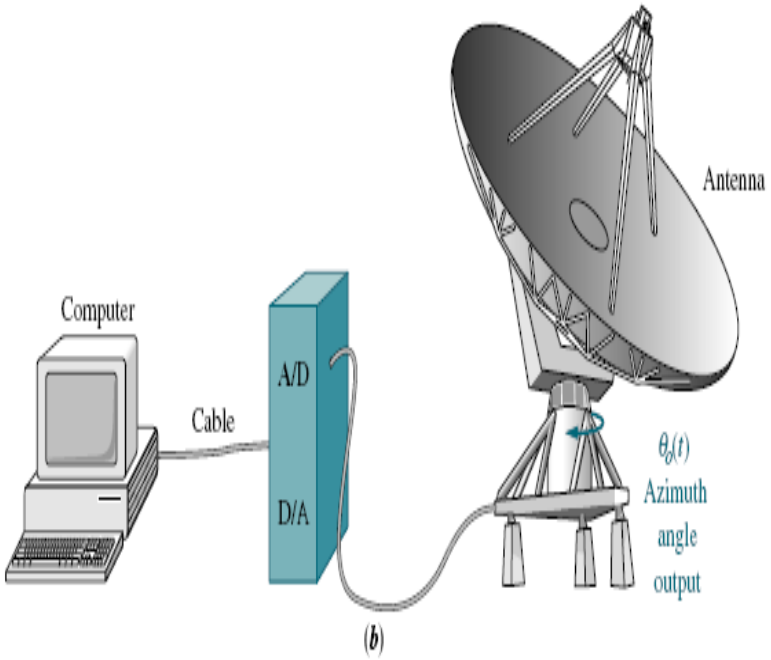
WHY SIGNAL CONDITIONING ?



Analog- Digital Converter

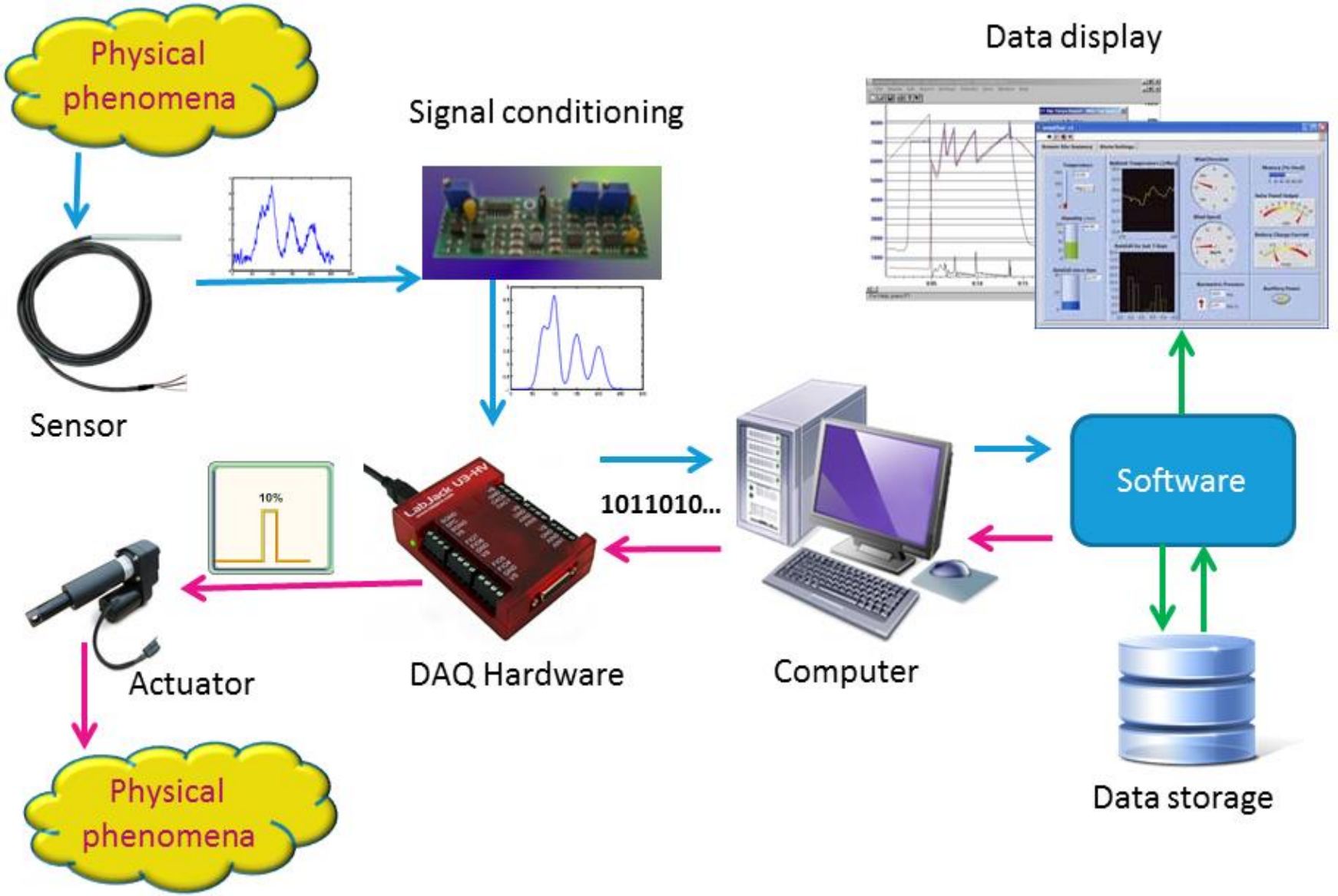
- **Analog-to-Digital Conversion (ADC) and Digital-to-Analog Conversion (DAC) allow digital computers to interact with these Signals.**



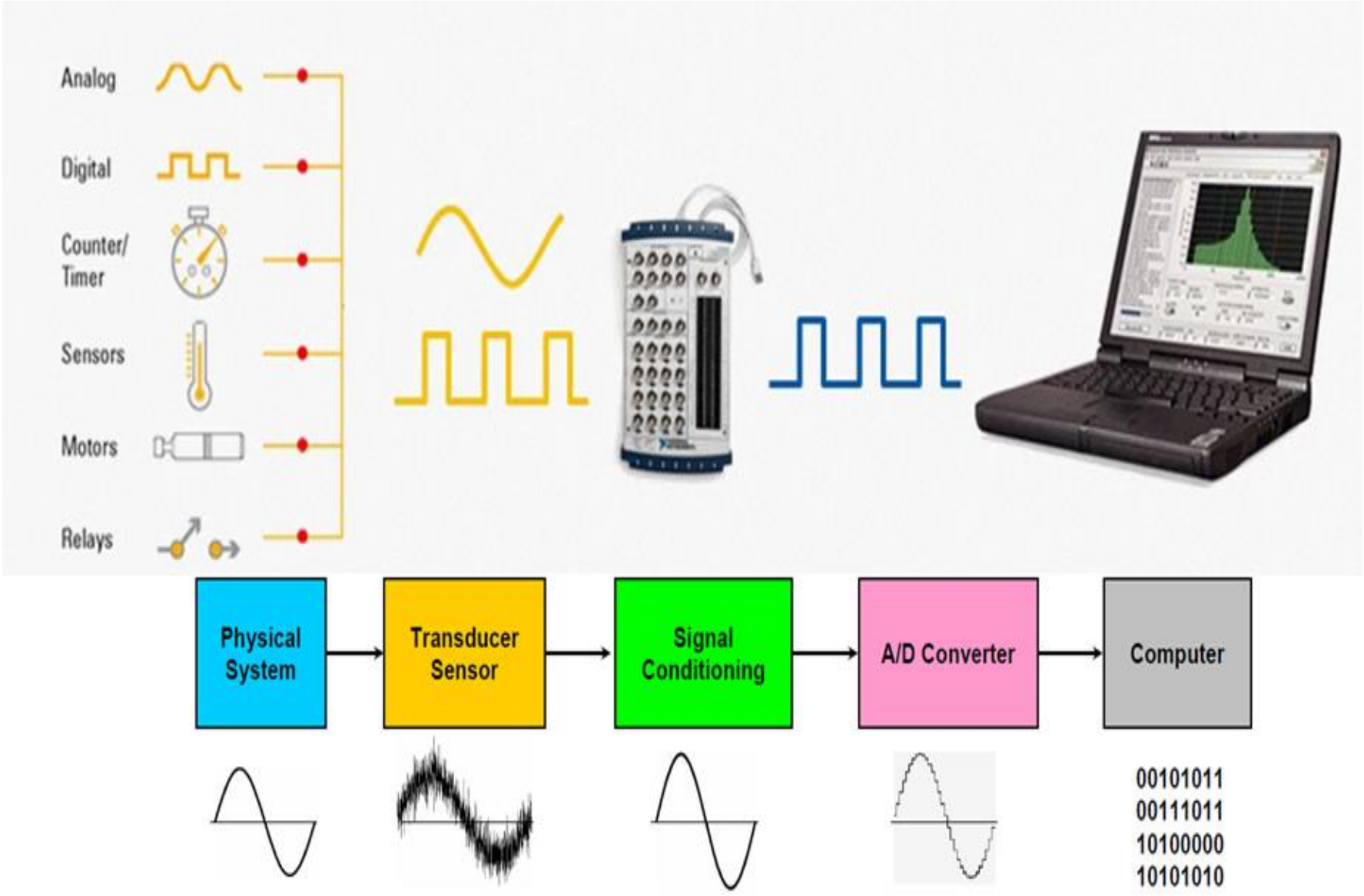


Analog-Digital Conversion Process

Interfacing of Sensor/Actuator to DAQ



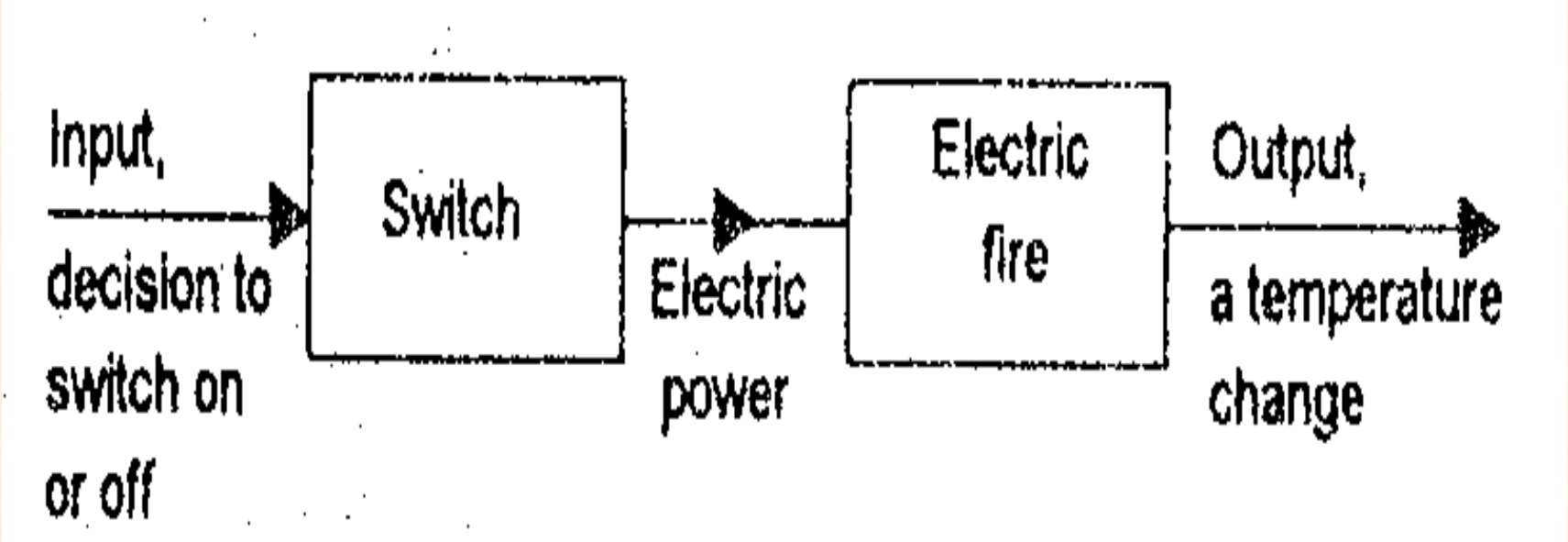
Interfacing of Sensor / Actuator to DAQ



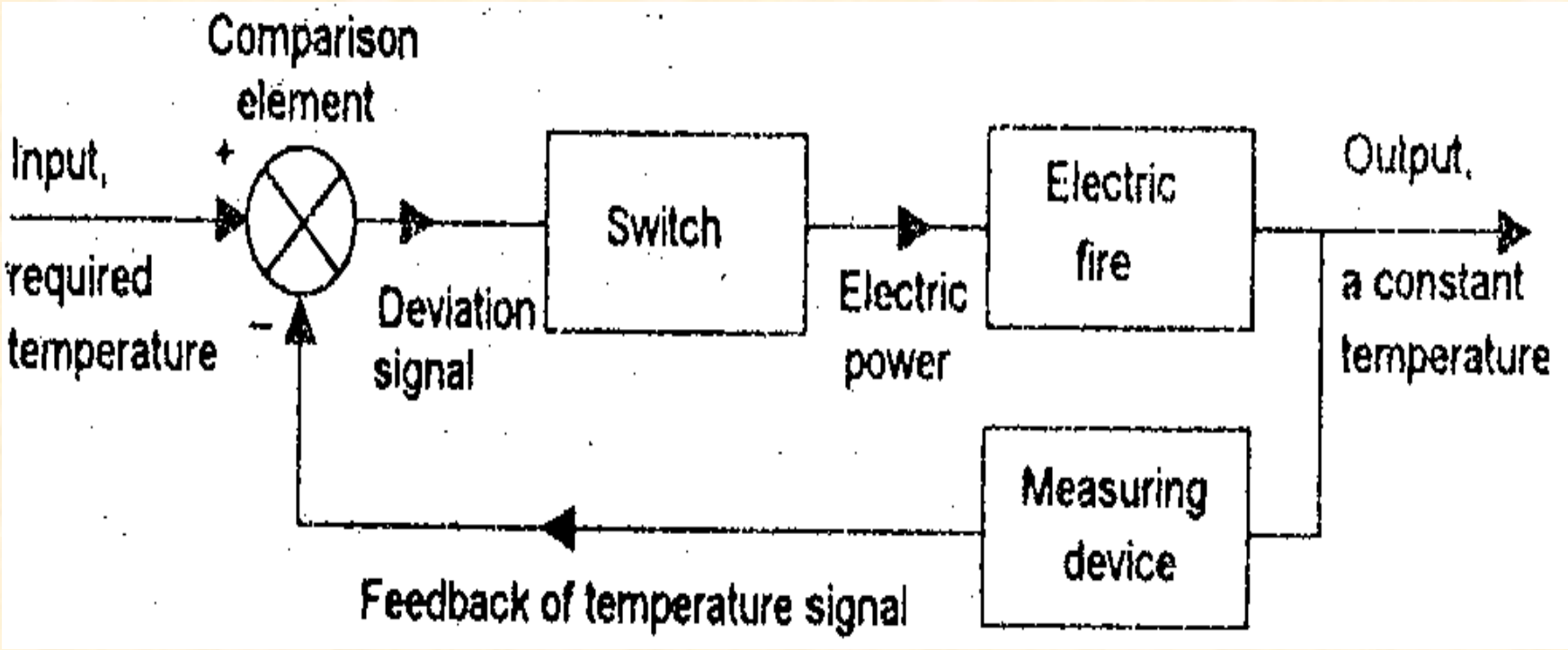
Open Loop System

Closed-Loop System

Open Loop System



Closed Loop System

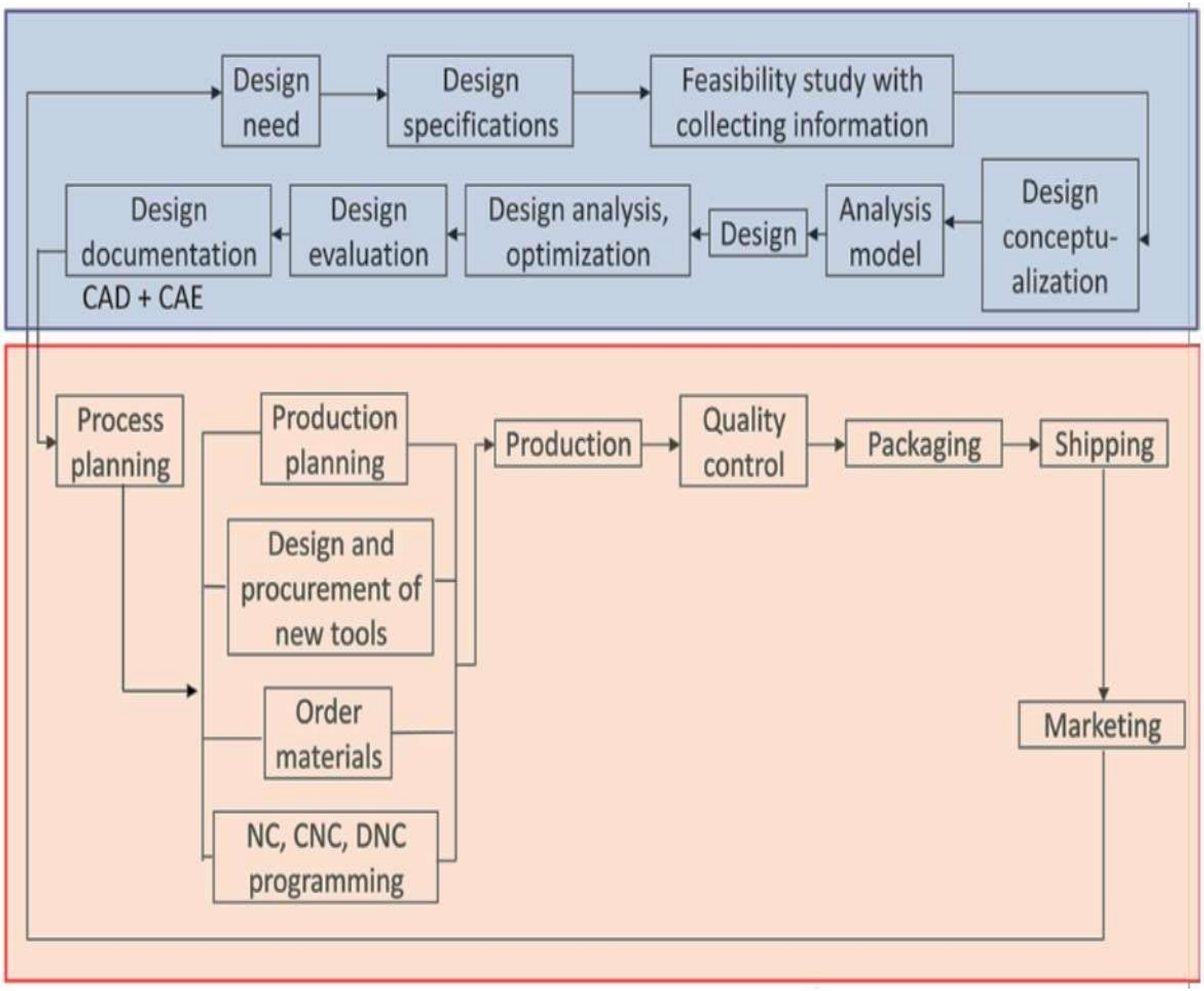


Importance of Mechatronics in Automation

CUSTOMERS ARE ALWAYS DEMANDING:

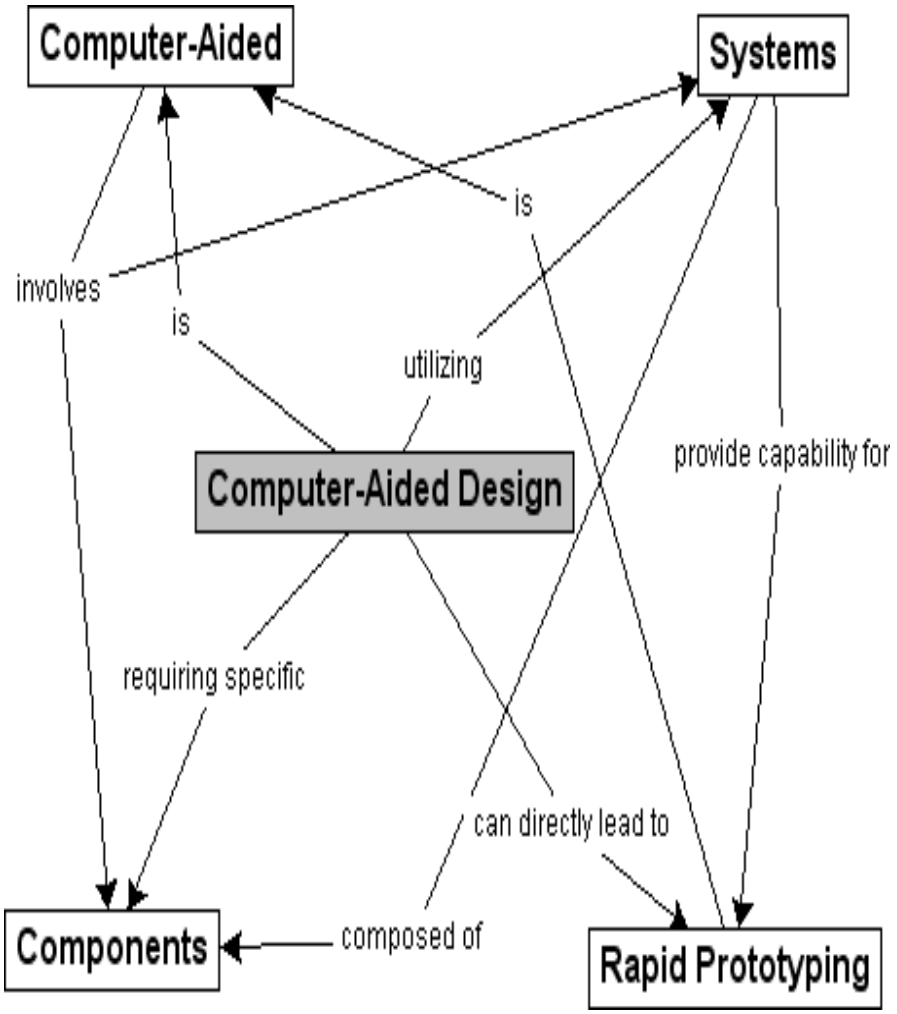
- More variety and different designs of products
- To meet the demands of people for different varieties, different designs and to fulfill the customer needs, to face competition in the market ---------
  - Manufacturers started launching new/modified products to survive from this competition
- Therefore, it became essential to automate the manufacturing and assembly operations in industry
- There are various activities involved in the product manufacturing process.

Automated Manufacturing Processes



What is CAD/CAM/CAE ?

- **CAD: Computer-Aided Design**
- **CAE: Computer-Aided Engineering**
- **CAM: Computer-Aided Manufacturing**



CAD/CAM/CAE Software

CAD: AutoCAD, Solid Edge, SolidWorks, Mechanical Desktop (MDT) etc.

CAE: ANSYS, ABAQUS, NASTRAN, ADAMS, MOLDFLOW etc

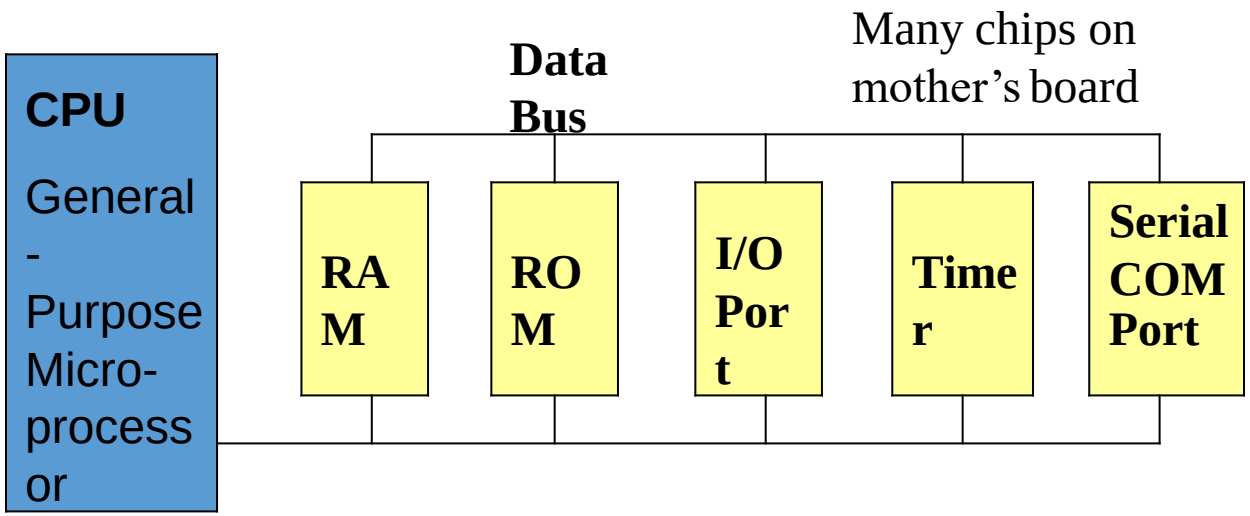
CAM: SOLIDCAM, SURFCAM, MasterCAM, SmartCAM etc.

Just-in-time (JIT) manufacturing

- **Just-in-time (JIT) manufacturing is a production model in which items are created to meet demand, not created in surplus or in advance of need. The purpose of JIT production is to avoid the waste associated with over production.**
    - **No surplus**
    - **No advance manufacturing**
    - **No over production**
    - **No inventory**
    - **Hence, No wastage of raw material/finished products**

Microprocessor

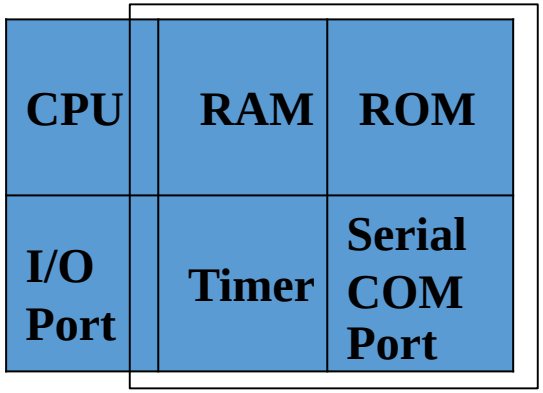
CPU for Computers



General-Purpose Microprocessor System

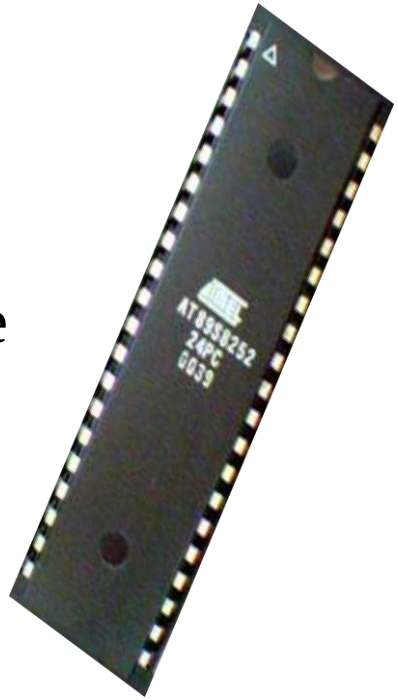
Microcontroller

- A smaller computer
- On-chip each for RAM, ROM & I/O ports...



A single chip

Microcontroller



Sensors and Actuators
(Practical Definition)

Sensor

A device that converts an environmental condition into an electrical signal.

Actuator

A device that converts a control signal (usually electrical) into mechanical action (motion).

Mechatronics Applications

- **Smart consumer products:** Home security, Camera, Microwave oven, Toaster, Laundry washer-dryer, Climate control units, Automatic Digital Camera etc.

- **Computer** disk VCR/DVD drives, ATM, etc

- **Medical:** Implant-devices, Assisted surgery, Haptic, etc.

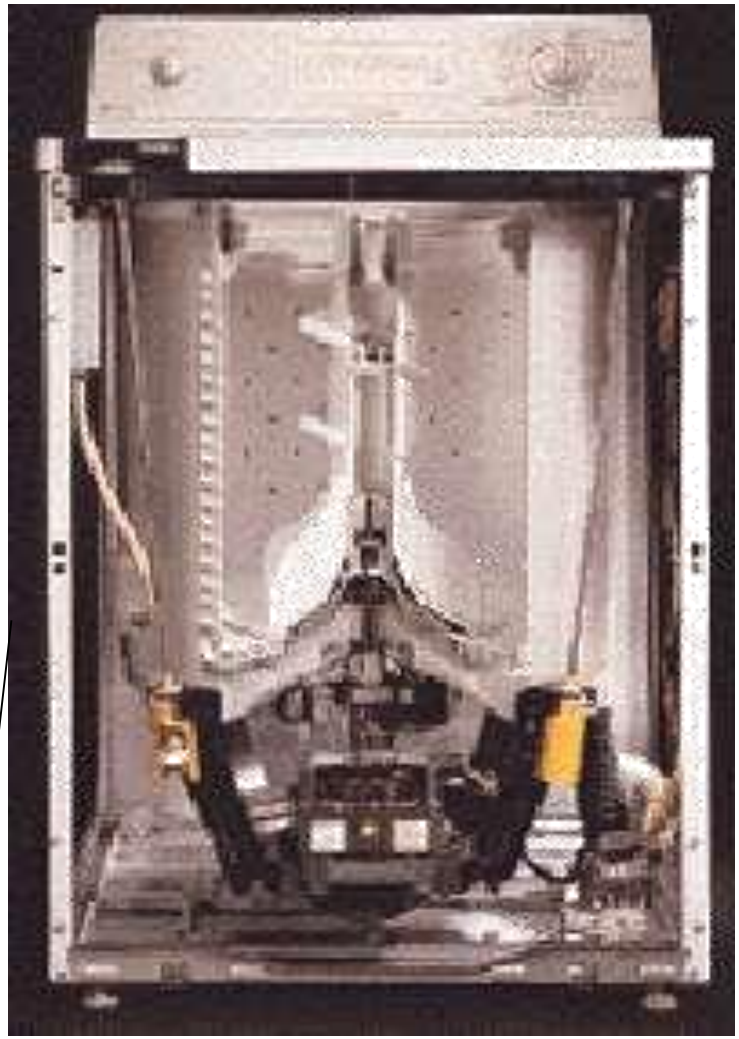
- **Defense:** Unmanned air, ground, and underwater vehicles, Smart weapons, Jet engines, etc.

- **Manufacturing:** NC & CNC machine tools, Rapid Prototyping, Robotics, etc.

- **Automotive:** Climate control, Active suspension, Air bags, Engine management, Safety, etc.

Examples of Mechatronic Systems

computer disk drive



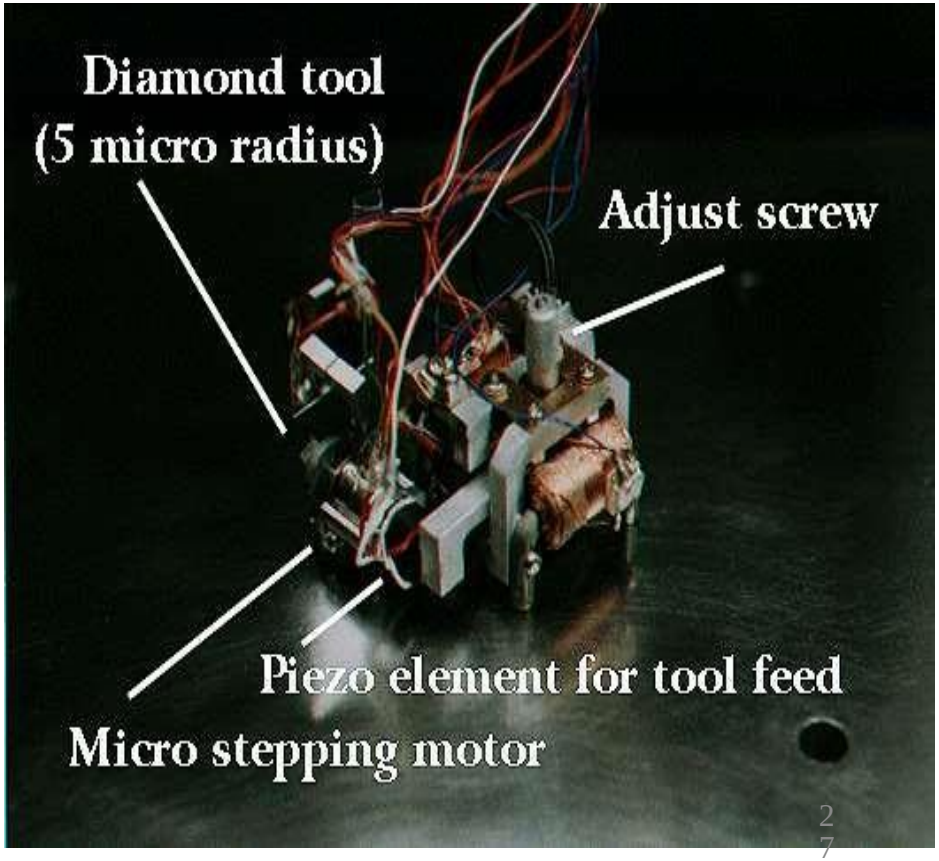
clothes washer

Mechatronics Systems in Manufacturing Applications

Micro Factory

- Desktop sized Factory
- Build small parts with a small factory
- Greatly reduces space, energy, and materials

Micro Factory Drilling Unit



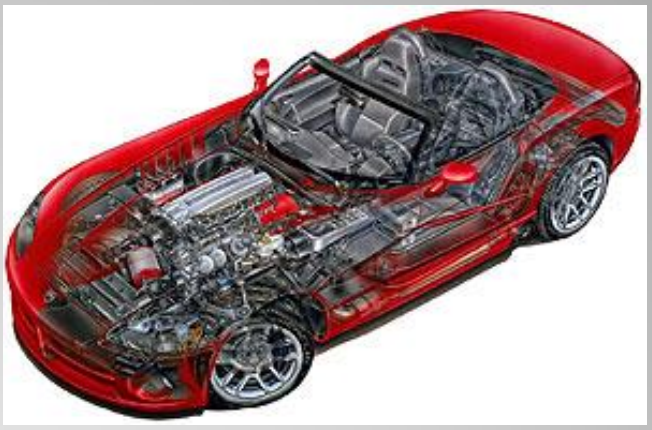
Mechatronics Systems in Manufacturing Applications

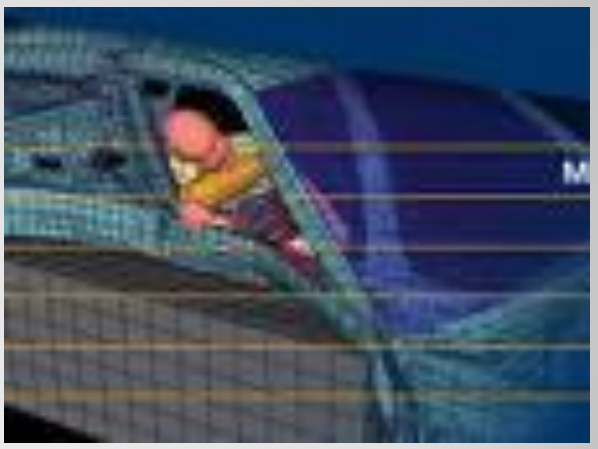
CNC Bending

- Fully automated bending: load sheet metal and the finished bent parts come out
- Can bend complex shapes

Embedded Systems in Automotive Applications

- Entertainment
- Anti skid braking
- Heads-up monitoring
- Back-up collision sensor
- Navigation
- Tire pressure sensing
- Auto parking





Transportation Applications

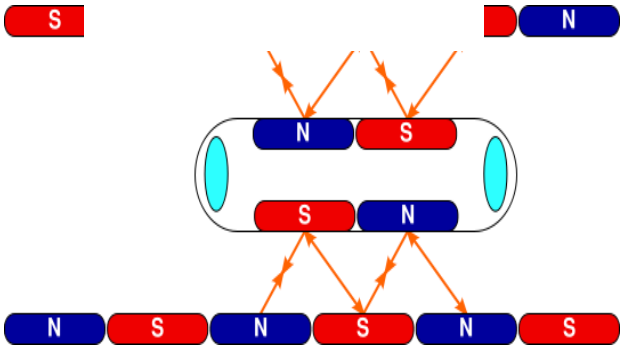
High Speed Trains

- Train Position and Velocity constantly monitored from main command center.
- Error margin in scheduling no more than 30 seconds
- Fastest trains use magnetic levitation

JR-Maglev
Top Speed: 574 km/h (357 mph)
Country: Japan

Transrapid
Top Speed: 550 km/h (340 mph)

Magnetic Levitation

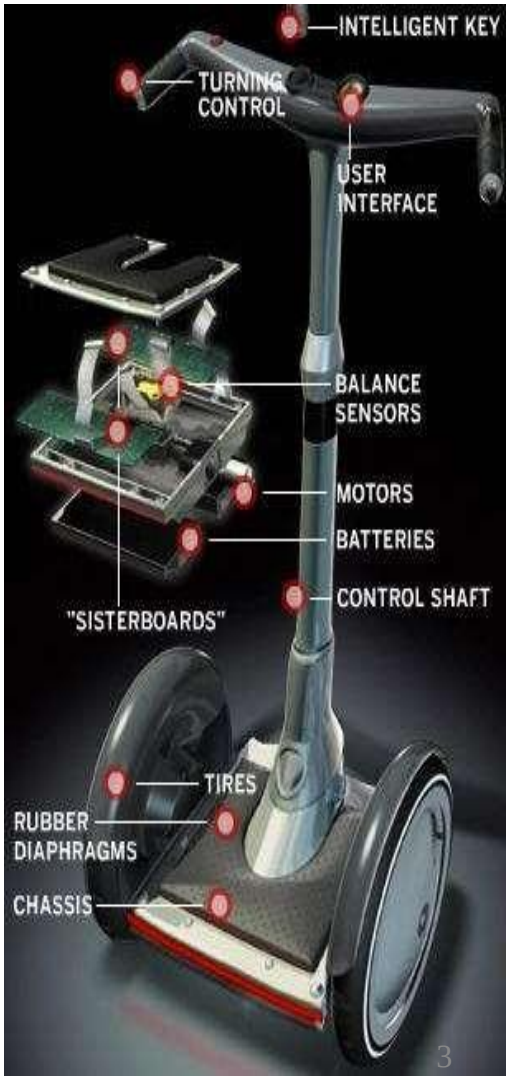


Transportation Applications

Systems Uses

- Tilt and pressure sensors
- Microcontroller
- Motors
- Onboard power source

Segway



Advantages

Simple and intuitive personal transport vehicle

Smart Robotics Application

BigDog

System Can

- Carry 340 lb
- Run 4 mph
- Climb, run, and walk
- Move over rough terrain

Advantages

Robot with rough-terrain mobility that could carry equipment to remote location.

Smart Robotics Application

Robots can vacuum floors and clean gutters so you don't have to.

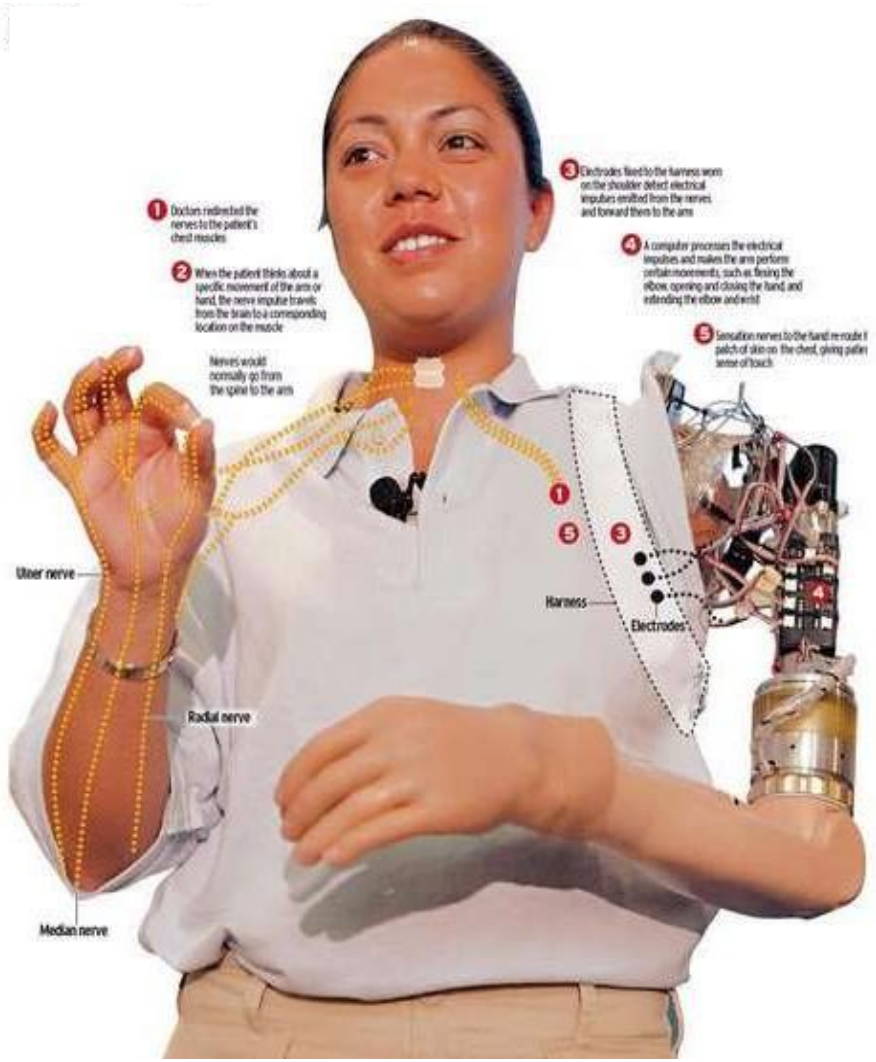
Vacuum Floors

Cleans Gutter

Medical Applications

Prosthetics

Arms, Legs, and other body parts can be replaced with electro-mechanical ones.



Medical Applications

Used by patients with slow or erratic heart rates. The pacemaker will set a normal heart rate when it sees an irregular heart rhythm.

Pace Maker

Implantable Defibrillation

Monitors the heart. If heart fibrillates or stops completely it will shock the heart at high voltage to restore a normal heart rhythm.

Defense Applications

- Advanced technology is making our soldiers safer.
- Some planes can now be flown remotely.

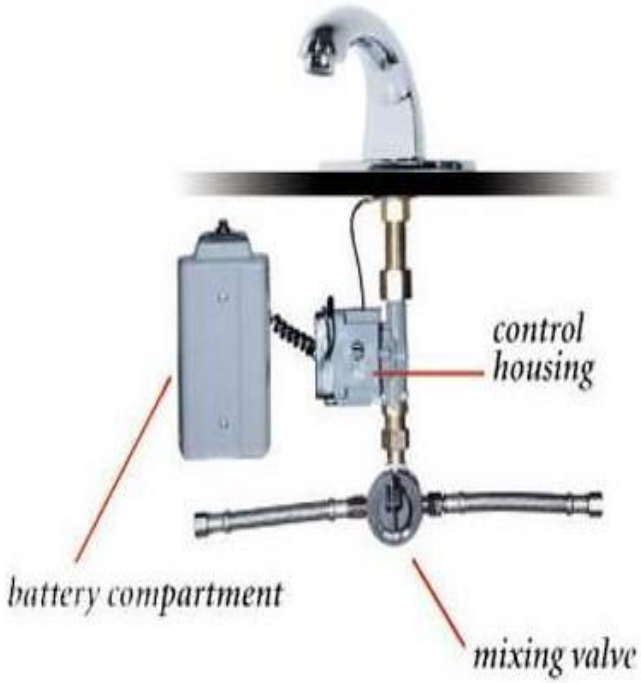
Unmanned Aerial Vehicle (Drones)

Stealth Bomber

Sanitation Applications

System Uses

- Proximity sensors
- Control circuitry
- Electro-mechanical valves
- Independent power source



Advantages

- Reduces spread of germs by making device hands free
- Reduces wasted water by automatically turning off when not in use

Sanitation Applications

Systems Uses

- Motion sensors
- Control circuitry
- Electromechanical actuators
- Independent power source

Paper Towel Dispenser

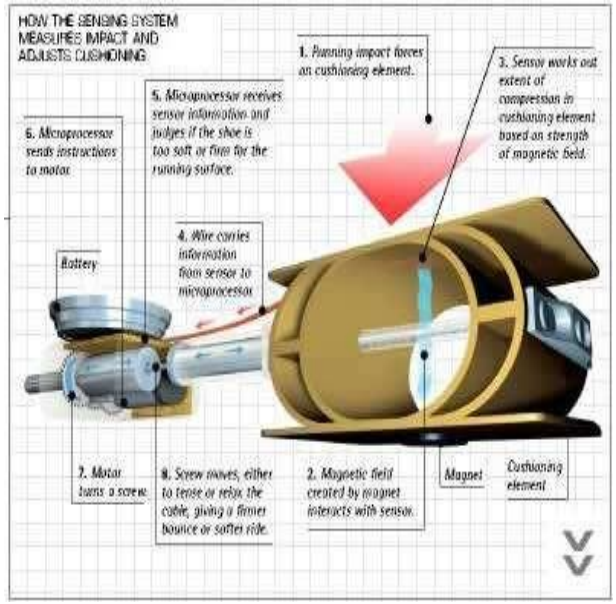
Soap Dispenser

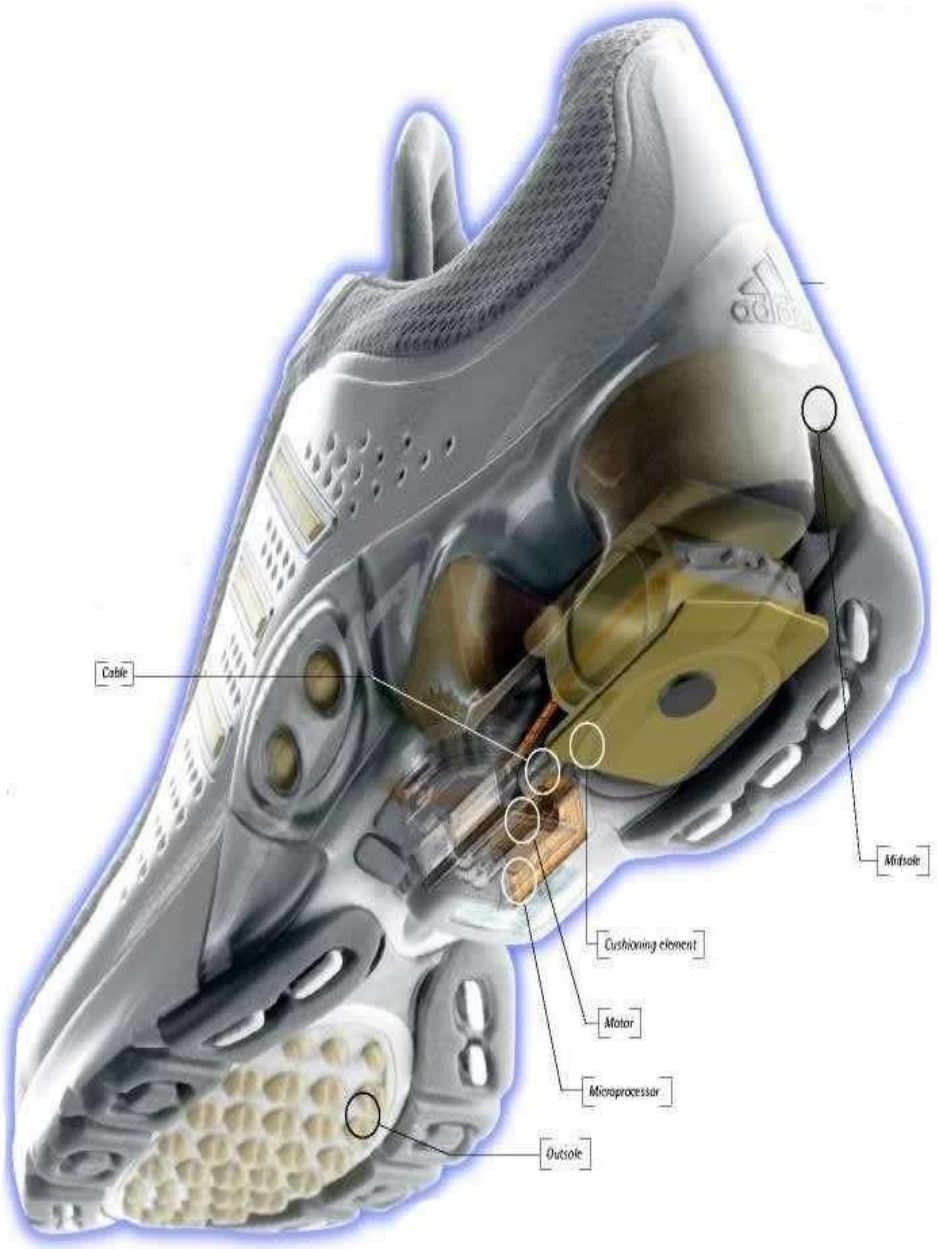
Advantages

- Reduces spread of germs by making device hands free
- Reduces wasted materials by controlling how much is dispensed

Sports Applications

Running Shoes

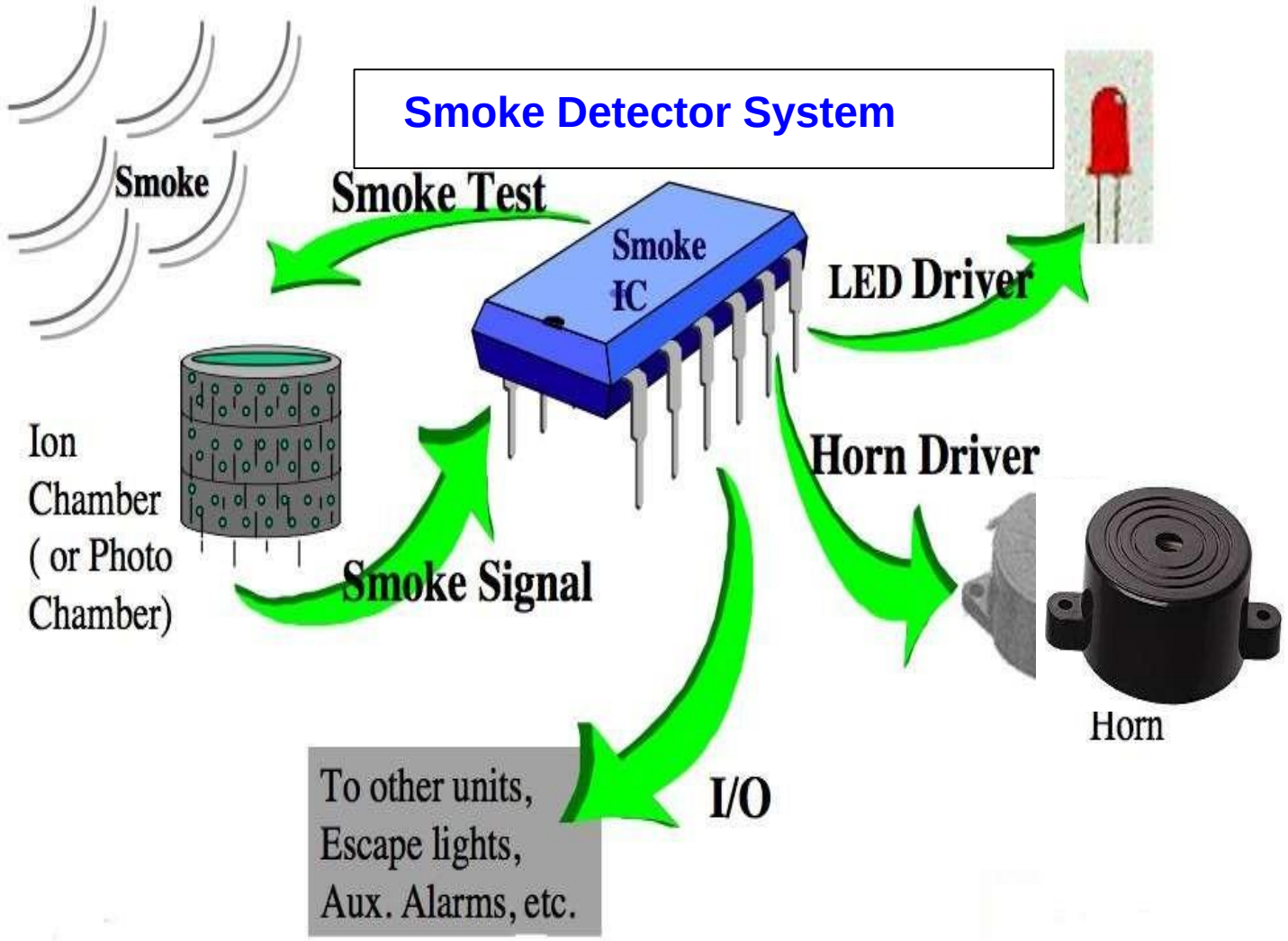




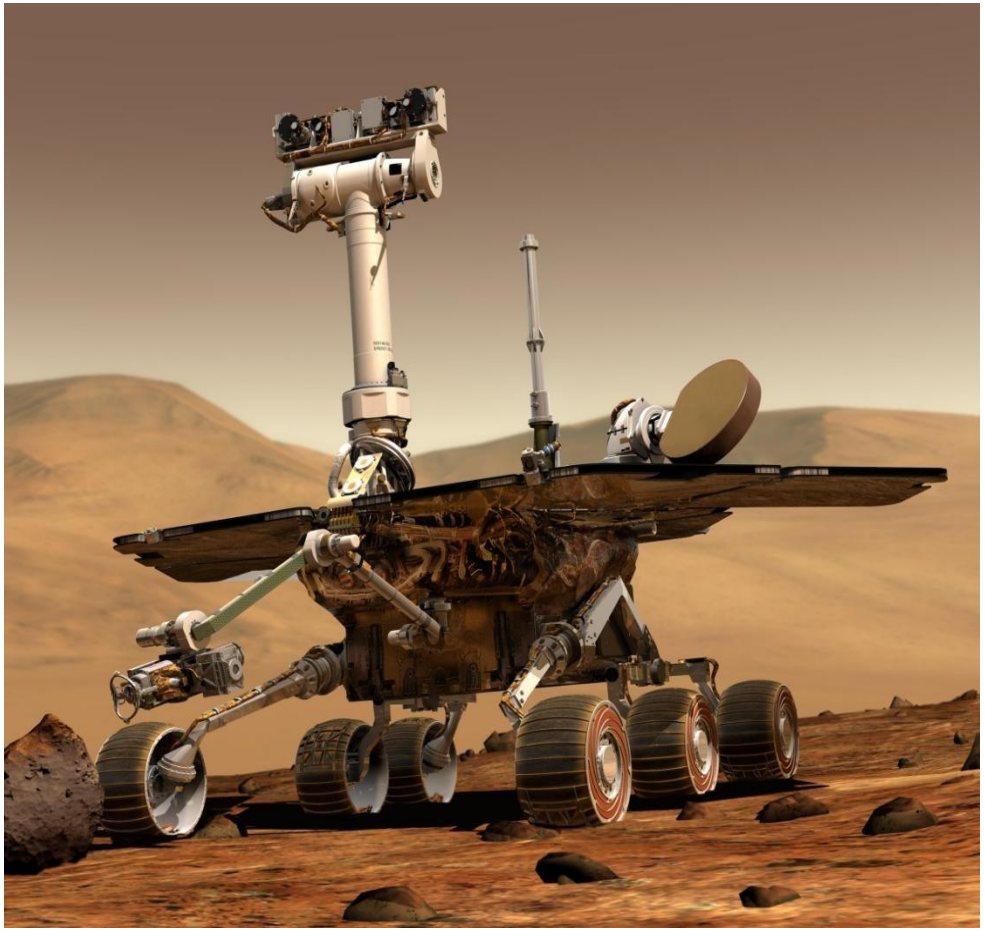
Advantages

- Automatically changes cushioning in shoe for different running styles and conditions for improved comfort

Smart Fire Protection Applications



Examples of Mechatronic Systems



Wheeled Robots

Examples of Mechatronic Systems

Aerial Robots (Drones)

Examples of Mechatronic Systems

Industrial Robots

Mechatronics Curricula

- Introduction to engineering
- Engineering Software: C, Java, Matlab, Labview, Linux etc.
- Fundamental of mechanical system Design and Analysis
- Electronic Devices, Circuits and Systems
- Digital systems and Computer architecture
- Applied Control Theory
- Robotics (Sensors, Actuators, Control Valves, etc.)
- Instrumentation and Measurements
- Signal & Image processing
- CAD/CAM, NC and CNC
- Integrated mechanical/electrical systems

PRACTICAL RAILWAY SYSTEMS

PRACTICAL ASPECTS:

1) Sensors, Actuators

2) Earthing Protection, Noise control

3) Management aspects – AMC, Spares

COACHING SYSTEMS:

1) Bio-Toilets System

2) WSP System in LHB Coaches

3) PLCs used in various control systems such as BioToilets

FREIGHT & OTHERS:

5) Newly Inducted technologies

6) Electronic In-Motion Weighbridge systems

Indian Railways

- Wheel Impact Load Detection System (WILD)
- Derailment Detection Devices
- Measuring Wheel Technology
- Onboard Diagnosis
- Bogie Design

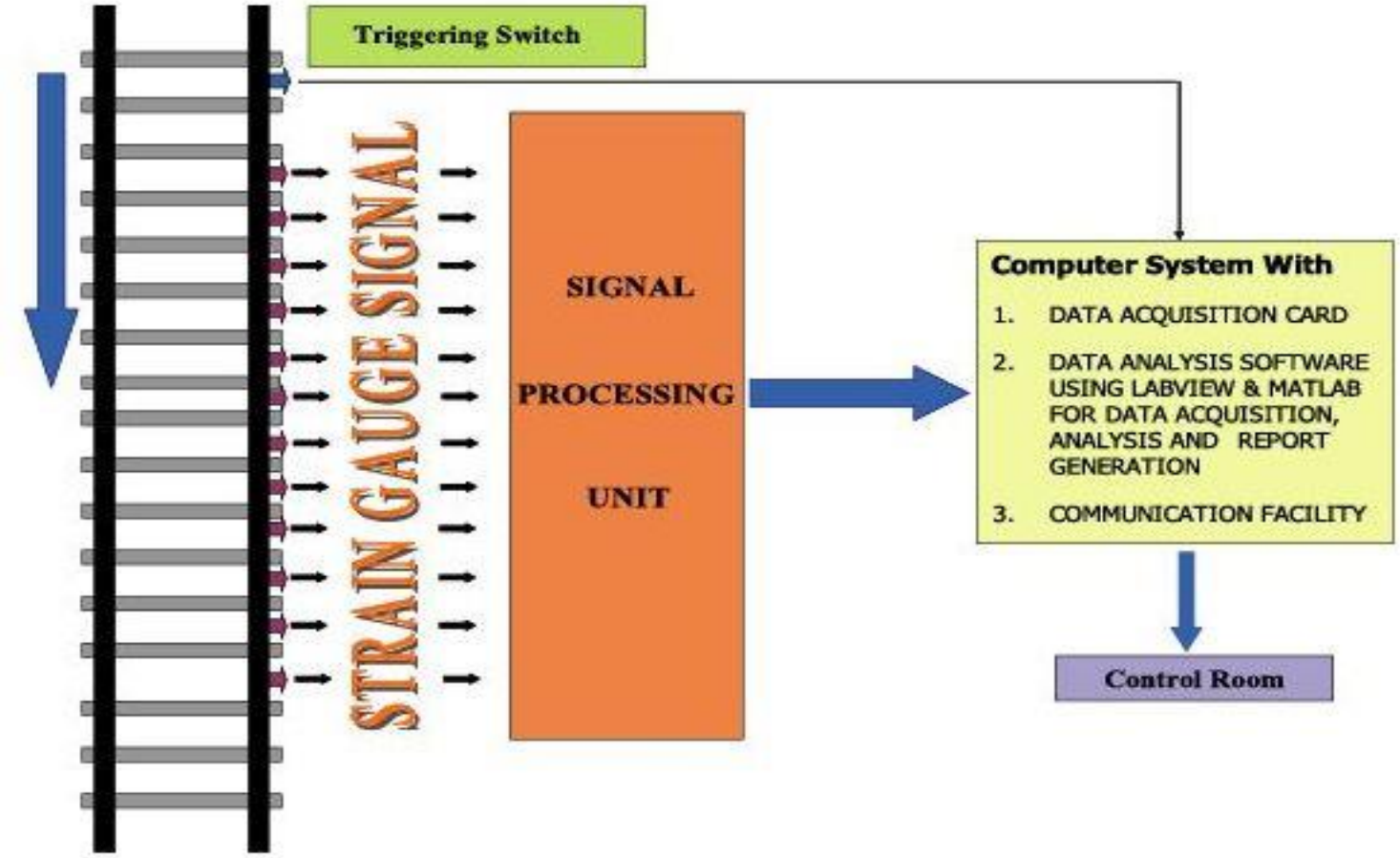
WHEEL IMPACT LOAD DETECTION SYSTEM (WILD)

- **WILD is a prototype automated system for on-line estimation of wheel impact loads and detection of wheel flats of running trains.**
- **Wheel Impact Load Detector (WILD) is a Safety System used to identify the defective wheel by measuring the dynamic impact on the track at a very early stage and thereby protect the Rail Infrastructure, avoid derailments and catastrophic failures.**

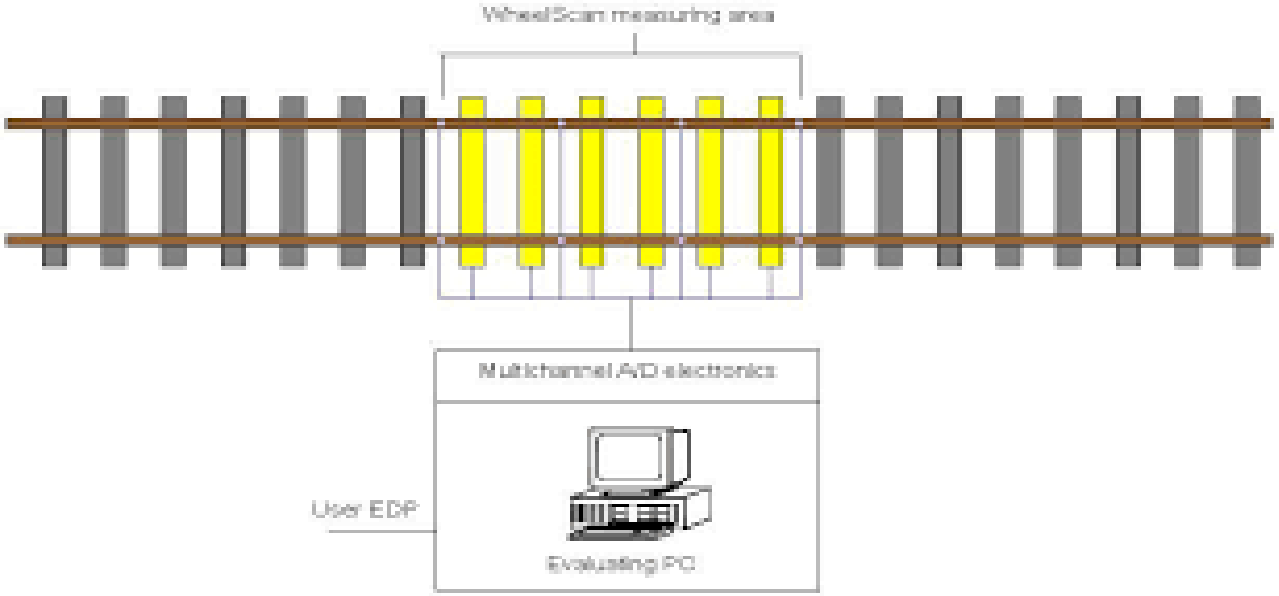
WHEEL IMPACT LOAD DETECTOR

- **Impact load occurs on rail when a defective portion of wheel falls on rail head.**
- **Impact load is transferred to rail head from wheel through combination of any or all of the following defects like:**
  - **Wheel having a flat / out of roundness**
  - **Overloaded Axles**
  - **Defect in suspension system**
  - **Miss-alignment of Bogies**

- **Wheel Impact Load Detector (WILD) system consists of both hardware and software components.**
- **Strain Gauge Technology has been employed and data is collected over 24-Channels along a rail length of 5 metres. Intelligent software Algorithms and Codes have been developed and embedded into the hardware processors.**



IMPACT LOAD MEASUREMENT



Indian Railways

Derailment Detection Devices

This project envisages development of On-Board equipment for sensing derailment possibilities of rolling stock. Development includes appropriate instrumentation and signal processing strategy and its integration with the existing brake mechanism for minimizing losses due to dragging of derailed vehicle. Presently there is no instrumentation on Indian Railways for detecting derailment possibilities.

For more Details visit site: *Technology Mission on Railway Safety (TMRS)*

DERAILMENT DETECTION DEVICE

- Level of vibrations increases dramatically if a coach, wagon or locomotive derails. The severe increase in vibrations can be sensed by a **DERAILMENT DETECTION DEVICE**.

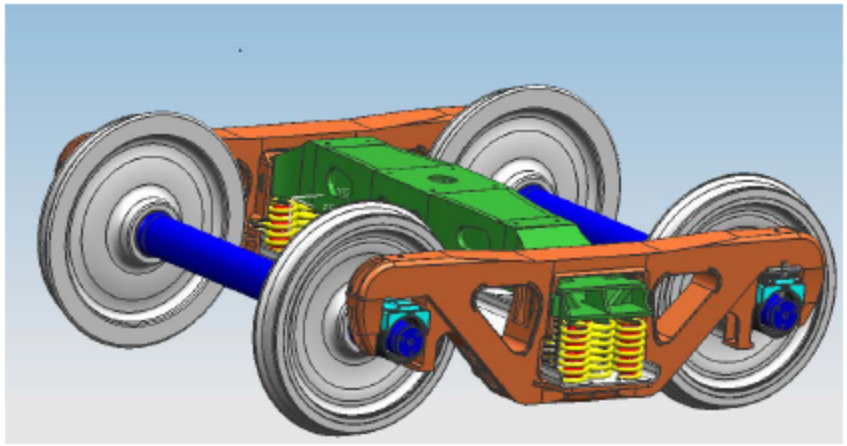
  The **Derailment Detectors** are fitted on the end of a coach or wagon, and are designed to immediately apply brakes in the event of such unusually high level of vibrations.

- The **Derailment Detector** is devices which stops the train by activating automatic application of brakes or send a signal to the train driver when its triggering threshold has been reached following a rolling stock derailment.

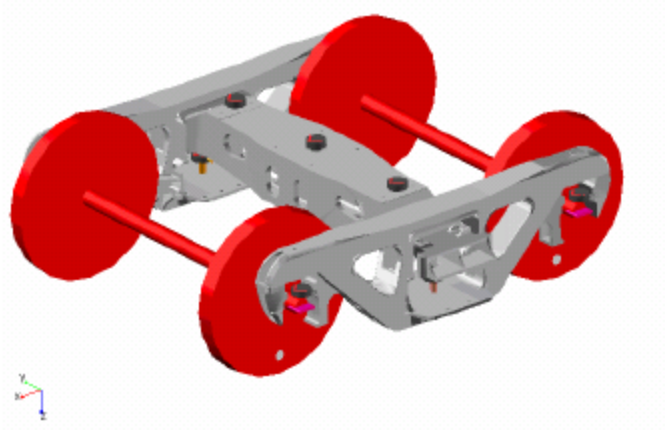
- Hence, rolling stock equipped with Derailment Detector, apart from saving human life, shall reduce the damage to track, rolling stock and operation disruption.

Indian Railways

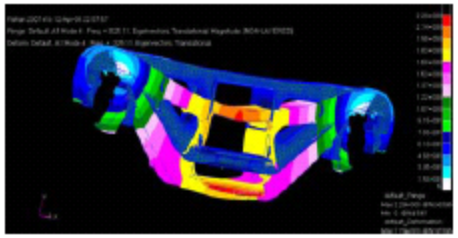
Bogie Design

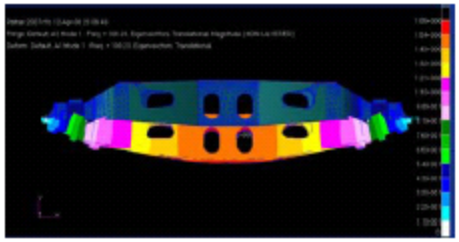


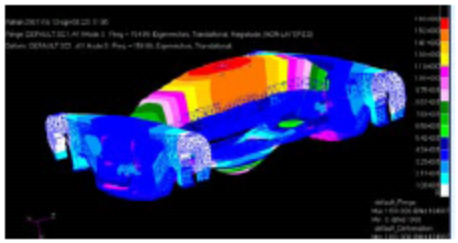
CASNUB bogie Assembly



Model of CASNUB bogie in ADAMS





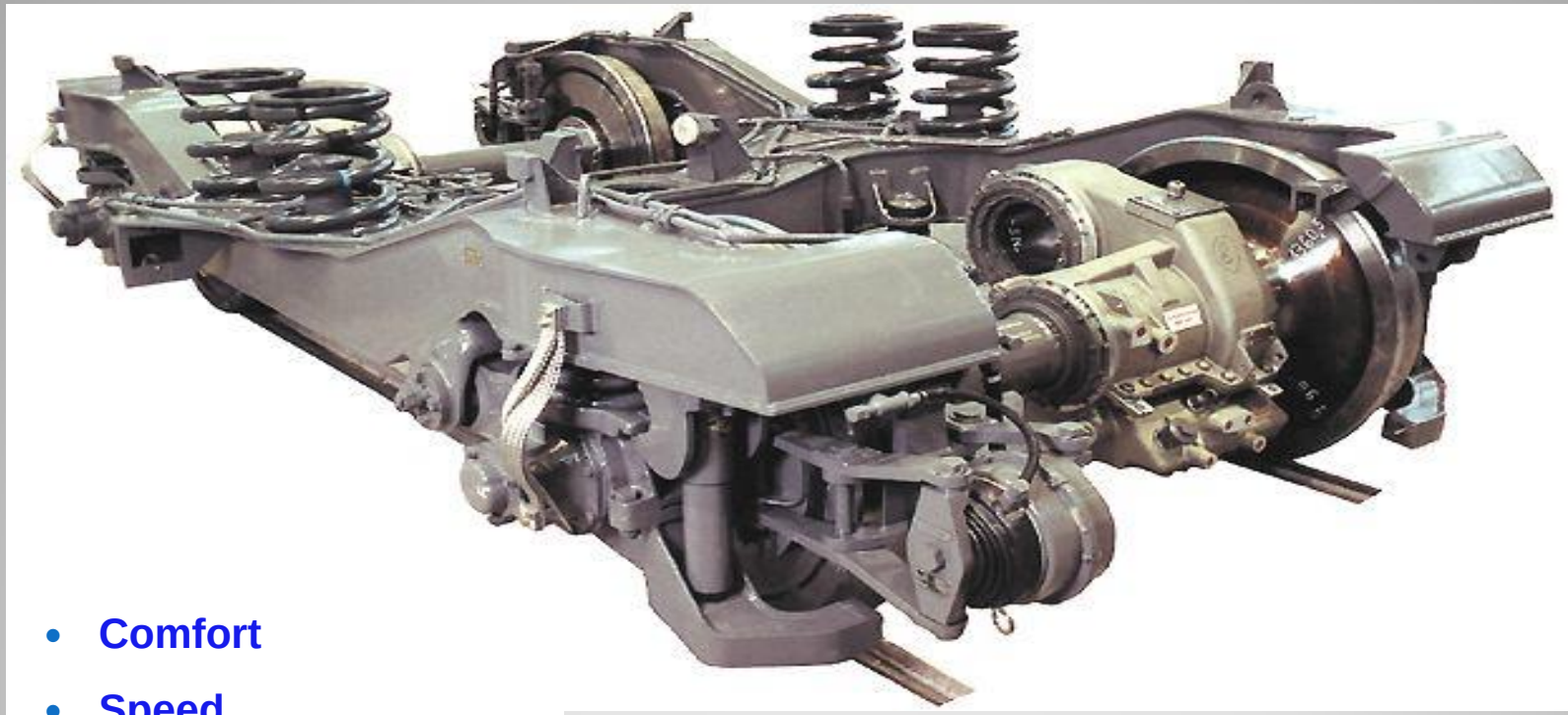


Finite element analysis of some wagon components

Future developments aim to Improve:

- Performance
- Energy use and environmental performances
- Comfort
- Safety and Security
- Reduction in investment and maintenance costs

Railways around the World



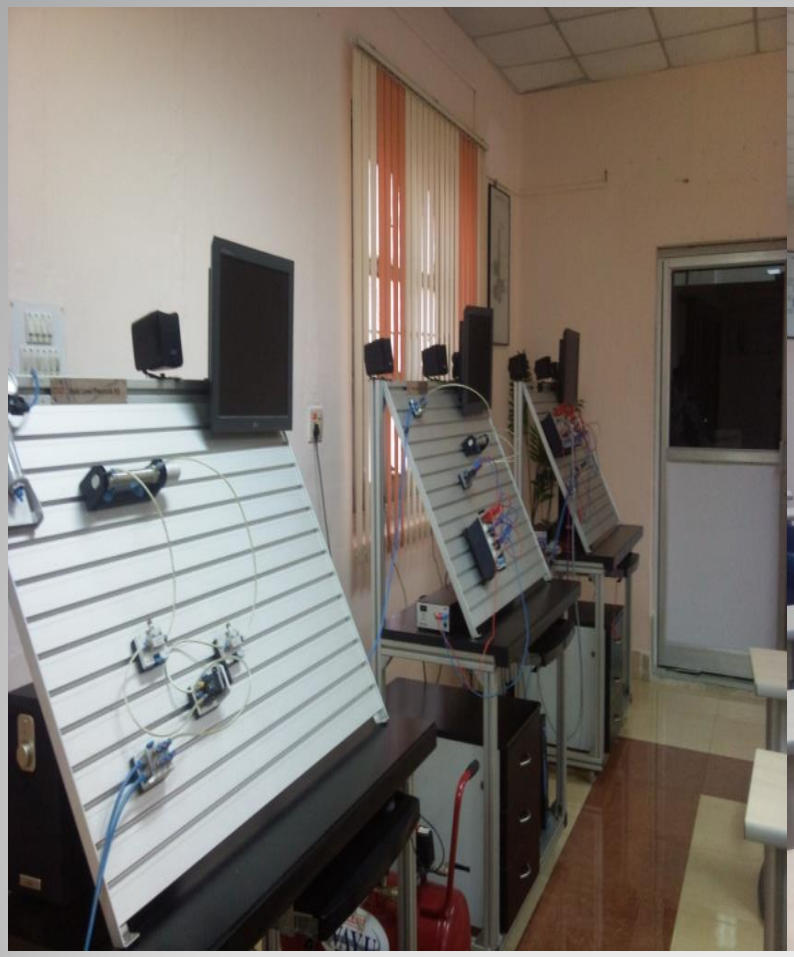
- Comfort
- Speed
- Stability and
- Safety

Tilting trains

Coaching - Future

- Bearing Temperature Monitoring
- Bogie Vibration Monitoring
- Water Pump, level control
- On-board entertainment and information system on back of reclining chairs in CCs
- On-line information systems

Training facilities at Mechatronics Lab, IRIMEE



Training facilities at Mechatronics Lab, IRIMEE

Training facilities at Mechatronics Lab, IRIMEE

THANK YOU