Introduction to Mechatronics MEC100x – Lectures 1

Energy, Power and Intelligent Control

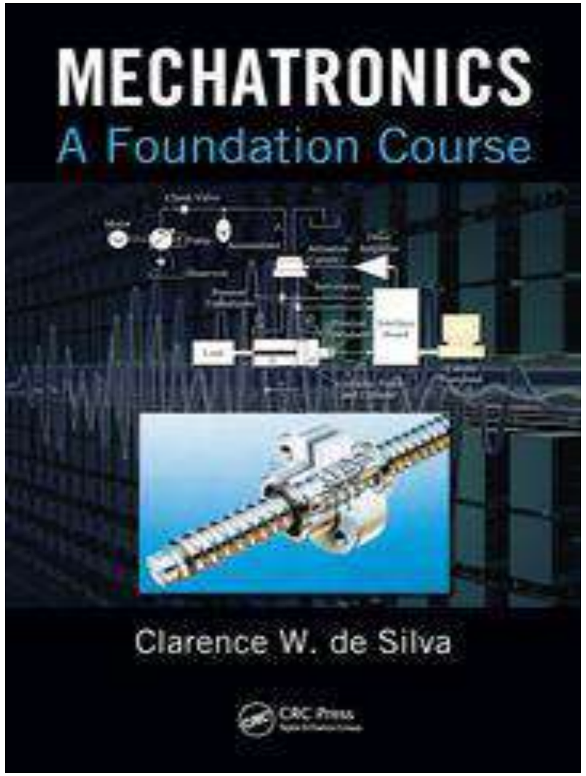
School of Electronics, Electrical Engineering and Computer Science

Ashby Building

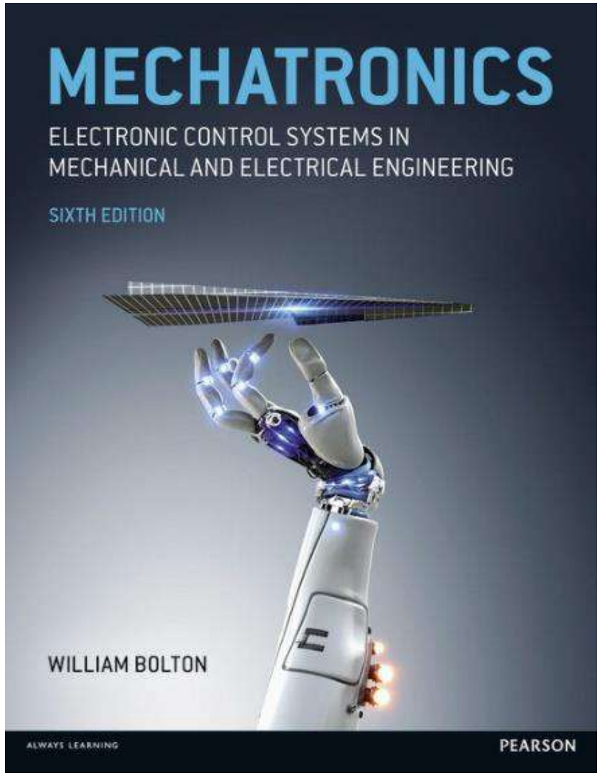
Queen's University Belfast

References:

Textbook: [1] C. W. de Silva, **Mechatronics: A Foundation Course,** CRC Press, Boca Raton, FL 2010.



Textbook: [2] W. Bolton, **Mechatronics:** Electronic Control Systems in Mechanical and Electrical Engineering (Sixth edition), Pearson: Edinburgh Gate, UK 2015.



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Course structure

- ❑ **Lecture + Tutorial + Lab**
- ❑ **Theory → Coding → Real systems**

❑ Assessments:

Examination, Lab's, homework

❑ Lecture

This covers two introductory topics: Introduction for Mechatronics.

❑ Tutorial

- ❑ The tutorial sessions focus on practical implementations of some of the algorithms discussed in the lecture.

❑ Lab

- ➢ Experiment design.
- ➢ Scientific report writing.

❑ Desired skills

- ❖ We encourage you to build teams that draw on your individual strengths- Group Lab1 , ….
- ❖ Programming in MATLAB and DAS software
- ❖ Knowledge of DAS

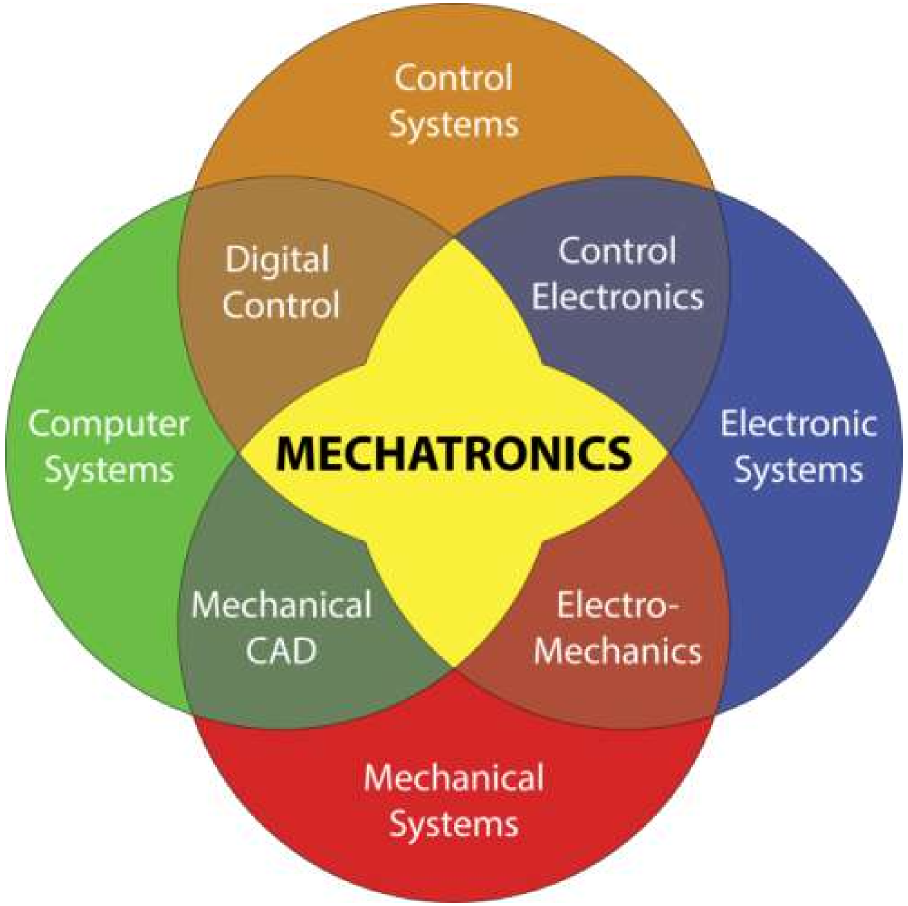
Aims

1. What is mechatronics, and why is it important?
2. Mechatronics Applications
3. Real life applications of Mechatronics - Mechatronics in Automotive Applications
4. Medical application of Mechatronics - Mechatronics in Consumer Products-Mechatronics in Manufacturing
5. Description of mechatronics concept map

What is Mechatronics?

- Mechatronics basically refers to mechanical electronic systems and normally described as a synergistic combination of **mecha**nics, electrical, elec**tronics**, computer and control.

- The **term "mechatronics" was first assigned** by **Mr. Tetsuro Mori,** a senior engineer of the Japanese company Yaskawa, in 1969.

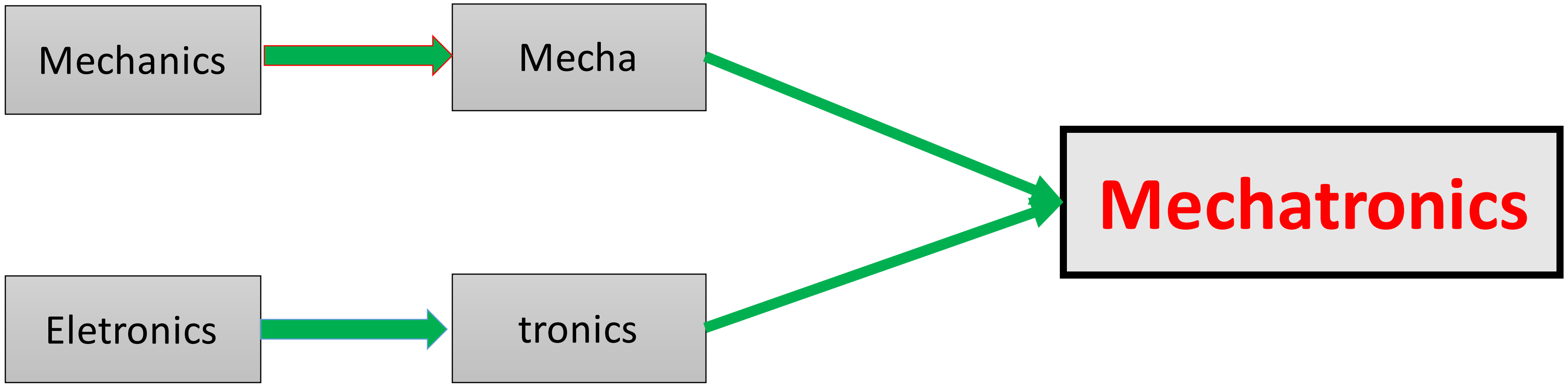


Mechatronics Defined - I

"The name [mechatronics] was coined by **Ko Kikuchi**, now president of Yasakawa Electric Co, Tokyo."

– T. Mori, "Mechatronics," Yasakawa Internal Trademark Application Memo, 21.131.01, July 12, 1969.

– R. Comerford, "Mecha … what?" IEEE Spectrum, 31(8), 46-49, 1994.



Mechatronics Defined - II

- "**Integration of** electronics, control engineering, and mechanical engineering."

– W. Bolton, Mechatronics: Electronic Control Systems in Mechanical Engineering, Longman, 1995.

- "**Synergistic integration** of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes."

– F. Harshama, M. Tomizuka, and T. Fukuda, "Mechatronics-what is it, why, and how?-and editorial," IEEE/ASME Trans. on Mechatronics, 1(1), 1-4, 1996.

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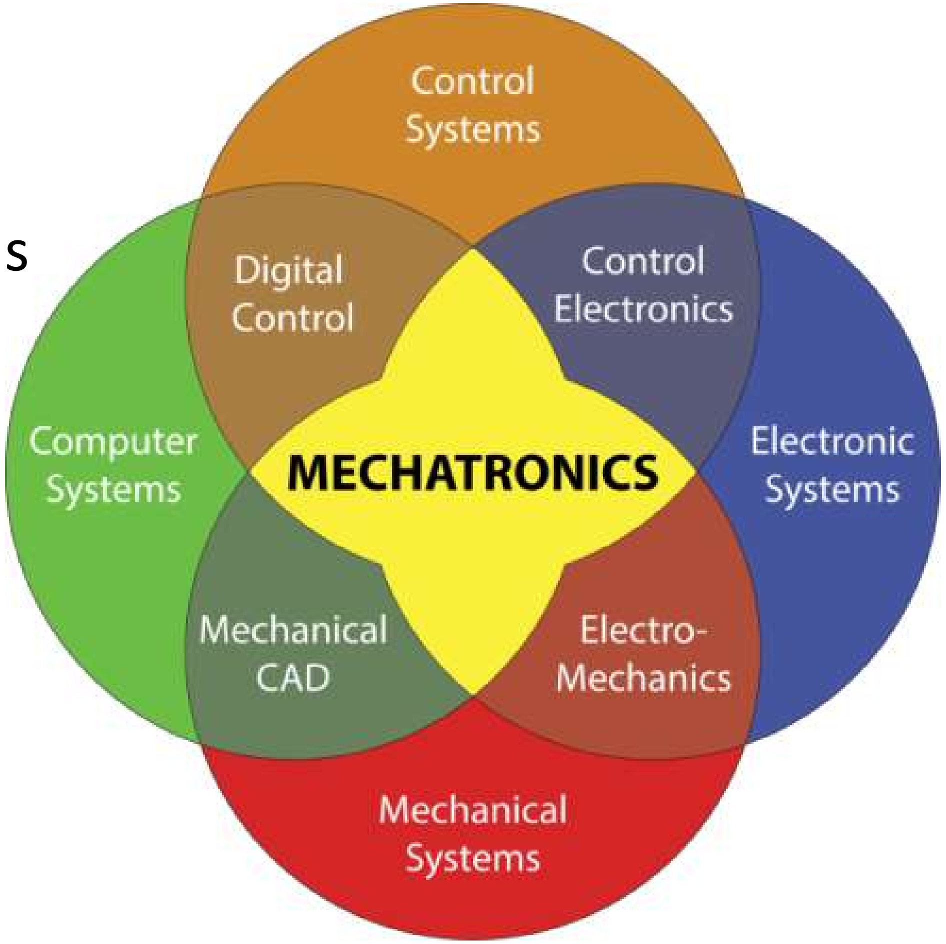
Mechatronics is an interdisciplinary process

❑ Mechanical

- ➢ Solid Mechanics
- ➢ Dynamics and Vibrations

❑ Control

- ➢ Classical control theory
- ➢ Modern control theory



❑ Electronic

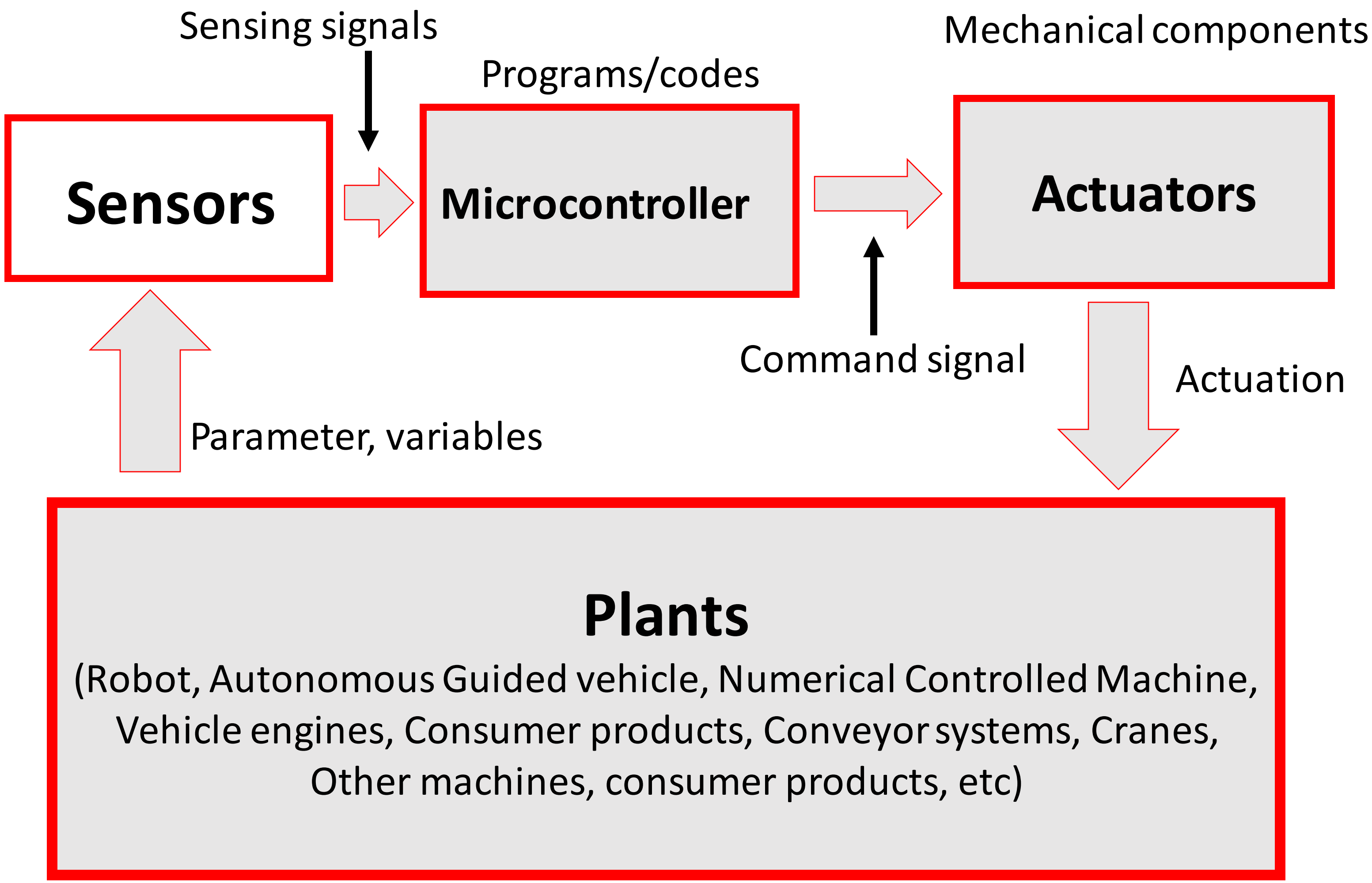
- ➢ Sensors and actuators
- ➢ Power systems

❑ Computer

- ➢ Design computation
- ➢ Microprocessors

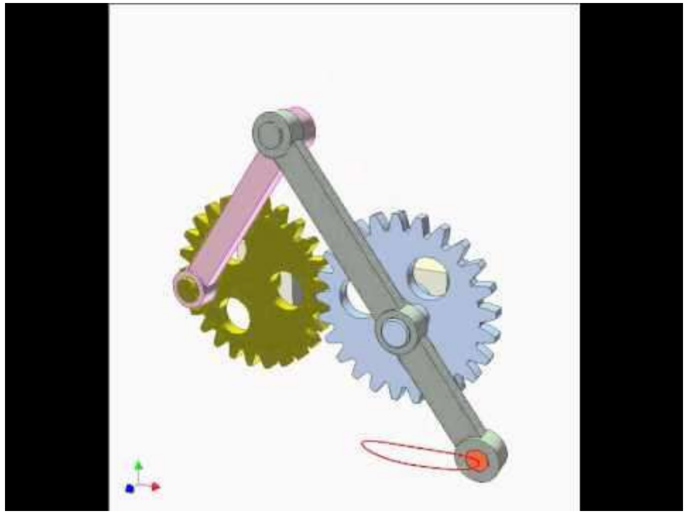
Mechatronics: Working Definition

- Physically, a mechatronic system is composed of **four prime components**.
- They are **sensors, actuators, controllers and mechanical components**.
- Figure shows a schematic diagram of a mechatronic system integrated with all the above components.



1. Industrial Revolution (Mechanical)

- Engineering designs of this era were largely mechanical – e.g., operations of motion transmission, sensing, actuation, and computation were performed using **mechanical components** such as **cams, gears, and linkages**.

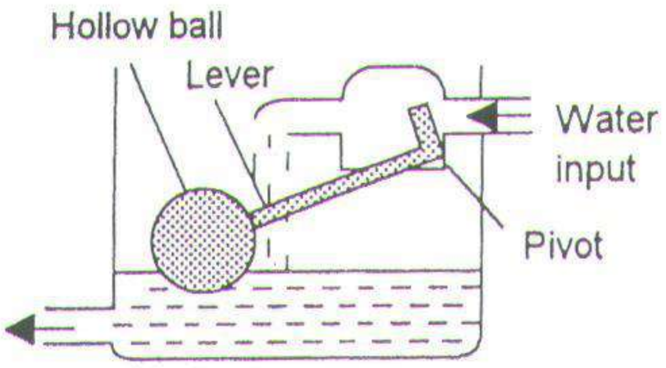


Video

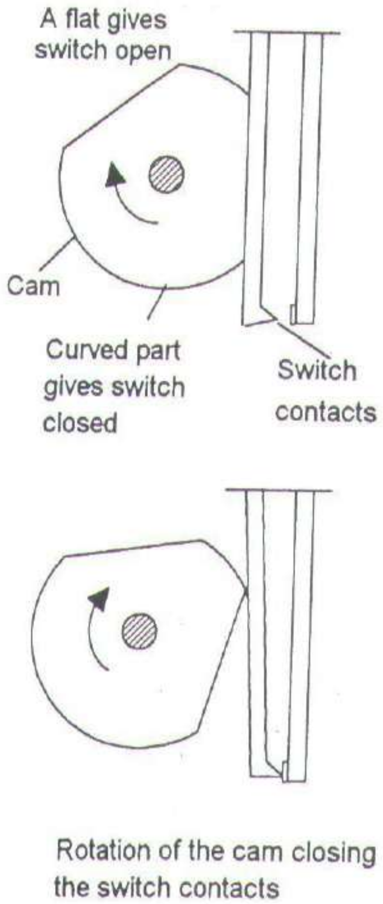
Disadvantages:

- Purely mechanical systems suffer from – Power amplification inability
- Energy losses due to tolerances, inertia, and friction

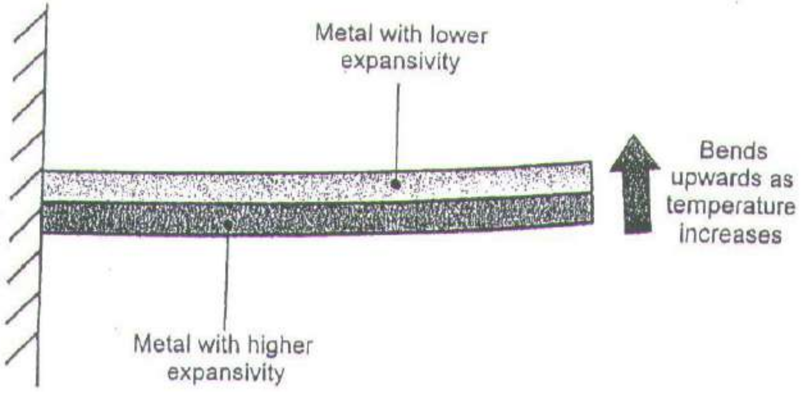
Examples of Mechanical Designs: This era were largely mechanical



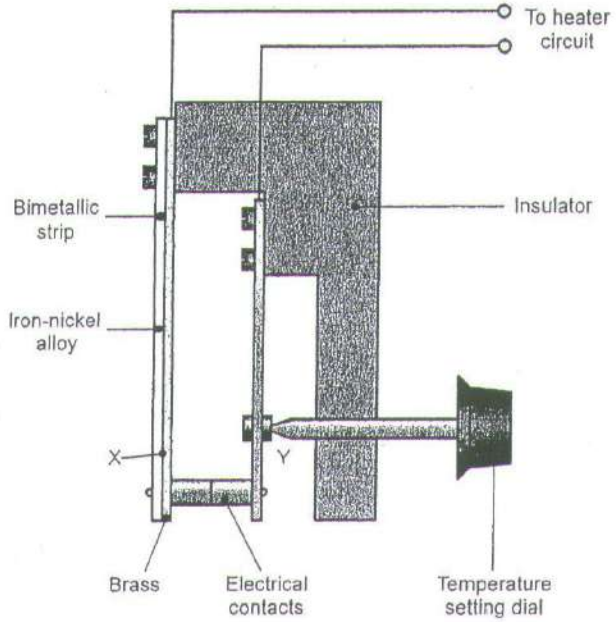
Float Valve



Shaft Cam Operated Switch



Bi-metallic Strip



Thermostat

2. Semiconductor Revolution (Electronic)

- Led to the creation of integrated circuit (IC) technology.

- Effective, minimize, power electronics **could amplify and deliver** needed amount of power to actuators.

- Hard-wired, on-board, discrete analog/digital ICs provided rudimentary computational and decision-making circuits for **control of mechanical devices**.

An Integrated Circuit

A2D Converter

An Operational Amplifier

3. Mechatronics Revolution

Mechatronics Systems

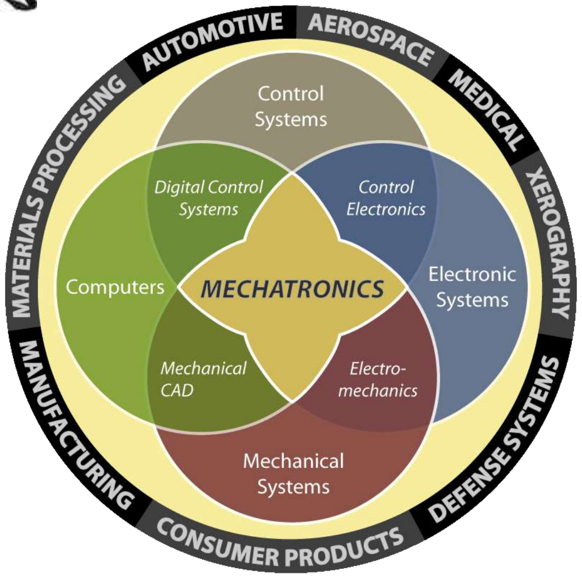
Tools

Computers

Cars

Consumer Electronics

MEMS
(Micro-electromechanical Systems)



Micro to Macro Applications

High Speed Trains

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3.1. Elements of Mechatronics-Mechanical

- Mechanical elements refer to :

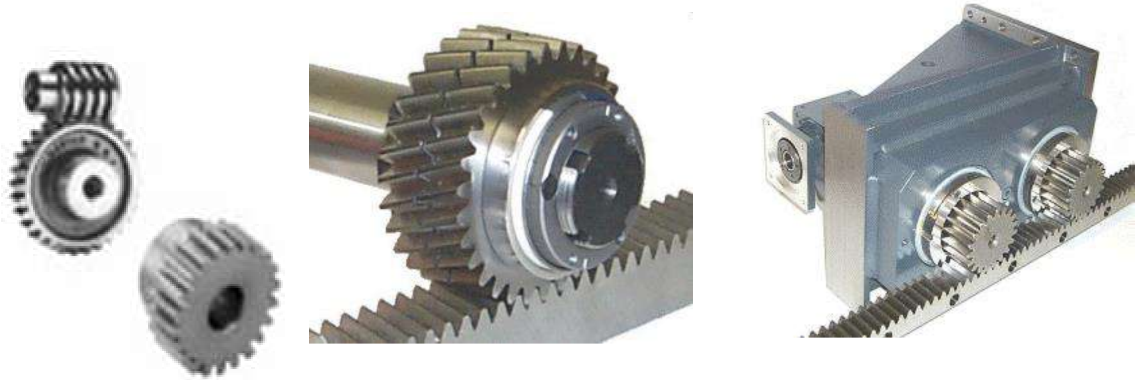
mechanical structure, mechanism, thermo-fluid, and hydraulic aspects of a mechatronics system.

- Mechanical elements may include **static/dynamic characteristics.**

- Mechanical elements require physical power to produce **motion, force, position,** etc.

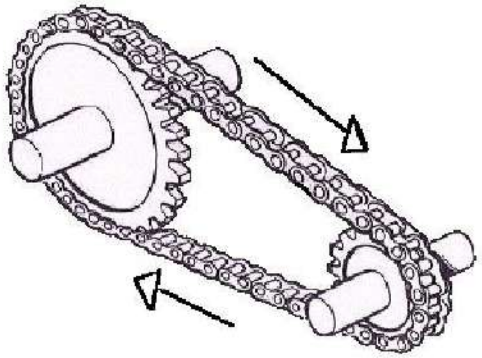
Machine Components: Basic Elements

Gears

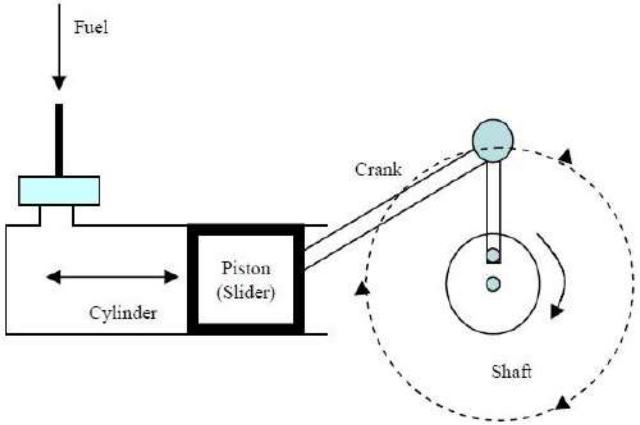


Springs

Wheel/Axle



Chain and sprocket



Slider-Crank

3.2. Elements of Mechatronics- Electromechanical

Electromechanical elements refer to:

- Sensors

✓ A variety of physical variables can be measured using sensors:

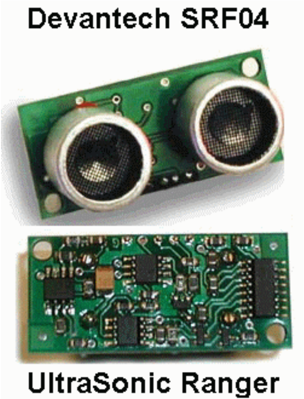
- Light using photo-resistor,
- Level and displacement using potentiometer,
- Stress and pressure using strain gauge,
- Touch using micro-switch,
- Temperature using thermistor,
- Humidity using conductivity sensor

- Actuators

- DC servomotor, stepper motor, relay, solenoid, speaker, light emitting diode (LED), electromagnet, and pump apply commanded action on the physical process

- **IC-based sensors and actuators:** digital-compass, -potentiometer, etc.

Flexiforce Sensor



DC Motor

Pneumatic Cylinder

3.3. Elements of Mechatronics- Electrical/Electronic

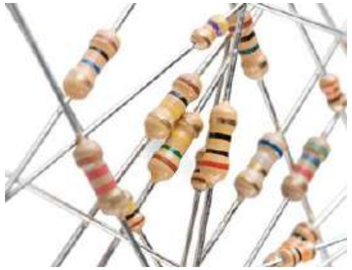
Electrical elements refer to:

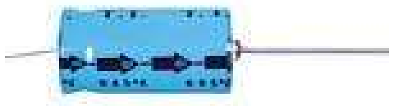
– Electrical components (e.g., resistor (R), capacitor (C), inductor (L), transformer, etc.), circuits, and analog signals.

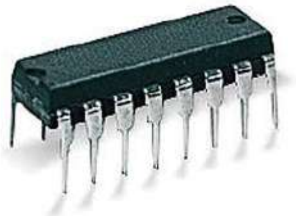
Electronic elements refer to:

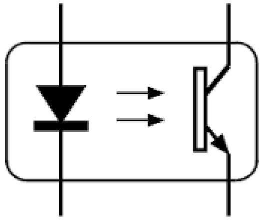
– Analog/digital electronics, transistors, thyristors, **opto-isolators**, operational amplifiers, power electronics, and signal conditioning

- The electrical/electronic elements are used to interface **electromechanical sensors and actuators to the control interface/computing hardware elements.**









3.4. Elements of Mechatronics- Control Interface/Computing Hardware

- **Control interface/computing hardware elements refer to:**

– Analog-to-digital (A2D) converter, digital – to - analog (D2A) converter, digital input/output (I/O), counters, timers, microcontroller, data acquisition and control (DAC) board, … .

- **Control interface hardware allows analog/digital interfacing**

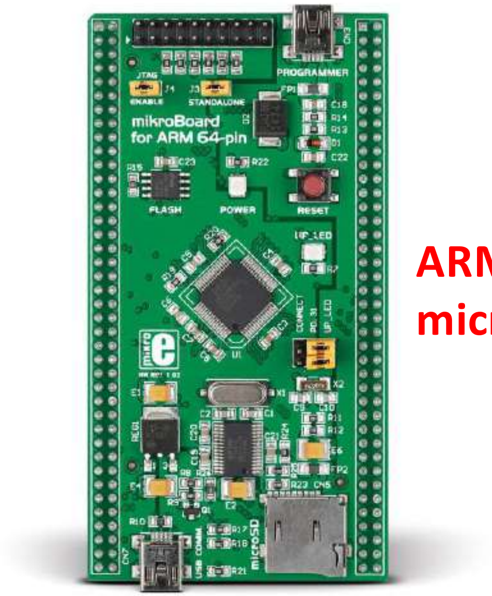
– communication of sensor signal to the control computer and communication of control signal from the control computer to the actuator

- **Control computing hardware implements a control algorithm,**

which uses sensor measurements, to compute control actions to be applied by the actuator.

A/D

Arduino



ARM cortex microcontroller

https://www.mikroe.com/mikroboard-arm-64-pin

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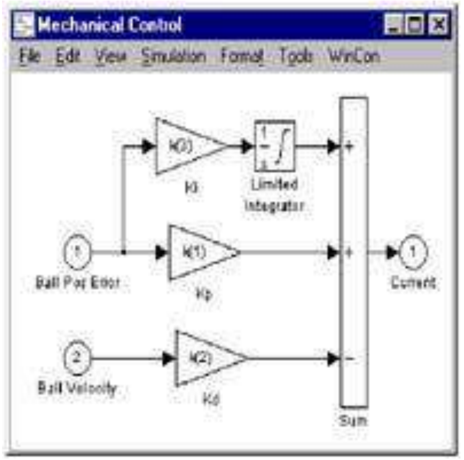
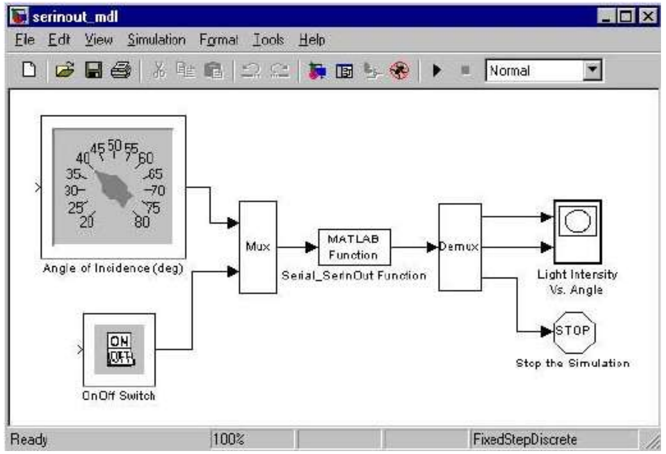
3.5. Elements of Mechatronics- Computer/Information System

Computer elements refer to hardware/software utilized to perform:

- ❑ **Hardware-in-the-loop simulation**
- ❑ **PC-based data acquisition and control**

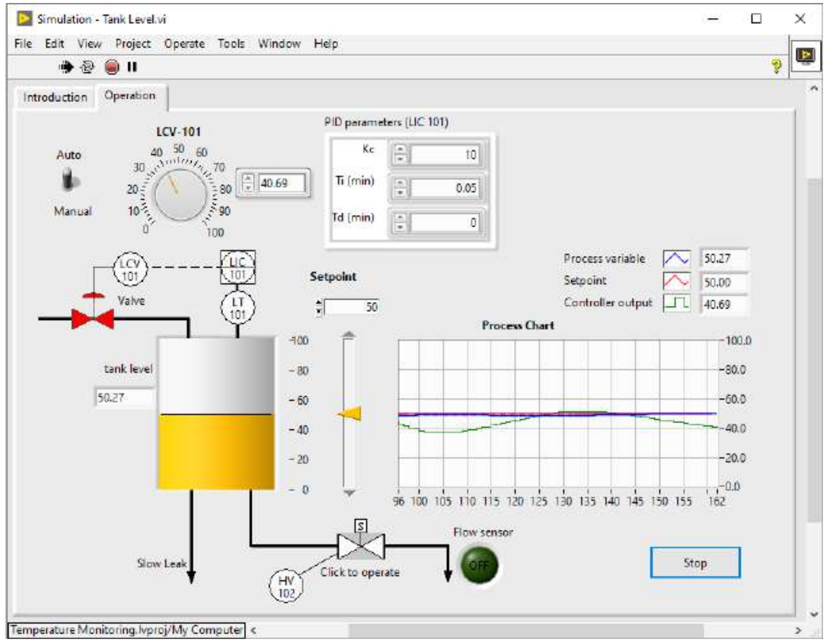


MATLAB software



MATLAB software

LabVIEW software



Mechatronics: Balance between theory, simulation, hardware, and software

Example of Mechatronic Systems

- The integration of:
  - Sensors
  - Actuators
  - Intelligence

  with a system to produce:
  - More capable, versatile, and robust performance

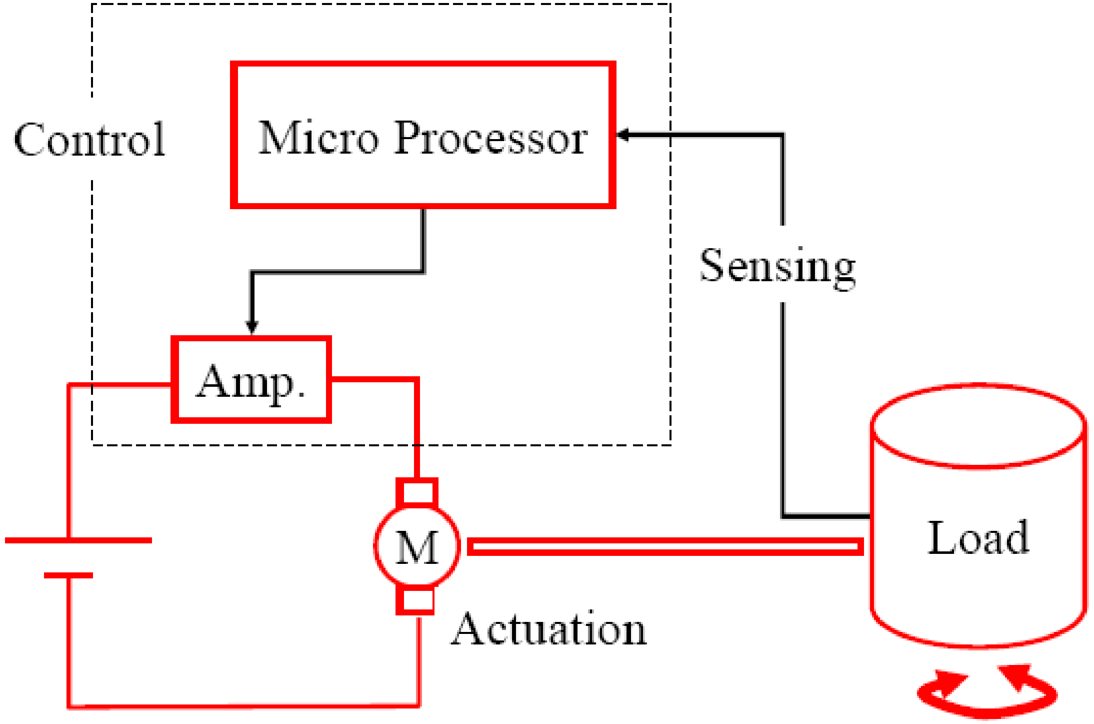
My dishwasher. Is it mechatronic?

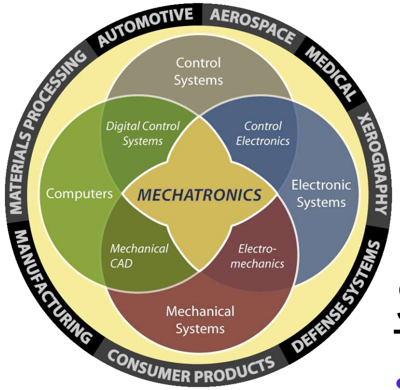
This is **not** mechatronic!

Example of Mechatronic Systems

Washing Machine

- **System Requirements**
  - Understanding of load sizes
  - Receptacle to hold clothes
  - ‘Plumbing’ (depth measurement)
  - Ease of use, Reliability
  - Low Cost
- **Actuators**
  - AC or DC Motors
  - Water inlet/drain
- **Sensors**
  - Water level
  - Load speed/balance



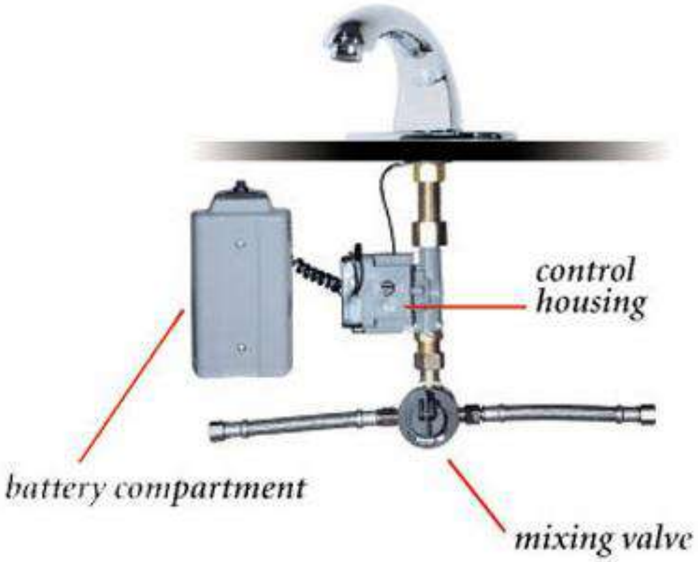


Mechatronics Systems

-Sanitation Applications-

System Uses

- **Proximity sensors**
- **Control circuitry**
- **Electromechanical 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**

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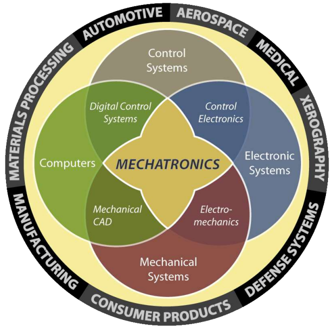
Example of Mechatronics Systems



-Smart Robotics Applications-

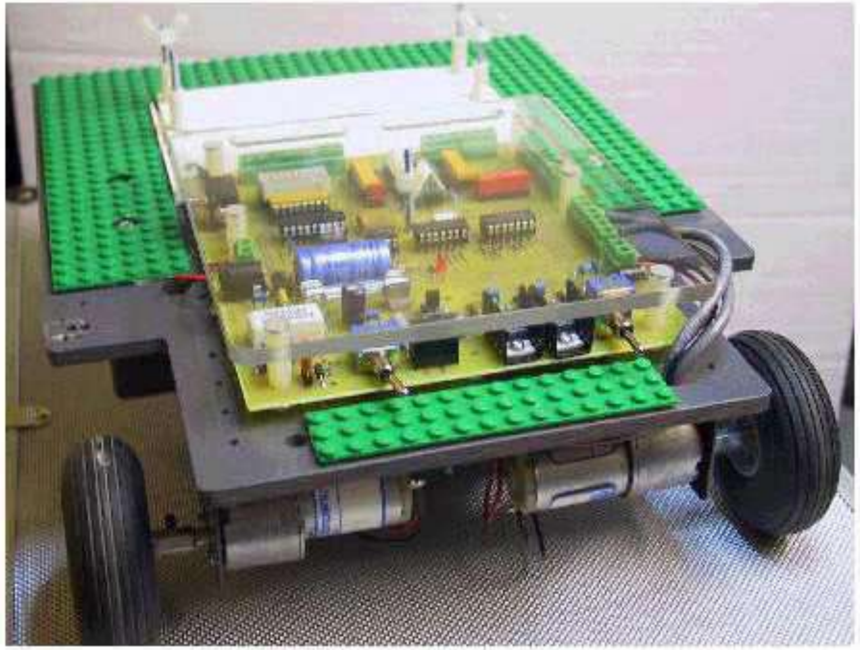
Vacuum Floors

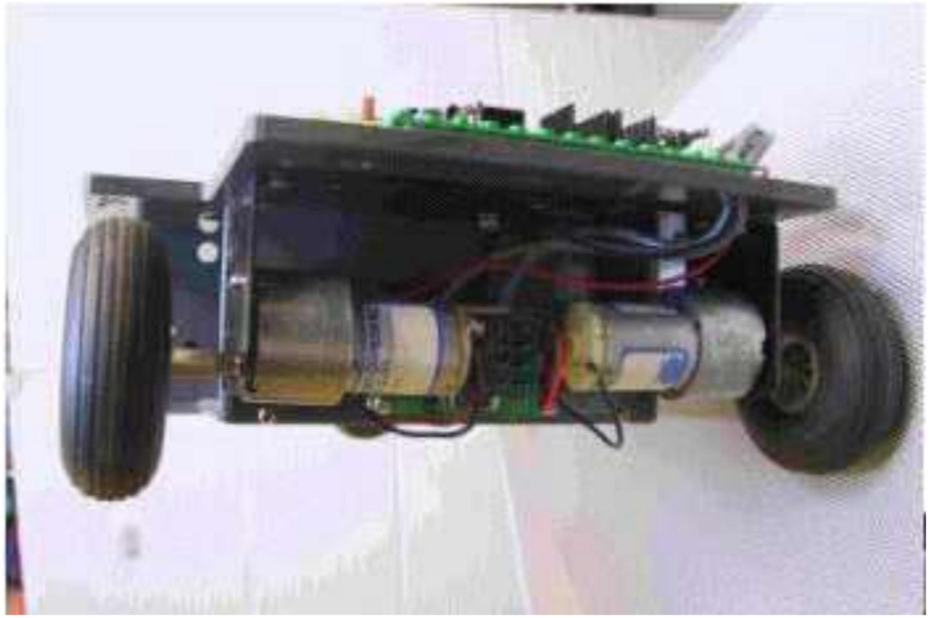
Robots can vacuum floors, so you don't have to.

Video

https://www.youtube.com/watch?v=XIPzSmwClJ8

Example of Mechatronic Systems





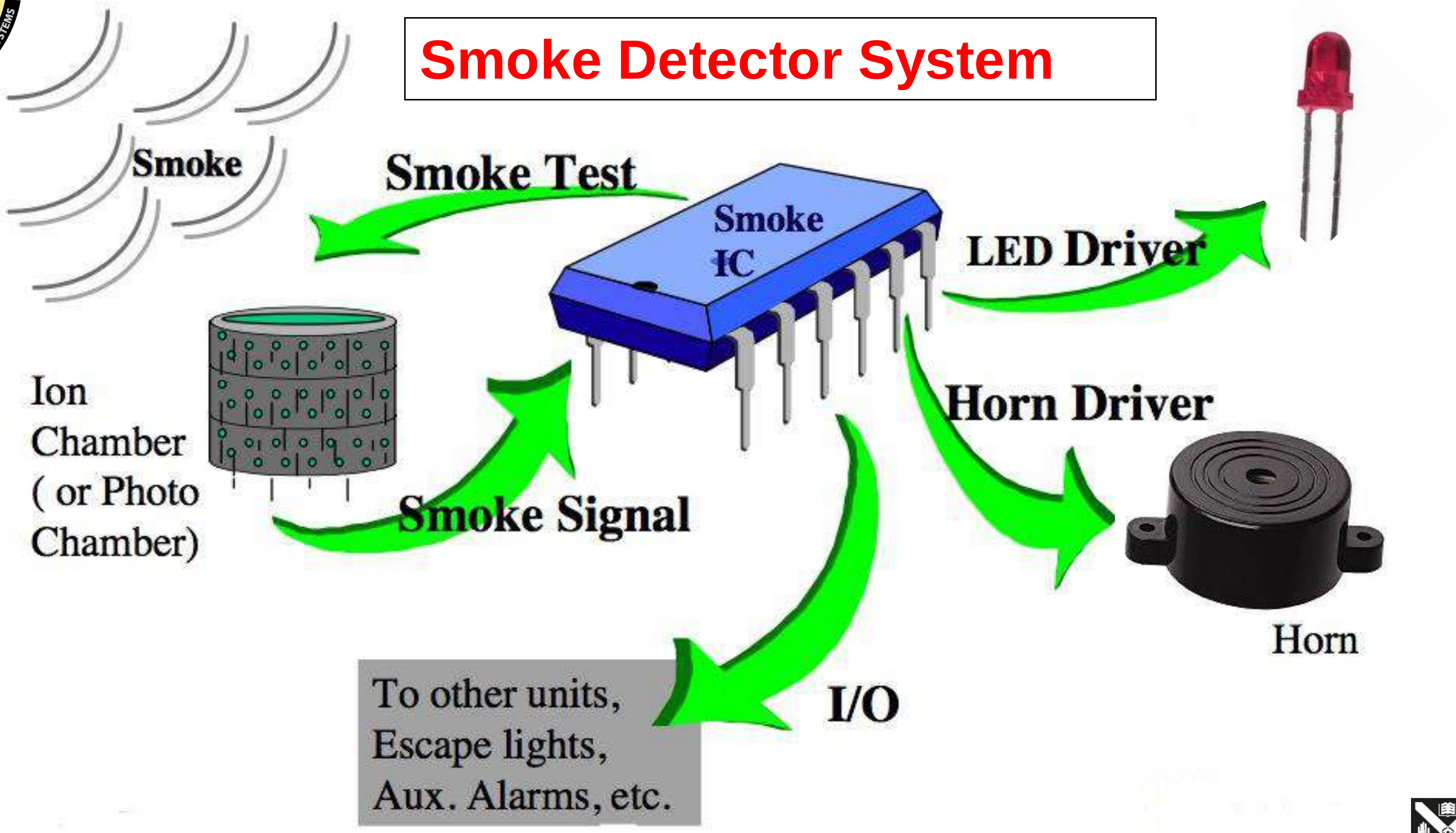
Program to track straight line

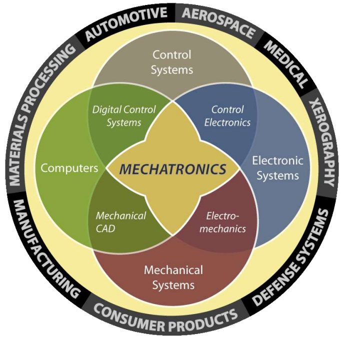
- program for collision avoidance in outside corridor

Mechatronics Systems

-Smart Home Applications-

Smoke Detector System





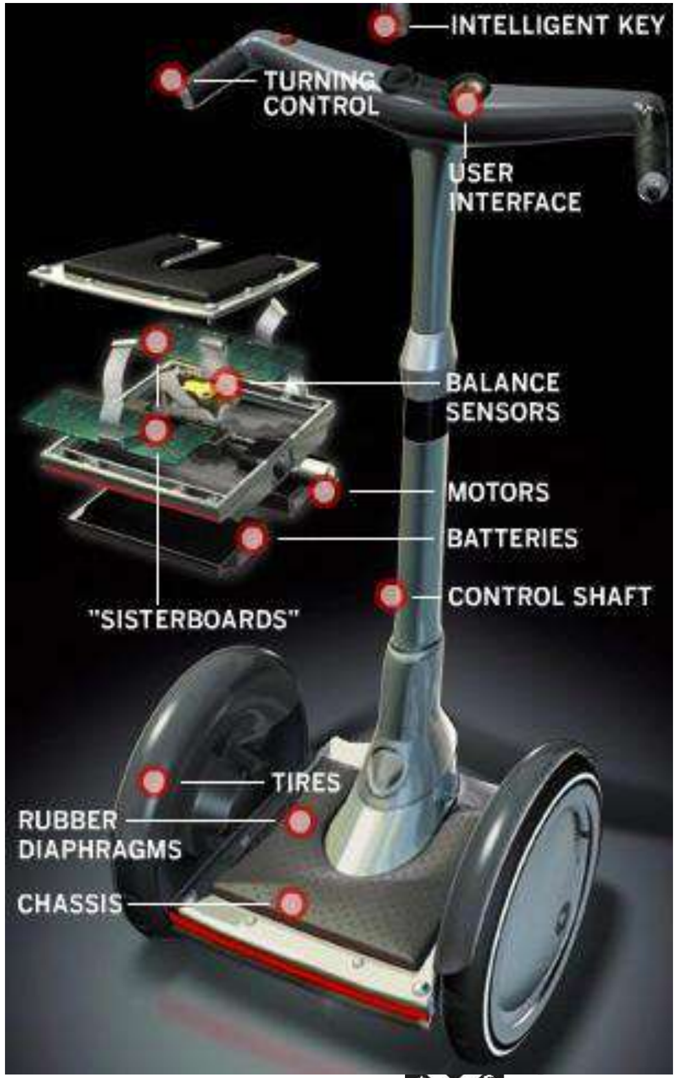
Mechatronics Systems

-Transportation Applications-

Segway

Systems equipments

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



Advantages

- **Simple** personal transportation device

Example of Mechatronic Systems

Mechatronics is everywhere:

Subsea Vehicles

- ❑ Control of Vehicle performed using on-board computer
- ❑ Sensors include: Sonar-vision- compass and pressure
- ❑ Used for underlying reef structure

https://subseavn.com/what-is-remotely-operated-underwater-vehicle-rov/

[Unmanned Underwater Vehicles (UUV)]

Example of Mechatronics Systems

- Medical Applications

Prosthetics

- **Arms, Legs, and other body parts** can be replaced with **electromechanical ones.**

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Robotic prosthetic leg and rehabilitation robots

Video

https://robotics.umich.edu/2021/humotech-partner-to-bring-open-source-bionic-leg-to-research-labs/

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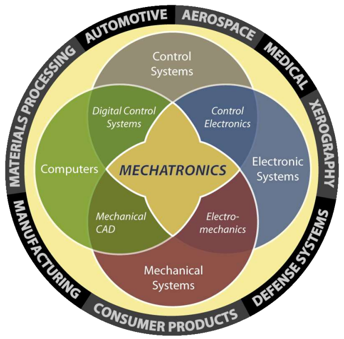
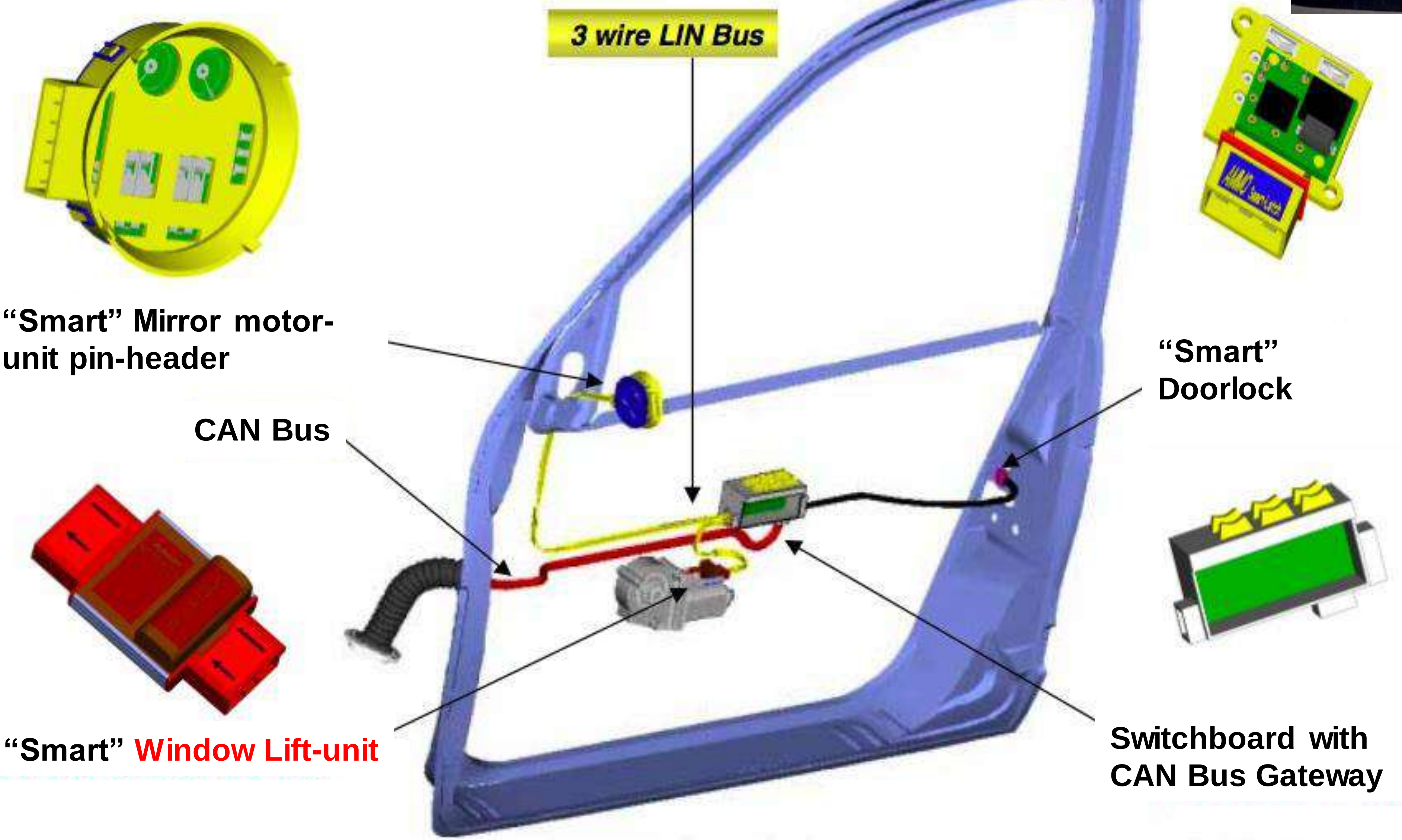
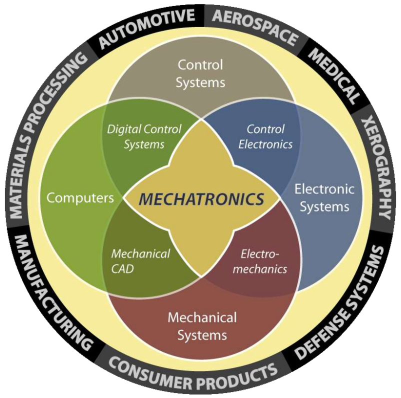


Mechatronics Systems

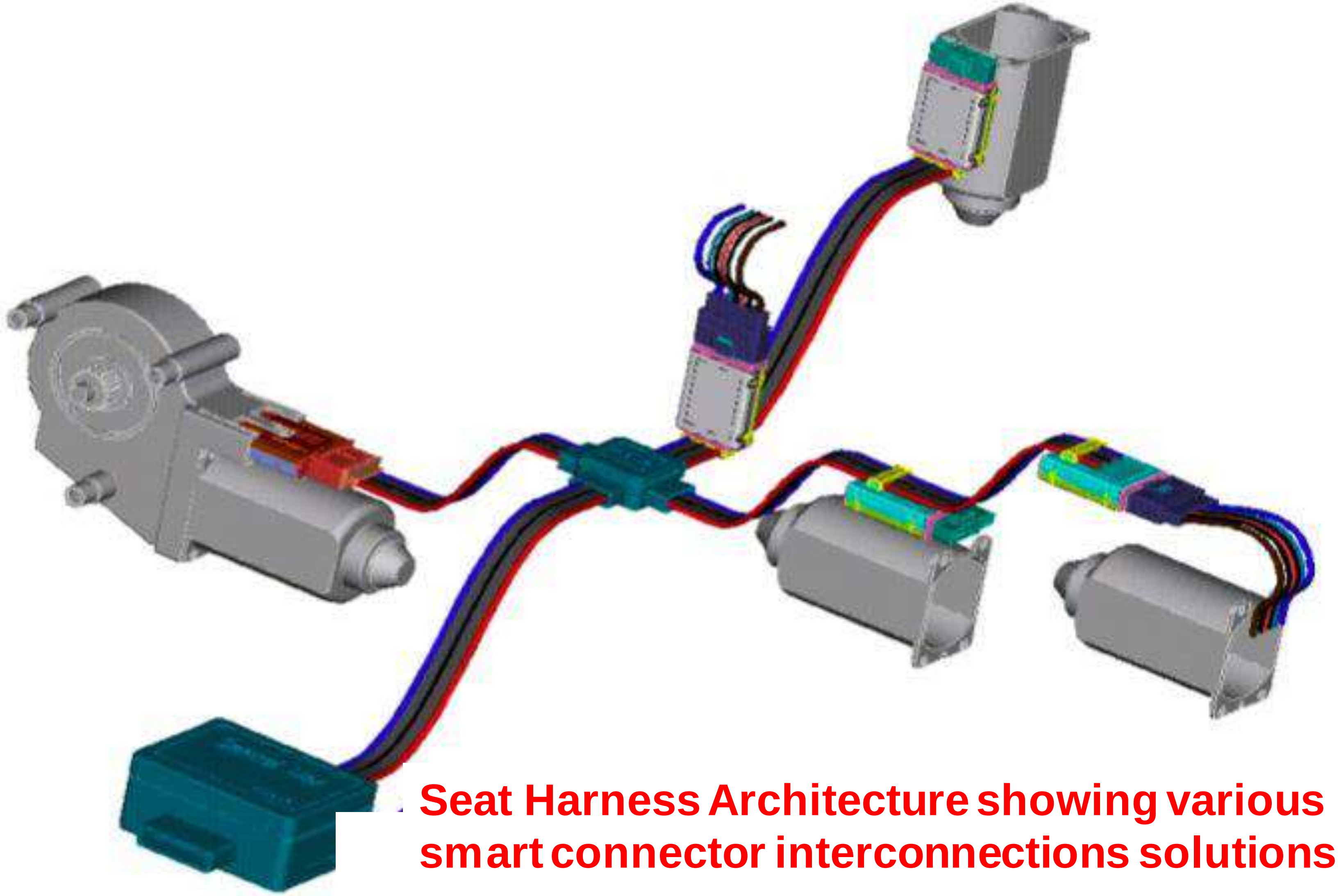
- Door System/Module-





Mechatronics Systems

- Seat System/Module



Seat Harness Architecture showing various smart connector interconnections solutions

Example of Mechatronics Systems

-Manufacturing Applications-

CNC Bending

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

Sheet Metal CNC Bending

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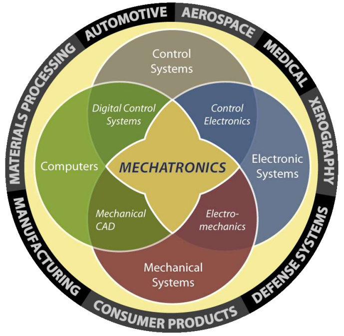
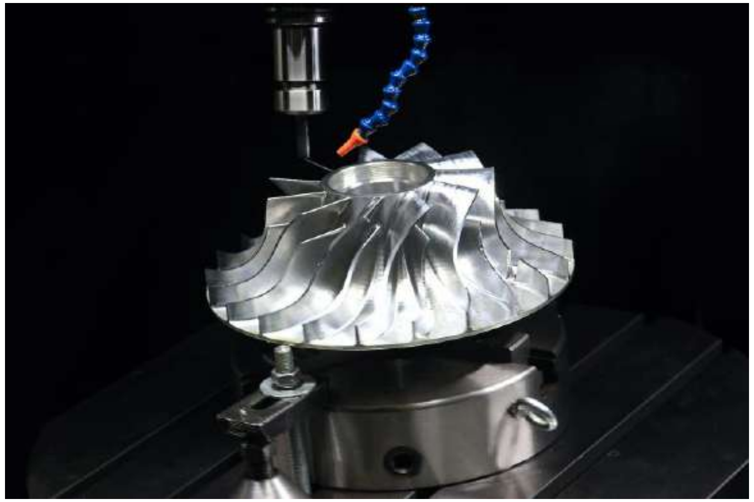


Mechatronics Systems

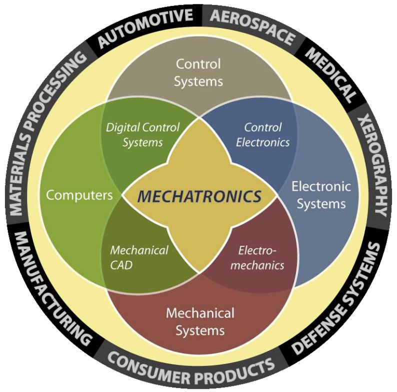
-Manufacturing Applications-

CNC Machining



Advantages

- ❑ **Deliver the highest accuracies**
- ❑ **Can create very complex shapes**



Mechatronics Systems

-Medical Applications-

Pace Maker

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

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.

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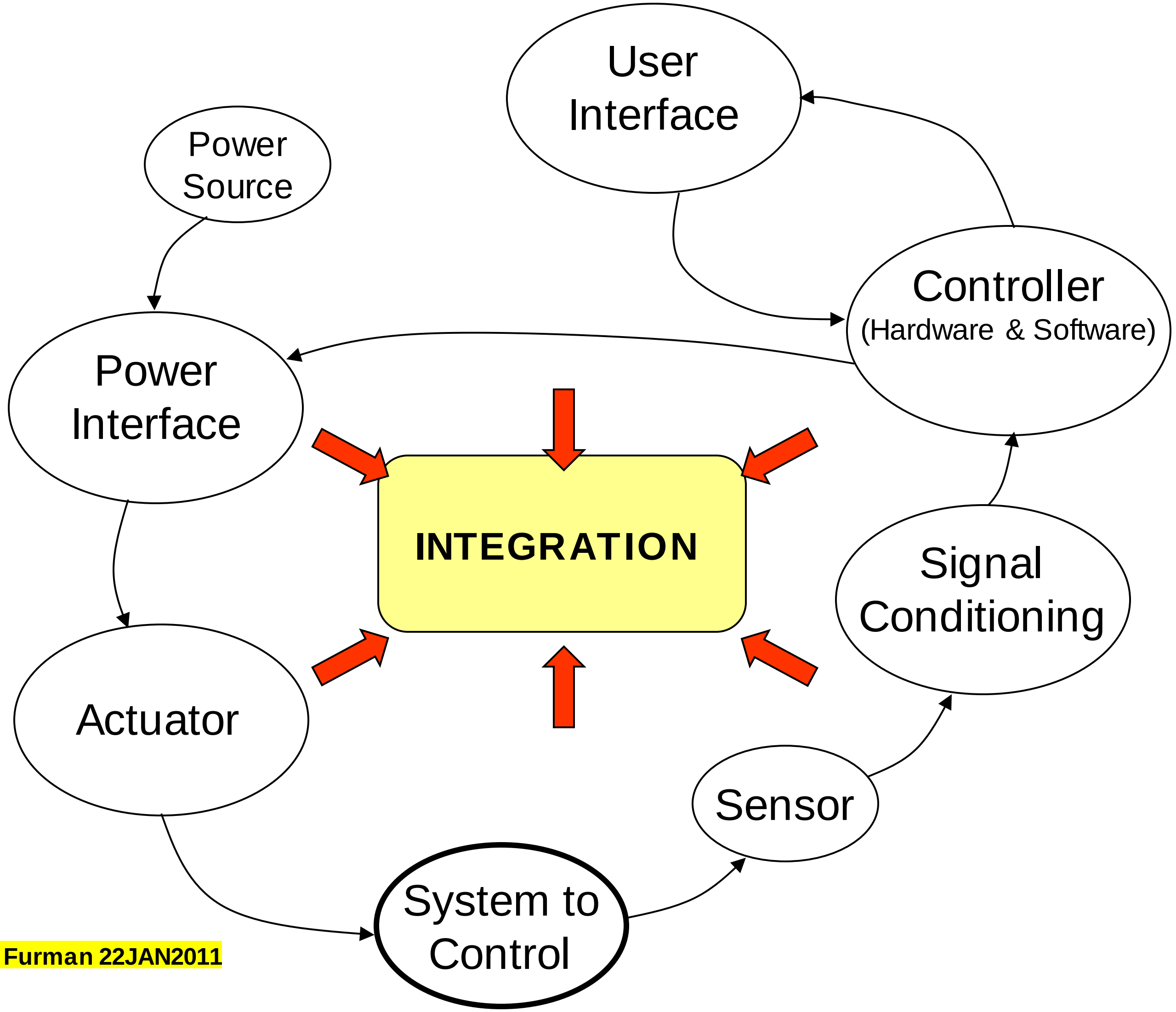
Mechatronics Concept Map



BJ Furman 22JAN2011

Thank You For Your Attention!

Any Question?