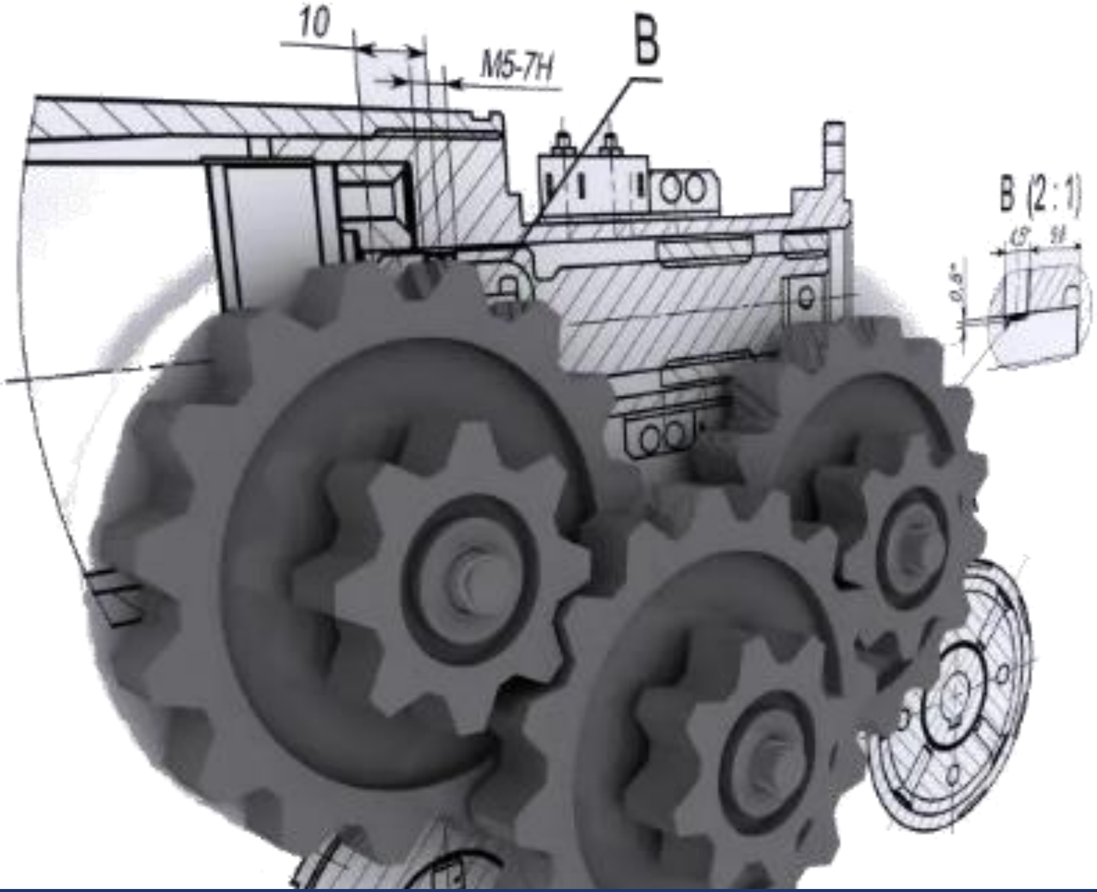


2021

MCTR 701_1

Master Advanced Mechatronics

Lecturers : Luc Marechal, Christine Barthod, Georges Habchi

UNIVERSITÉ SAVOIE MONT BLANC

POLYTECH® ANNECY-CHAMBÉRY

SYMME

Mechatronics common framework Lecture 1

Contents

Lecture 1

MECHATRONIC PRODUCT,

COMPLEX PRODUCT SPECIFIFICATIONS,

PRODUCT LIFECYCLE,

UNDERSTANDING OF STANDARDS

- What is Mechatronics
- Mechatronic product
- Product life cycles
- Designing a mechatronic product
- Examples of mechatronic product

Mechatronics definition

- Please give your definition :

Mechatronics – definition and meaning

1969

- First proposed by Tetsuro Mori, an engineer from Yaskawa Electric Co. in Japan, to designate the control of electric motors by computer [Yaskawa Electric, 1969].

1991

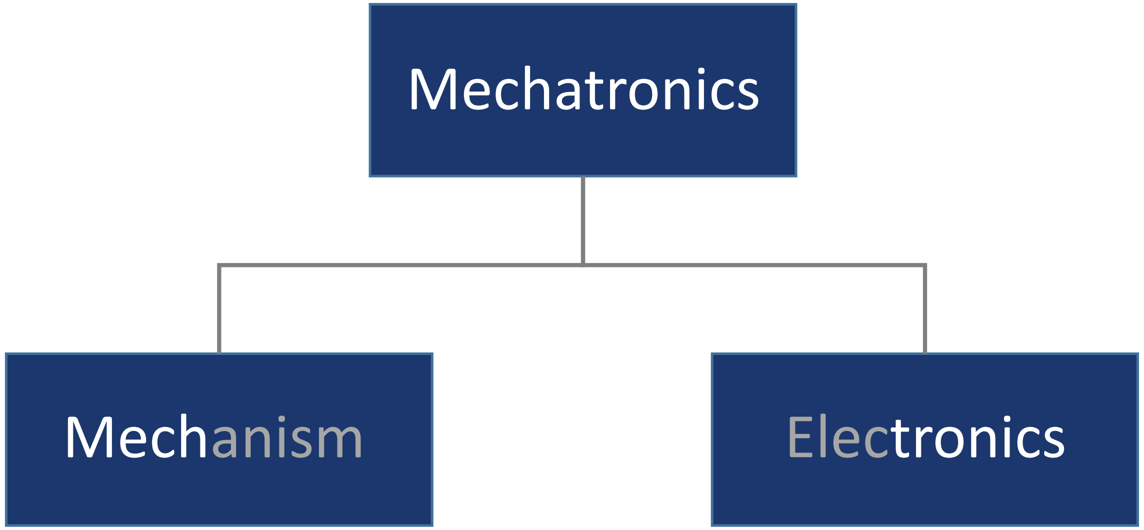
- Description proposed by the international journal Mechatronics, published for the first time: "**Mechatronics in its fundamental form can be regarded as the fusion of mechanical and electrical disciplines in modern engineering process.**
- **It is a relatively new concept to the design of systems, devices and products aimed at achieving an optimal balance between basic mechanical structures and overall control**" [Daniel and Hewit, 1991].

1994

- Official definition of the Industrial Research and Development Advisory Committee of the European Community in 1994 and proposed by the international journal *IEEE/ASME Transactions on Mechatronics* in 1996 : "**Mechatronics is the synergistic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and manufacturing processes**" [Comerford, 1994]

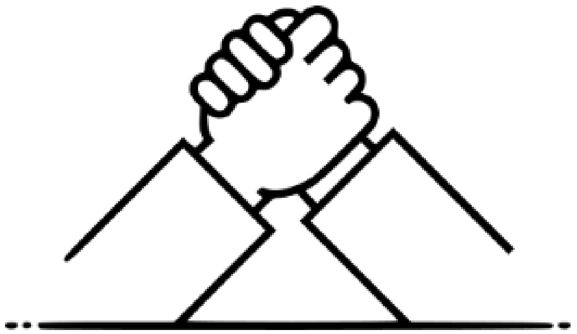
Mechatronics definitions

- The word, mechatronics, is of Japanese origin and is composed of "mecha" from mechanism and the "tronics" from electronics.



Mechatronics definitions

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



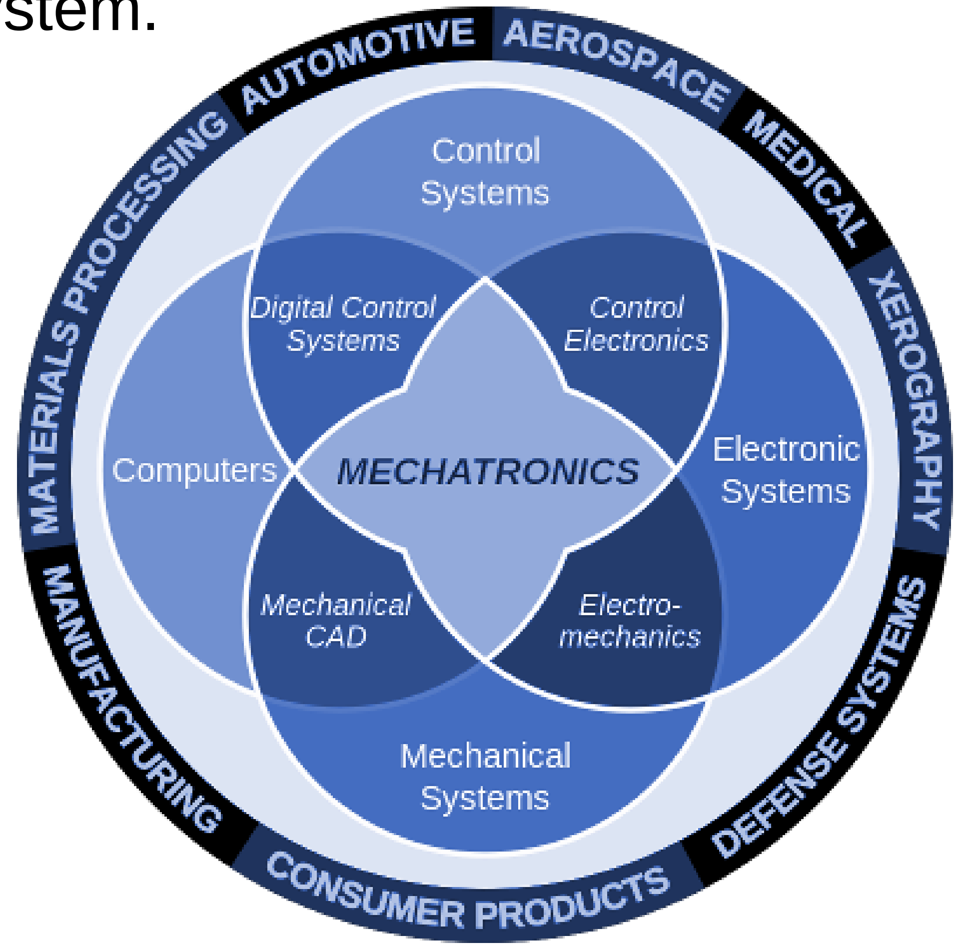
* the combined power of working together that is greater than the power achieved by working separately.
[Cambridge Dictionary]

- It aims at developing products, processes and systems with greater flexibility, ease in redesign and ability of reprogramming.

Mechatronics definitions

- An approach for product and manufacturing system.

- Disciplinary Foundations of Mechatronics :
  - Mechanical Engineering
  - Electrical Engineering
  - Electronics Engineering
  - Computer Engineering
  - Information & Technology Engineering

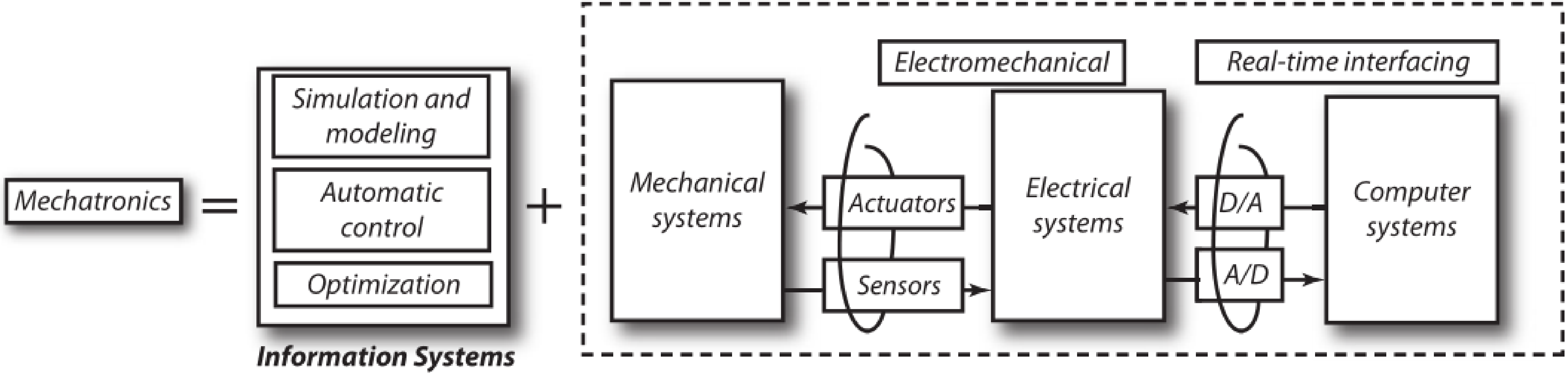


Mechatronics definitions

- This definition establishes the multidisciplinary nature of mechatronics, which combines several sectors of different technologies in the designing and manufacturing of a product.
- Mechatronics is not inherently a science or technology: it must be regarded as an attitude, a fundamental way of looking at and doing things, and, by its nature, requires a unified approach [Millbank, 1993].
- The Mechatronics methodology is used for the optimal design of electromechanical products.
- A mechatronic system is not just a mix of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them.

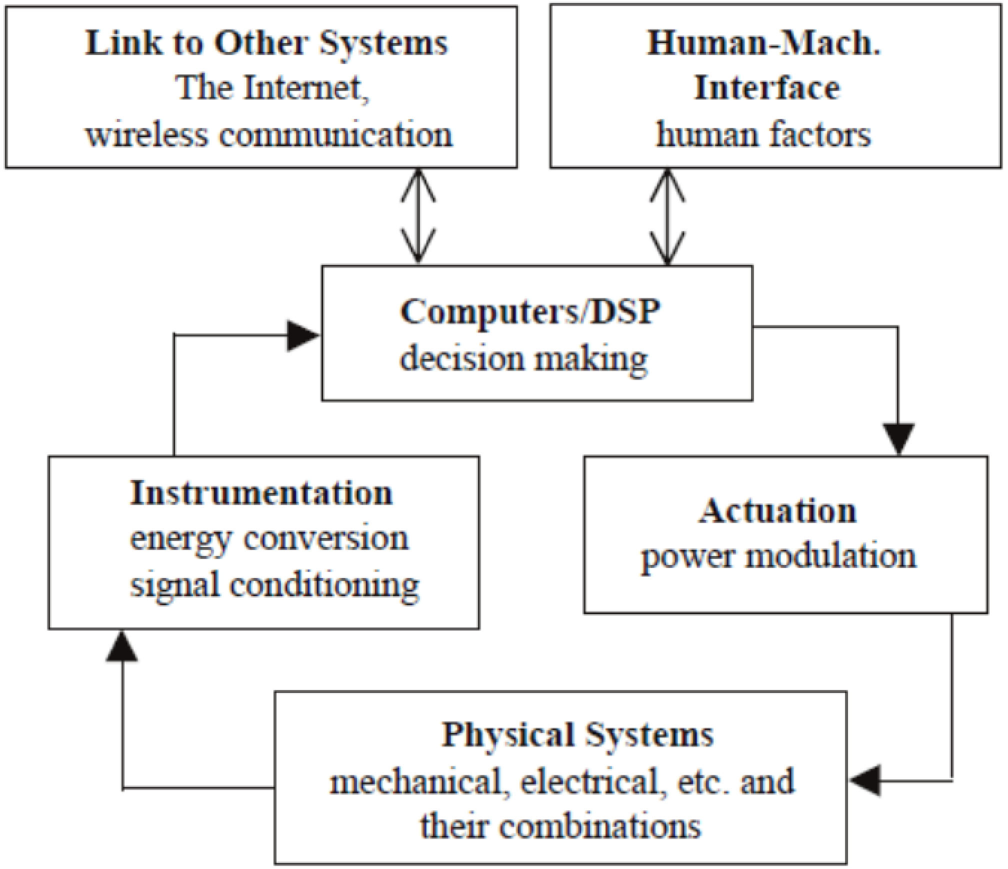
Not a science, a methodology !

Basic elements of a mechatronics system



Mechatronics system design, Devdas Shetty

Basic elements of a mechatronics system



[Ref.] Prof. Tomizuka

Multi-/Cross-/Inter-disciplinary

- When a design requires inputs from more than one discipline. It can be realized through following types of interactions :

Multi-disciplinary: This is an additive process of bringing multiple disciplines together to bear on a problem.

Cross-disciplinary: In this process, one discipline is examined from the perspective of another discipline.

Inter-disciplinary: This is an integrative process involving two or more disciplines simultaneously to bear on a problem

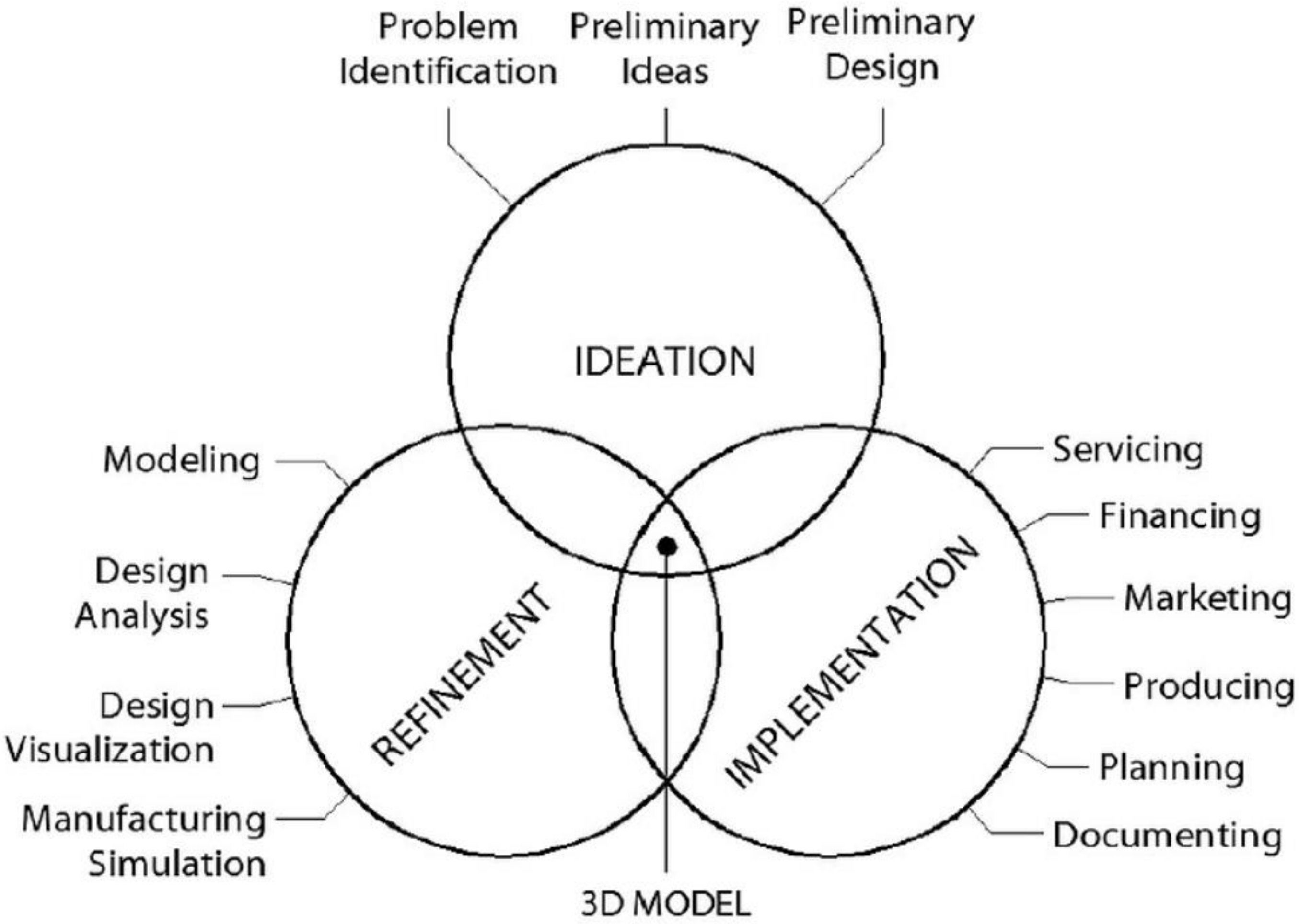
Mechatronic vs. Multidisciplinary

- The difference between a mechatronic system and a multidisciplinary system is not the constituents, but rather the order in which they are designed.

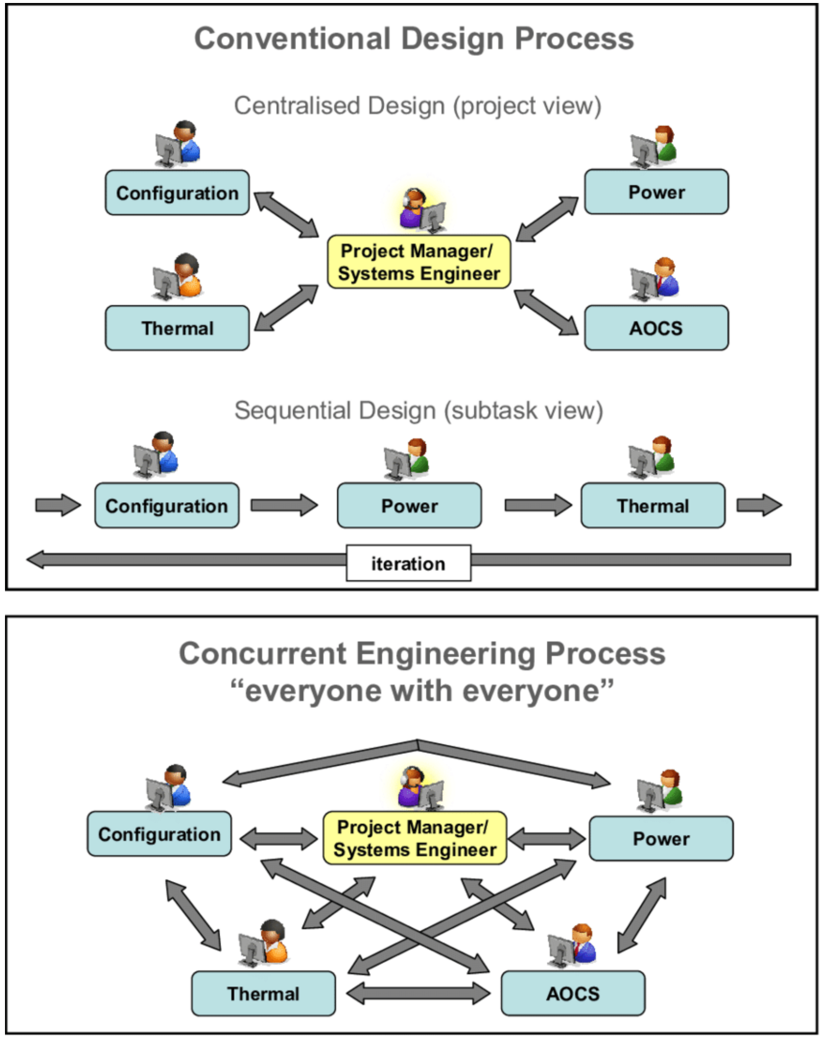
- Multidisciplinary system design employed a sequential design-by-discipline approach.

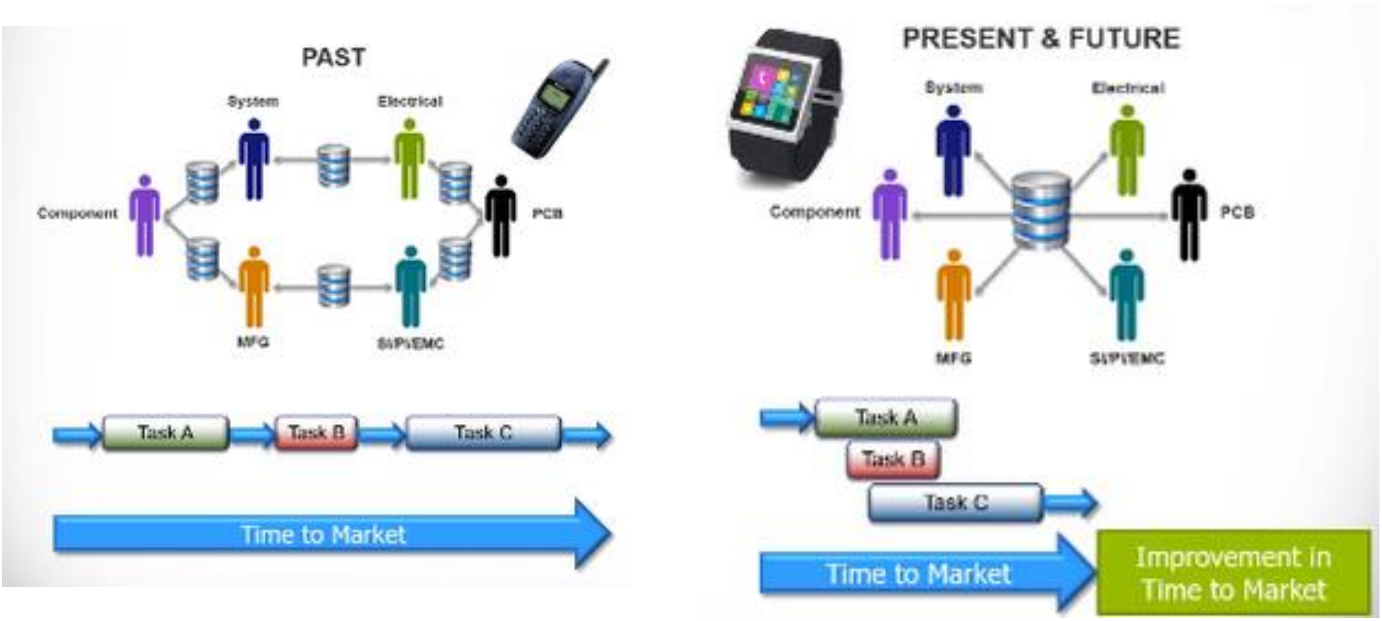
- Mechatronic design methodology is based on a concurrent (instead of sequential) approach to discipline design, resulting in products with more synergy.

Concurrent vs. Sequential Engineering



Concurrent vs. Sequential Engineering





Concurrent vs. Sequential Engineering

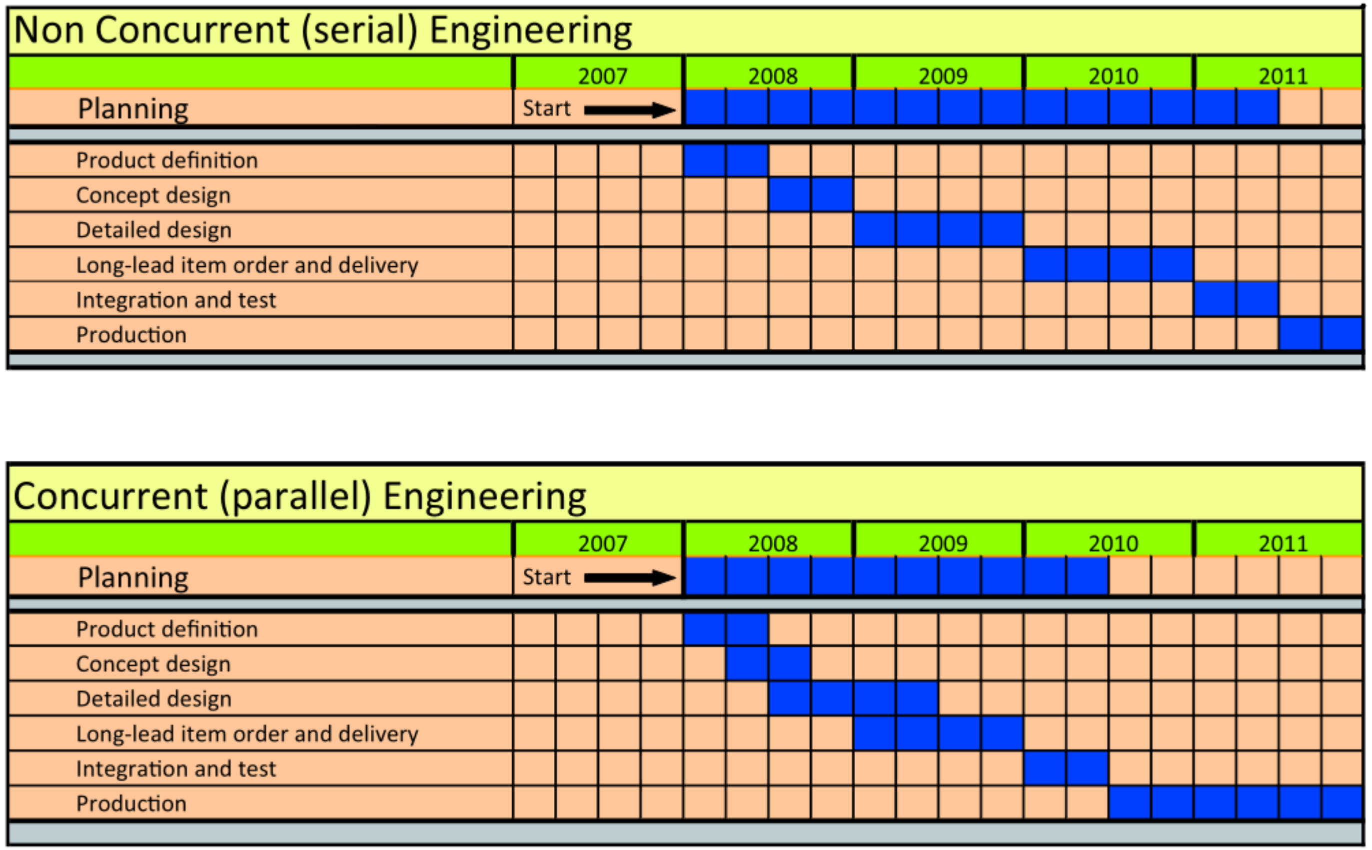


Figure 1.24: Concurrent engineering results in shorter lead times by working in parallel on different phases of the project. It requires a high discipline in communication and change control.

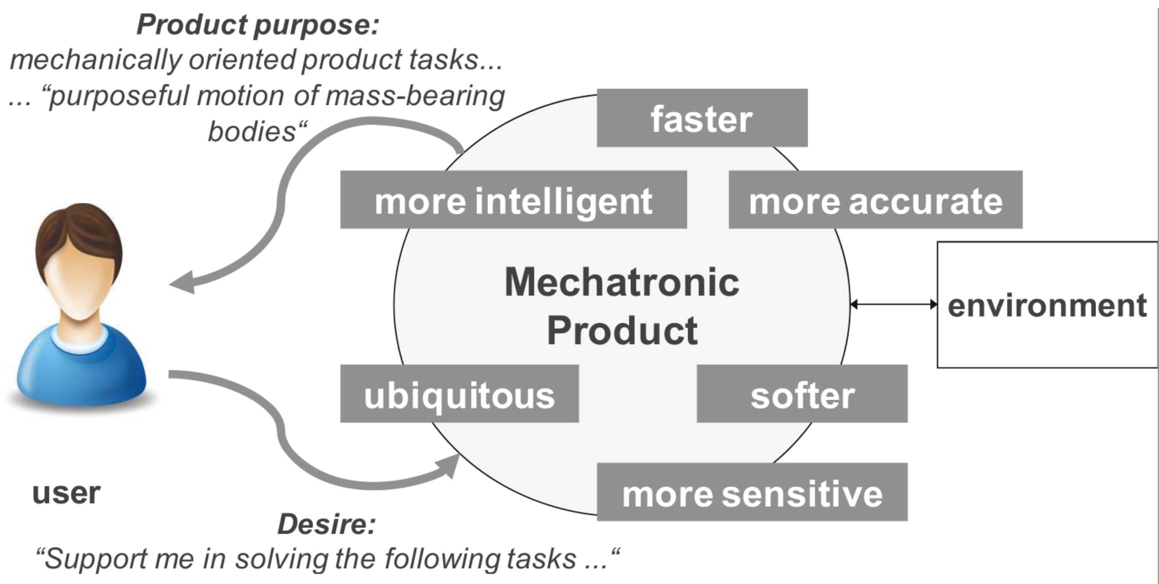
The Design of High Performance Mechatronics, Robert Munnig Schmidt

Product-Oriented Perspective

Mechatronics Engineering is the

- Analysis
- Design
- Manufacturing
- **Integration**
- and maintenance

of mechanics with electronics through intelligent computer control.



Mechatronic systems as products with exceptional attributes: external perspective

Mechatronics – standard aspects

References: NF E01-010 Mechatronics – Vocabulary (2008); NF E01-013 Mécatronique - Cycle de vie et conception des produits (2015)

- Mechatronics

An approach with the aim to reach the synergistic integration of mechanics, electronics, automation and computing in the design and the manufacture of a product in order to increase and / or optimize its functionality.

Physical integration

- Mechatronic product

Product with the ability to perceive its surrounding environment, to process information, to communicate and act on its environment, and that presents a complete level of mechatronic integration, from a functional and physical point of view

Functional integration

Mechatronics – constraints & benefits

- leads to new constraints, such as:
  - High Initial cost
  - the incorporation of several technologies,
  - the interactions between different functional entities,
  - taking into account the dynamics of the system,
  - taking into account the inability to perform exhaustive tests, etc.

- brings undeniable benefits such as:
  - Cost effective and good quality products
  - size and weight reduction
  - customer satisfaction by the proposed innovative solutions,
  - the positive response to societal demands increasingly important (pollution, consumption, safety)
  - High degree of flexibility to modify or redesign

[Millbank, 1993], [Hewit, 1996], [Kortum *et al.*, 1998], [Grimheden and Hanson, 2001], [Rzevski, 2003], [Ollero *et al.*, 2006], [Isermann, 2007], [Yeong and Do Soon, 2014].

From complex systems to mechatronic systems

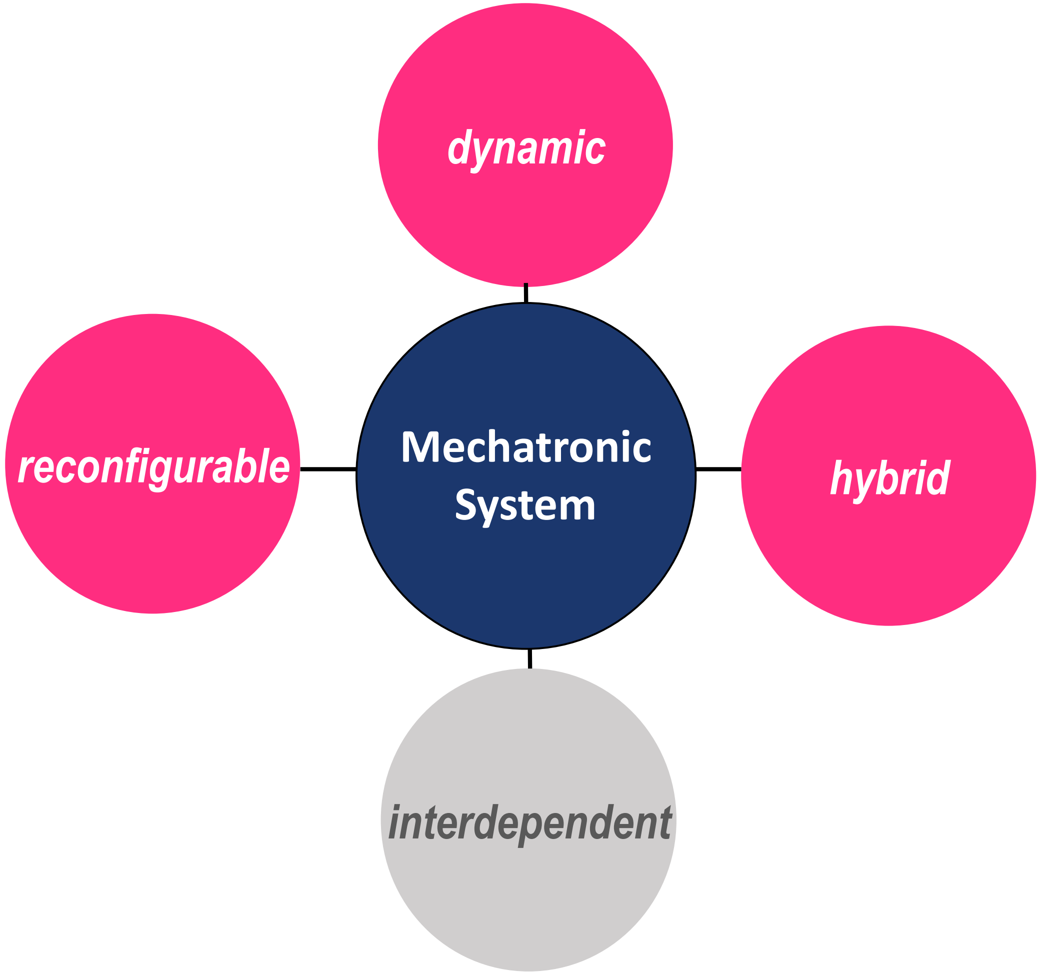
- Mechatronics has revolutionized the design and manufacturing of complex systems. In particular, its introduction in the automotive sector has deeply changed the development and manufacturing processes. Thus, a car is no longer conceived as a mechanical device that carries some electronic controls, but as a mechatronic system [Bertram *et al*, 2003],

- The synergy induced by mechatronic systems leads to an intelligent combination of technologies which leads to solutions with higher performance that cannot be obtained in separate applications. [Shetty and Kolk, 1997] [Breedveld, 2004].

Mechatronic system

A complex system with functional & physical integration.

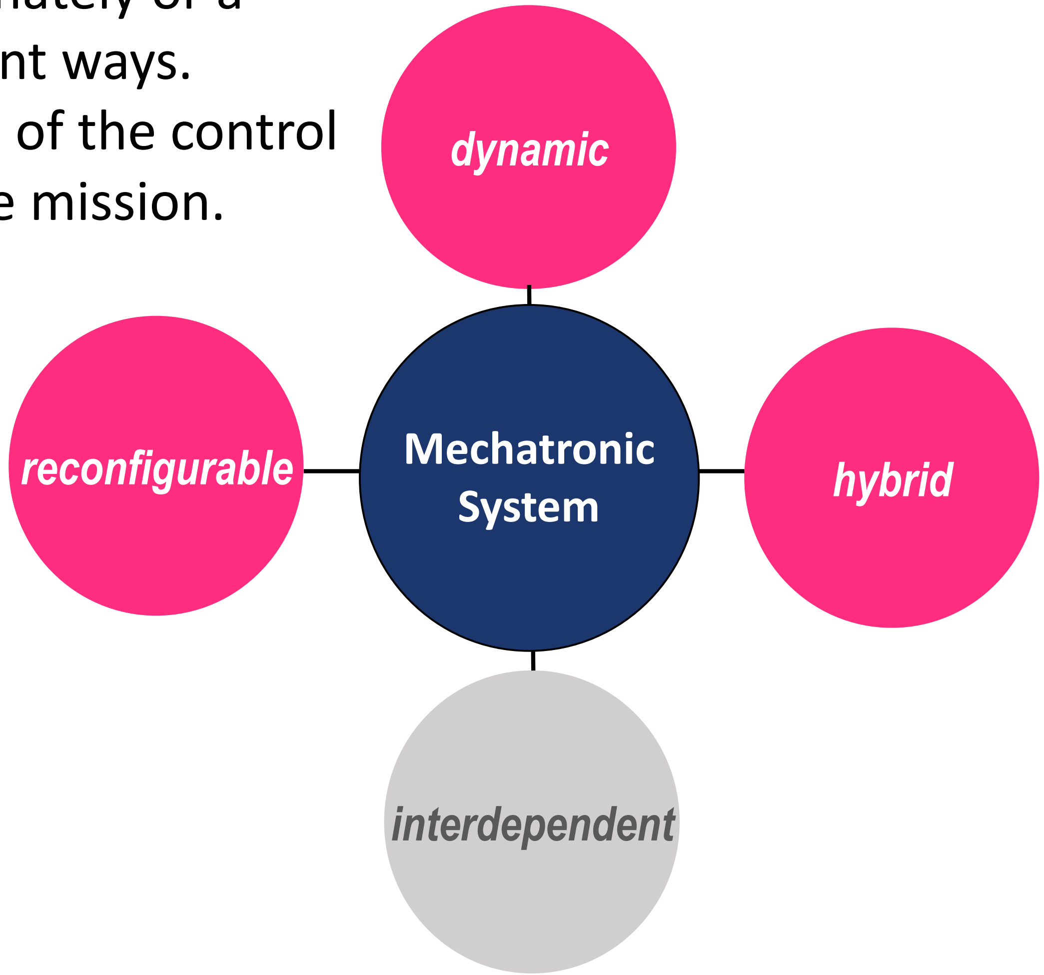
Characterized by four concepts:



Mechatronic system – re-configurability

It is intended to perform several functions alternately or a function by using its resources in several different ways.
For example, to ensure safety, a reconfiguration of the control system is carried out without interruption of the mission.

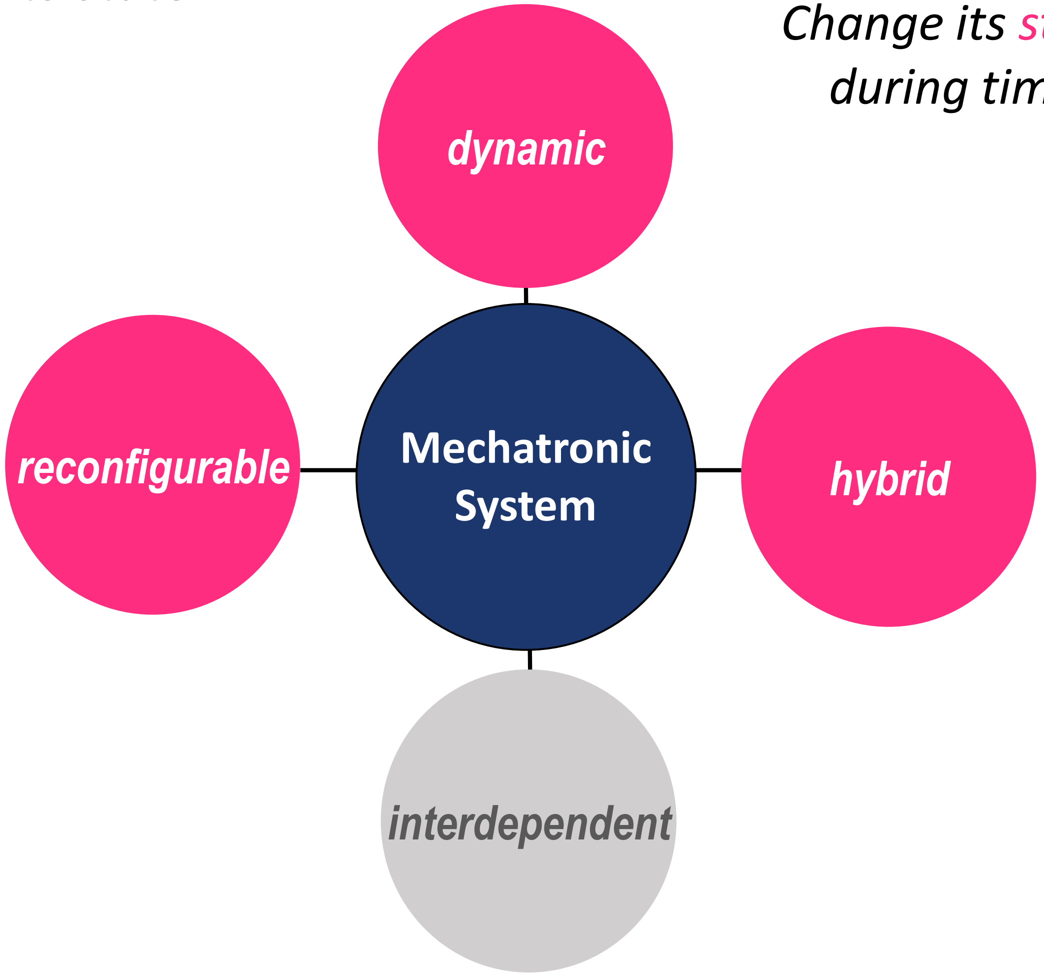
Assume *different functions alternatively* or a *function using its resources in different ways*



Mechatronic system - dynamic

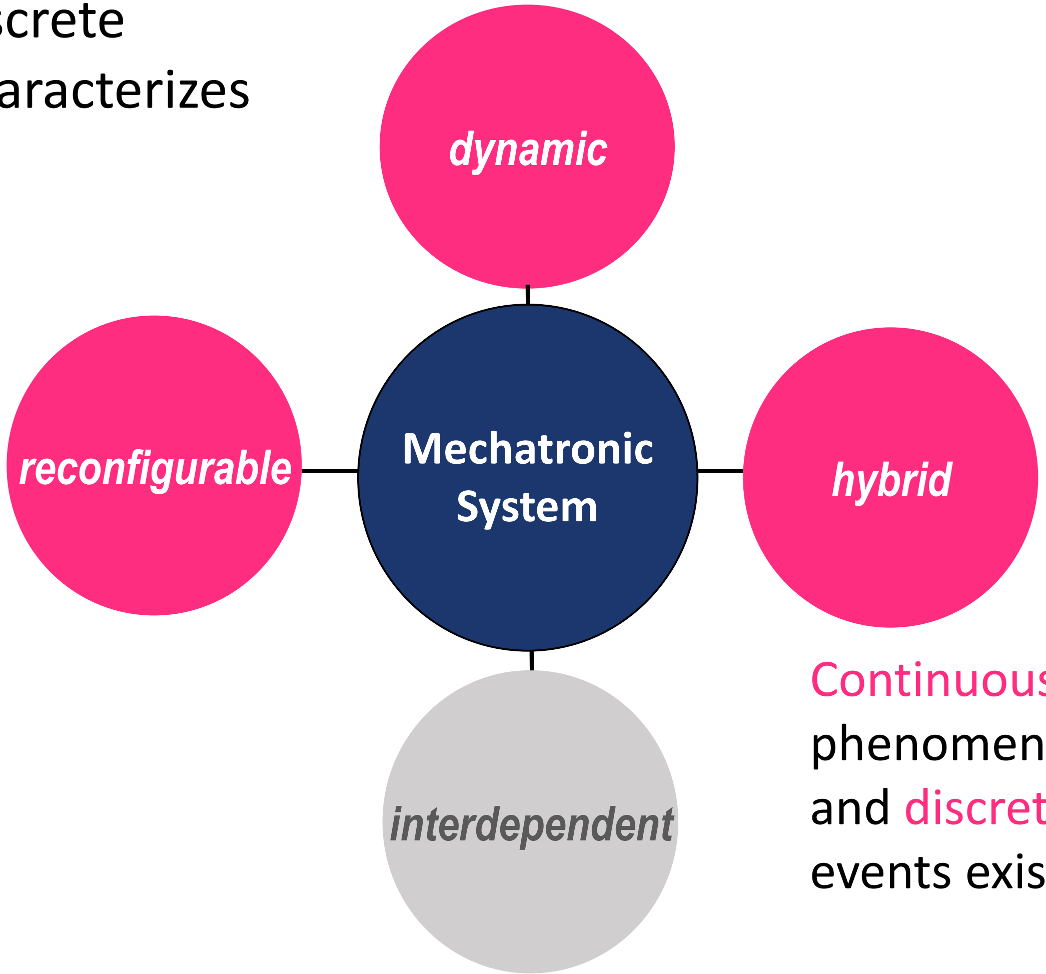
This characteristic lies in its aptitude to change its state during time.

Change its state during time



Mechatronic system - hybridity

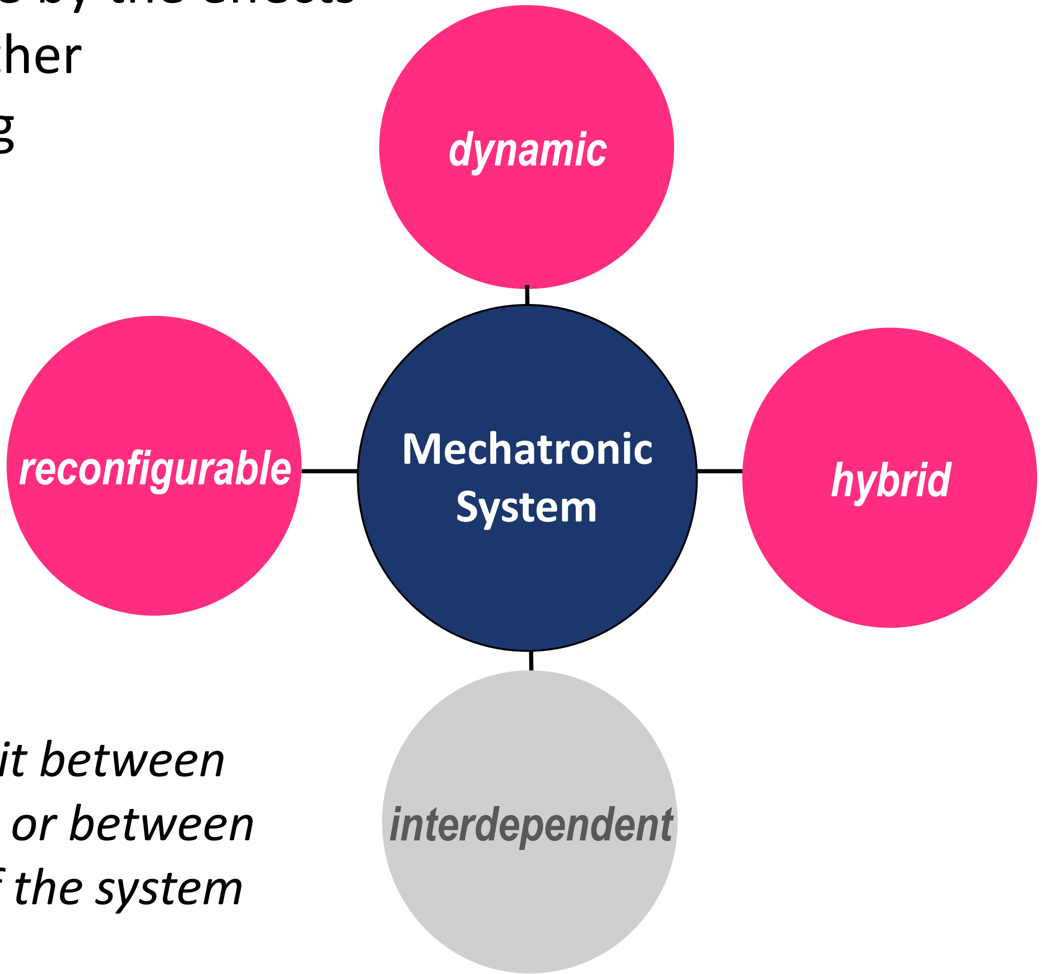
The presence of continuous phenomena and discrete events into the different states of the system characterizes the hybrid concept.



Continuous phenomenon and discrete events exist

Mechatronic system - dependency

The dependency or interaction is described here by the effects produced by the action of a component to another component in the system changing its operating performances, in terms of degradation.



Interactions exit between the components or between the functions of the system

Level of mechatronic systems integration

Primary Level **Mechatronics** : Integrates electrical signaling with mechanical action at the basic control level for e.g.fluid valves and relay switches

- Conveyors
- Rotary tables
- Auxiliary manipulators

Level of mechatronic systems integration

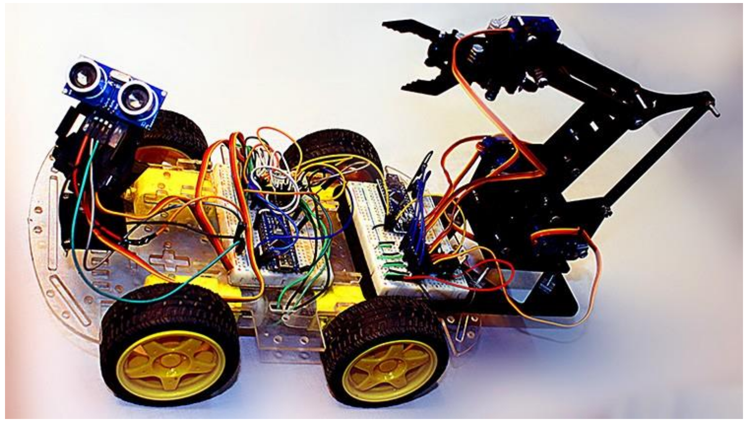
Secondary Level **Mechatronics** : Integrates microelectronics into electrically controlled devices for e.g. cassette tape player.

- Operated power machines (turbines & generators)
- Machine tools & industrial robots with numerical program management

Level of mechatronic systems integration

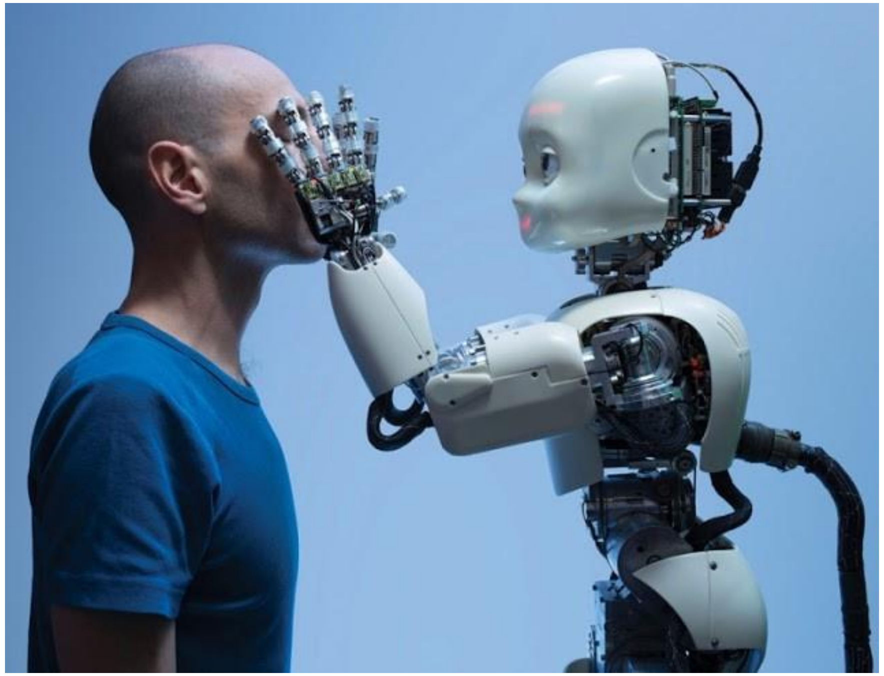
Tertiary Level Mechatronics : Incorporates advanced control strategy using microelectronics, microprocessors and other application specific integrated circuits for e.g. microprocessor based electrical motor used for actuation purpose in robots.

Specific Integrated Circuits' (ASIC), Control of electrical motor used to actuate industrial robots, hard disk, CD drives, automatic washing machines are typical examples

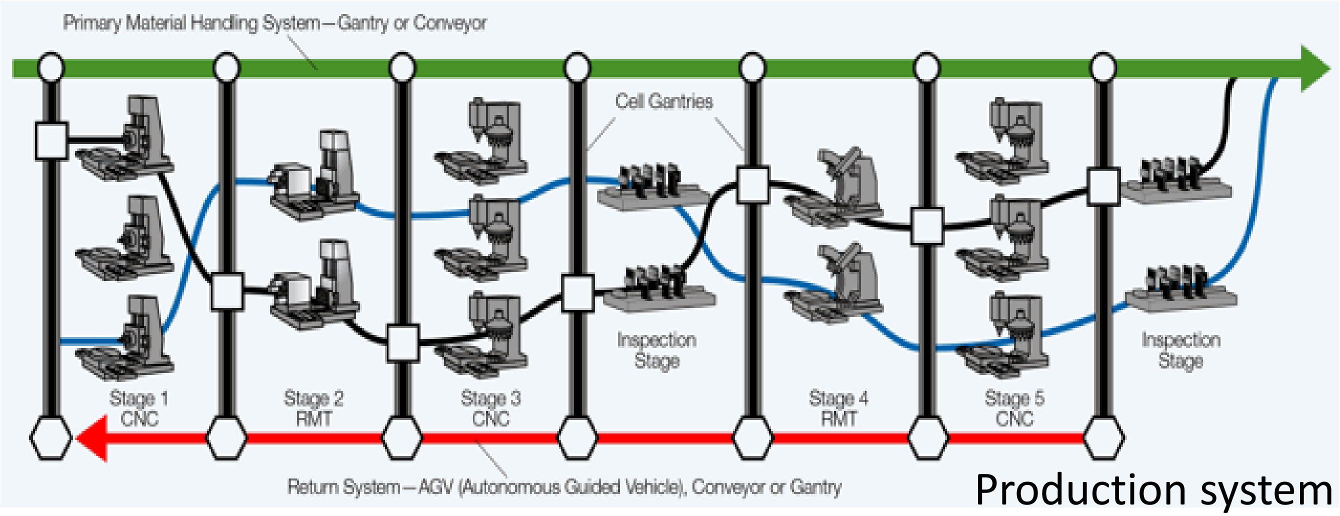


Level of mechatronic systems integration

Quaternary Level Mechatronics : This level attempts to improve smartness a step ahead by introducing intelligence (artificial neutral network and fuzzy logic) and fault detection and isolation (F.D.I.) capability into the system



Examples of mechatronic systems

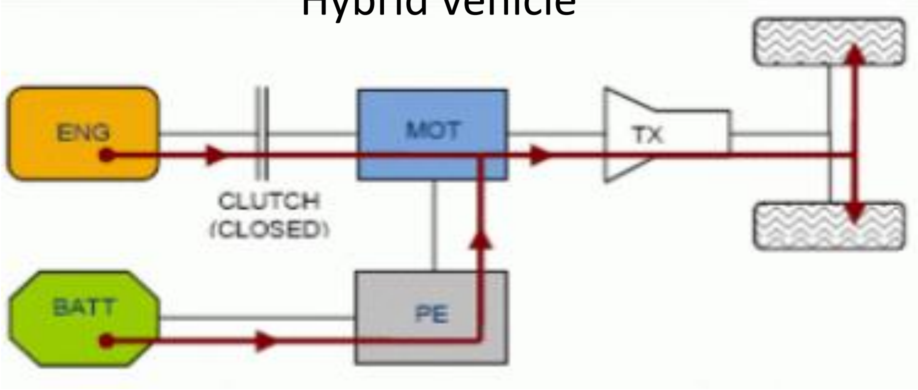


Production system

Landing system

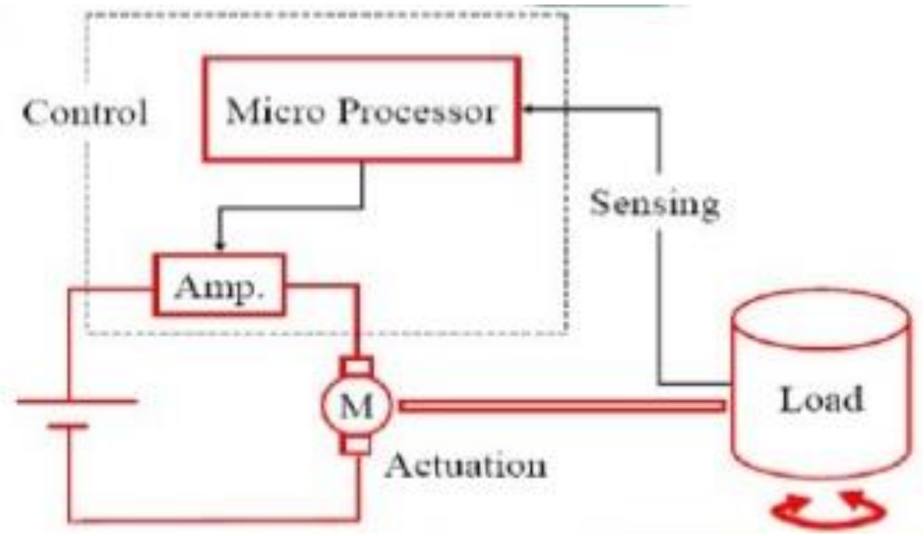
Amperemeter/Voltmeter…

Hybrid vehicle



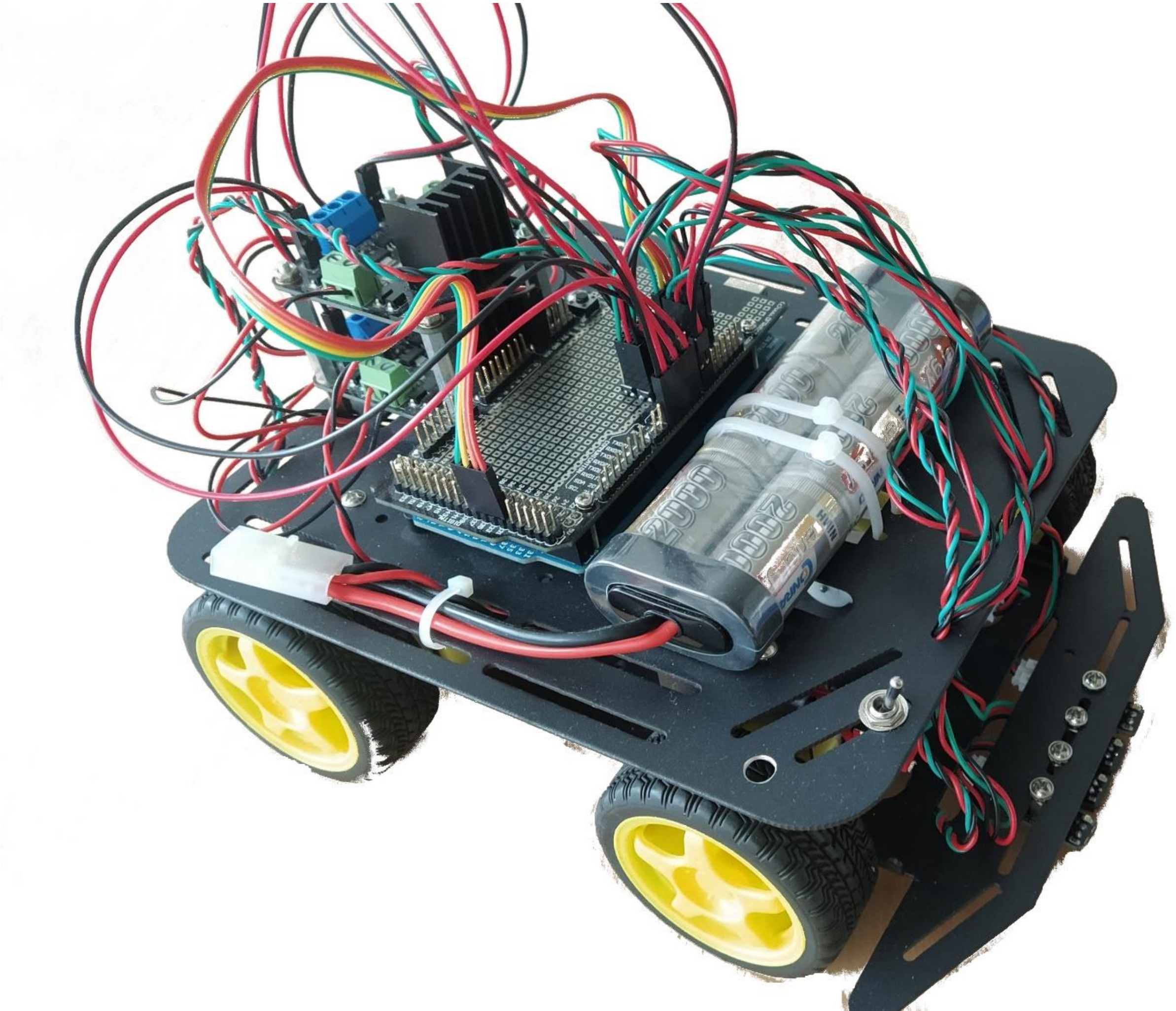
Examples of mechatronic systems

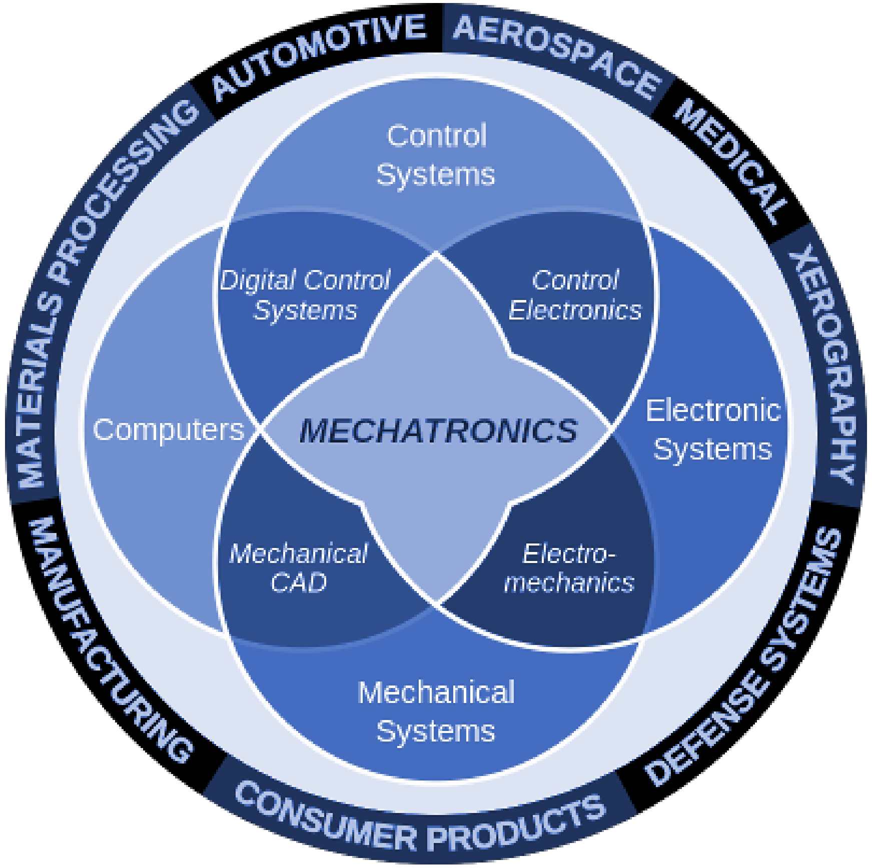
- System Requirements
  - Understanding of load sizes
  - Receptacle to hold clothes
  - 'Plumbing'
  - Agitation of drum
  - Ease of use, Reliability
  - Low Cost
- Actuators
  - AC or DC Motors
  - Water inlet/drain
- Sensors
  - Water level
  - Load speed/balance
- Control
  - Choice depends on design



Exercise

- Find out which discipline is involved





Exercise

Spot which system is **NOT** mechatronic

Computer

Drone

Car

Consumer Electronics

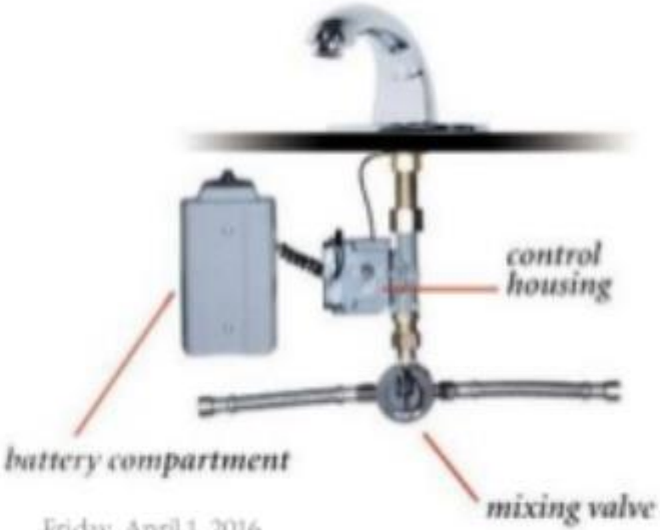
MEMS

Ski bindings

Exercise

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

Friday, April 1, 2016 Basic Mechatronics 37

Exercice

Sanitation Applications

Paper Towel Dispenser

Systems Uses

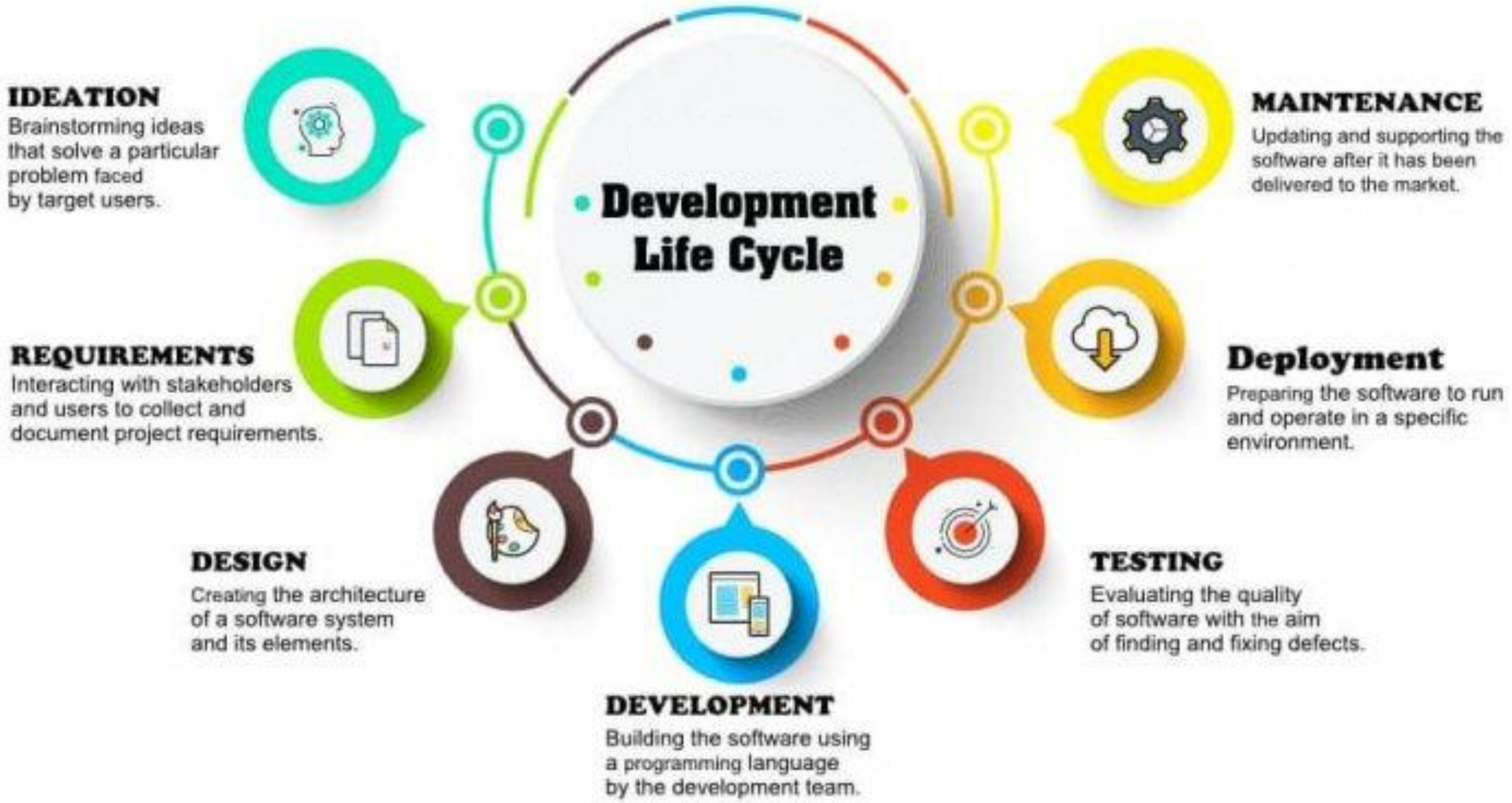
- Motion sensors
- Control circuitry
- Electromechanical actuators
- Independent power source

Soap Dispenser

Advantages

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

Designing a mechatronic system



Designing a mechatronic system

- A systems development life cycle is composed of a number of clearly defined and distinct work phases to plan for, design, build, test, and deliver information systems.

- **Different kinds of models** *:*

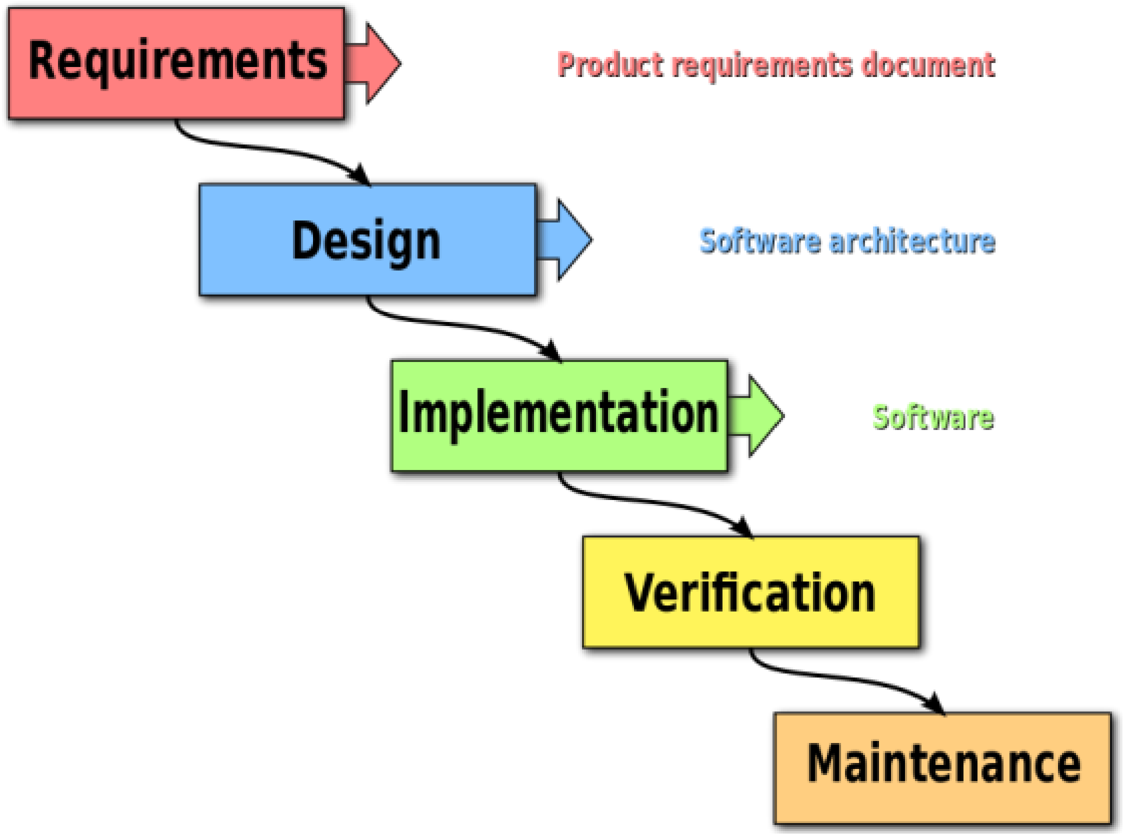
  - *The linear models (waterfall model, V-cycle) ;*

  - *The iterative models (incremental model, spiral model and by-prototype model).*

  - *Agile (new trend)*

Product life cycle: the waterfall cycle

- It is a sequential non-iterative design process



Manufacturing, construction and software industries

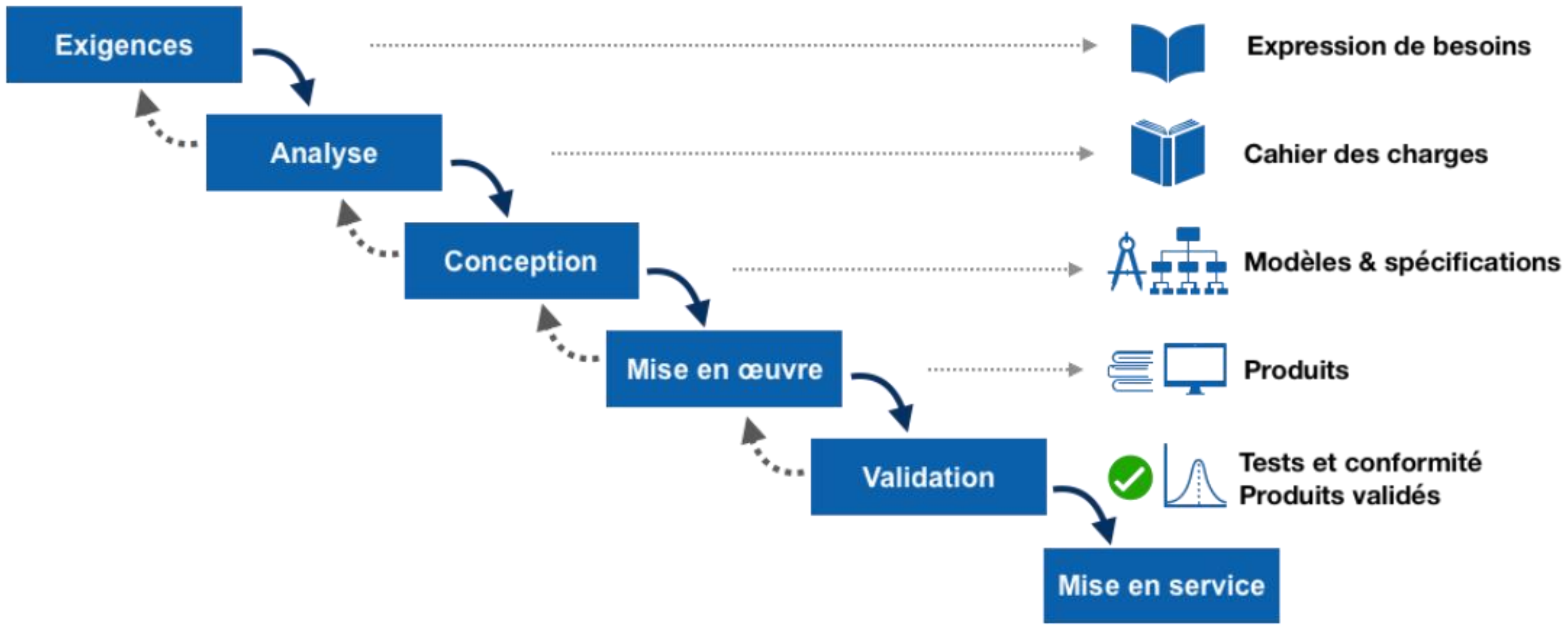
☺ adapted for designing simple products

☹ not adapted for designing complex ones

The **waterfall model** is a breakdown of project activities into linear sequential phases, where each phase depends on the deliverables of the previous one and corresponds to a specialisation of tasks.

Product life cycle: the waterfall cycle

- It is a sequential non-iterative design process



Manufacturing, construction and software industries

☺ adapted for designing simple products

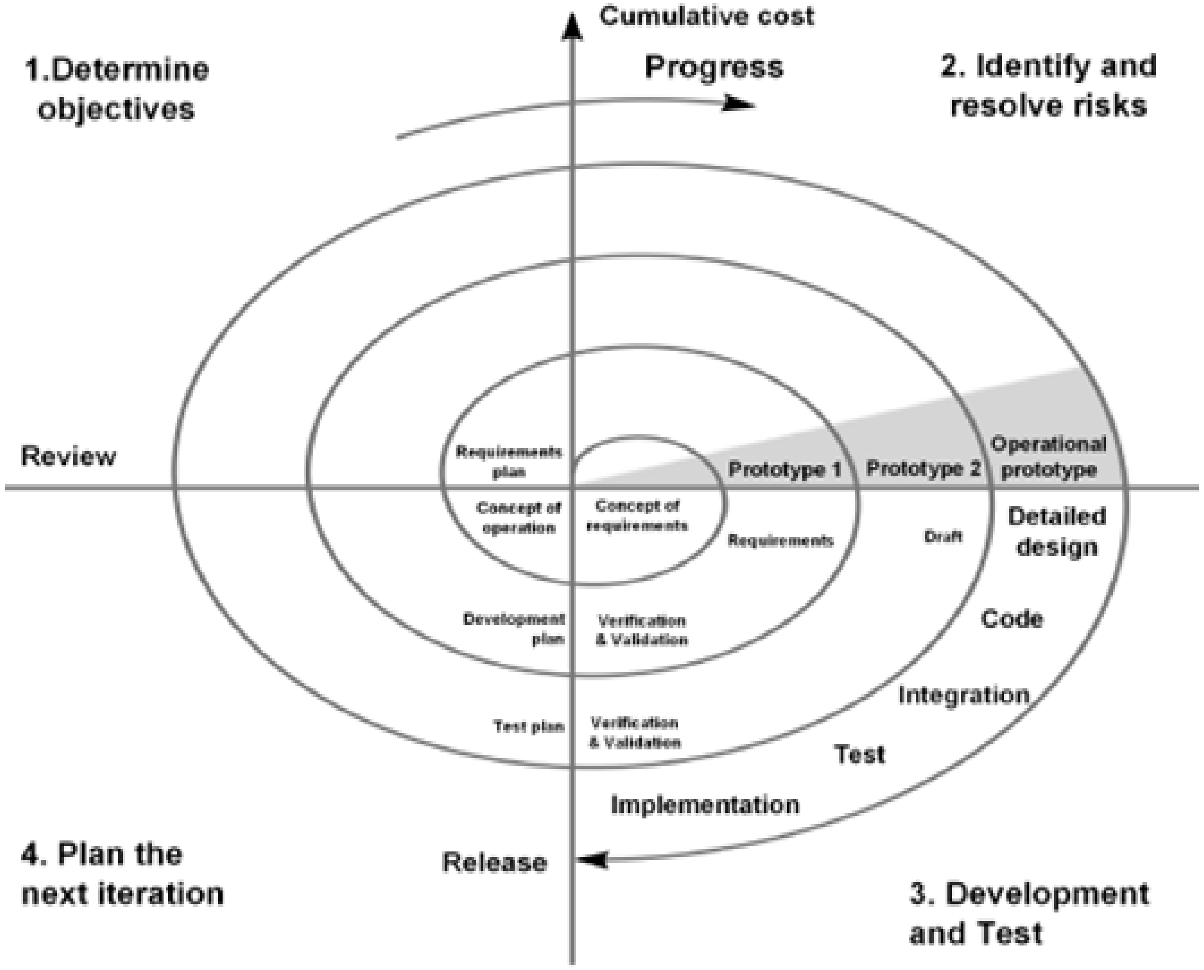
☹ not adapted for designing complex ones

The **waterfall model** is a breakdown of project activities into linear sequential phases, where each phase depends on the deliverables of the previous one and corresponds to a specialisation of tasks.

By Peter Kemp / Paul Smith - Adapted from Paul Smith's work at wikipedia, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=10633070

Product life cycle: the spiral model

- It is a risk-driven process model



Software industry

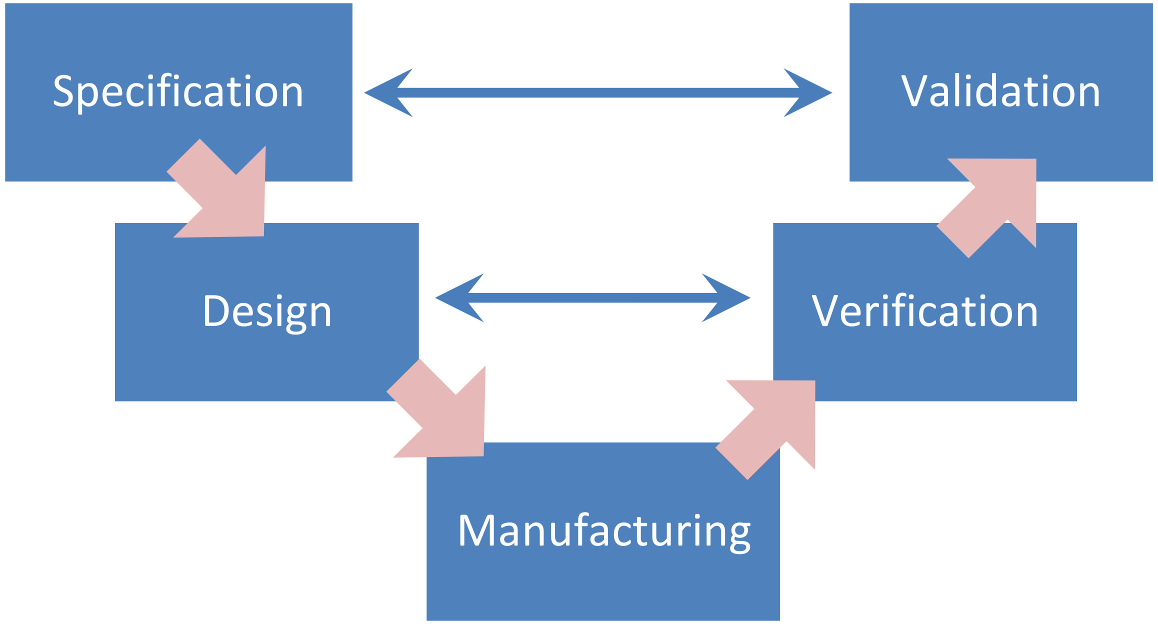
☺ short-time steps
☺ continuous dialogue with the customer and the user.
☺ risk minimization

☹ cost increase
☹ time increase

Boehm B, "A Spiral Model of Software Development and Enhancement“, "Computer", "IEEE", 21(5):61-72,1988.

Product life cycle: the V-cycle

- It is a rigorous development lifecycle model and a project management model.



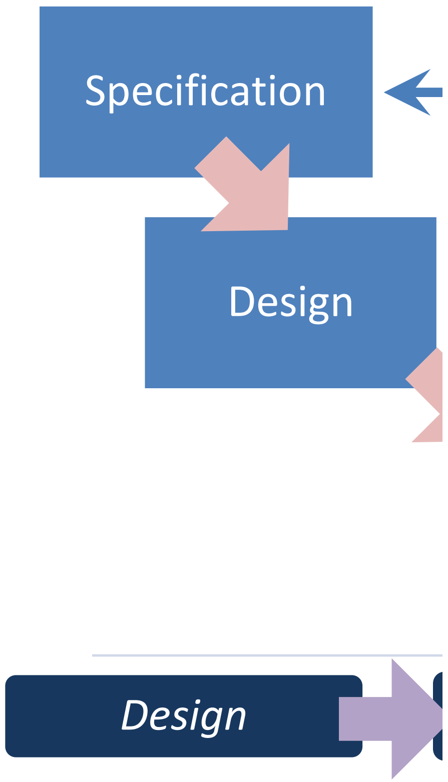
The horizontal axis represents time
The vertical axis represents the level of integration of the system
The left side of the "V" represents the decomposition of requirements, and creation of system specifications. The right side of the "V" represents integration of parts and their validation.

First used as a model of development in different technologies: mechanics, electronics, and software.

☺ an overall methodology with shared stages to the different technologies
☺ common terminology
☺ generalized to the development of complex systems
☹ maintenance and repair not taken into account

The V-cycle

- Design phase



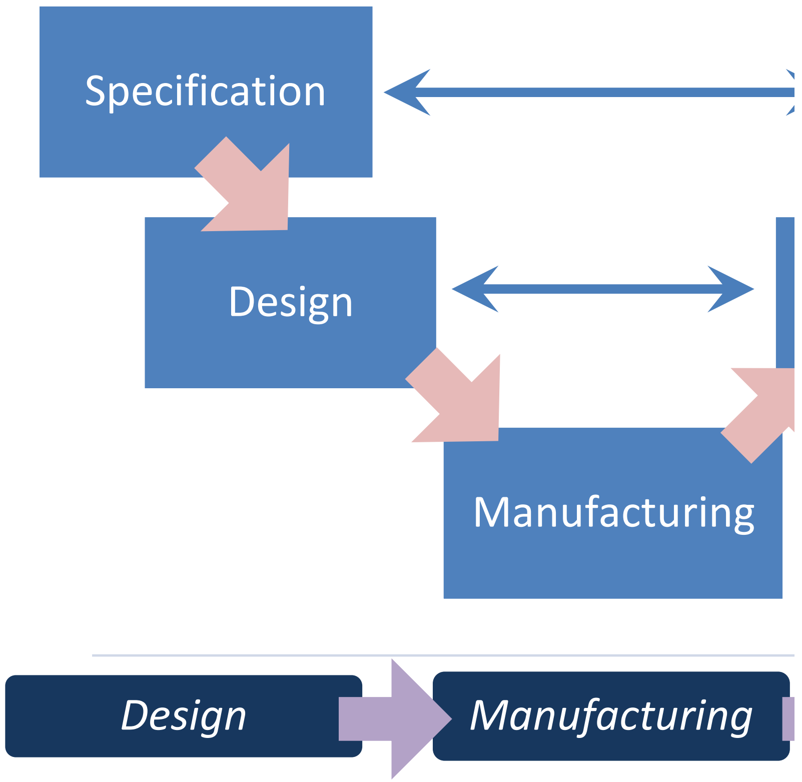
For a mechatronic system, the major difficulty is the **translation** of the global system specification into specifications for each component with different technologies.
[Rieuneau, 1993], [DesJardin, 1996]

Then, it is increasingly necessary to integrate **security** in the first phase of the development cycle.
[DesJardin,1996]

This integration leads to develop a **collaborative methodology** that promotes their inclusion in projects and through the different communities.

The V-cycle

- Manufacturing phase

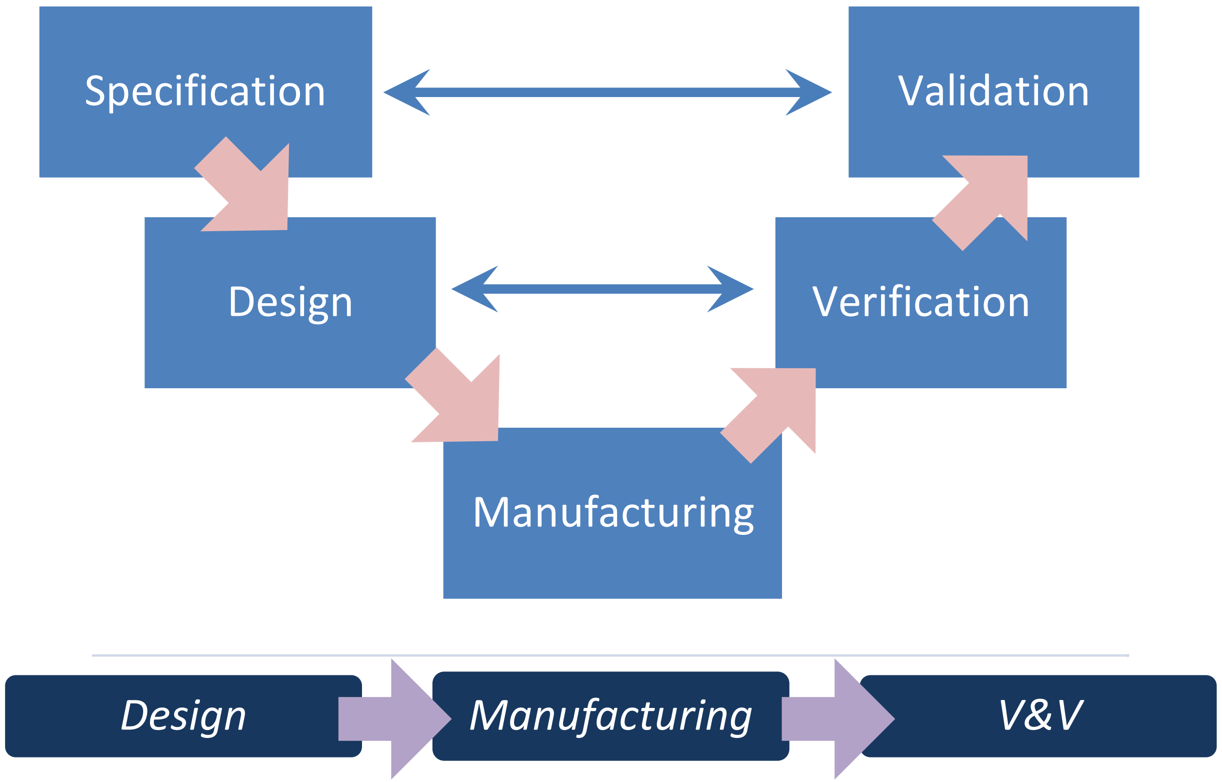


The manufacturer specifies not only the functionality but also the objectives in terms of **dependability**.

Must be studied during the design phase

The V-cycle

- Verification & validation phase

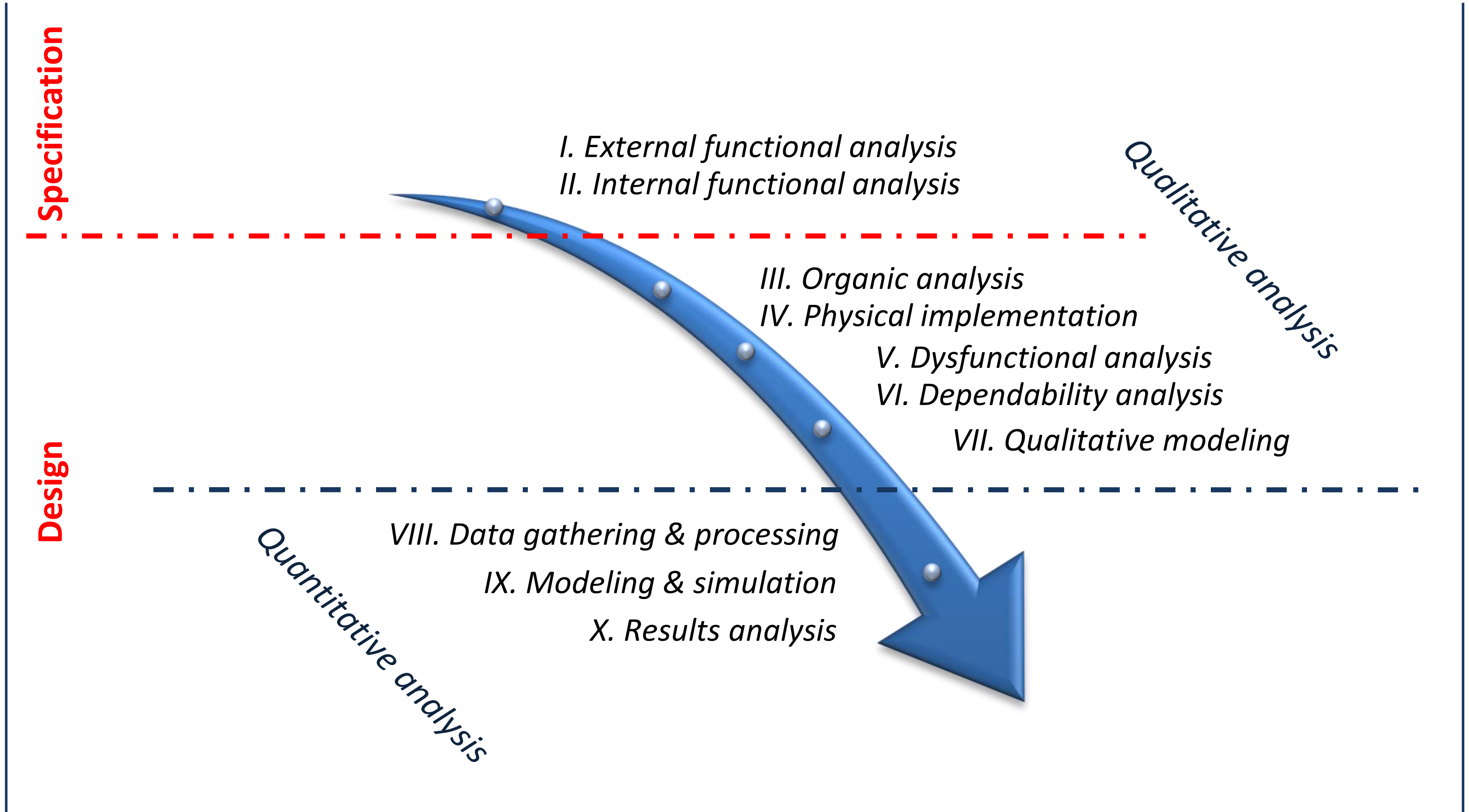


This phase intends to show the functional validation of the sub-systems and of the whole system. Quality must be compared to the specifications.

The interactions between the different technologies must be characterized. This step may help to obtain return data and feed the database.

Designing a mechatronic product

- It is necessary to develop a collaborative methodology very early in the project
- New approach for the first phases of the V-cycles



This method will be detailed in Lecture 2

Examples of two industrial products

Simple mechatronic systems

- Smart actuator

PACK'AERO MÉCATRONIQUE

  - Medical imaging & robotics
  - Bio prosthesis
  - Ultra rapid Optronics
  - Scientific Instrumentation
  - Electrodynamic actuators
  - ...

- Instrumented wheel bearing

NTN SNR

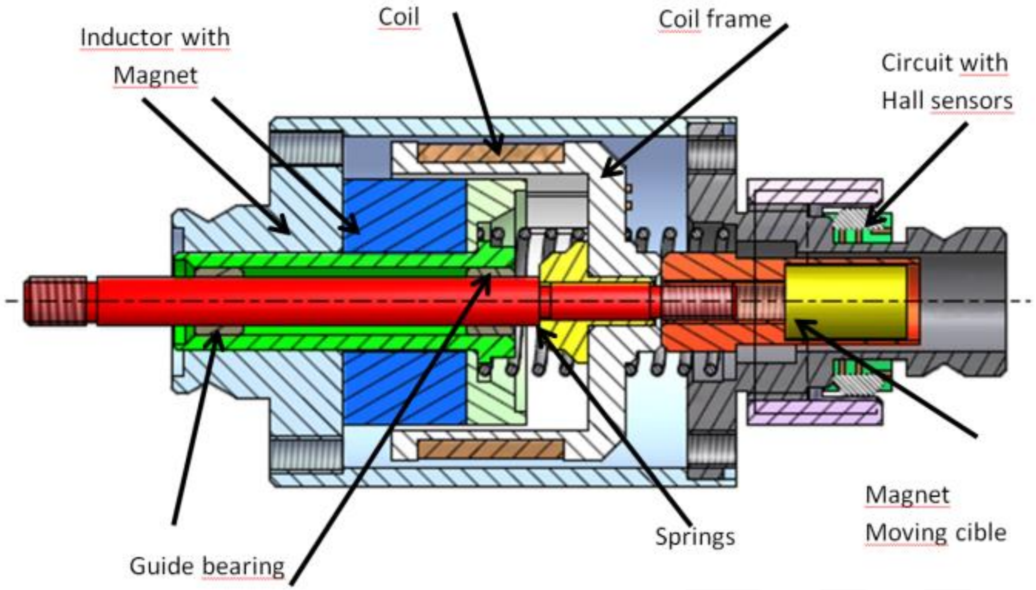
  - Sensors & magnetic rings
  - Ball bearings
  - Bearing units

For aerospace, automotive, rail, steel industry, wind energy,...

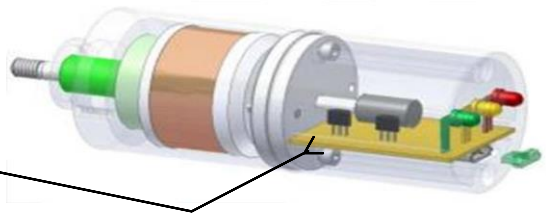
Example: smart actuator

Continuous sorting on a production line

- ❑ The wagons carry parts from a station to another of the chain in continuous motion
- ❑ The smart actuator contributes to the realization of the function of wagons unloading



PACK'AERO MÉCATRONIQUE



circuit board

The finger of the smart actuator is used as a stop to open the shutter and release the load of wagon without stopping

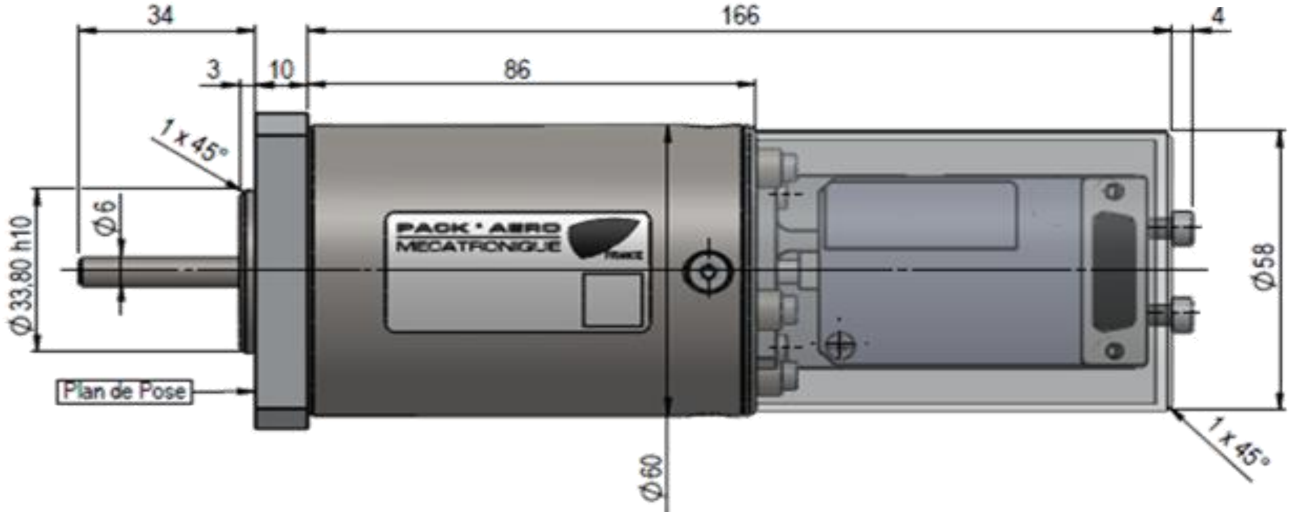
Example: smart actuator

❑ Specifications

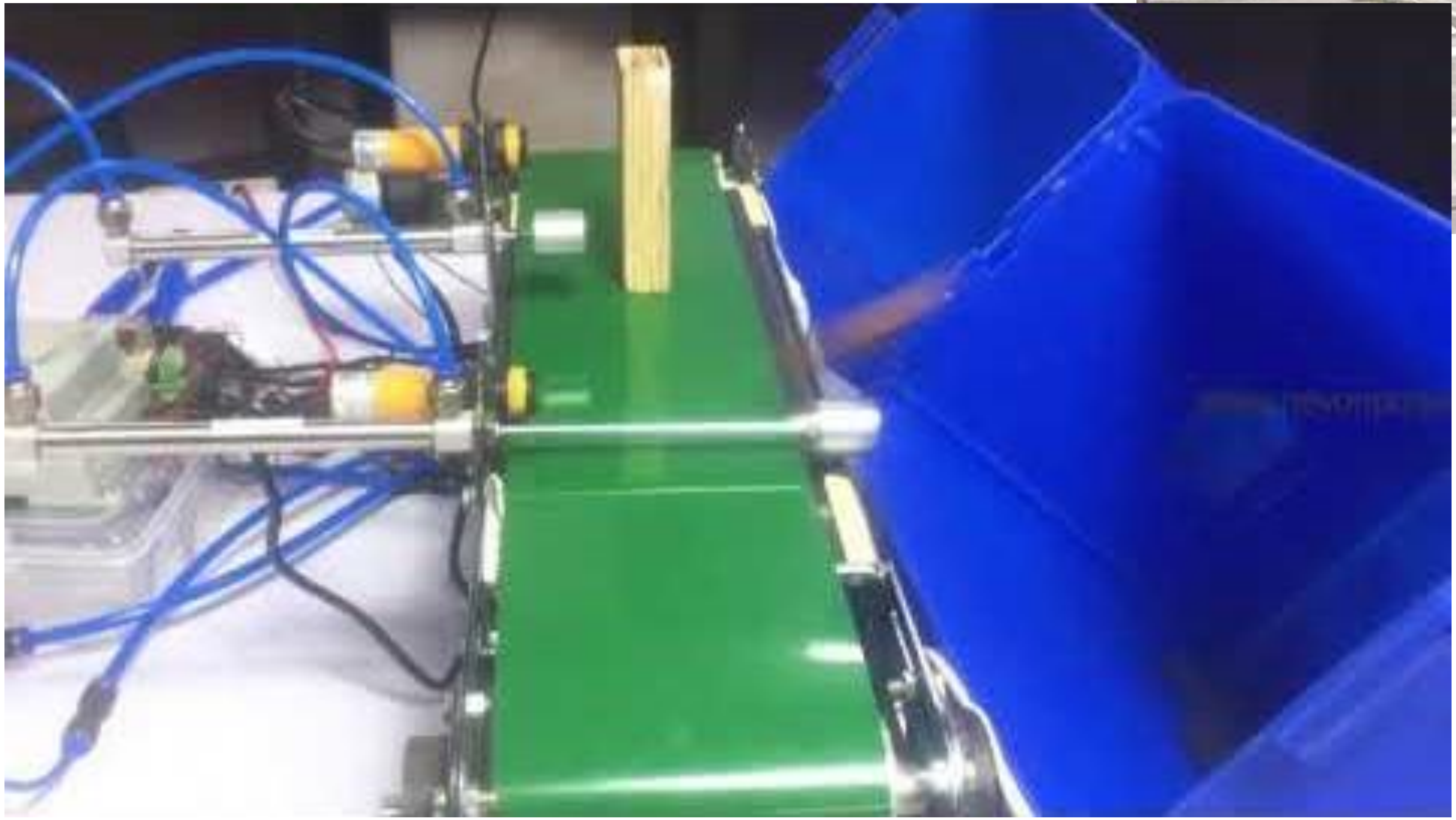
In addition to be a classical actuator, the smart actuator assumes additional functions such as operating, monitoring, communicating, data processing, etc.

> Transition from passive state to active state
> Using a linear direct action instead of a linear indirect one
> Optimization of the immediate answer according to the needs
> Integration of electrical locking functions with or without electricity consumption

PACK'AERO MÉCATRONIQUE



Example to illustrate



Example: smart actuator

- a mechatronic product ?
  - Incorporate several technologies?
  - Physical integration?
  - Functional integration?

- what about its intrinsic characteristics
  - Dynamic?
  - Reconfigurable?
  - Hybrid?
  - Interactive/interdependent?

PACK'AERO MÉCATRONIQUE

- Transition from passive state to active state
- Optimization of the immediate answer according to the needs
- Integration of electrical locking functions
- …

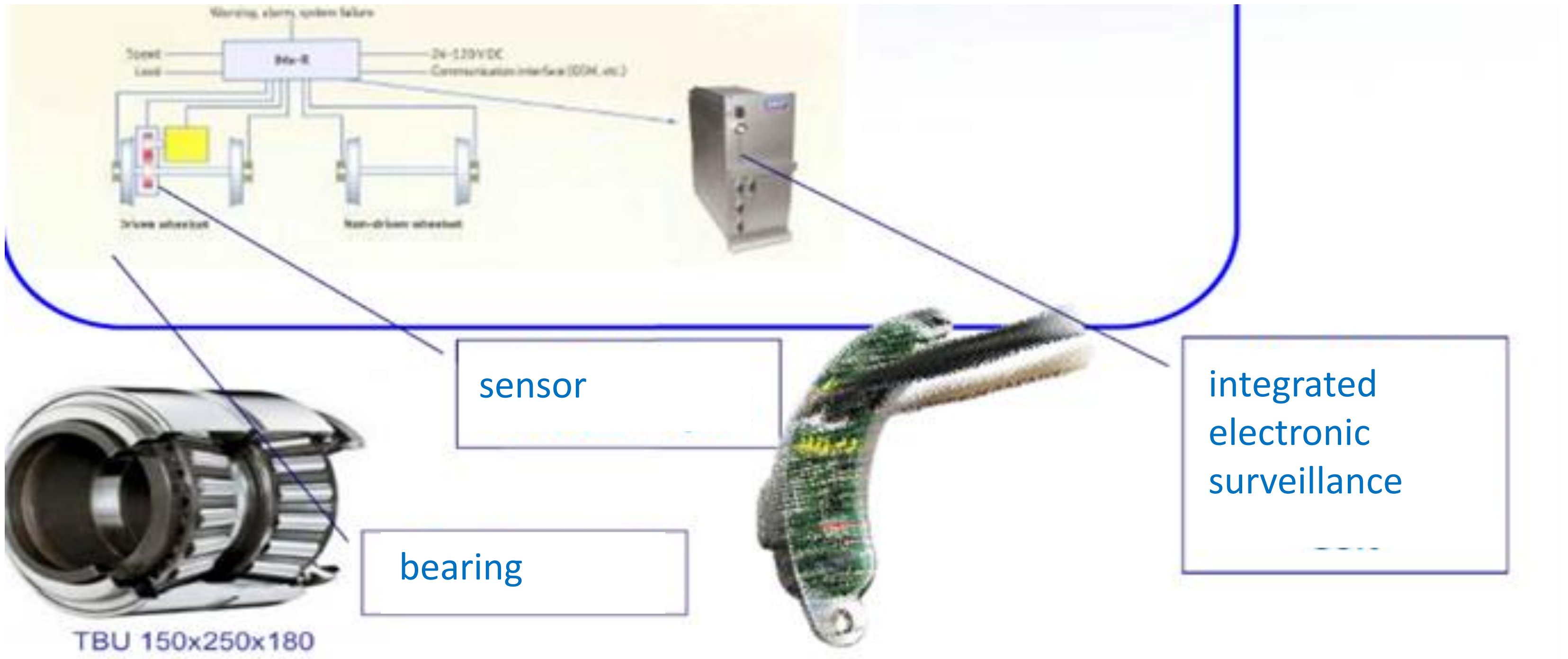
Example: instrumented wheel bearing

NTN SNR

- Using context

Fixed on axle tree

Integrated electronic surveillance



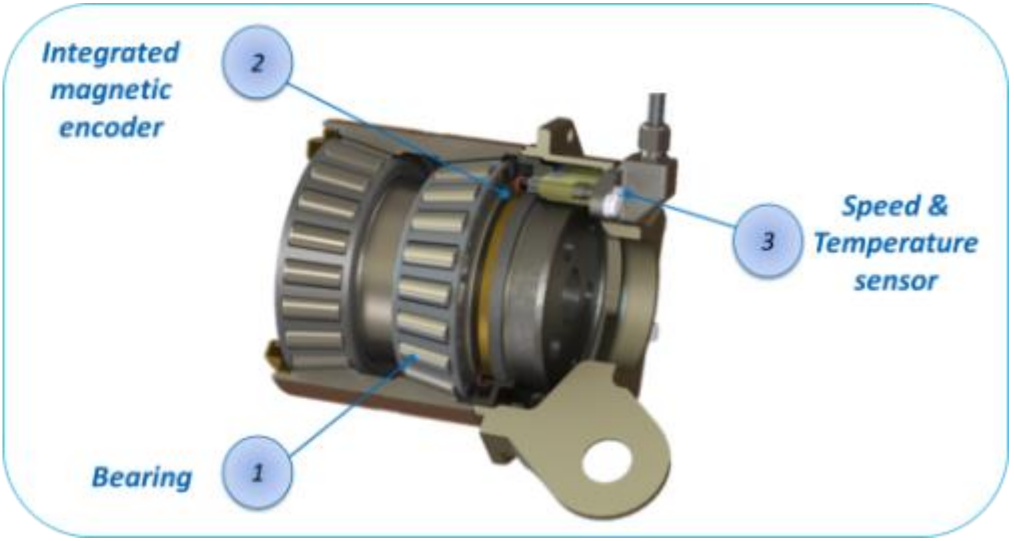
Example: instrumented wheel bearing

NTN SNR

Specifications

In addition to be a classical wheel bearing, the instrumented wheel bearing assumes additional functions such as temperature and speed measurements.

- One sensor for both measurement
- Two electronic circuits are working in parallel (active redundancy)
- The speed measurement is working from 0 km/h (high security)
- Measured data are saved by the calculator



Example: instrumented wheel bearing

NTN SNR

- a mechatronic product?
  - Incorporate several technologies?
  - Physical integration?
  - Functional integration?

- what about its intrinsic characteristics
  - Dynamic?
  - Reconfigurable?
  - Hybrid?
  - Interactive/interdependent?

> Transition from passive state to active state

> Active redundancy

> Continuous phenomenon and discrete events

> ...

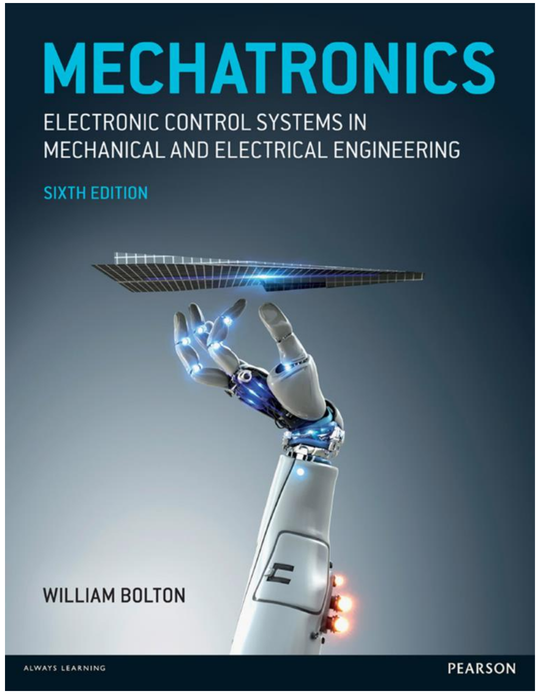
Assignment 1

- Read Chapter 1 of the book MECHATROMICS, W. Bolton
- Read this web page on Software Development Life Cycle

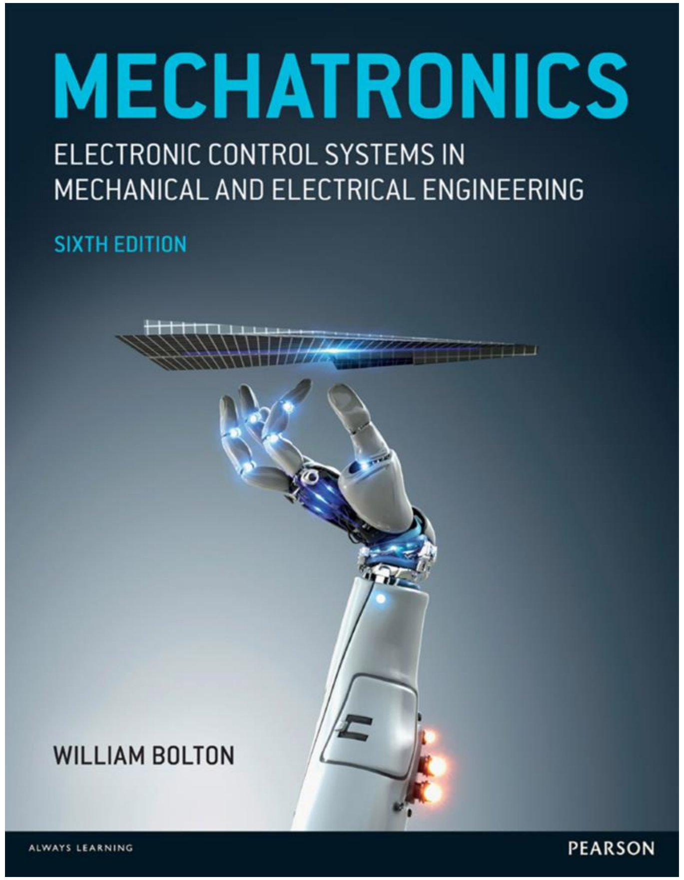
- Answer the Quizz Assignement1 on the Moodle plateform

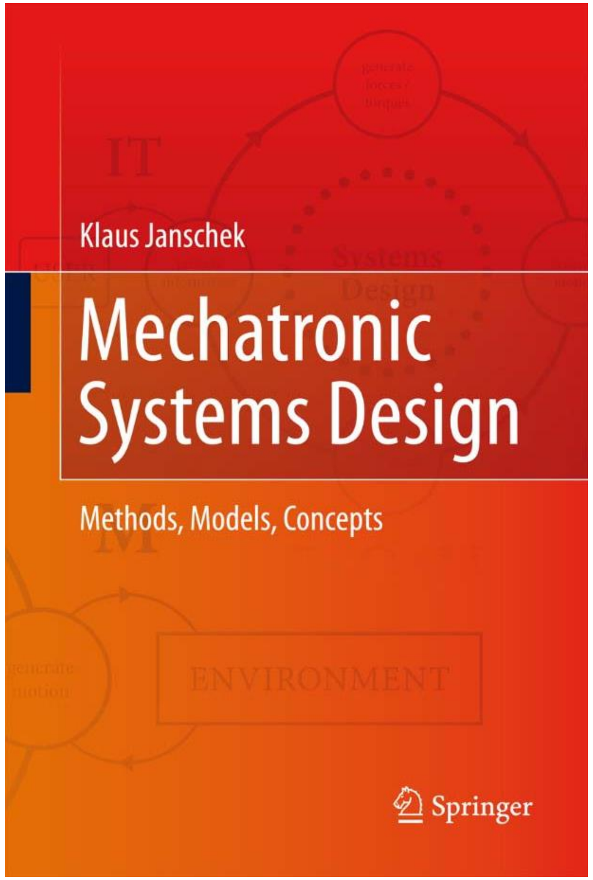
- Find on the internet an example of a smart actuator

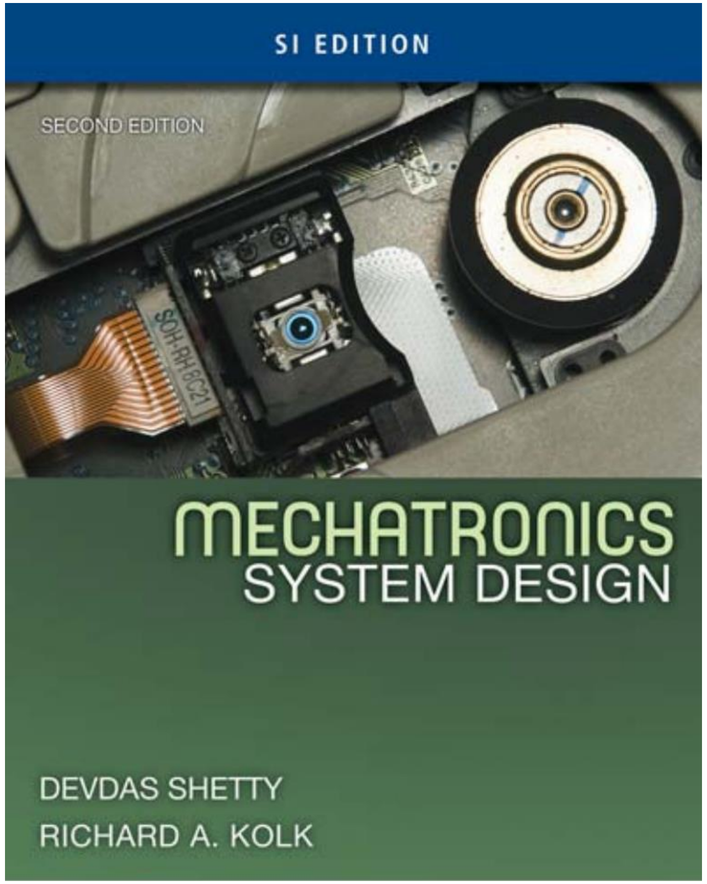
- Due to Tuesday October 6, 2020. (10am max. deadline)
- This will count towards 10% of the final grade.



Relevant books







Contact Information

Université Savoie Mont Blanc

Polytech' Annecy Chambery
Chemin de Bellevue
74940 Annecy
France

https://www.polytech.univ-savoie.fr

Lecturer

Dr Luc Marechal (luc.marechal@univ-smb.fr)
SYMME Lab (Systems and Materials for Mechatronics)

Acknowledgement

Pr Georges Habchi
Pr Christine Barthod
SYMME Lab (Systems and Materials for Mechatronics)
for the original writing of this lecture