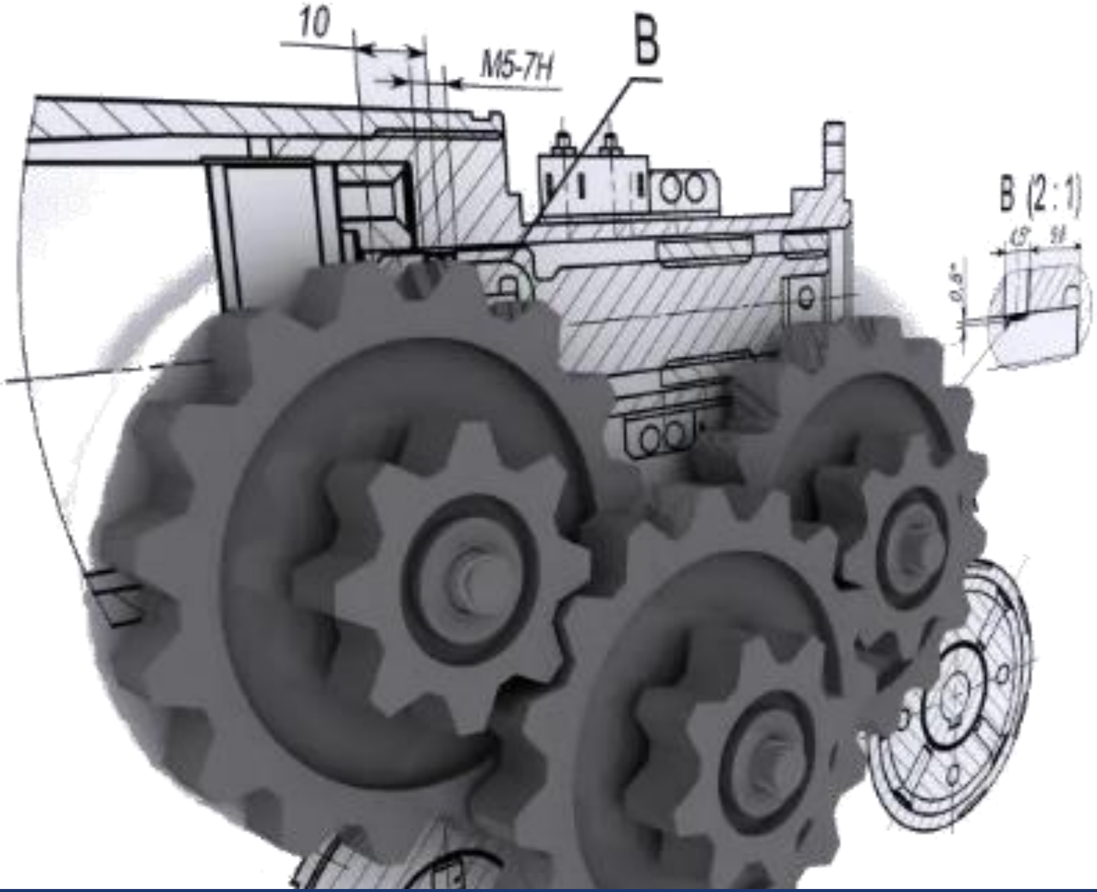


2021

MCTR 701_1

Master Advanced Mechatronics

Lecturer : Luc Marechal

UNIVERSITÉ SAVOIE MONT BLANC

POLYTECH ANNECY-CHAMBÉRY

SYMME

Mechatronics common framework
Lecture 1

Contents

Lecture 1

MECHATRONIC & COMPLEX PRODUCT :

SPECIFICATIONS,

PRODUCT LIFECYCLE,

UNDERSTANDING OF STANDARDS

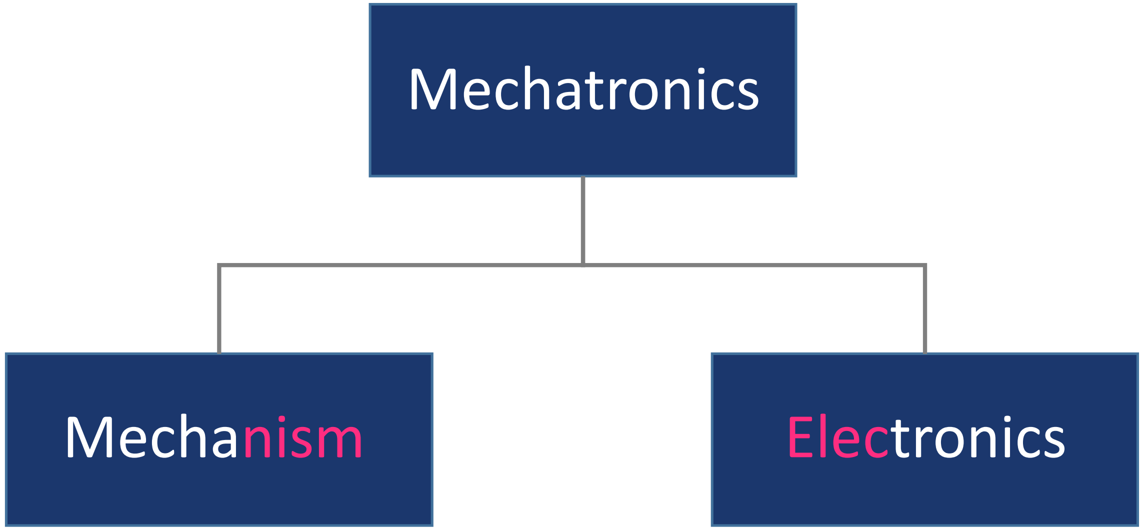
- What is Mechatronics
- Mechatronic product
- Product life cycles
- Designing a mechatronic product
- Examples of mechatronic product

What is Mechatronics ?

- Please give your definition :

What is Mechatronics ? – Definitions and meaning

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



What is Mechatronics ? – Definitions 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].

YASKAWA

What is Mechatronics ? – Definitions and meaning

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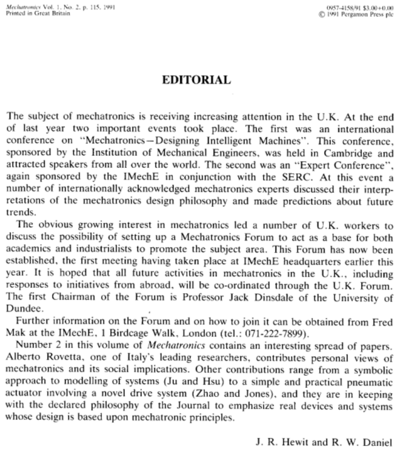
1991

- 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].



Mechatronics Vol. 1, No. 2, p. 115, 1991
Printed in Great Britain

0957-4158/91 $3.00+0.00
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EDITORIAL

The subject of mechatronics is receiving increasing attention in the U.K. At the end of last year two important events took place. The first was an international conference on "Mechatronics—Designing Intelligent Machines". This conference, sponsored by the Institution of Mechanical Engineers, was held in Cambridge and attracted speakers from all over the world. The second was an "Expert Conference", again sponsored by the IMechE in conjunction with the SERC. At this event a number of internationally acknowledged mechatronics experts discussed their interpretations of the mechatronics design philosophy and made predictions about future trends.

The obvious growing interest in mechatronics led a number of U.K. workers to discuss the possibility of setting up a Mechatronics Forum to act as a base for both academics and industrialists to promote the subject area. This Forum has now been established, the first meeting having taken place at IMechE headquarters earlier this year. It is hoped that all future activities in mechatronics in the U.K., including responses to initiatives from abroad, will be co-ordinated through the U.K. Forum. The first Chairman of the Forum is Professor Jack Dinsdale of the University of Dundee.

Further information on the Forum and on how to join it can be obtained from Fred Mak at the IMechE, 1 Birdcage Walk, London (tel.: 071-222-7899).

Number 2 in this volume of *Mechatronics* contains an interesting spread of papers. Alberto Rovetta, one of Italy's leading researchers, contributes personal views of mechatronics and its social implications. Other contributions range from a symbolic approach to modelling of systems (Ju and Hsu) to a simple and practical pneumatic actuator involving a novel drive system (Zhao and Jones), and they are in keeping with the declared philosophy of the Journal to emphasize real devices and systems whose design is based upon mechatronic principles.

J. R. Hewit and R. W. Daniel

R.W Daniel, J.R. Hewit, Editorial. Mechatronics, 1(1): i–ii, 1991

What is Mechatronics ? – Definitions and meaning

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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]

IEEE/ASME TRANSACTIONS ON MECHATRONICS

What is Mechatronics ? – Definitions and meaning

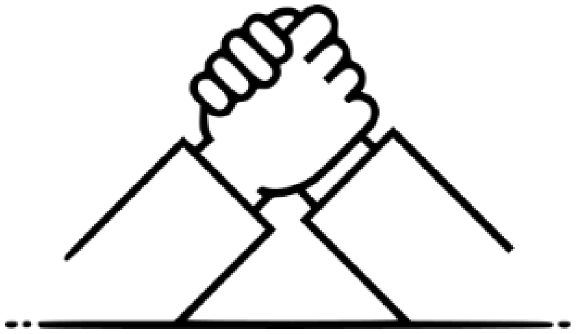
- It aims at developing products, processes and systems with greater flexibility, ease in redesign and ability of reprogramming.

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

- An approach for product and manufacturing system

- Leads to solutions with higher performance that cannot be obtained in separate applications [Shetty and Kolk, 1997] [Breedveld, 2004].

IEEE/ASME TRANSACTIONS ON MECHATRONICS



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

What is Mechatronics ? – Definitions and meaning

- 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.

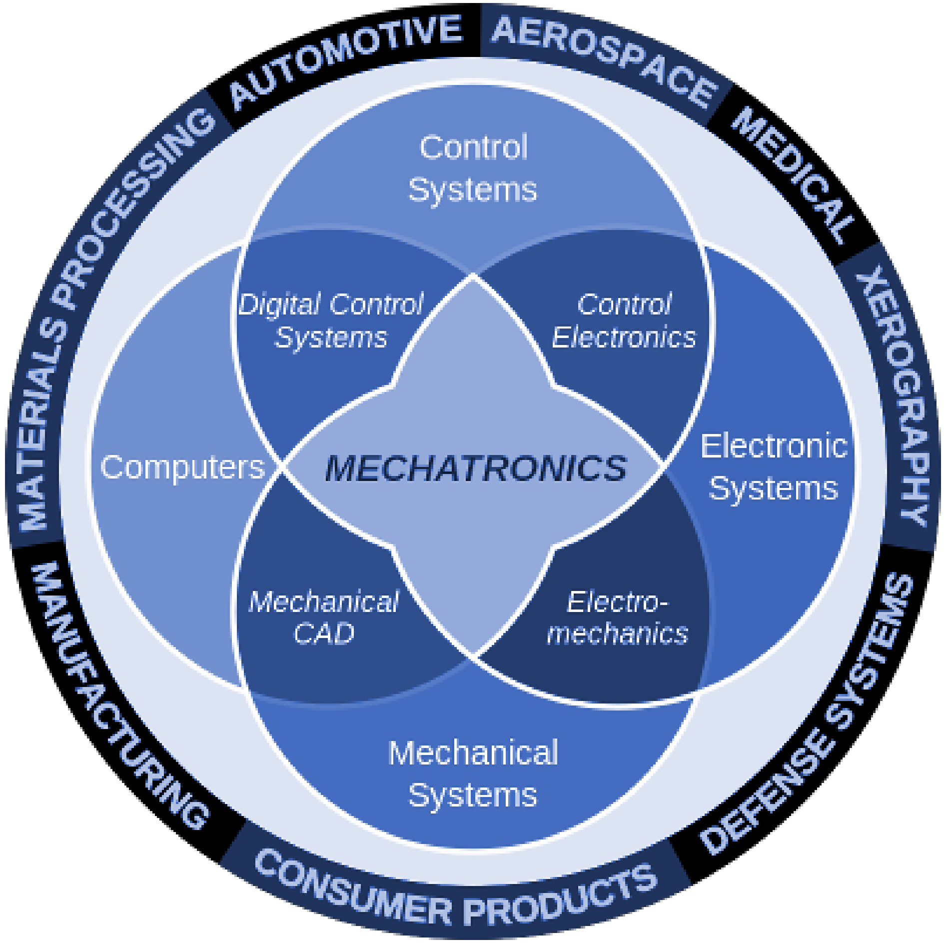
Not a science
nor a technology,

a methodology !

What is Mechatronics ? – Definitions and meaning

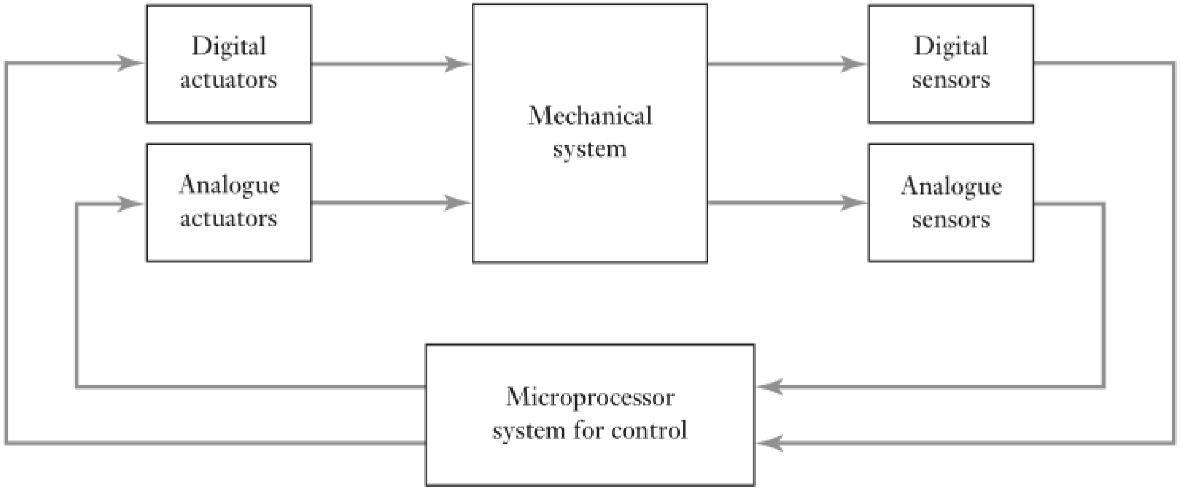
- The multidisciplinary nature of mechatronics combines several sectors of different technologies in the designing and manufacturing of a product.

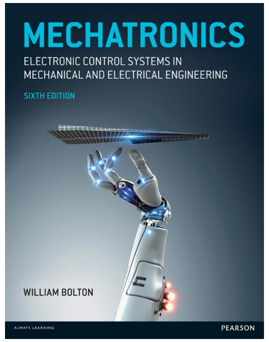
- Disciplinary Foundations of Mechatronics :
  - Mechanical Engineering
  - Electrical Engineering
  - Electronics Engineering
  - Computer Engineering
  - Information & Technology Engineering



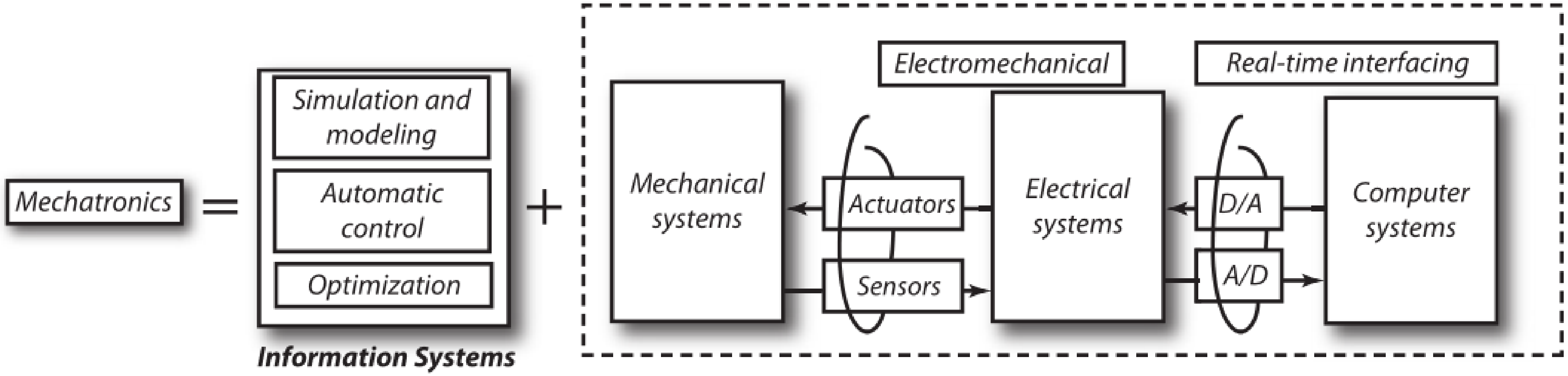
Basic elements of a mechatronics system

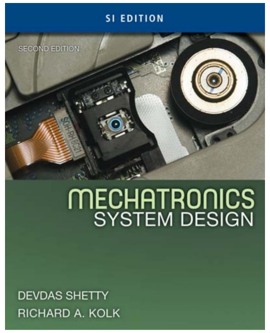
Figure 1.1 The basic elements of a mechatronic system.





Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, 6th Edition, W. Bolton

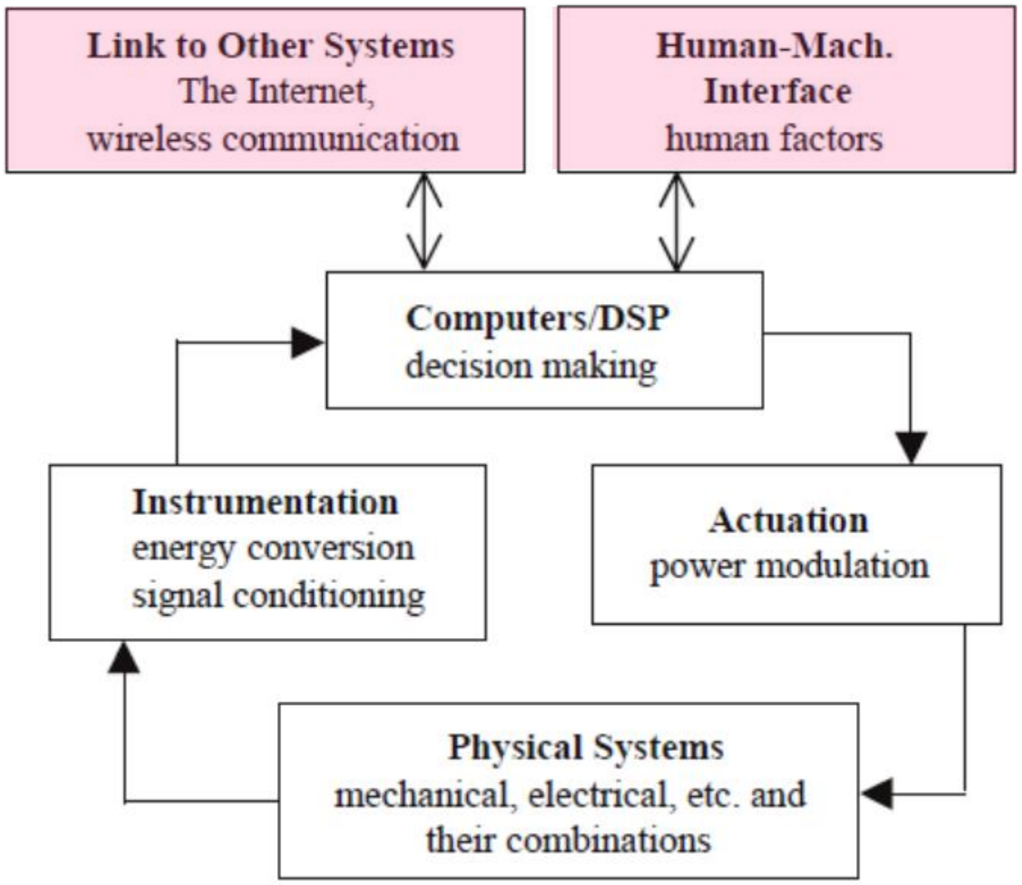


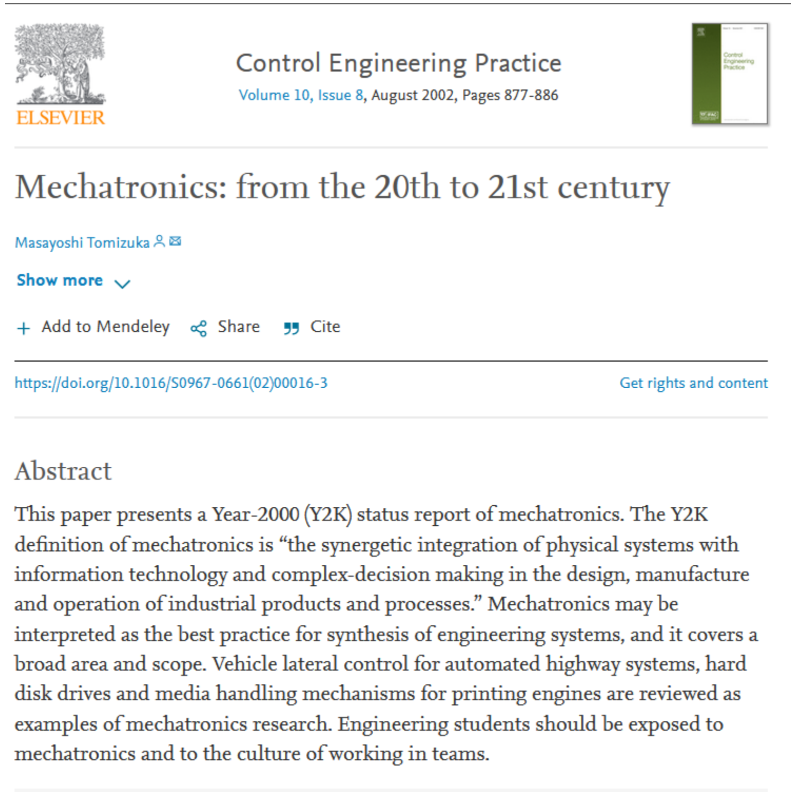


Mechatronics system design, Devdas Shetty

Basic elements of a mechatronics system

Do not forget the user !





ELSEVIER
Control Engineering Practice
Volume 10, Issue 8, August 2002, Pages 877-886

Mechatronics: from the 20th to 21st century

Masayoshi Tomizuka

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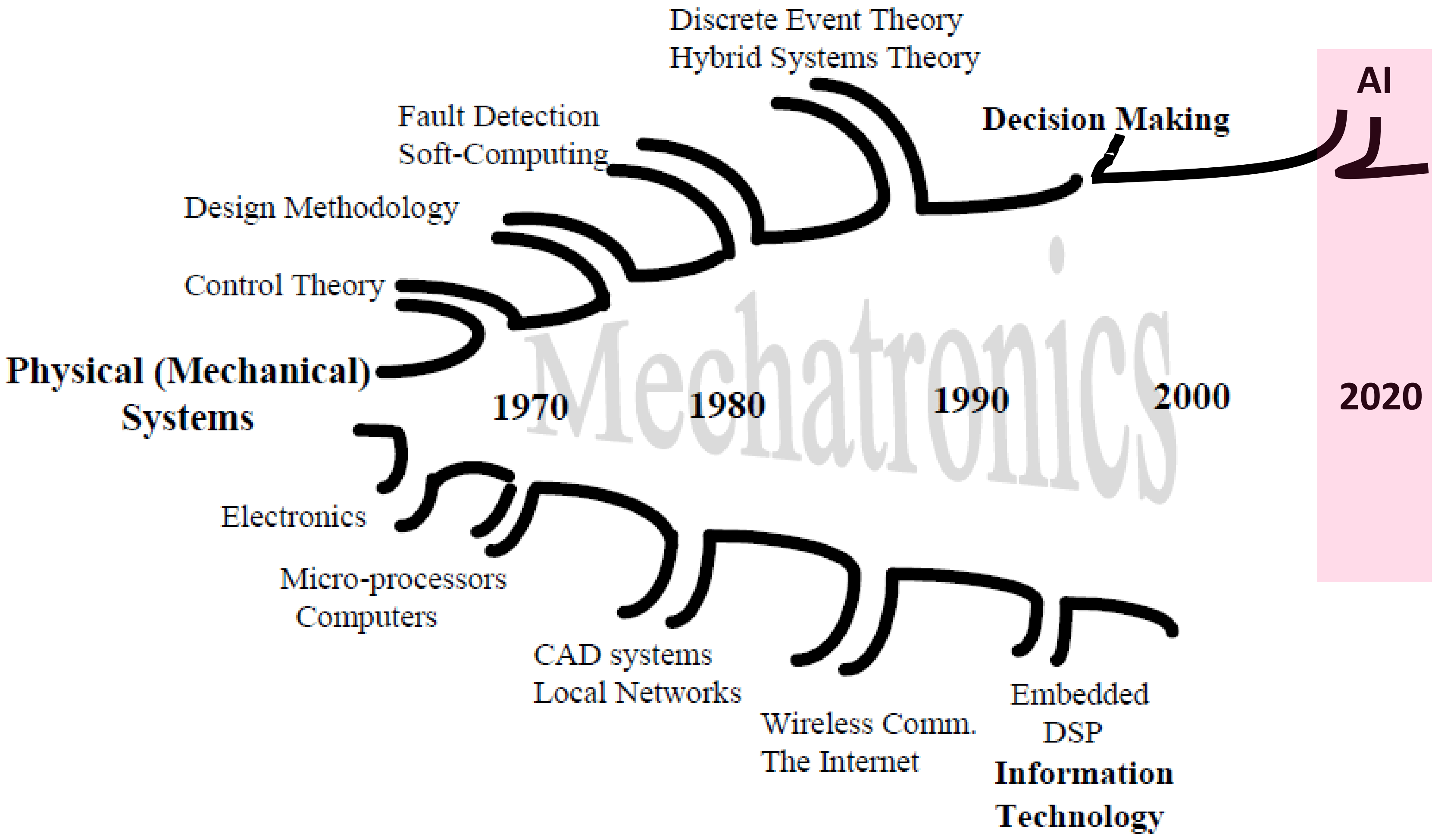
Abstract

This paper presents a Year-2000 (Y2K) status report of mechatronics. The Y2K definition of mechatronics is "the synergetic integration of physical systems with information technology and complex-decision making in the design, manufacture and operation of industrial products and processes." Mechatronics may be interpreted as the best practice for synthesis of engineering systems, and it covers a broad area and scope. Vehicle lateral control for automated highway systems, hard disk drives and media handling mechanisms for printing engines are reviewed as examples of mechatronics research. Engineering students should be exposed to mechatronics and to the culture of working in teams.

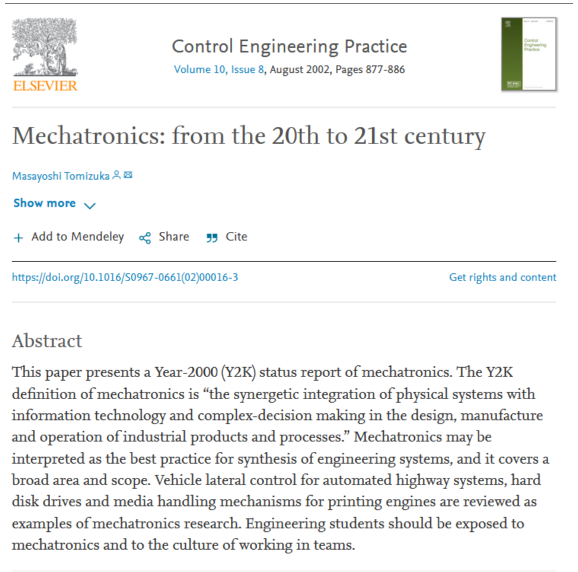
Masayoshi Tomizuka, Mechatronics: from the 20th to 21st century, Control Engineering Practice, Volume 10, Issue 8, August 2002

Evolution of mechatronics

Future of Mechatronics



Mechatronics is still evolving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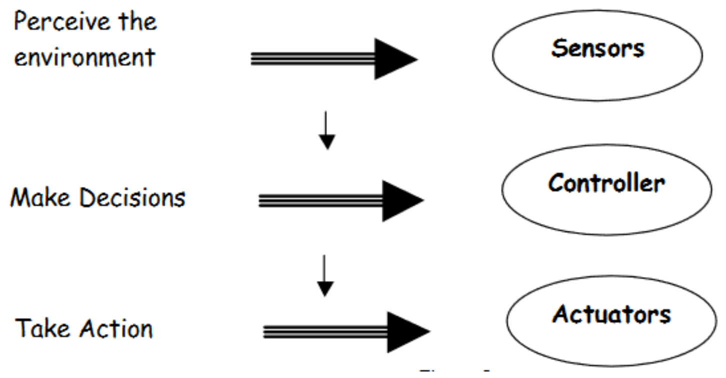
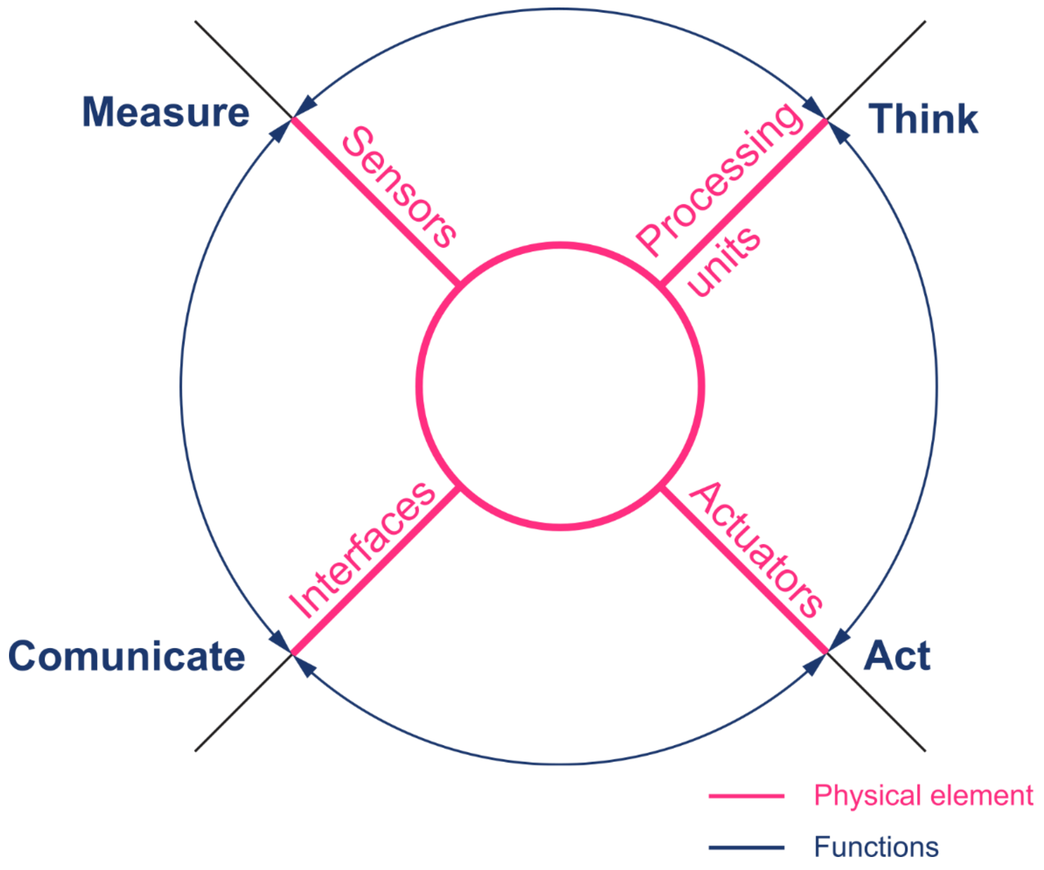
Masayoshi Tomizuka, Mechatronics: from the 20th to 21st century, Control Engineering Practice, Volume 10, Issue 8, August 2002

Couplings between major supplementary functions



A mechatronic system could be characterized by the added values of the **functions couplings.**

The density of couplings present in the mechatronic system therefore appears to be a determining factor of the system compared to non-mechatronic systems.



Techniques de l'Ingénieur, BM8000 V2

Mechatronic product

> “ A product with the ability to perceive its environment, to process information, to communicate and to act on its environment, and with a complete level of mechatronic integration, from a functional and physical point of view. ”

afnor

Interpenetration of mechanical and electronic components

Physical integration

Addition of sensing, communication, information processing and feedback functions to basic mechanical functions

Functional integration

From complex systems to mechatronic systems

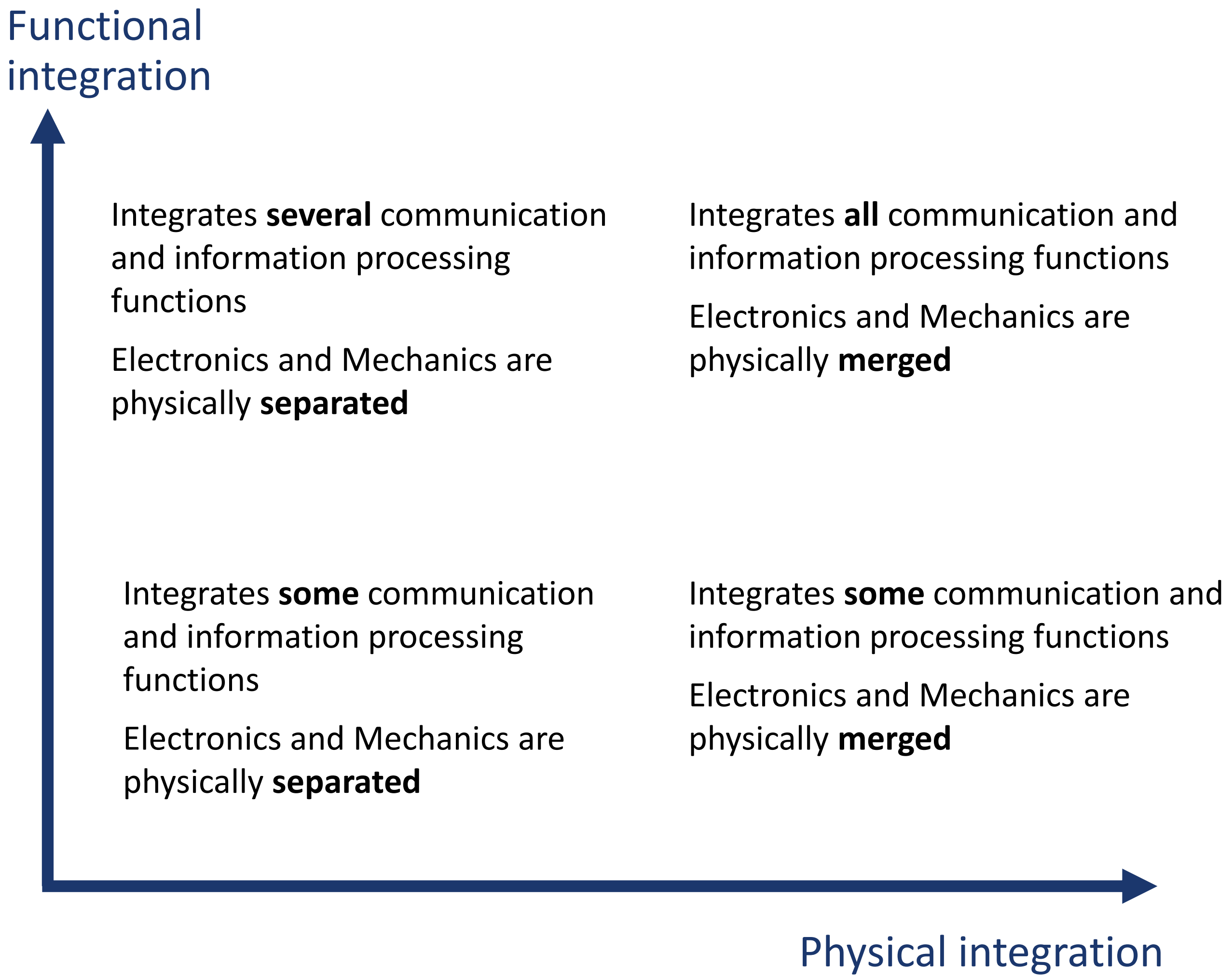
- Traditionally, the transition from **component to product** is made through the addition of functionalities that give the component more and more autonomy.

But

- Mechatronics imposes, in addition, the interpenetration between the supports

  = **strong technological coupling**

  = the mechanical, electronic parts,… are **physically merged**.



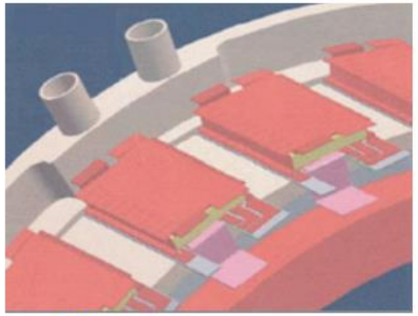
Level of mechatronic systems integration

Mechanics and Electronics
Separated

Mechanics and Electronics
Joined

Mechanics and Electronics
Included

Mechanics and Electronics
Merged



Intégration croissante

Projet O2M (Outils de Modélisation Mécatronique) (document Mov'eo-System@tic)

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

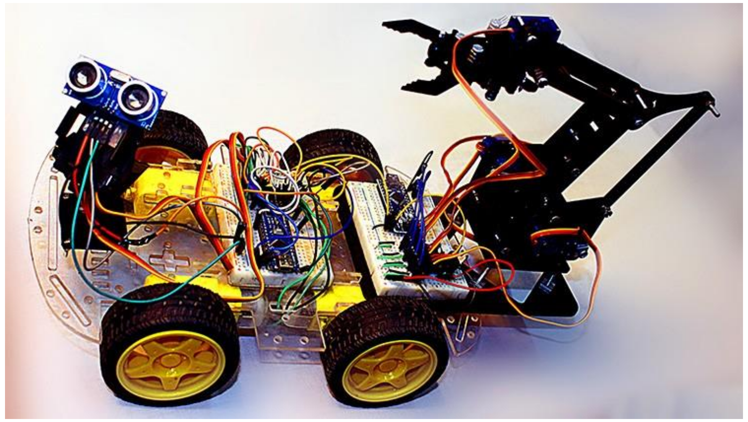
Secondary Level Mechatronics : Integrates microelectronics into electrically controlled devices for e.g. cassette tape player.

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

Level of mechatronic systems integration

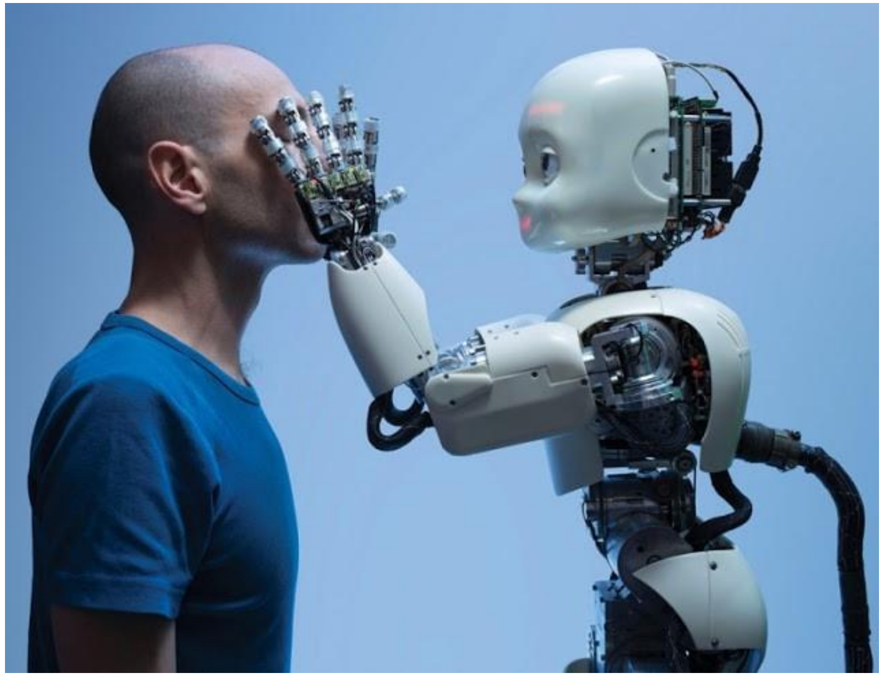
Tertiary Level Mechatronics : Incorporates advanced control strategy using microelectronics, microprocessors and other application specific integrated circuits for e.g. microprocessor based electrical motor used for actuation purpose in robots.

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

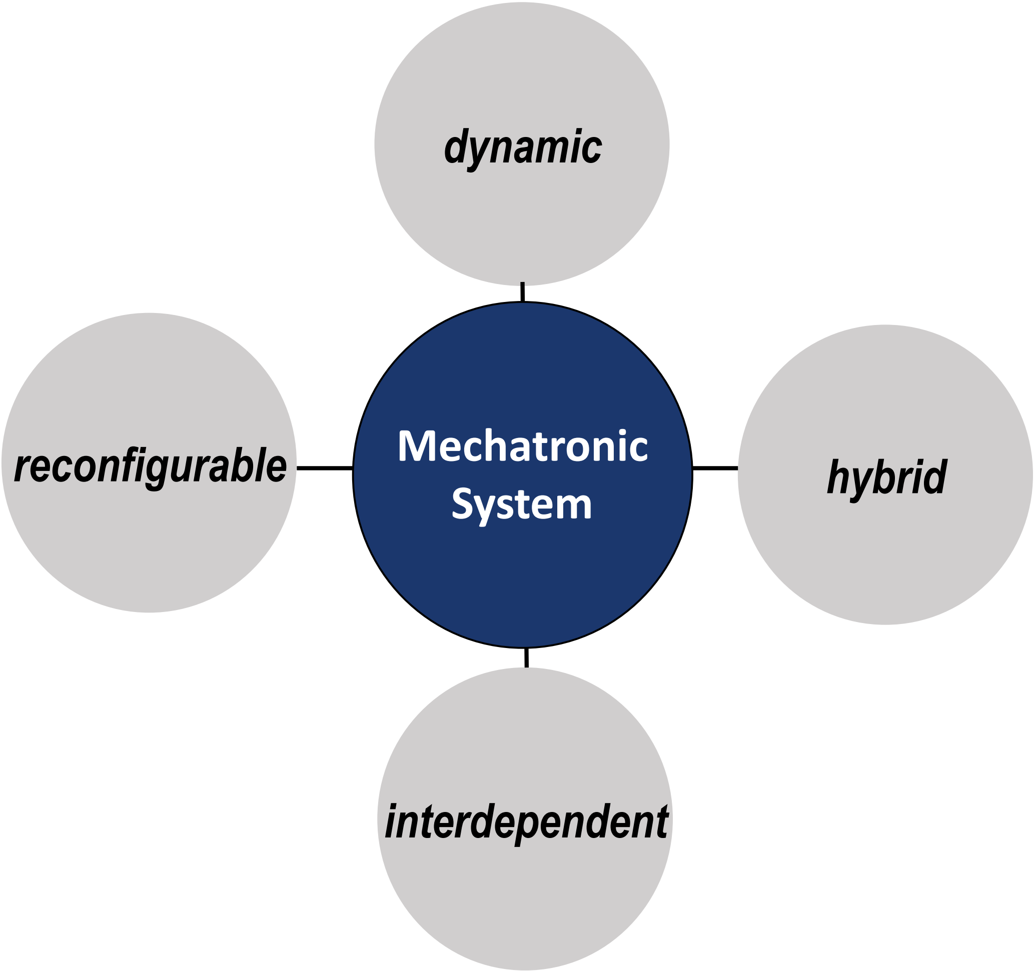
Quaternary Level **Mechatronics** : This level attempts to improve smartness a step ahead by introducing intelligence (artificial neutral network and fuzzy logic) and fault detection and isolation (F.D.I.) capability into the system



Mechatronic system

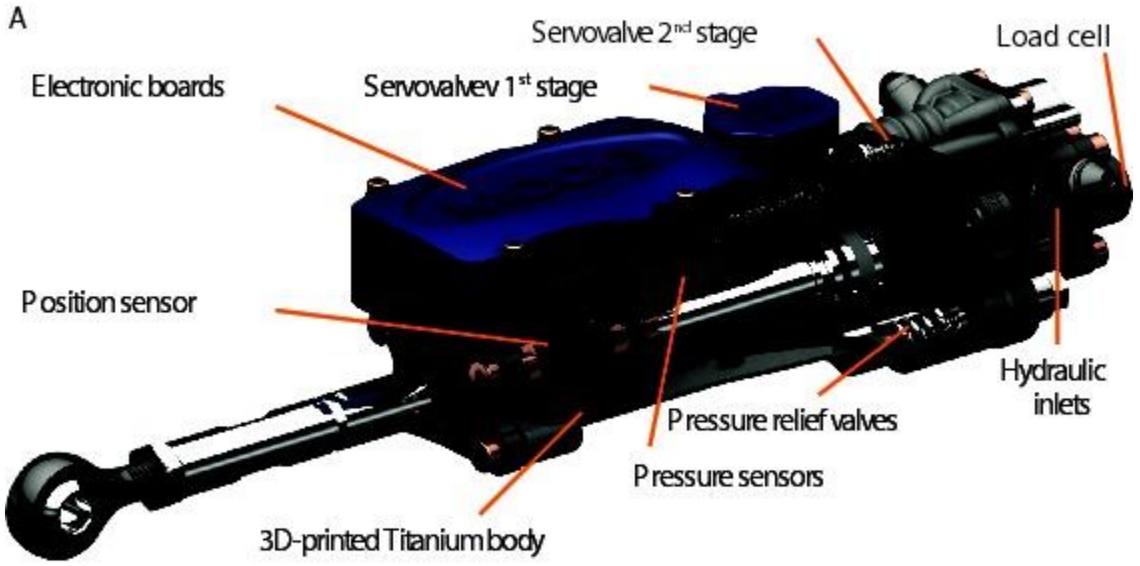
A complex system with **functional** & **physical integration**.

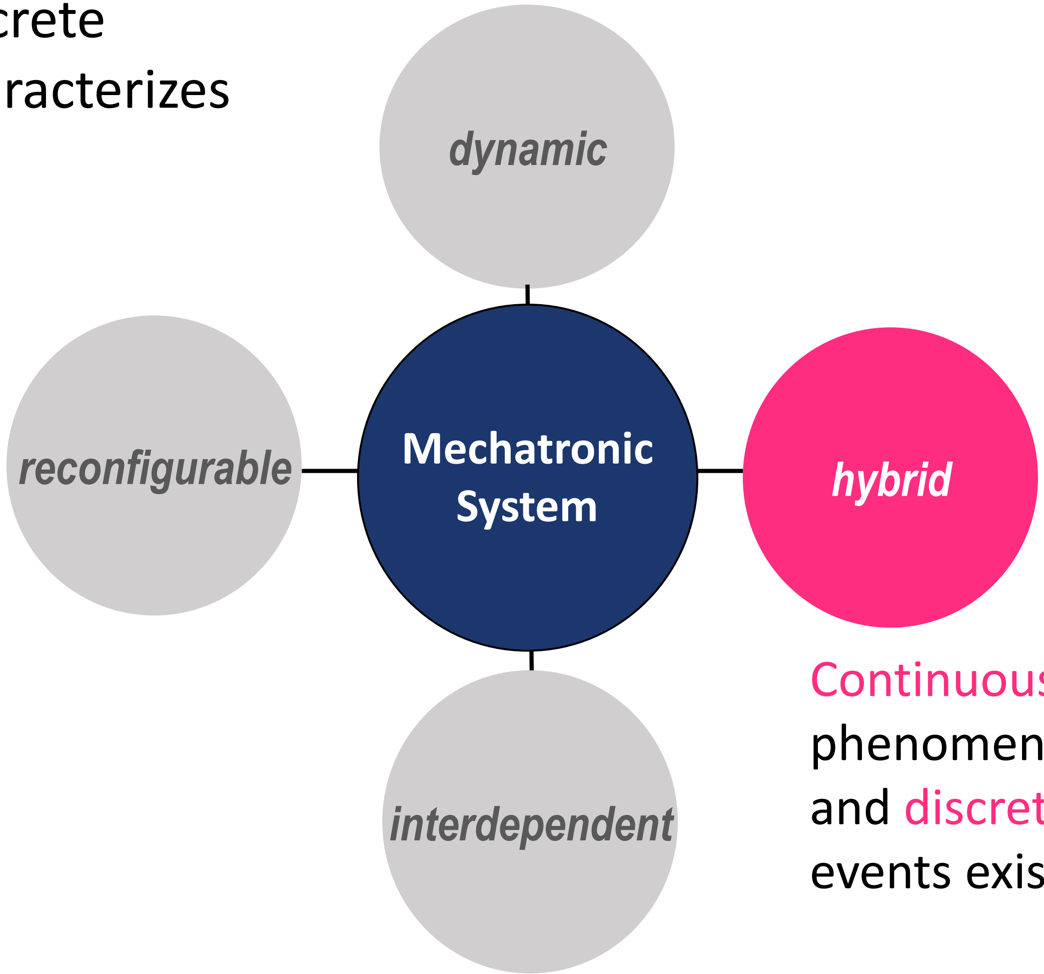
Characterized by four concepts:



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 – 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.

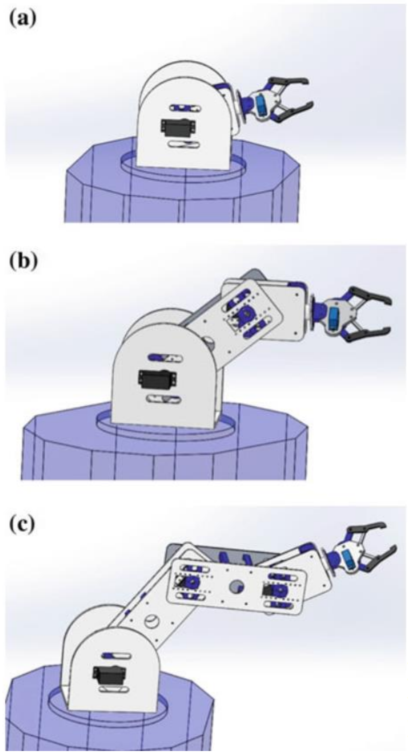
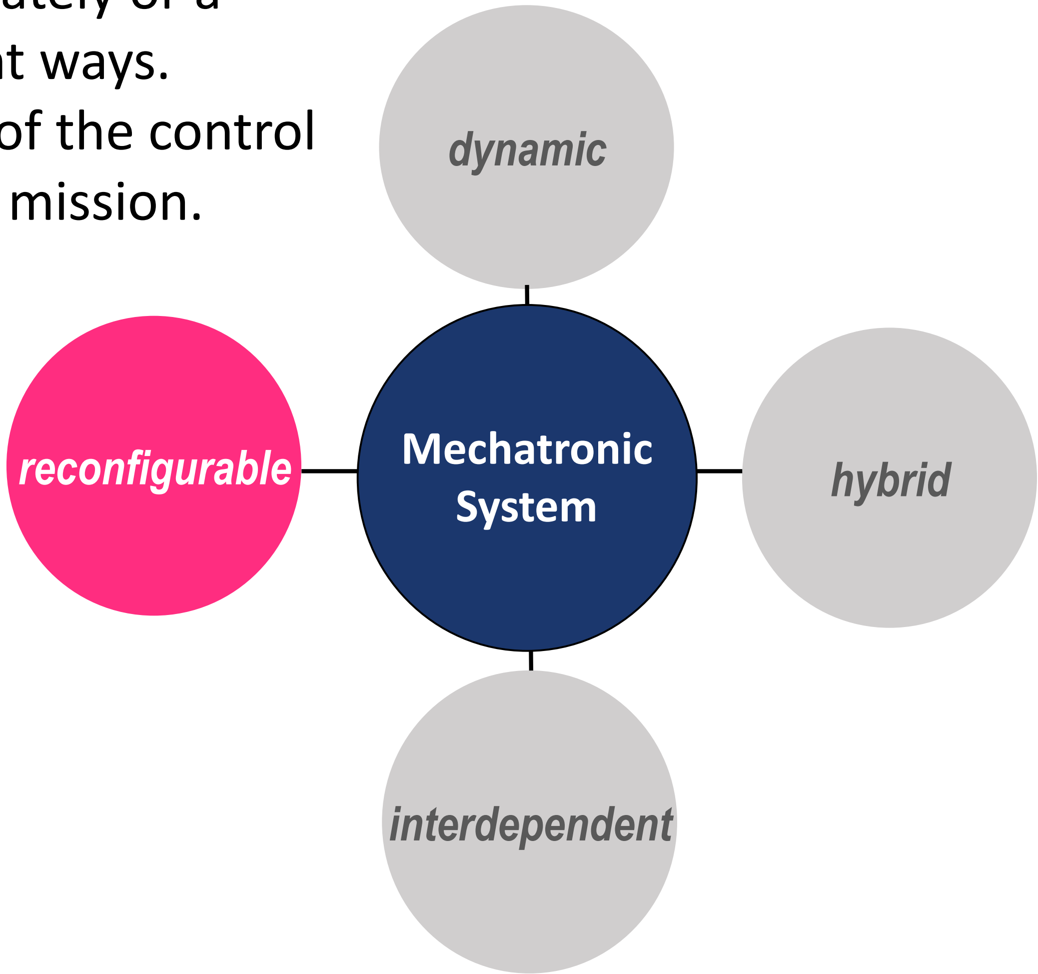


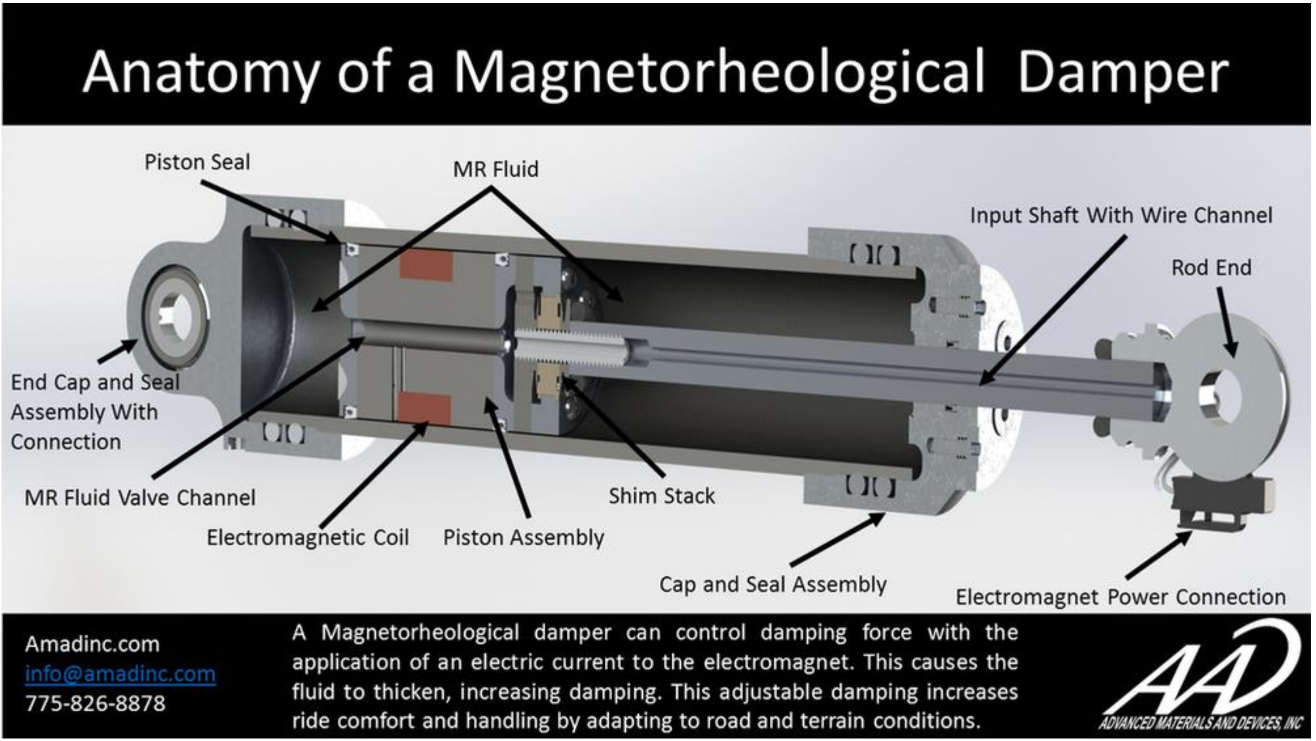
Fig. 5 Reconfiguration of the robotic arm. **a** 1 DOF, **b** 2 DOF, **c** 3 DOF configurations

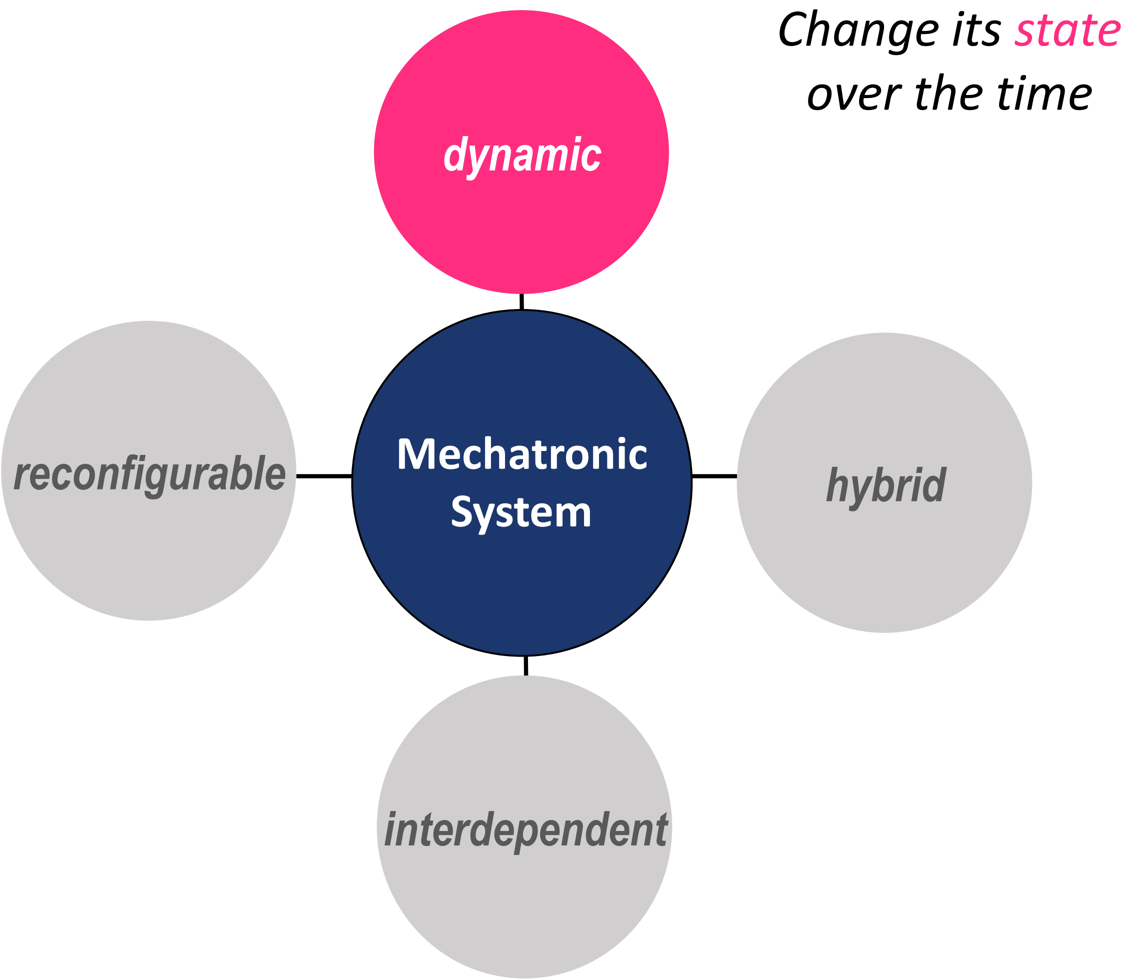
Assume *different functions alternatively* or a *function using its resources in different ways*



Mechatronic system - dynamic

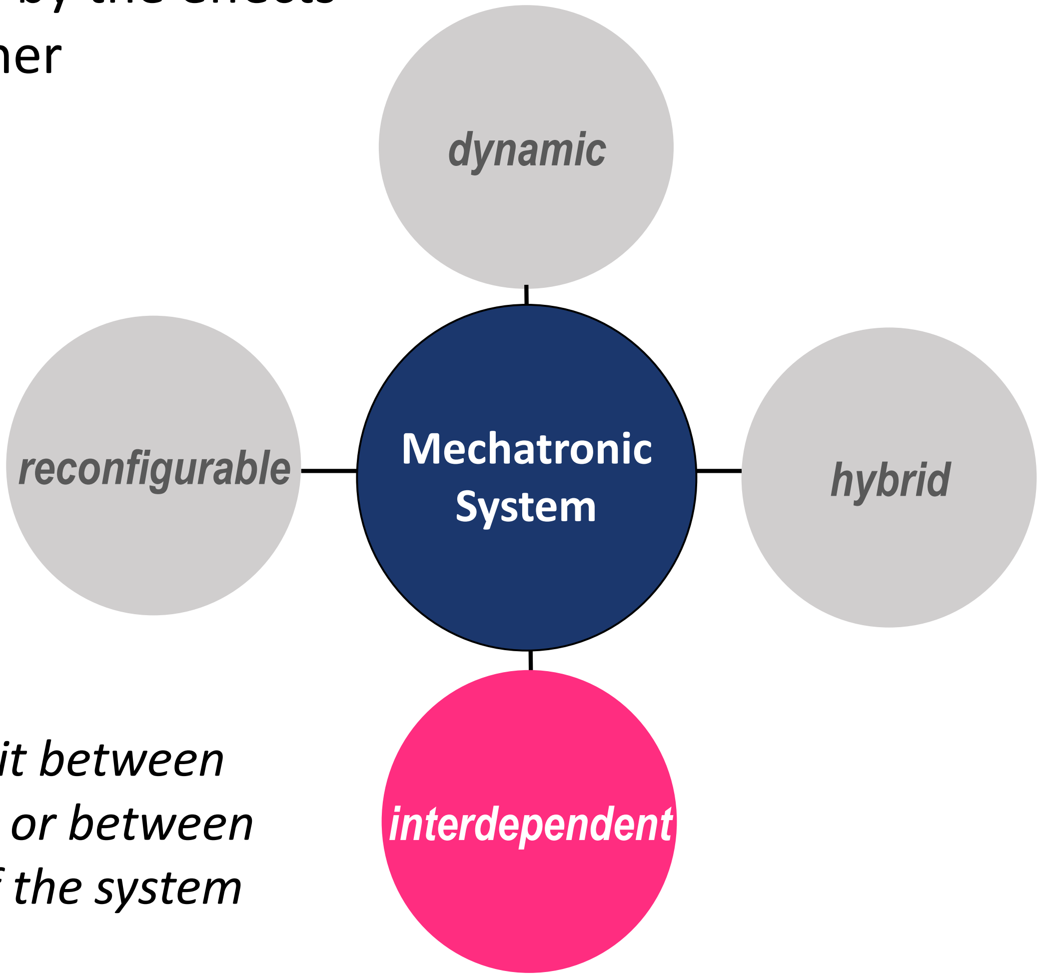
This characteristic lies in its aptitude to change its state during time.





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

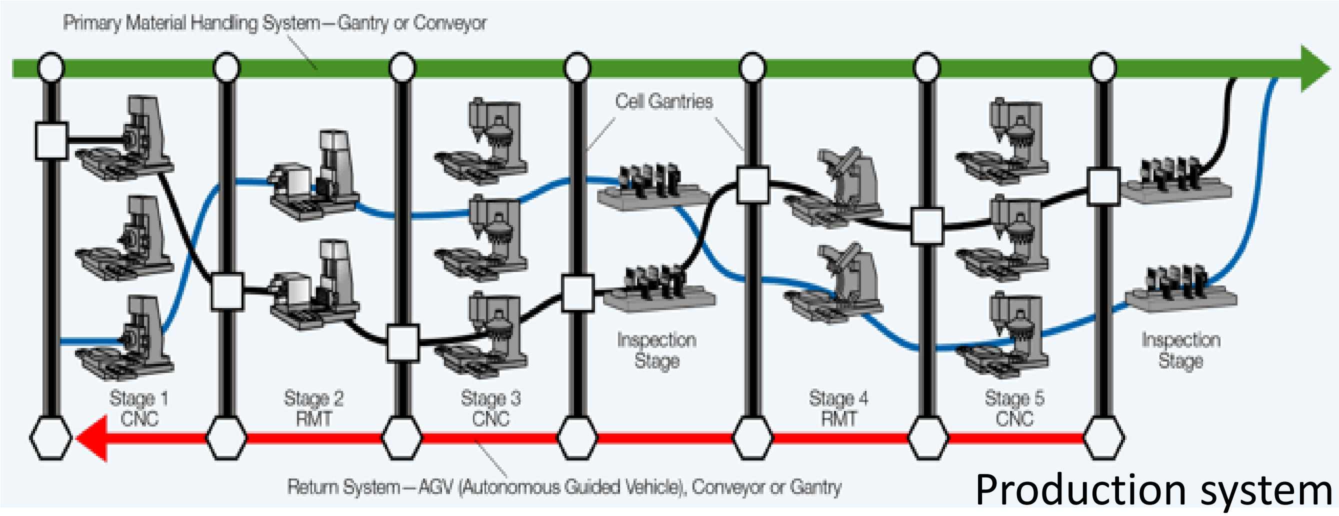
Mechatronics – constraints & benefits

- 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].

Examples of mechatronic systems

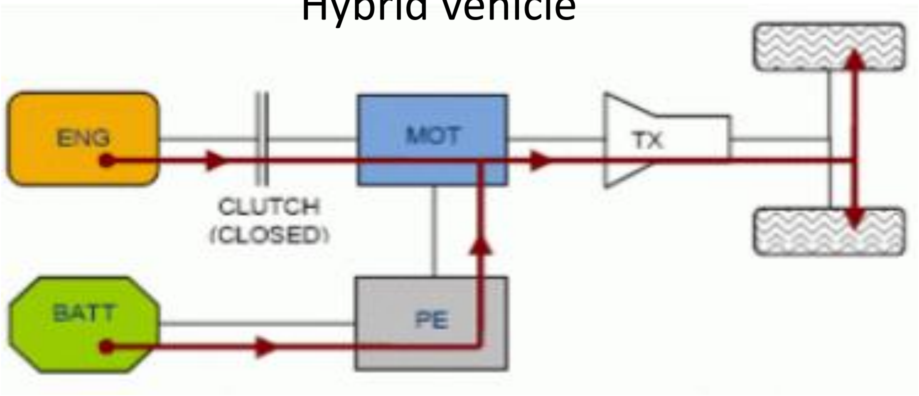


Production system

Landing system

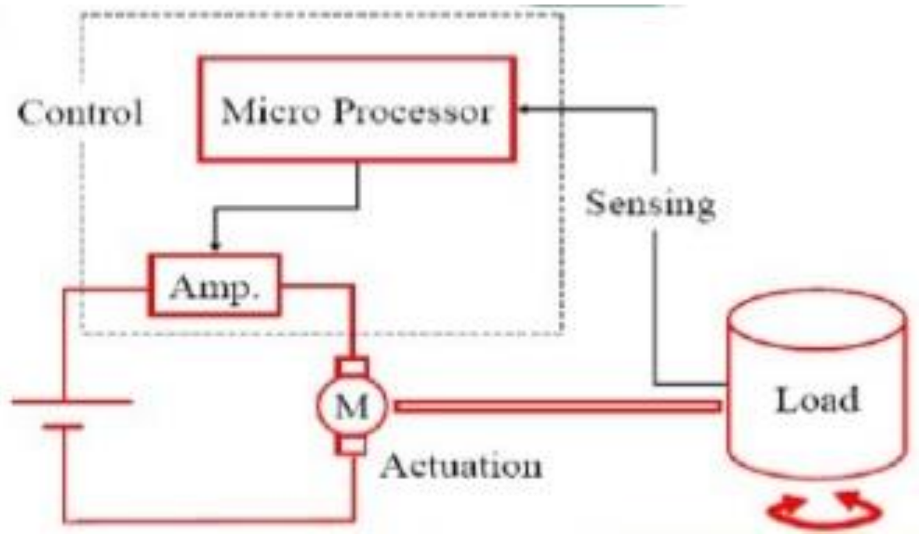
Amperemeter/Voltmeter…

Hybrid vehicle



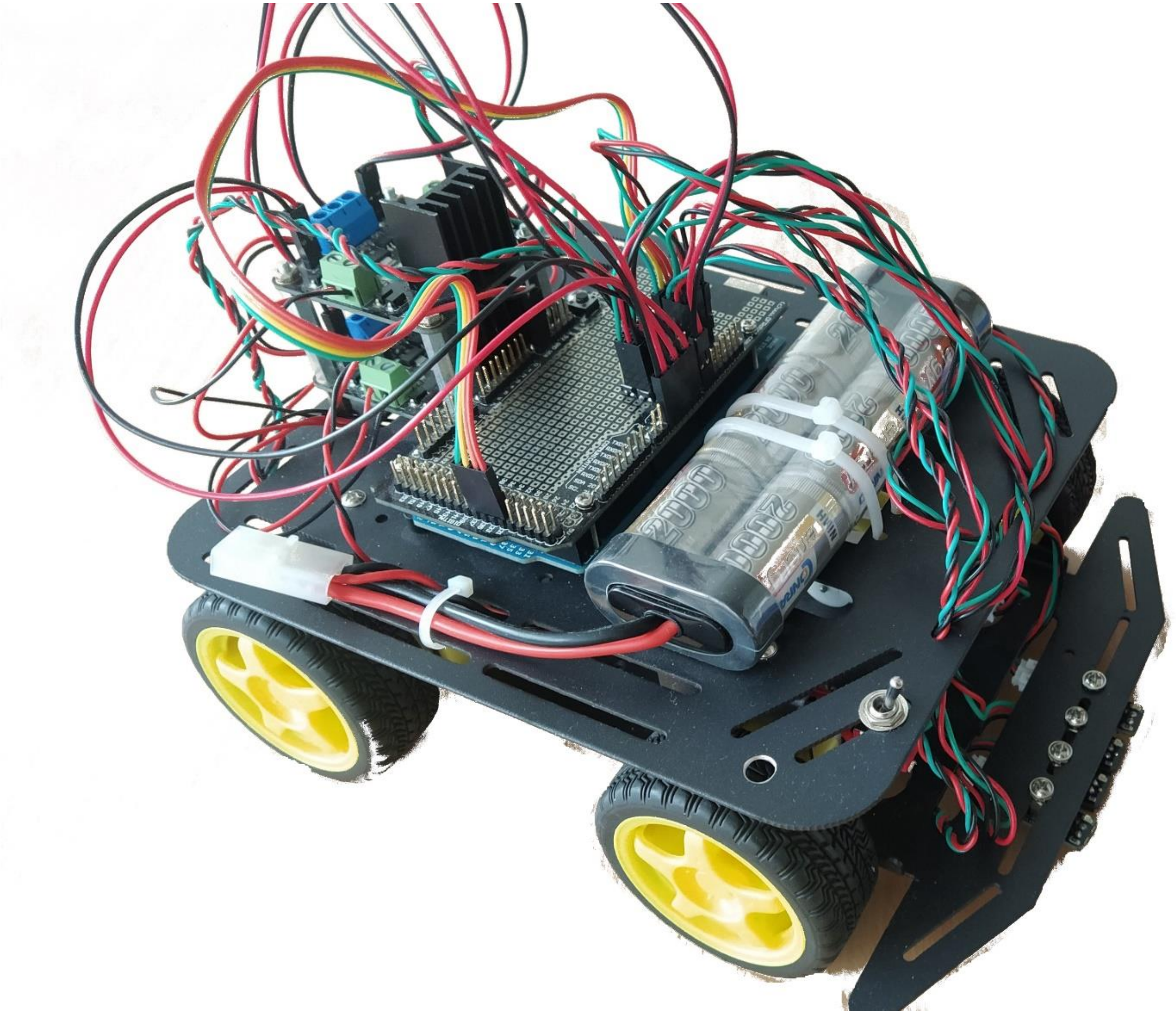
Examples of mechatronic systems

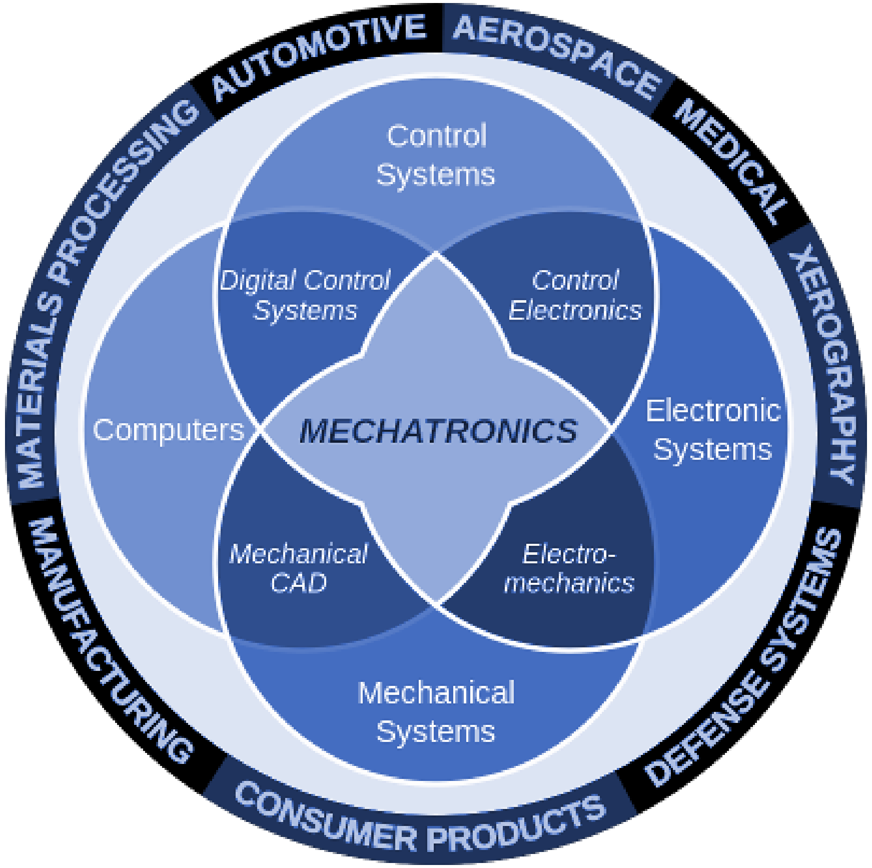
- System Requirements
  - Understanding of load sizes
  - Receptacle to hold clothes
  - 'Plumbing'
  - Agitation of drum
  - Ease of use, Reliability
  - Low Cost
- Actuators
  - AC or DC Motors
  - Water inlet/drain
- Sensors
  - Water level
  - Load speed/balance
- Control
  - Choice depends on design



Exercise

- Find out which discipline is involved





Exercise

Spot which system is NOT mechatronic

Computer

Drone

Car

Consumer Electronics

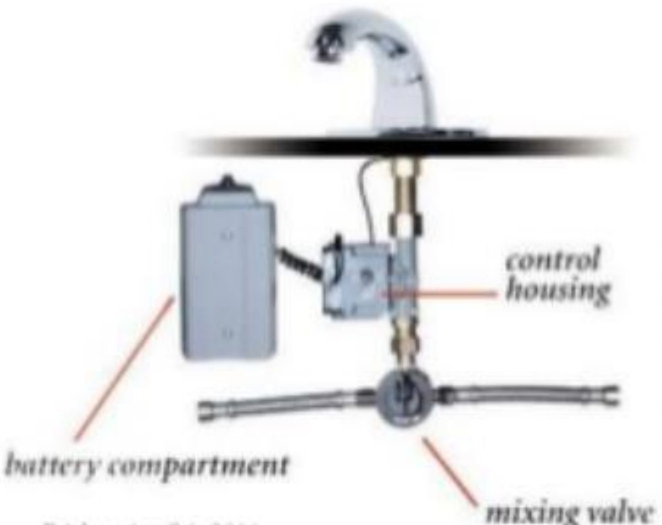
MEMS

Ski bindings

Exercise

Sanitation Applications

System Uses



Advantages

Friday, April 1, 2016

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.

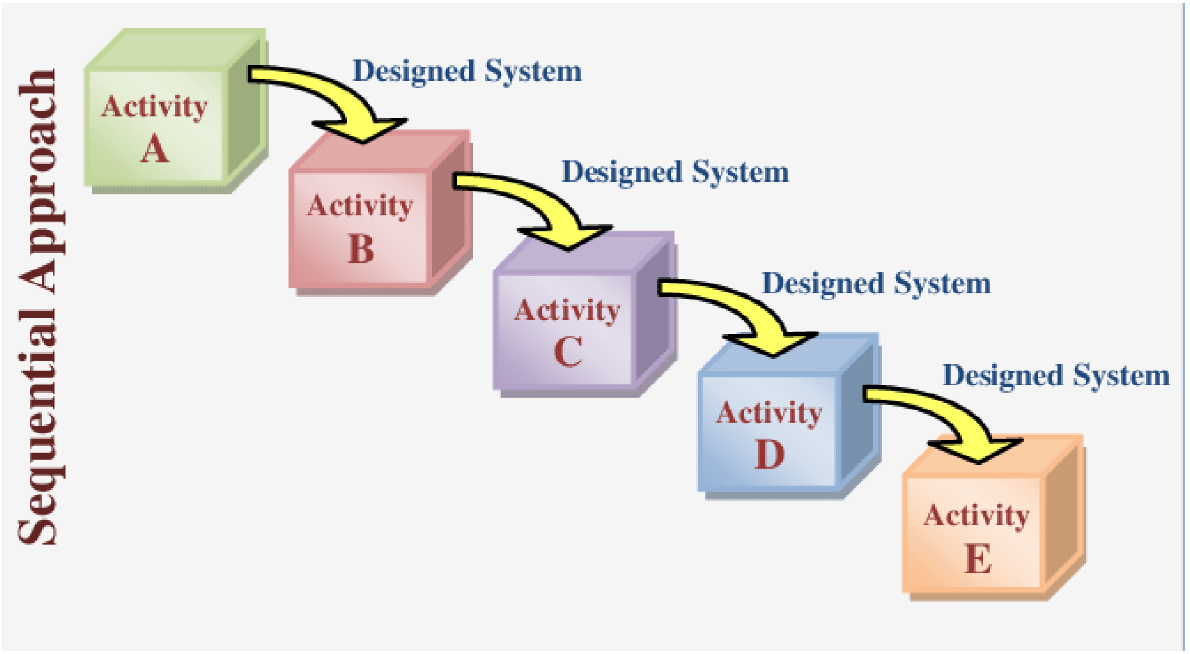
Cross-disciplinary: In this process, one discipline is examined from the perspective of another discipline.

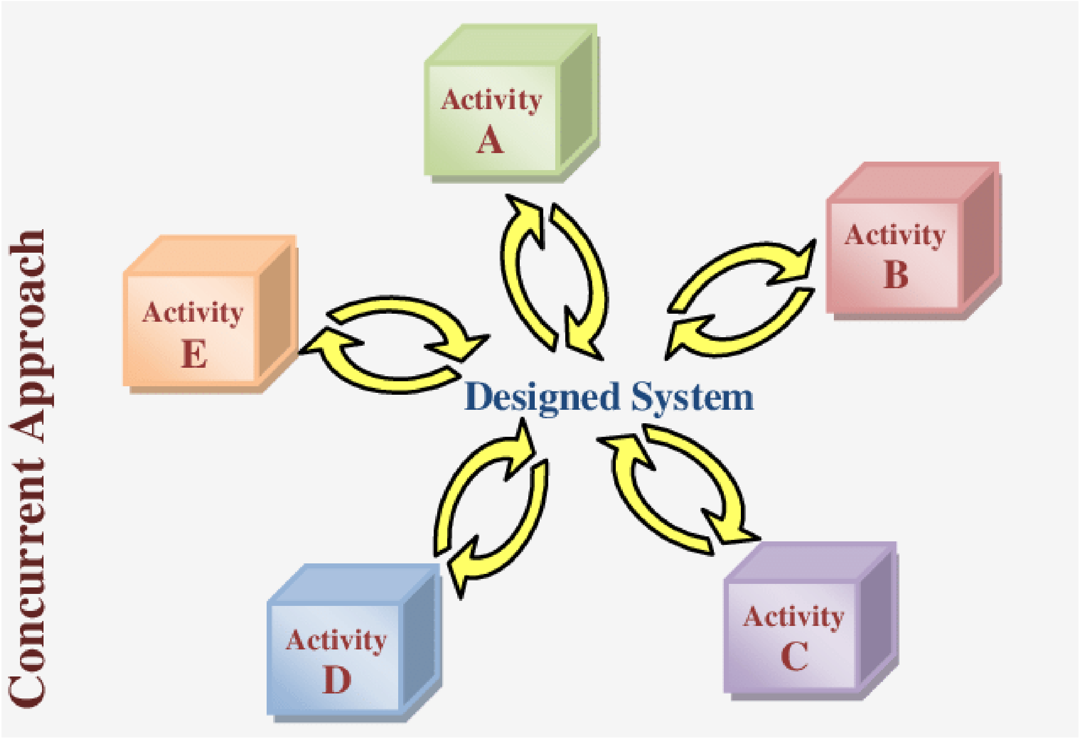
Inter-disciplinary: This is an integrative process involving two or more disciplines simultaneously to bear on a problem

Mechatronic vs. Multidisciplinary

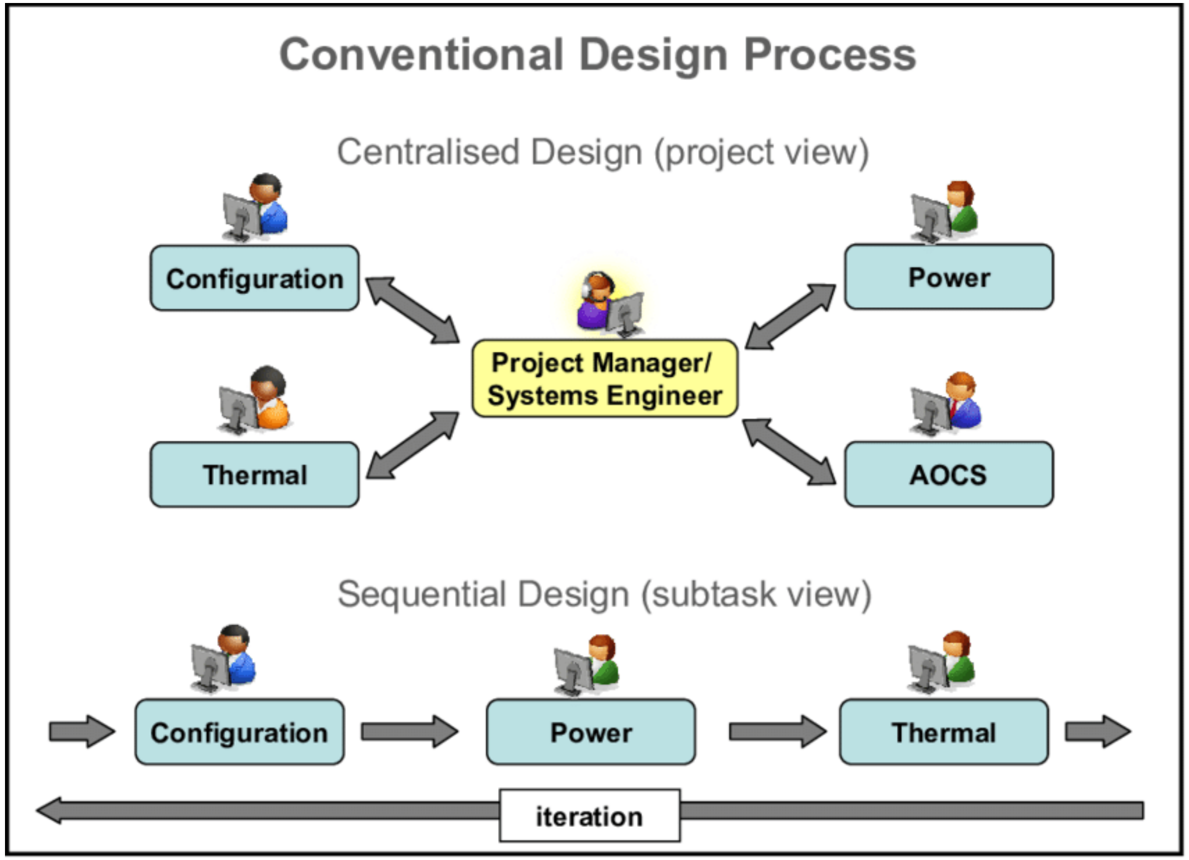
- The difference between a mechatronic system and a multidisciplinary system is not the constituents, but rather the order in which they are designed.
- Multidisciplinary system design employed a sequential design-by-discipline approach.
- Mechatronic design methodology is based on a concurrent (instead of sequential) approach to discipline design, resulting in products with more synergy.

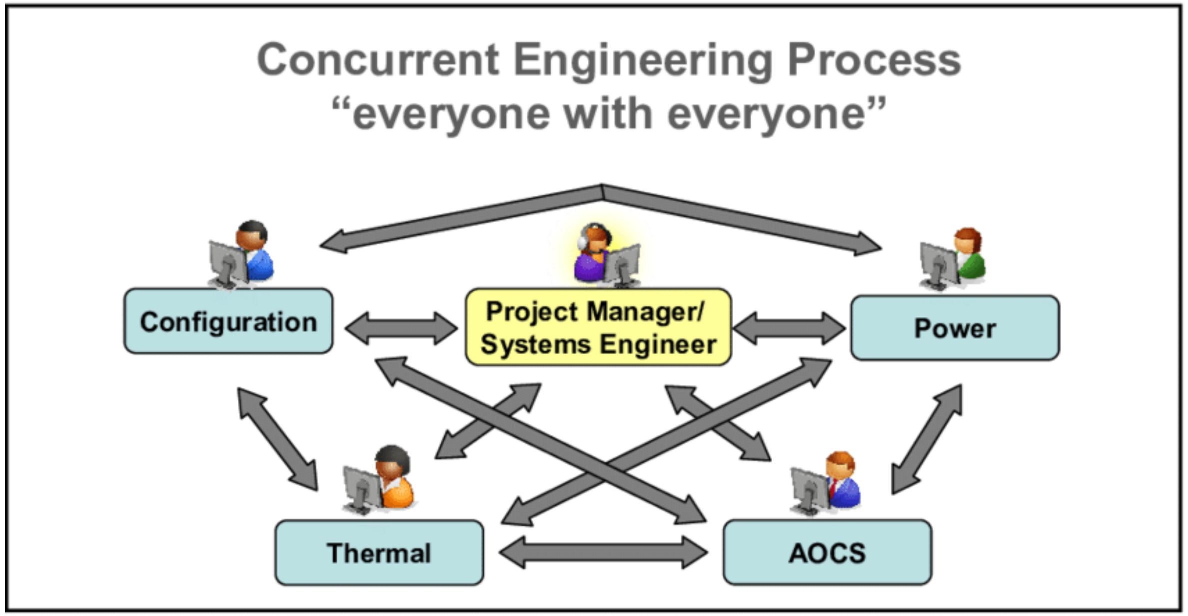
Sequential vs. Concurrent Engineering

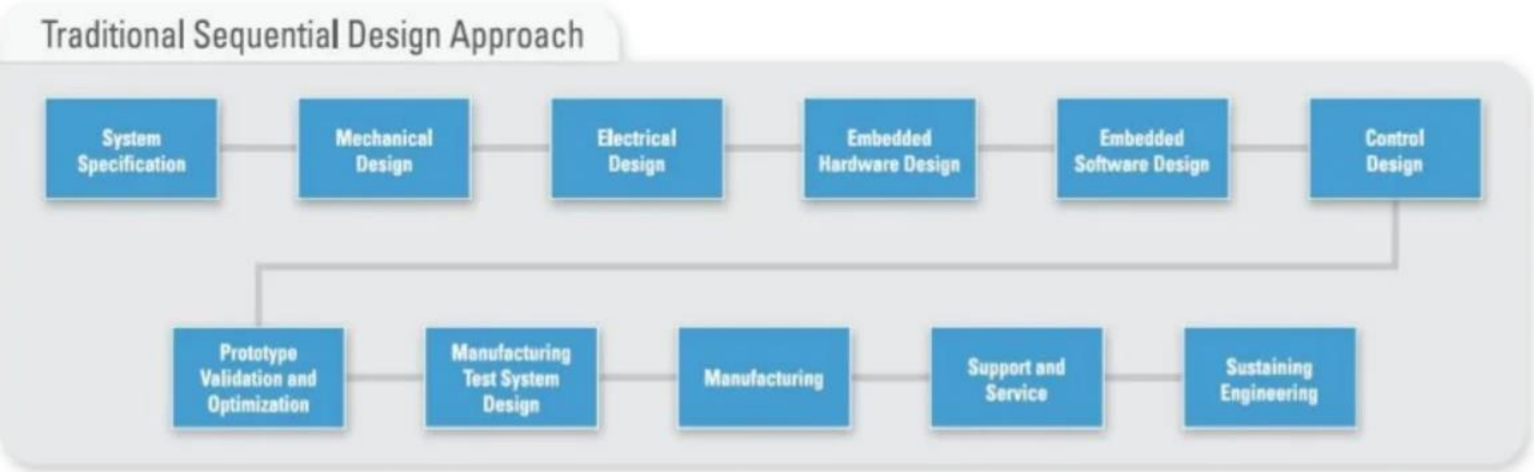


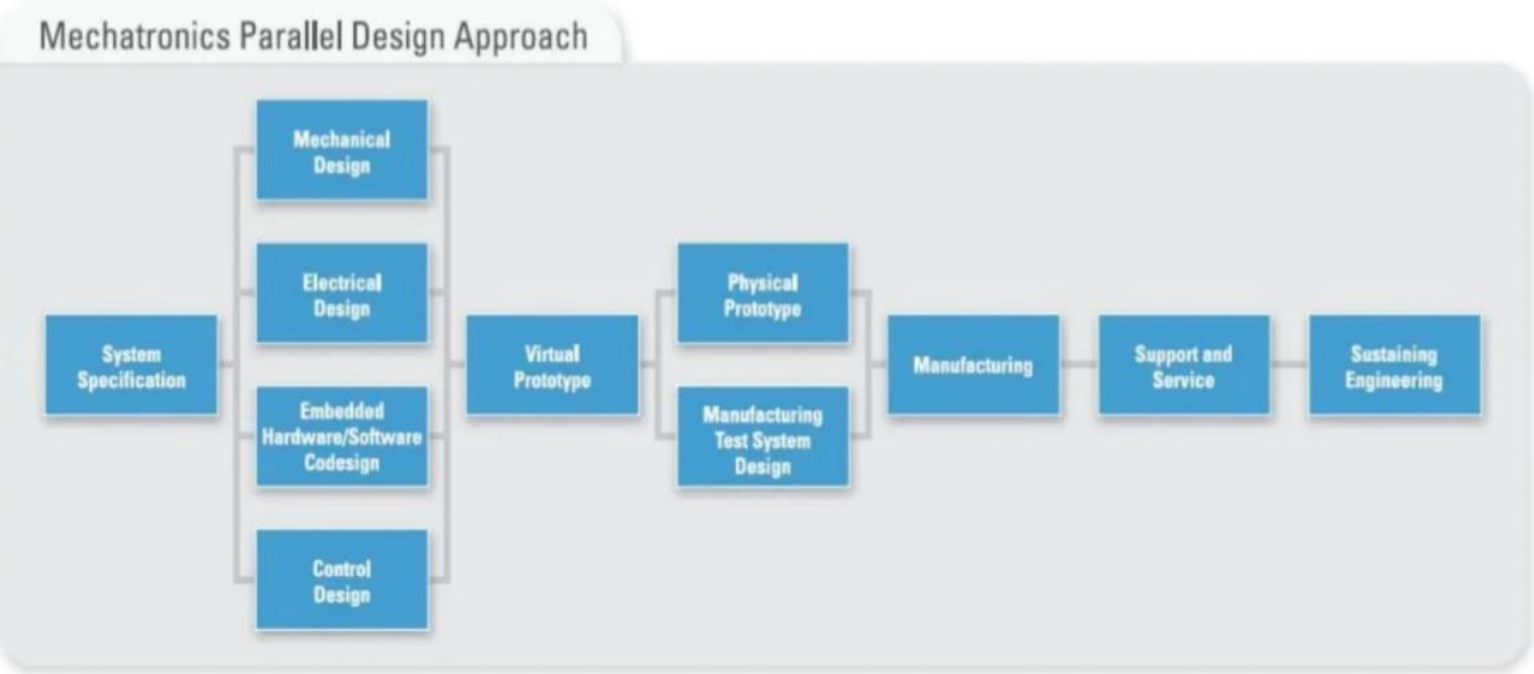


Conventional vs. Concurrent Engineering






Traditional Sequential Design Approach
System Specification
Mechanical Design
Electrical Design
Embedded Hardware Design
Embedded Software Design
Control Design
Prototype Validation and Optimization
Manufacturing Test System Design
Manufacturing
Support and Service
Sustaining Engineering


Mechatronics Parallel Design Approach
System Specification
Mechanical Design
Electrical Design
Embedded Hardware/Software Codesign
Control Design
Virtual Prototype
Physical Prototype
Manufacturing Test System Design
Manufacturing
Support and Service
Sustaining Engineering

Conventional Design vs. Mechatronics Design

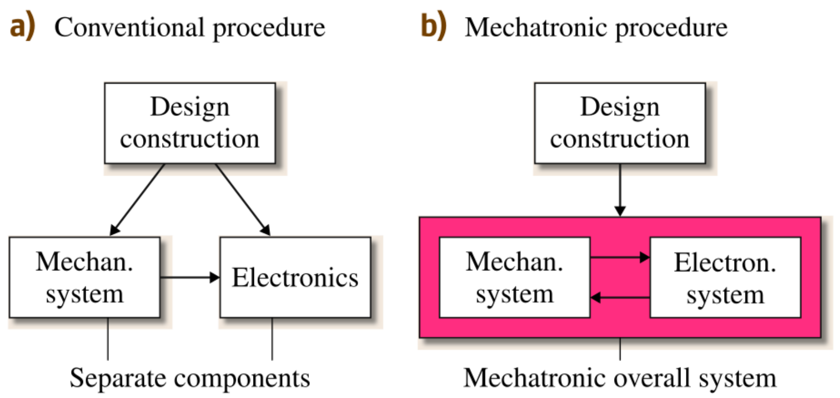


Fig. 19.4a,b Interrelations during the design and construction of mechatronic systems

Conventional Design	Mechatronics Design
Bulky componentized system	Compact integrated systems
Cable problem	Bus or wireless communication
Simple control • Stiff construction • Feedback control, linear (analog) control • Precision through narrow tolerance • Non measurable quantities changes arbitrarily • Simple monitoring • Fixed abilities	Integration by information processing (software) • Elastic construction with damping by electronic feedback • Programmable feedback, (nonlinear) digital control • Precision through measurement and feedback control • Control of non-measurable estimated quantities • Supervision over fault diagnosis • Learning ability
Centralized processing & control	Hybrid control: Adaptative and/or Multi-architecture control (e,g, Centralized, Centralized processing & control Decentralized and Ditributed)
Constant speed drives	Variable speed drives
Mechanical Systems	Mechanical, Computer, Electronic, Software, and/or Network interface and/or control of physical, chemical, biological and/or neurological systems

Sequential vs. Concurrent Engineering

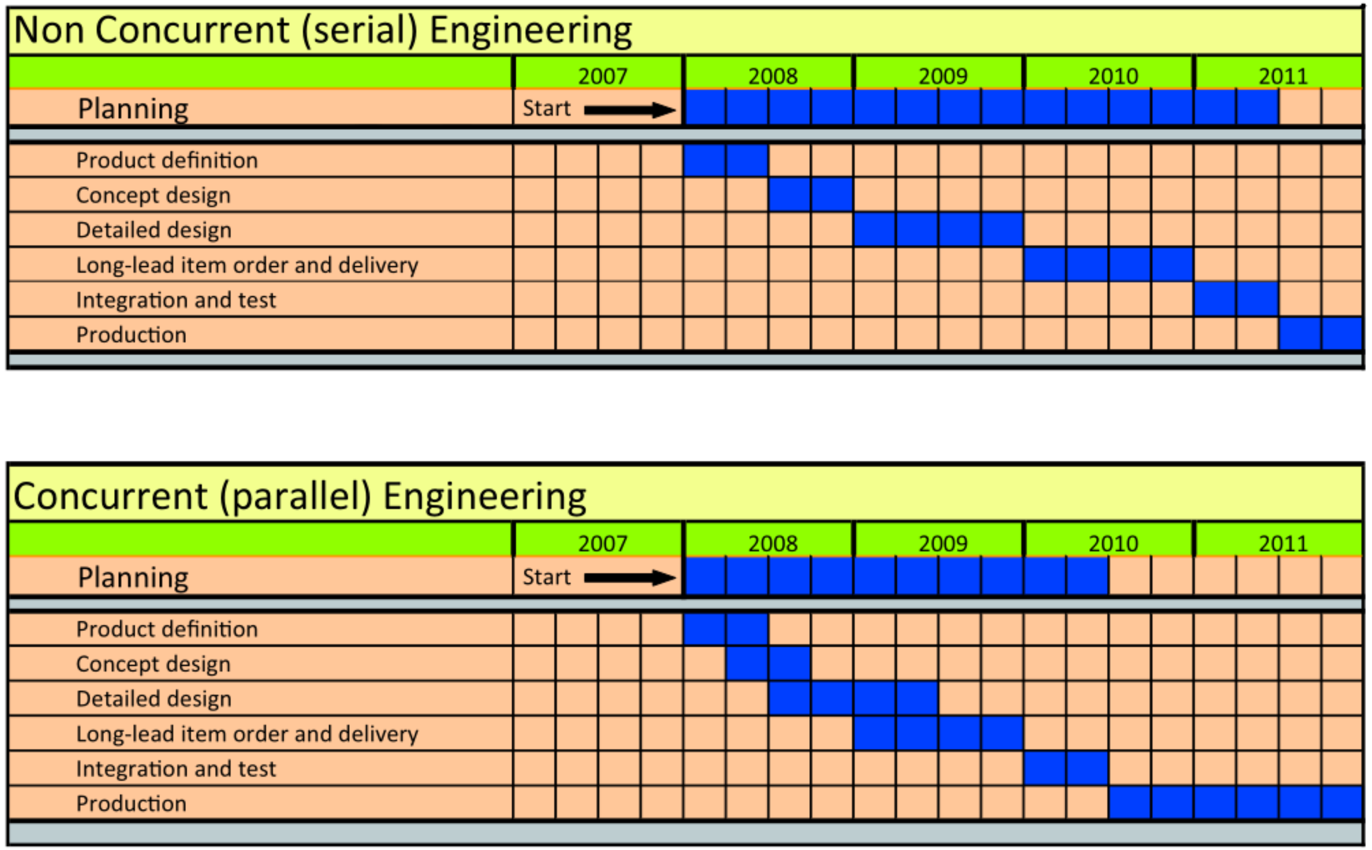
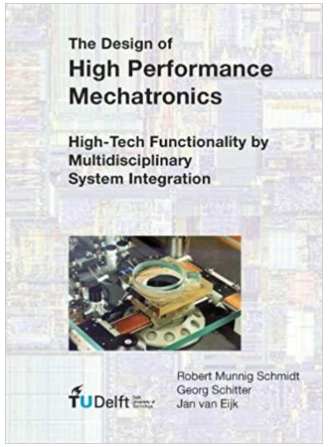
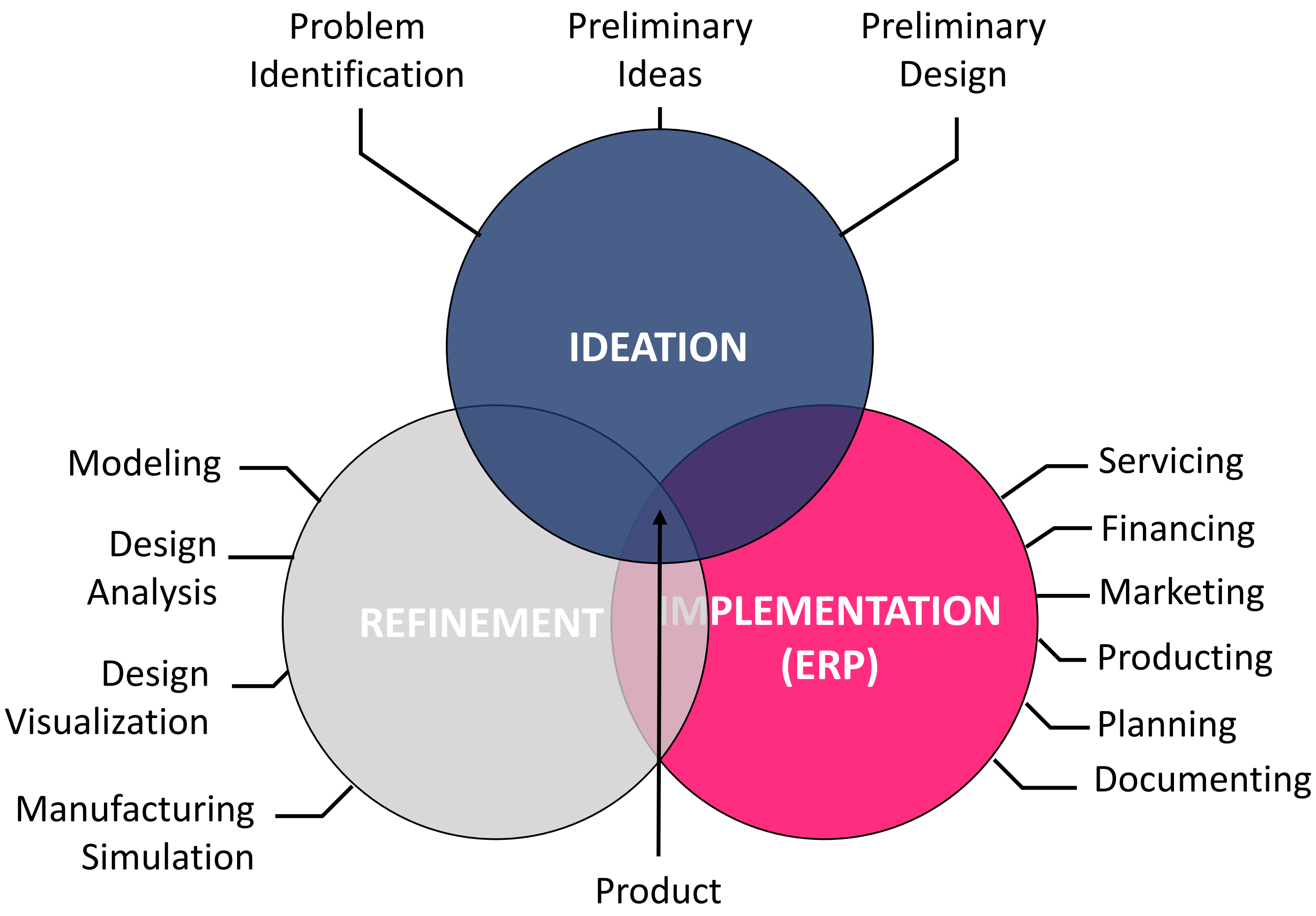


Figure 1.24: Concurrent engineering results in shorter lead times by working in parallel on different phases of the project. It requires a high discipline in communication and change control.



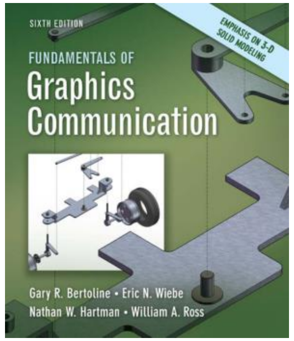
The Design of High Performance Mechatronics, Robert Munnig Schmidt

Concurrent Engineering



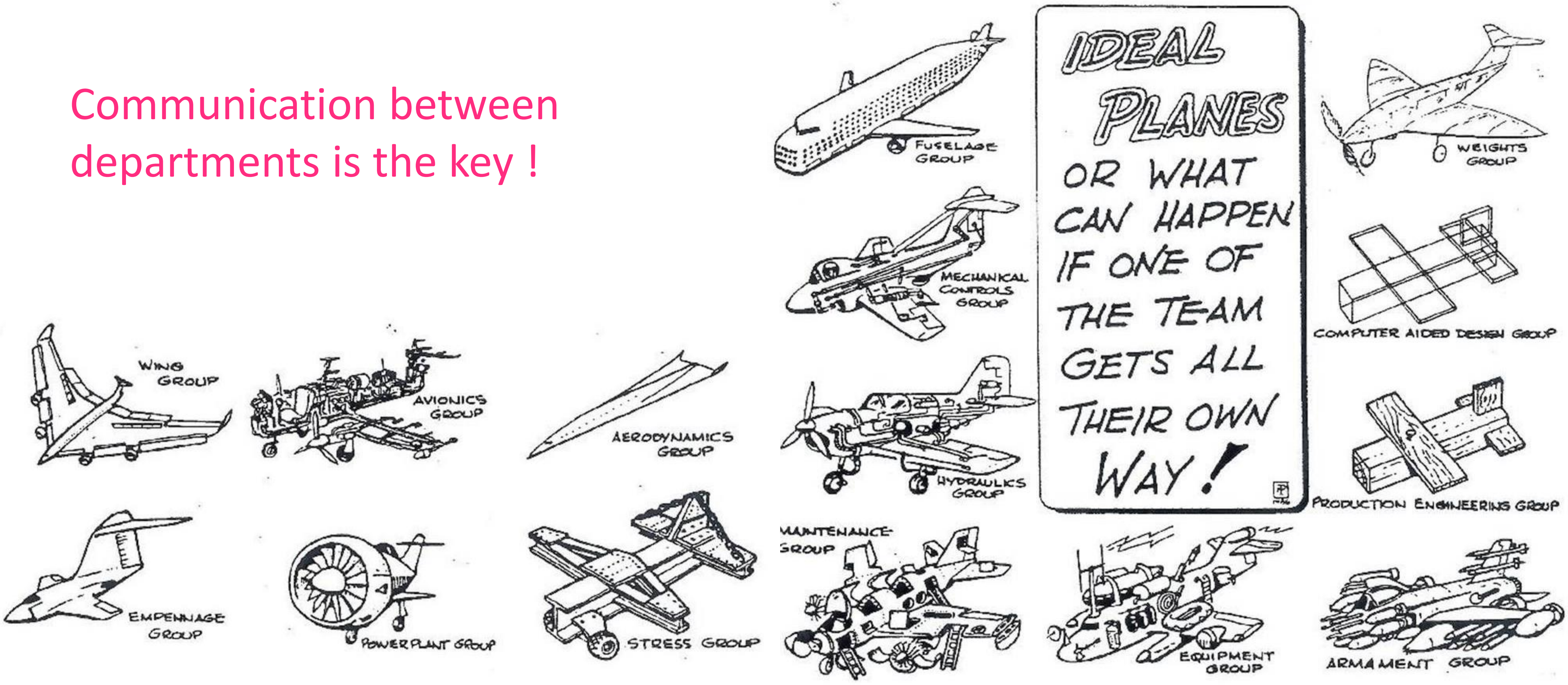
Through the **sharing of information**, it is possible for all areas of the enterprise to work simultaneously on their particular needs as the product is being developed

Bartoline, G.&Wiebe, E.(2005). Fundamentals of graphics communication. (4th ed.), Boston, McGraw-Hill



Concurrent Engineering

Communication between departments is the key !



Concurrent Engineering

Epic Fails in Mechatronics design

Google glass (2013-2015)

- $1,500 for pair of glasses
- Public backlash over privacy concerns
- Product looked like “dorks”

Leasson learned : Product designers need to solve problems that customers care about and are willing to pay to resolve.

Juicero Press (2017)

- $400 internet-connected juicer that used single-serving packets of chopped organic fruits
- Over-engineered device, which mechanism delivered 4 tons of force
- Does a juice machine truly need to be connected to the internet?

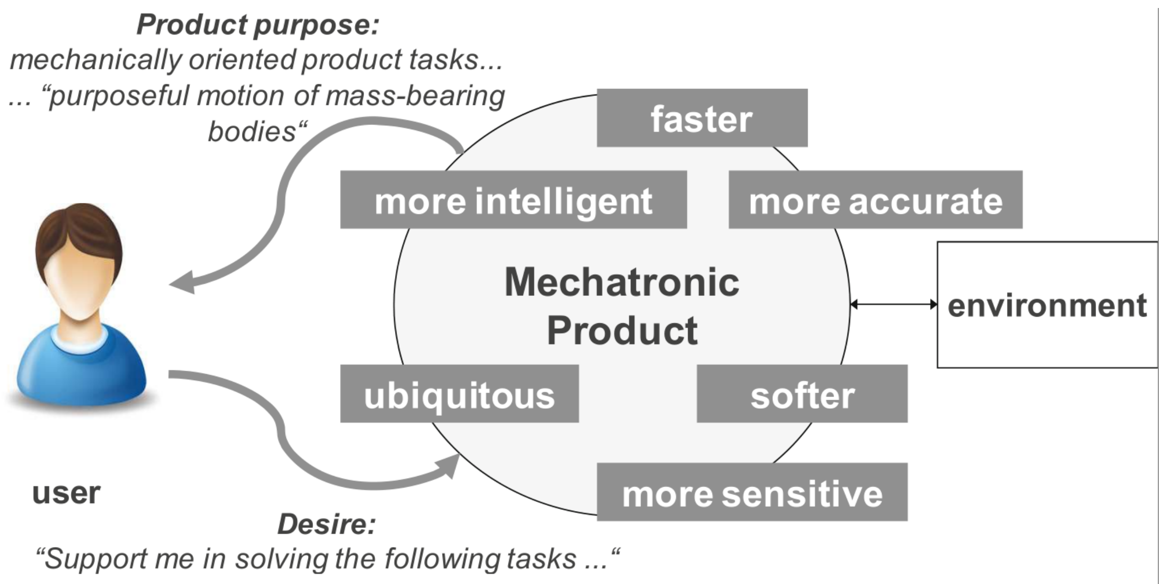
Leasson learned : Successful innovation is not about creating solutions in search of a problem. Seek “simple” solutions for even “complex” problems.

Product-Oriented Perspective

Mechatronics Engineering is the

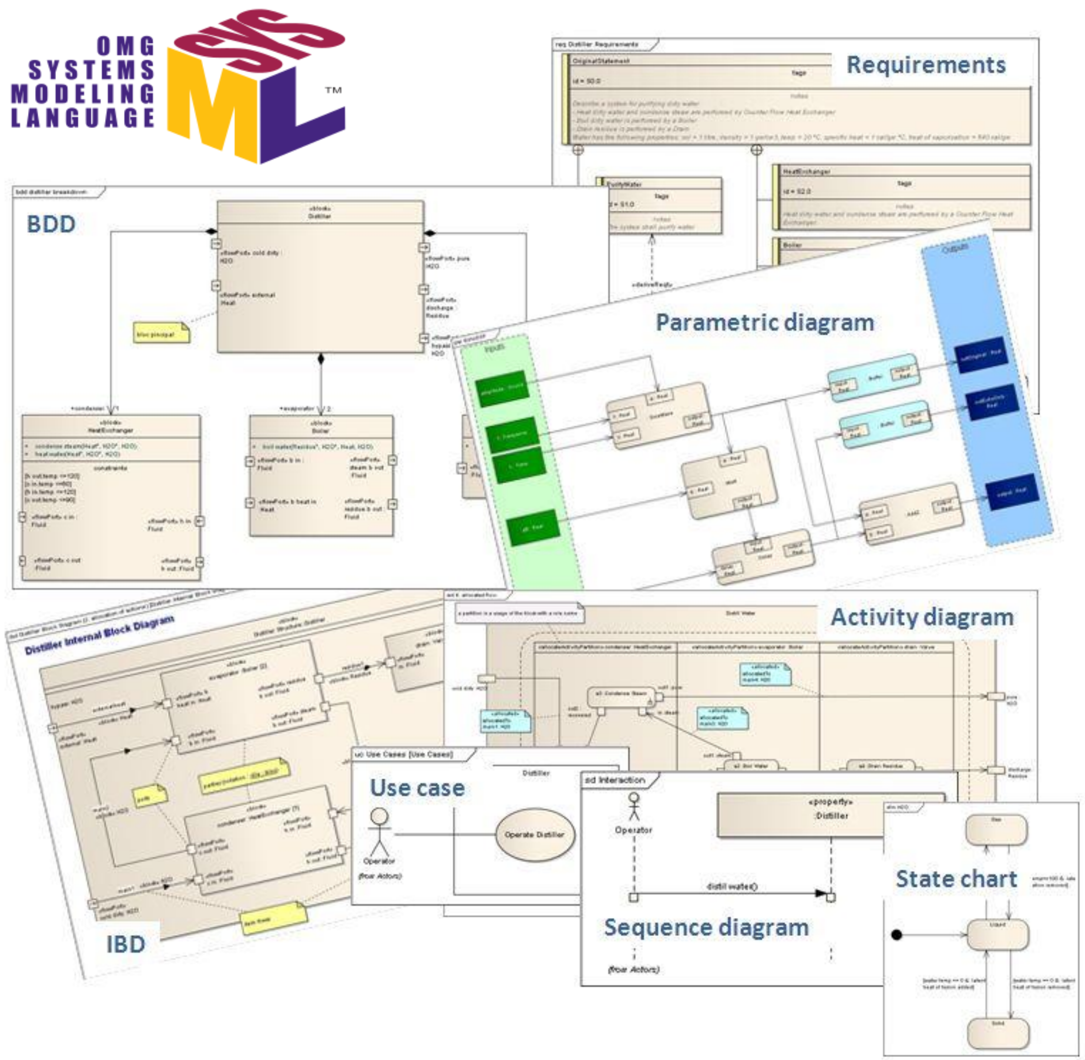
- Analysis
- Design
- Manufacturing
- Integration
- and maintenance

of mechanics with electronics through intelligent computer control.

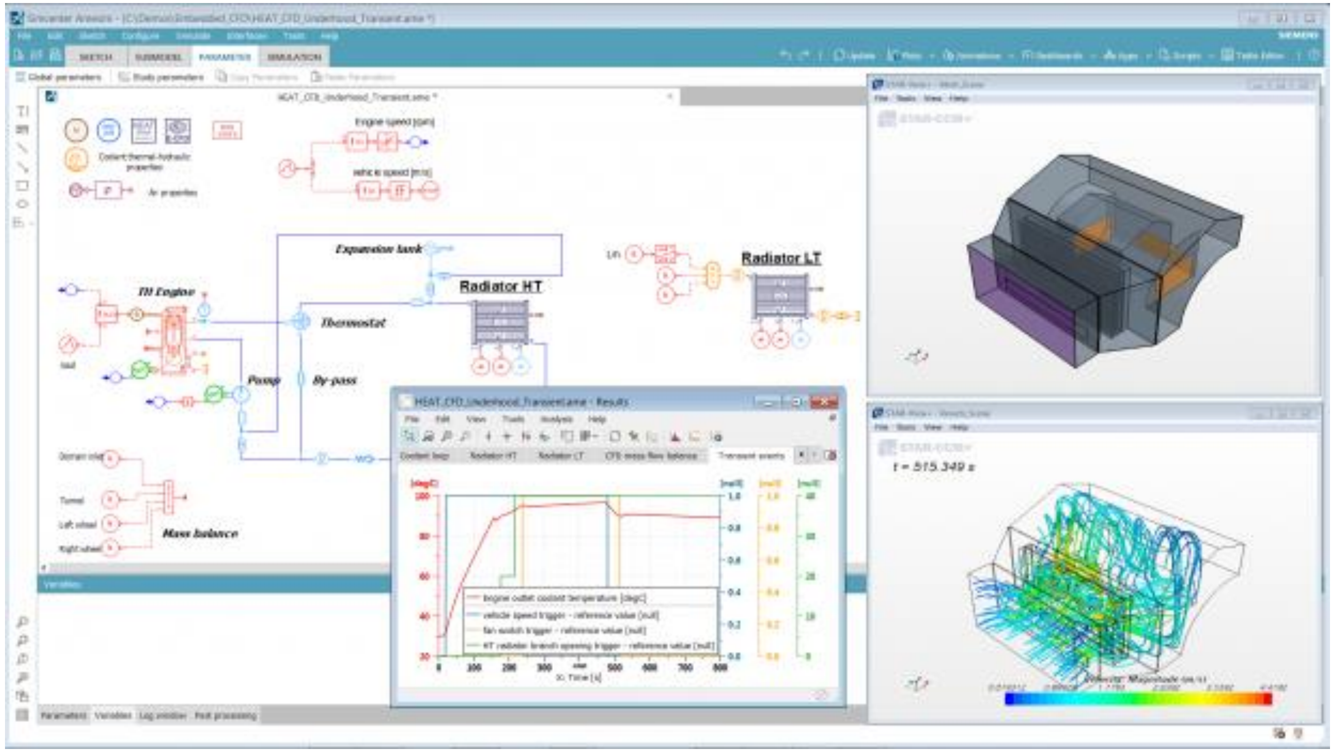


Mechatronic systems as products with exceptional attributes: external perspective

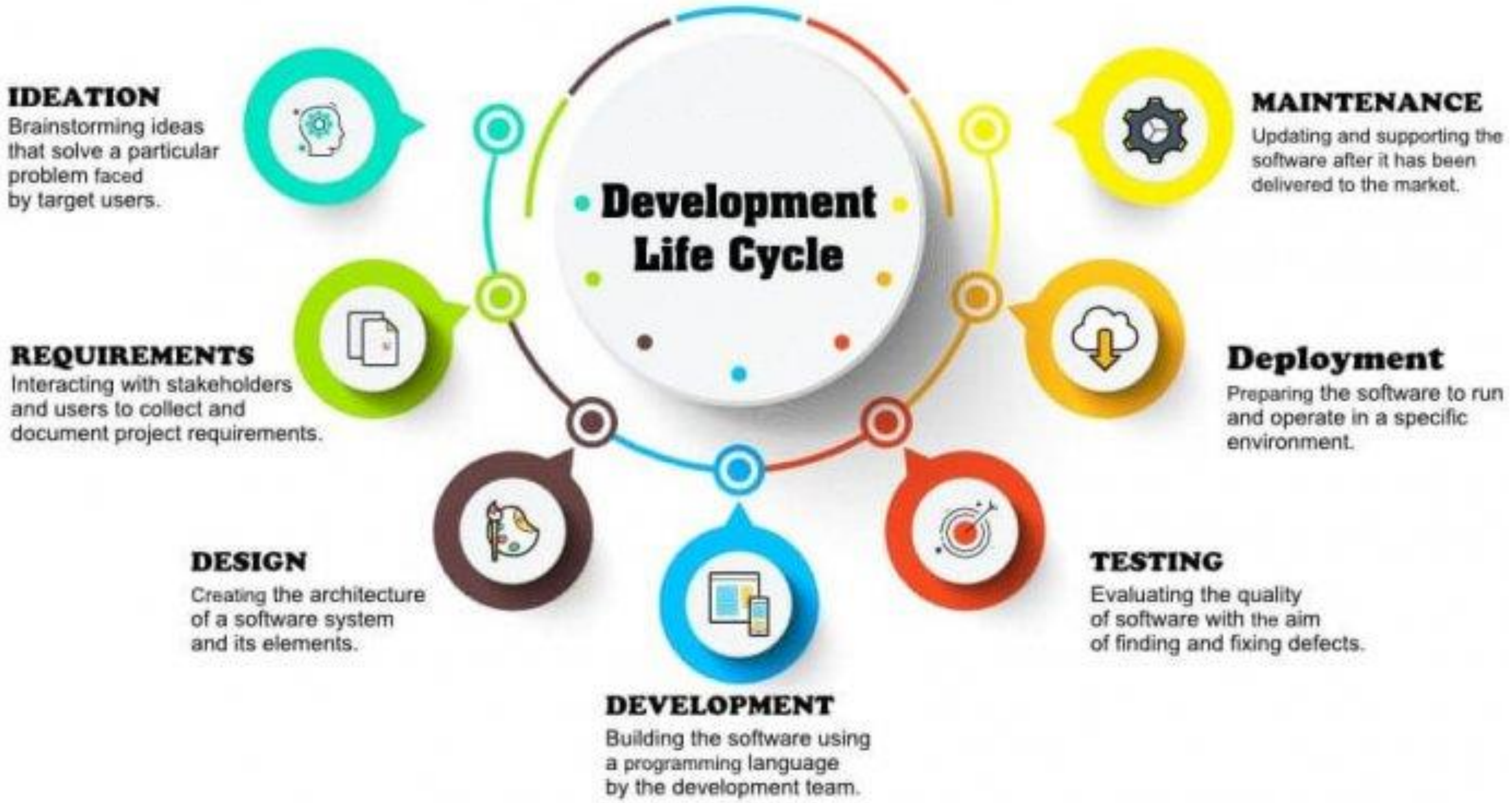
Tools



Simcenter AMEsim



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** :

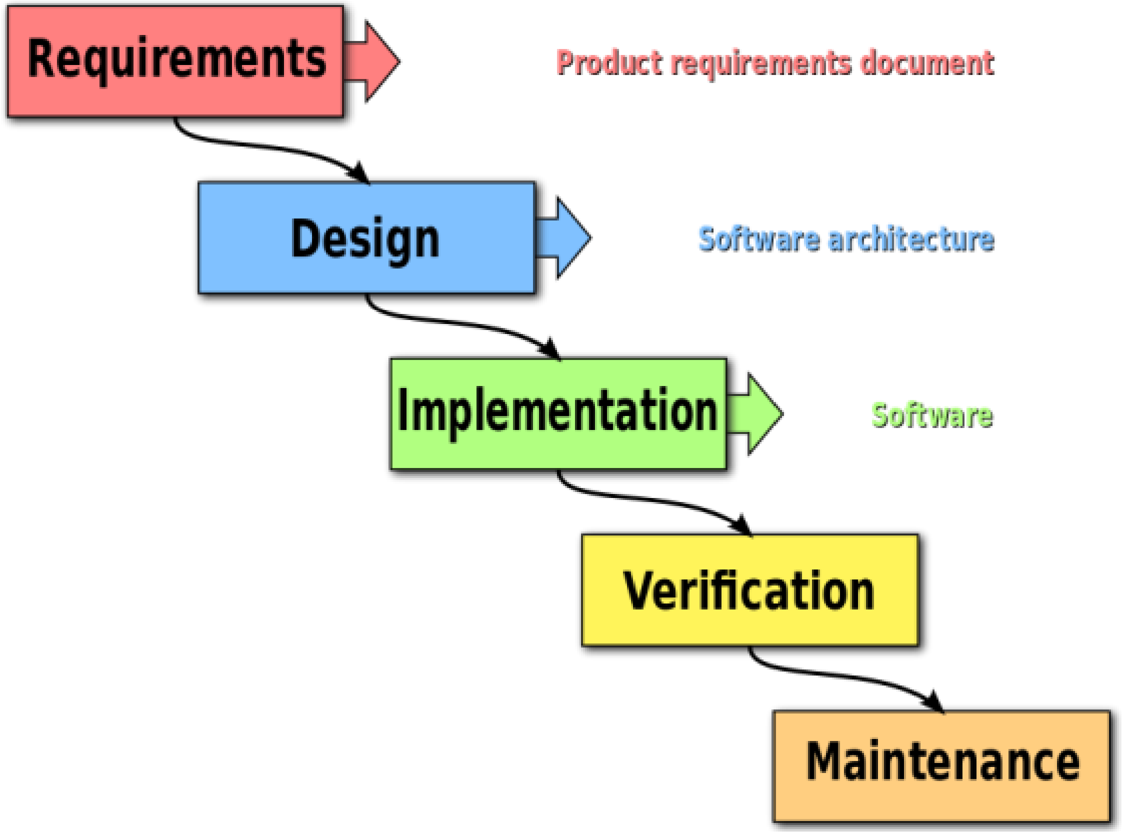
  - *The linear models (waterfall model, V-cycle) ;*

  - *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

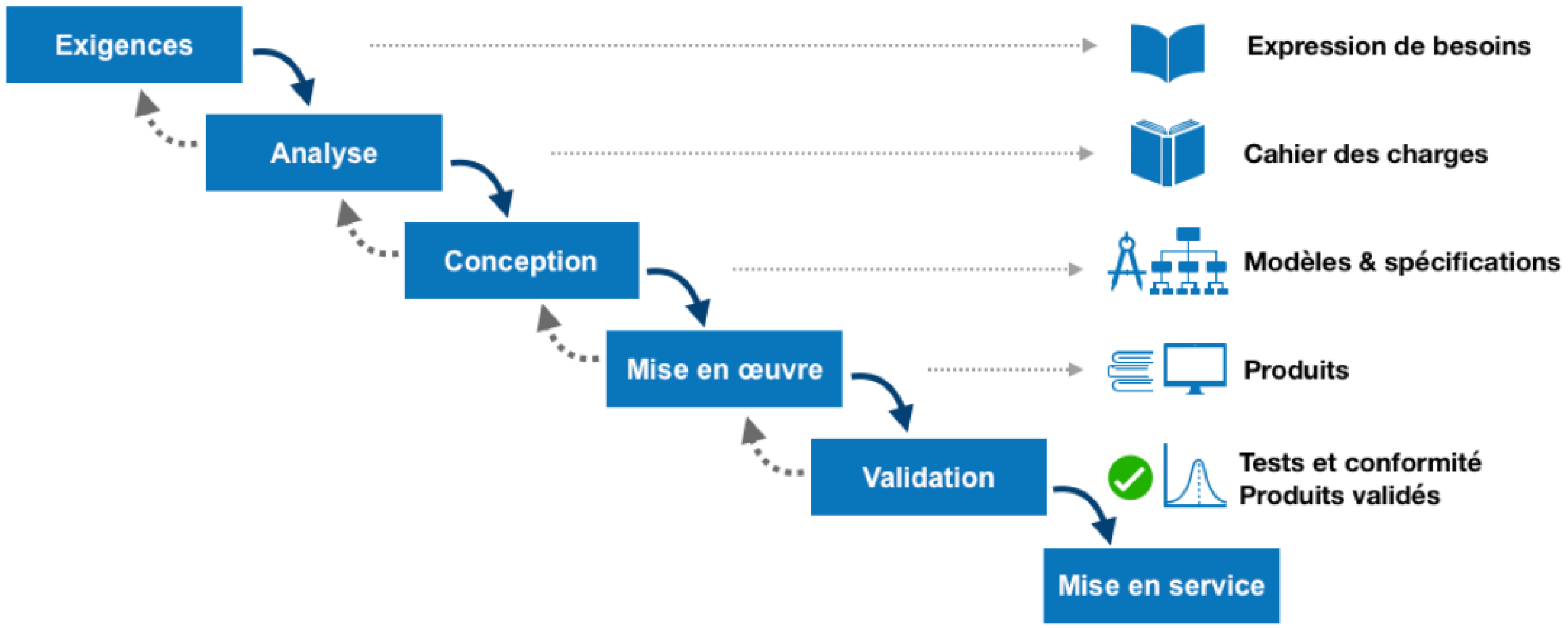
☺ adapted for designing simple products

☹ 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

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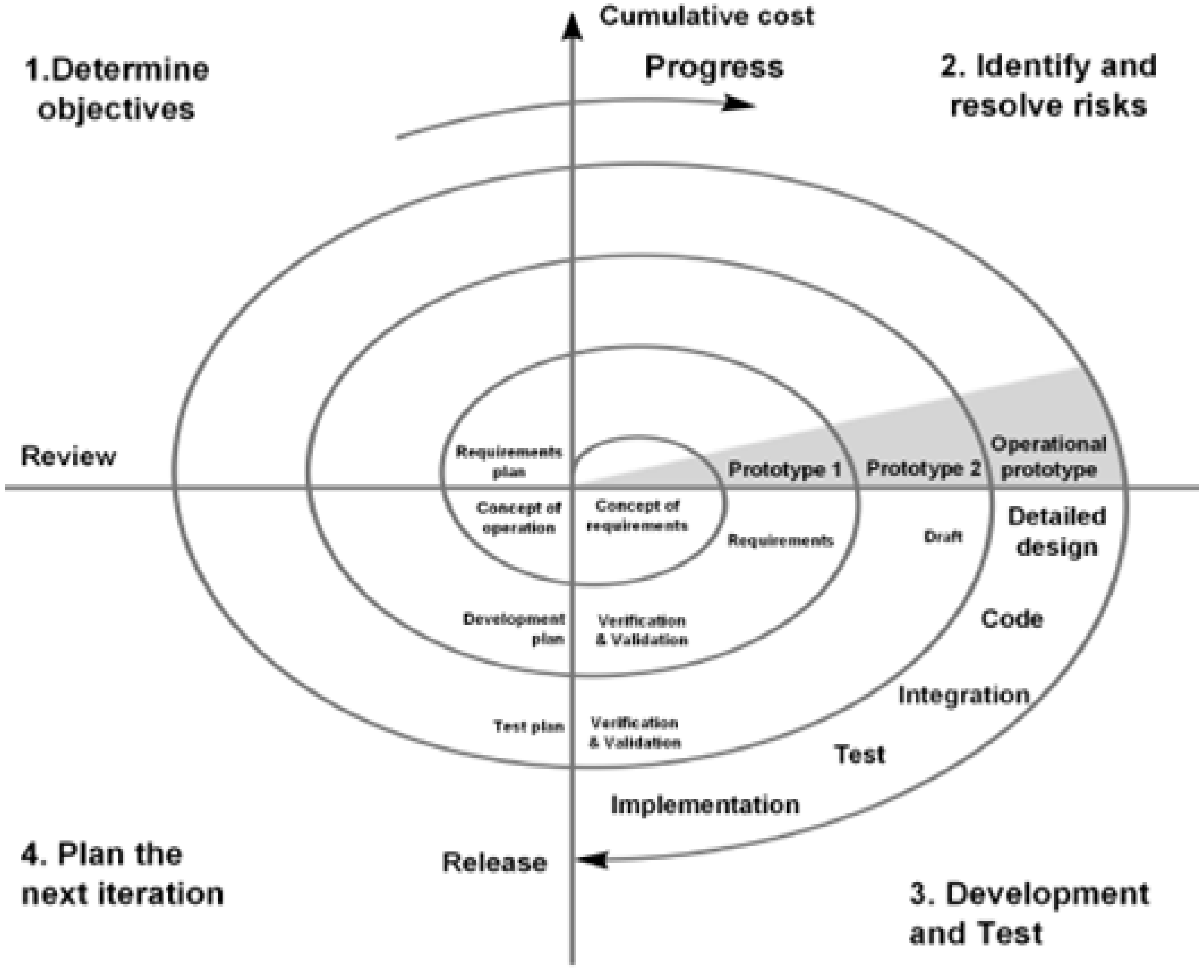
The **waterfall model** is a breakdown of project activities into linear sequential phases, where each phase depends on the deliverables of the previous one and corresponds to a specialisation of tasks.

Product life cycle: the 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

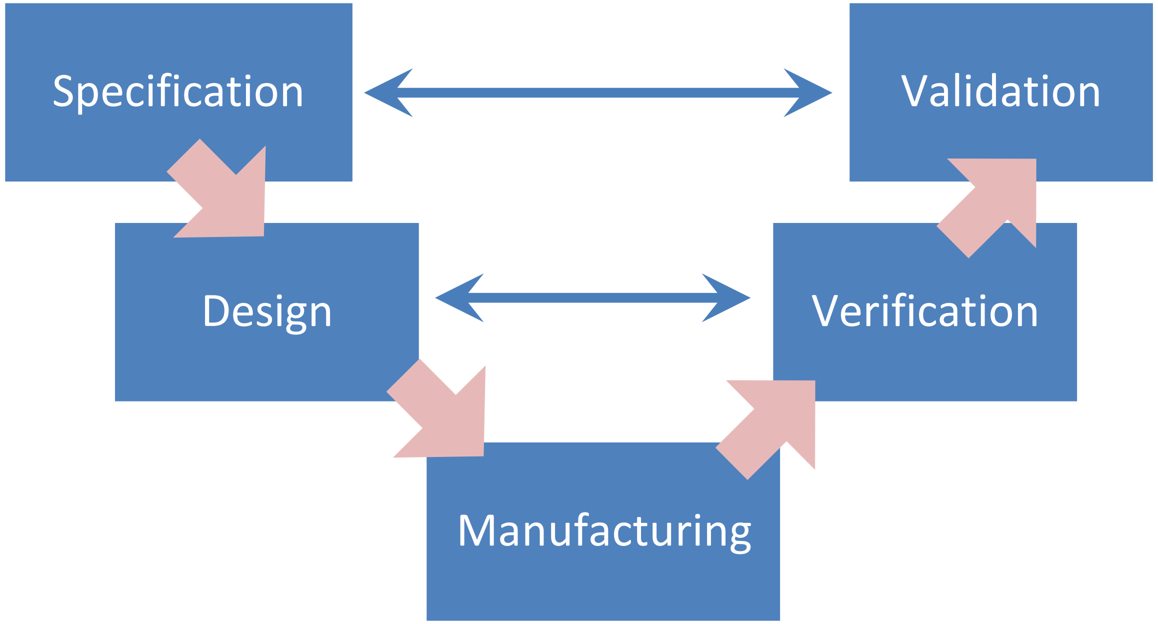
☹ time increase

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.

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

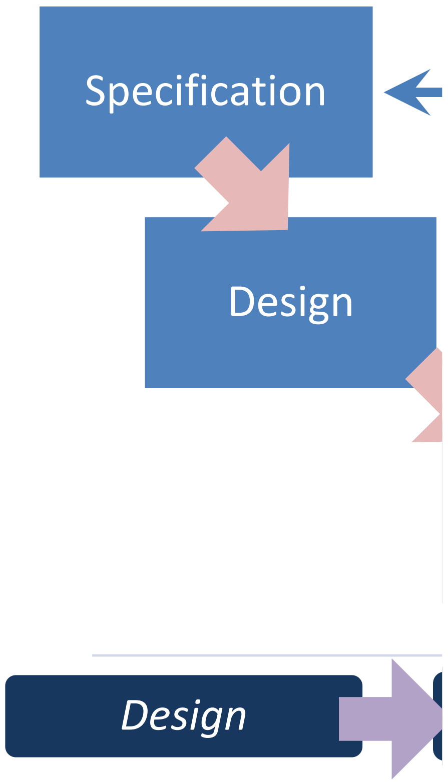


☺ an overall methodology with shared stages to the different technologies
☺ common terminology
☺ generalized to the development of complex systems
☹ maintenance and repair not taken into account

The 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.

Product life cycle: the V-cycle

- Design phase



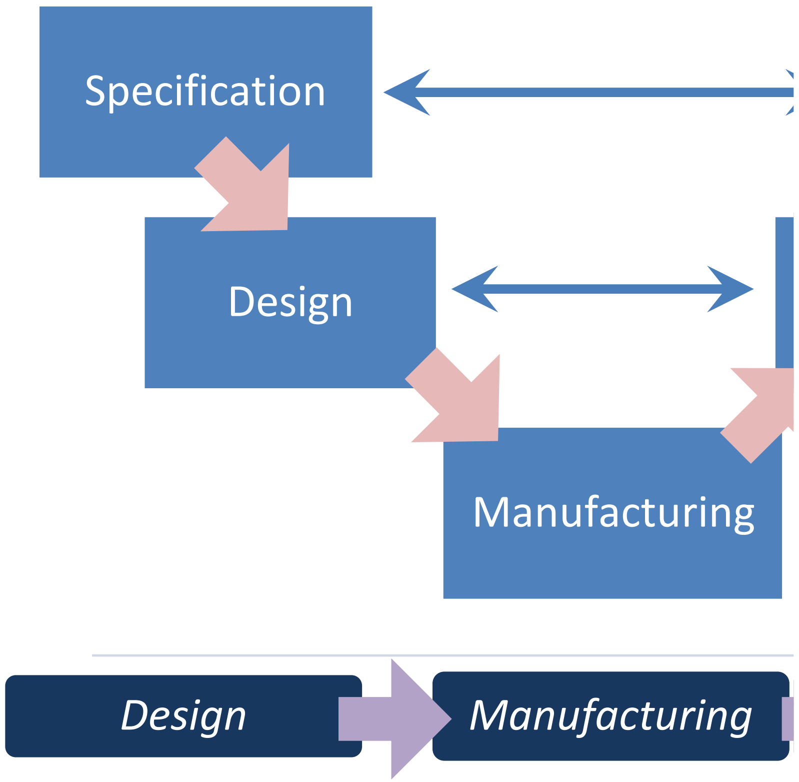
For a mechatronic system, the major difficulty is the **translation** of the global system specification into specifications for each component with different technologies.
[Rieuneau, 1993], [DesJardin, 1996]

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.

Product life cycle: the V-cycle

- Manufacturing phase

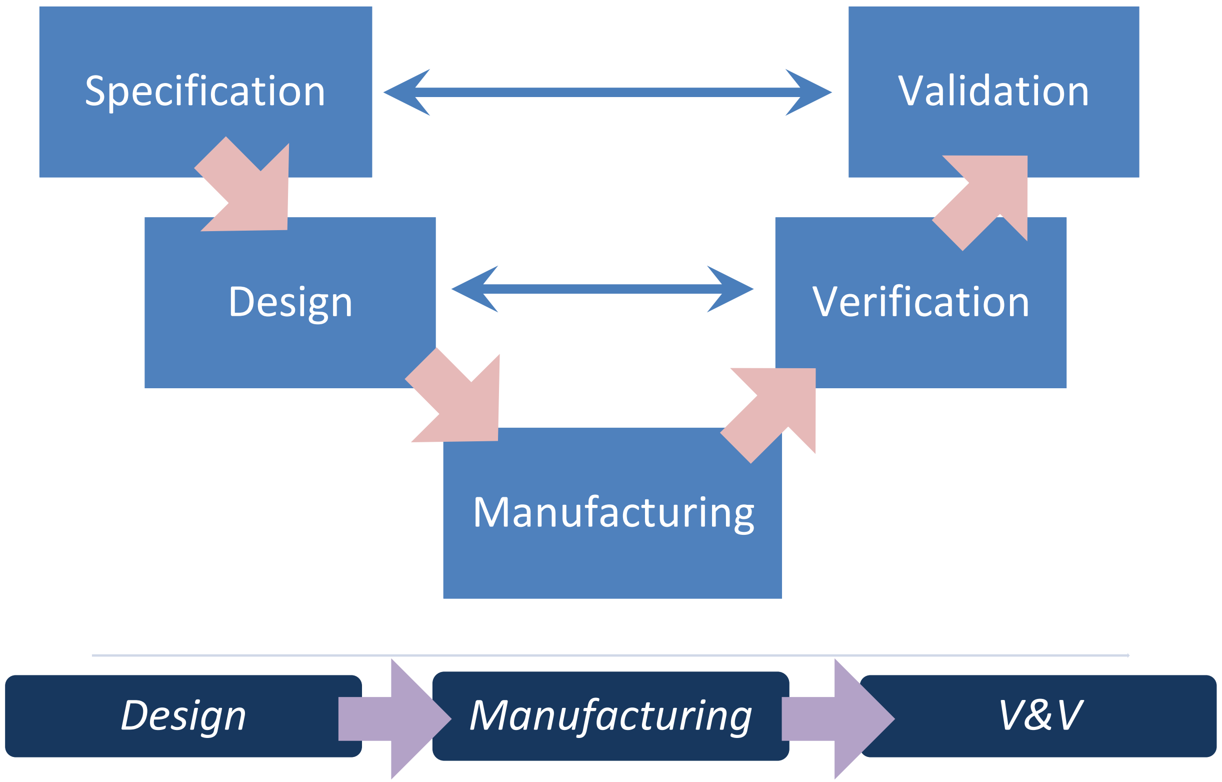


The manufacturer specifies not only the functionality but also the objectives in terms of **dependability**.

Must be studied during the design phase

Product life cycle: the V-cycle

- Verification & validation phase

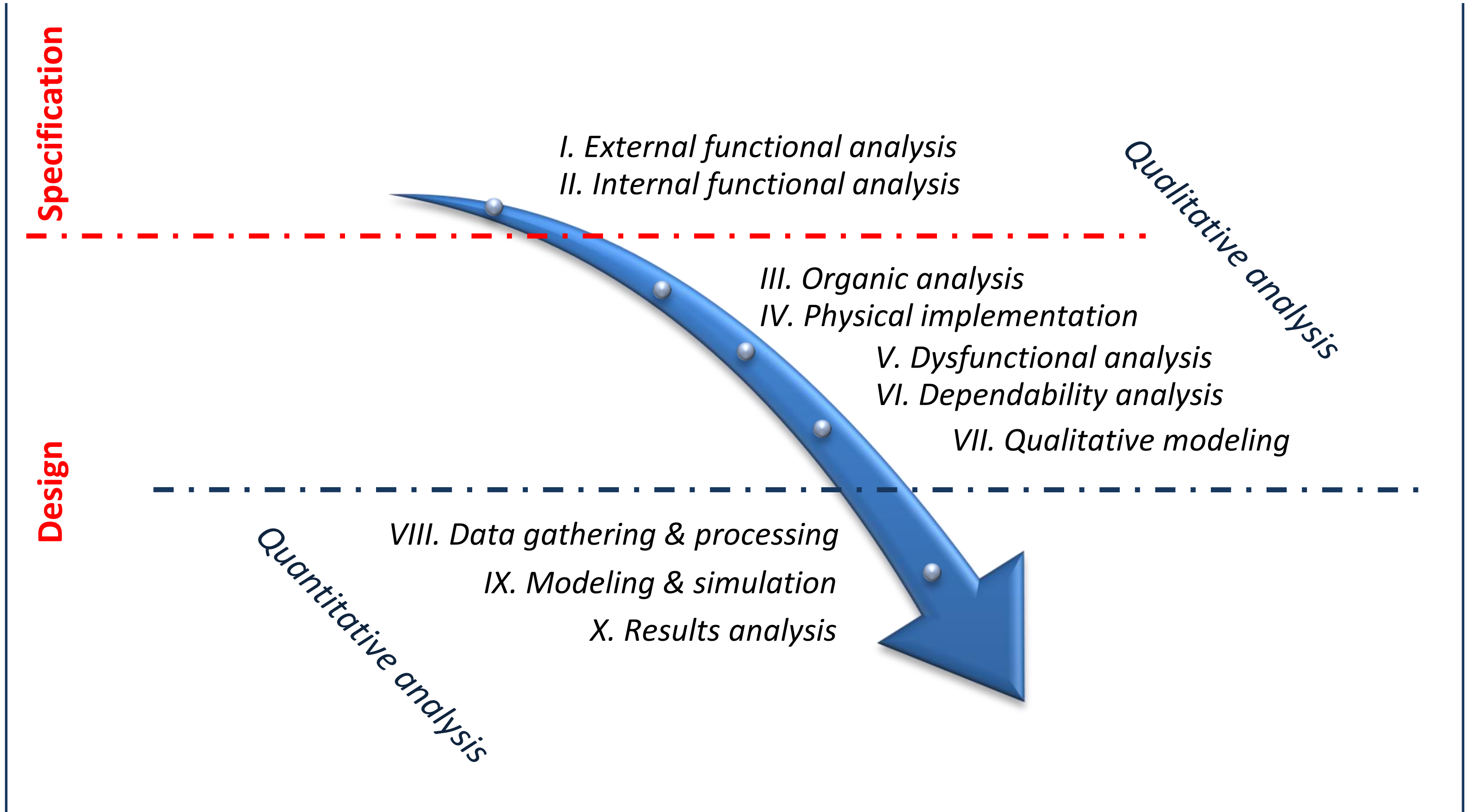


This phase intends to show the functional validation of the sub-systems and of the whole system. Quality must be compared to the specifications.

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

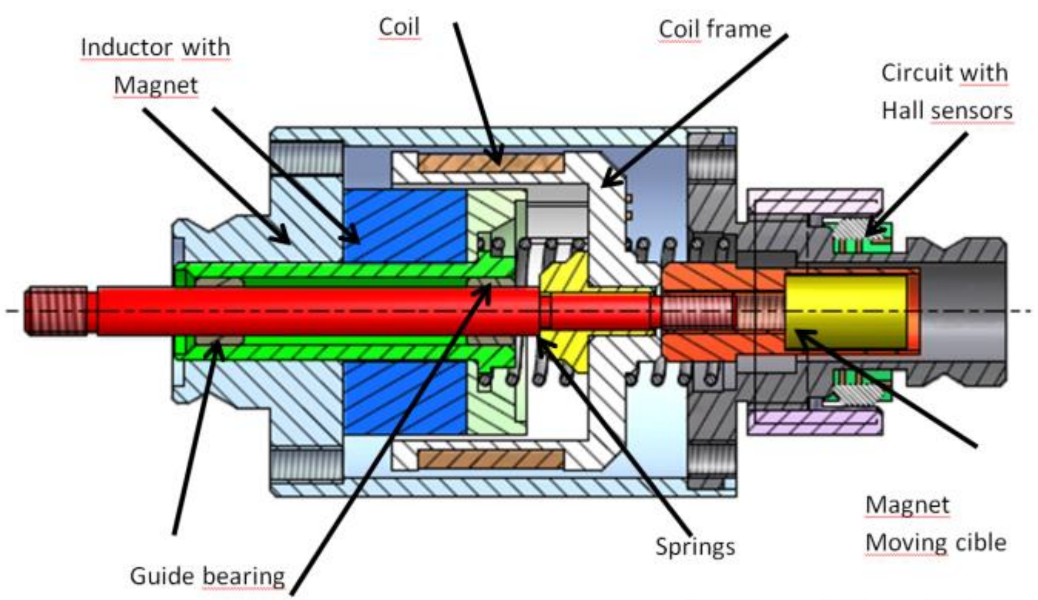
  - Sensors & magnetic rings
  - Ball bearings
  - Bearing units

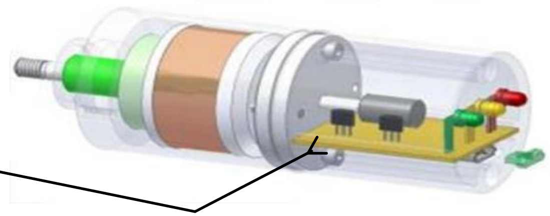
For aerospace, automotive, rail, steel industry, wind energy,...

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





circuit board

PACK'AERO MÉCATRONIQUE

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

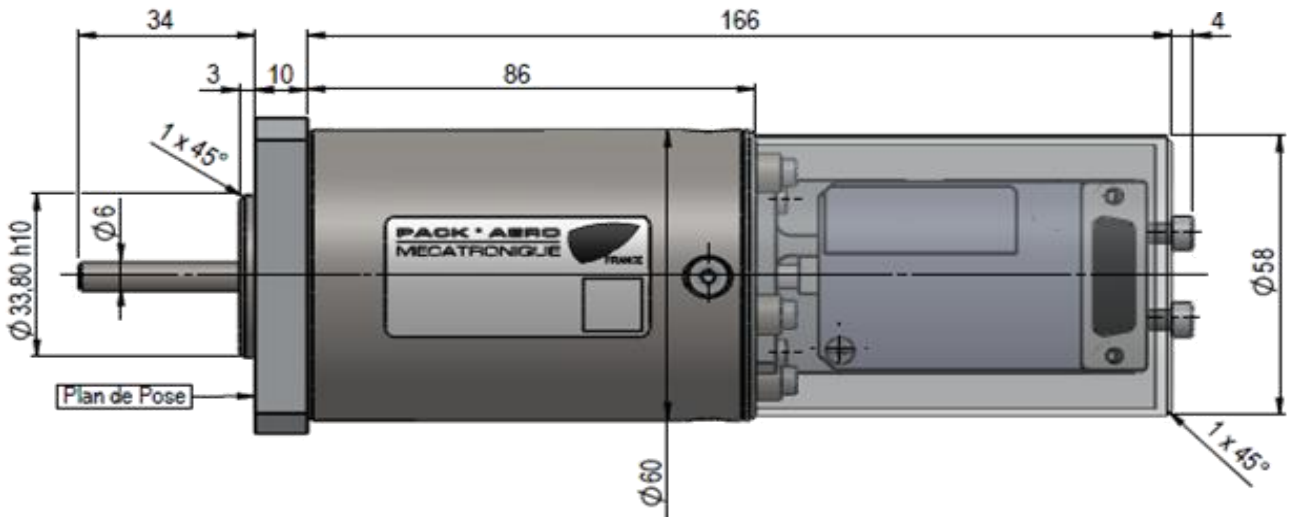
Example: smart actuator

❑ Specifications

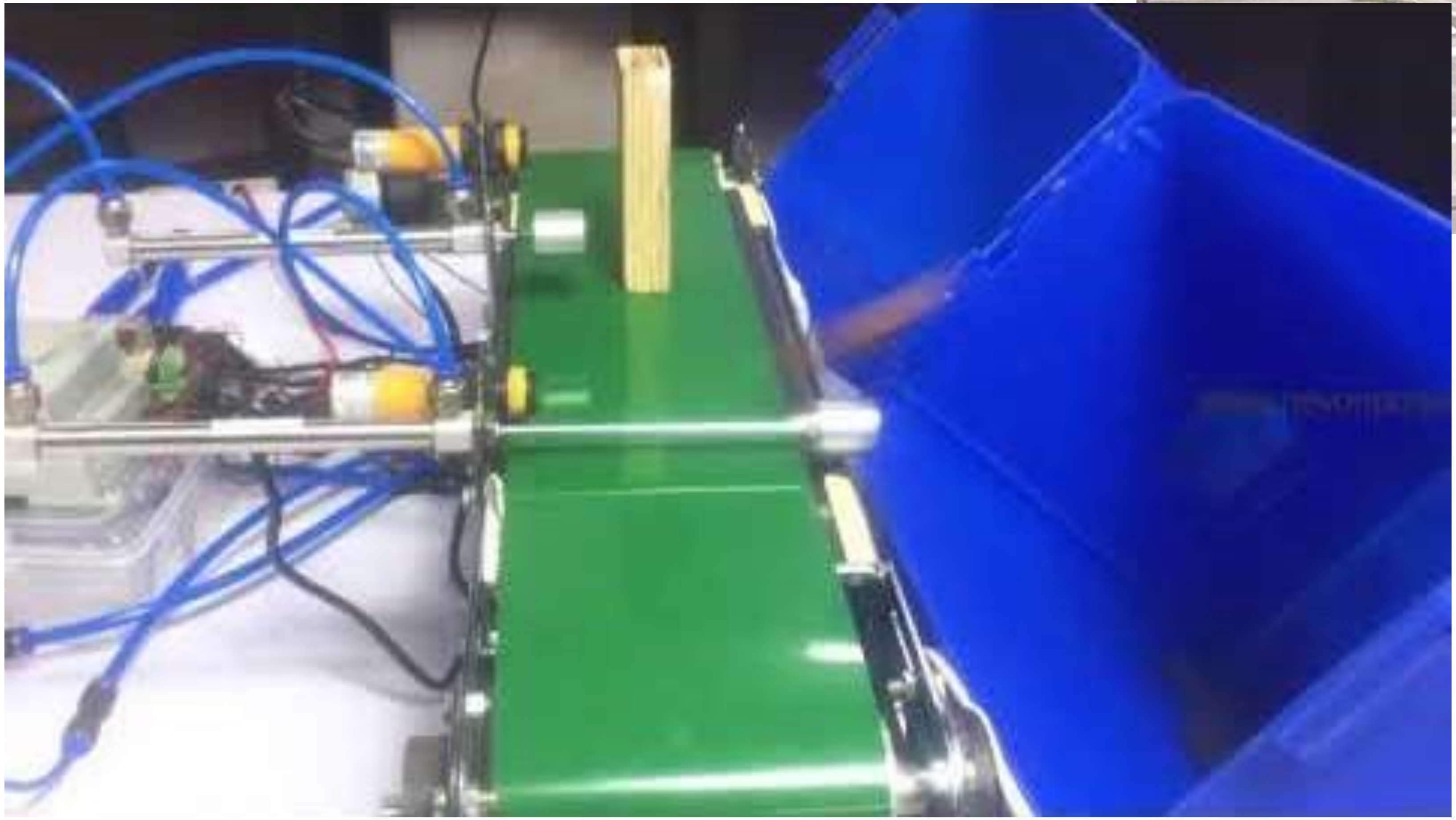
In addition to be a classical actuator, the smart actuator assumes additional functions such as operating, monitoring, communicating, data processing, etc.

- > 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
- ...

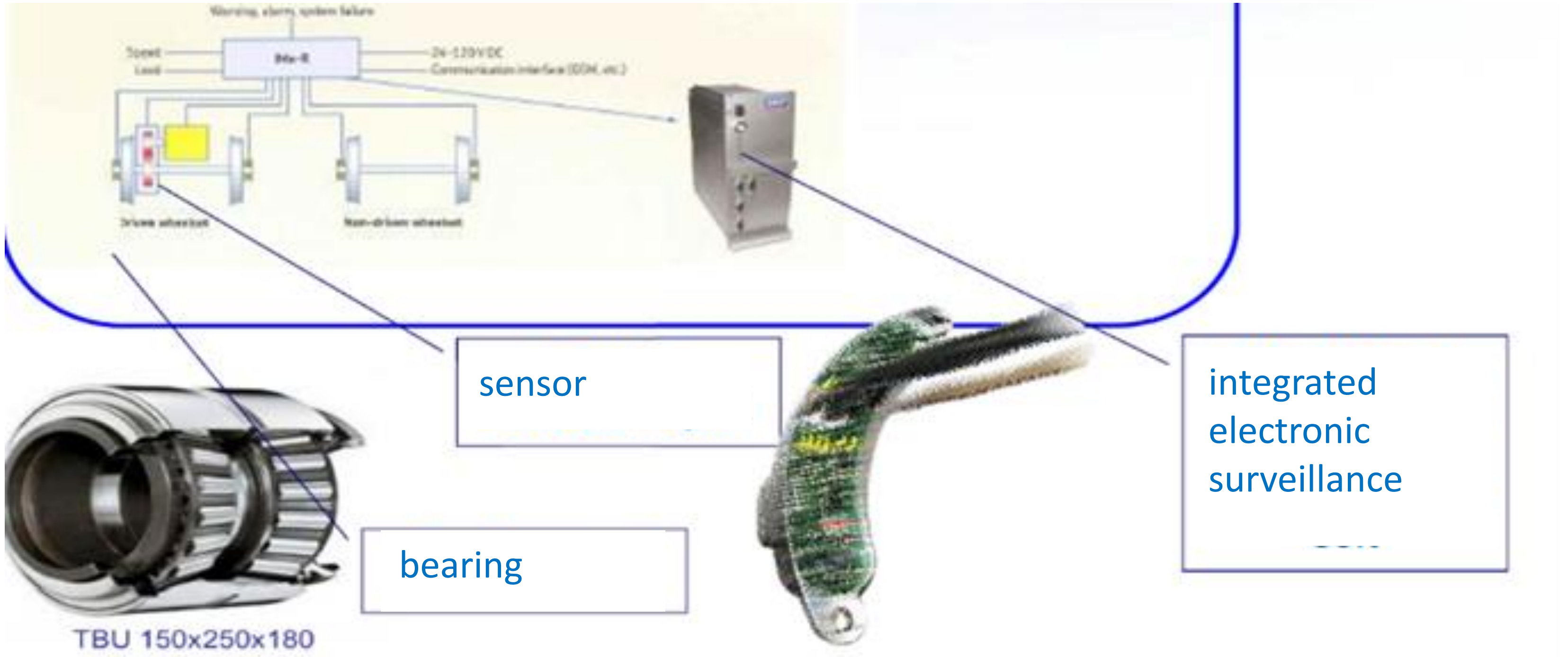
Example: instrumented wheel bearing

NTN SNR

- Using context

Fixed on axle tree

Integrated electronic surveillance



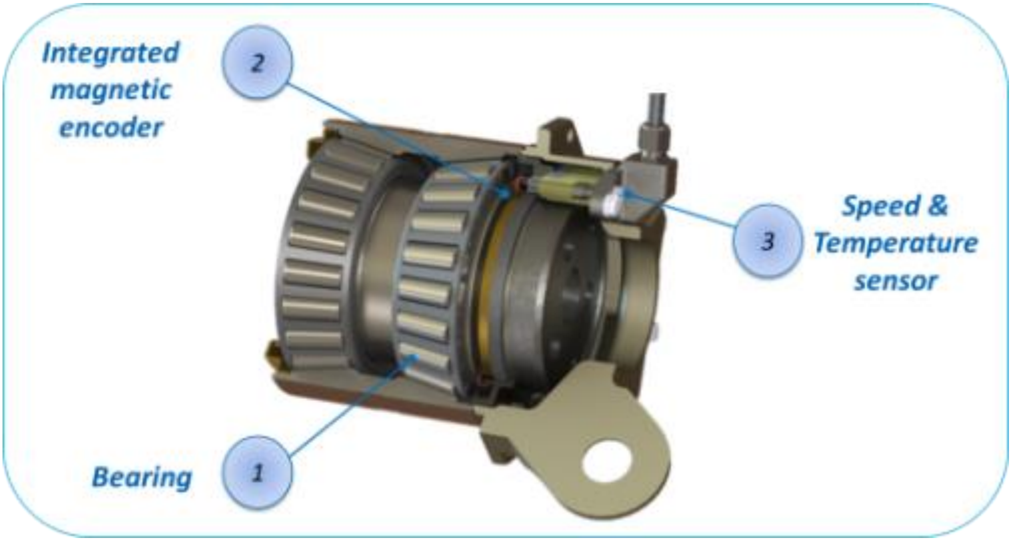
Example: instrumented wheel bearing

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?

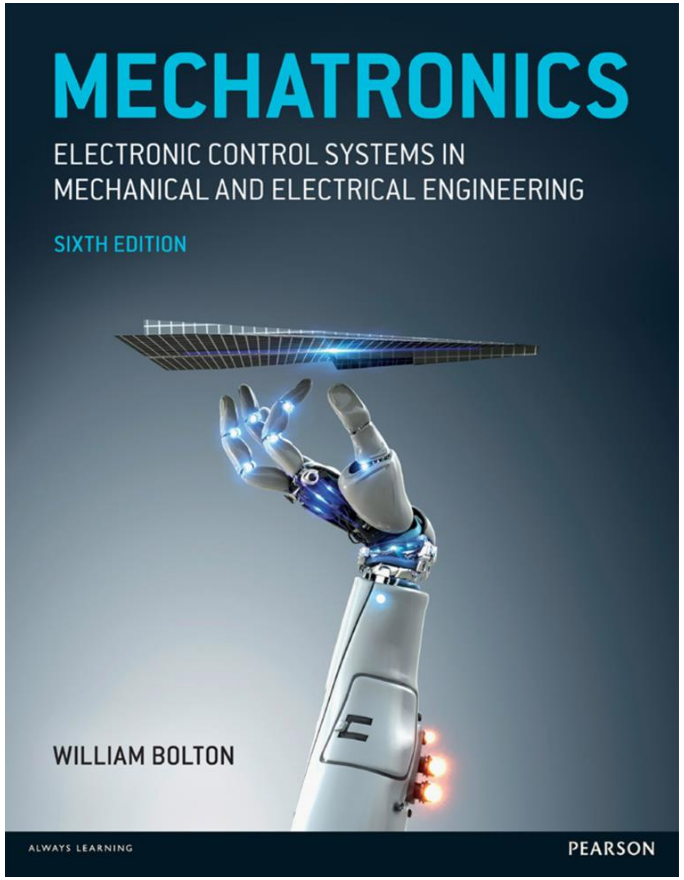
> Transition from passive state to active state

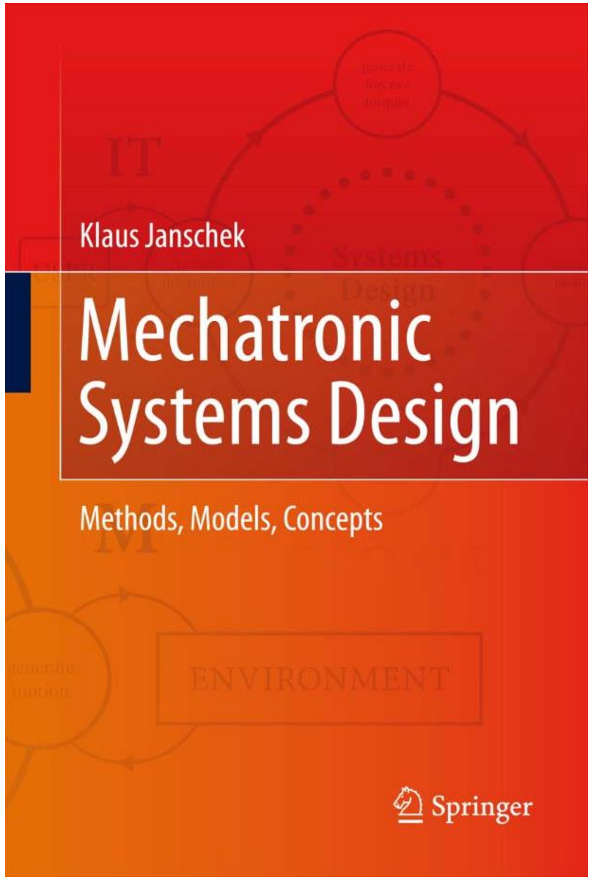
> Active redundancy

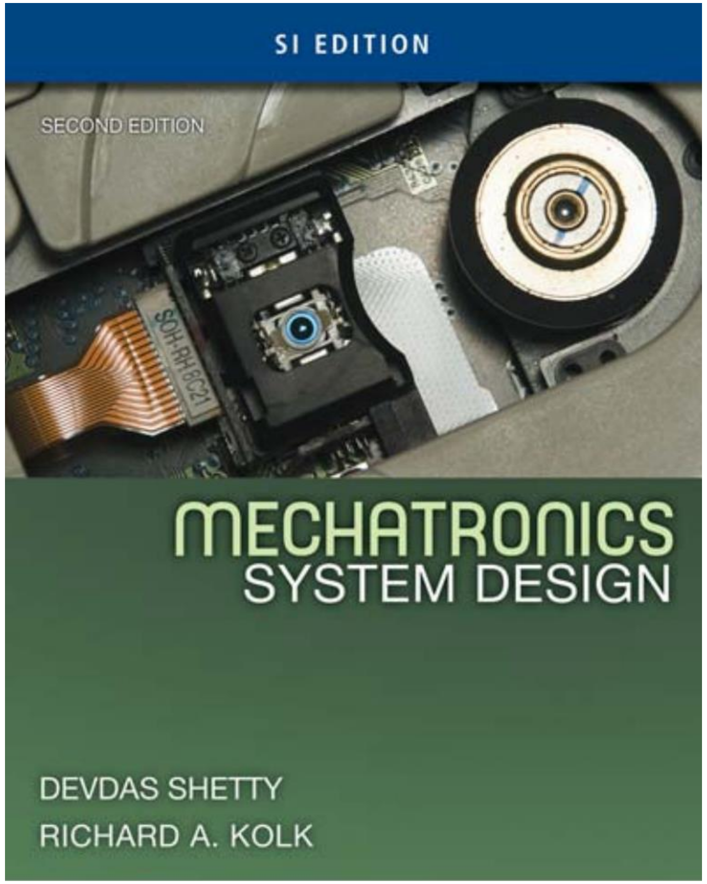
> Continuous phenomenon and discrete events

> ...

Relevant books







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