Functional and architectural design
Use case : Multi-field DRONE

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UTBM - FRANCE

Objective of the lecture

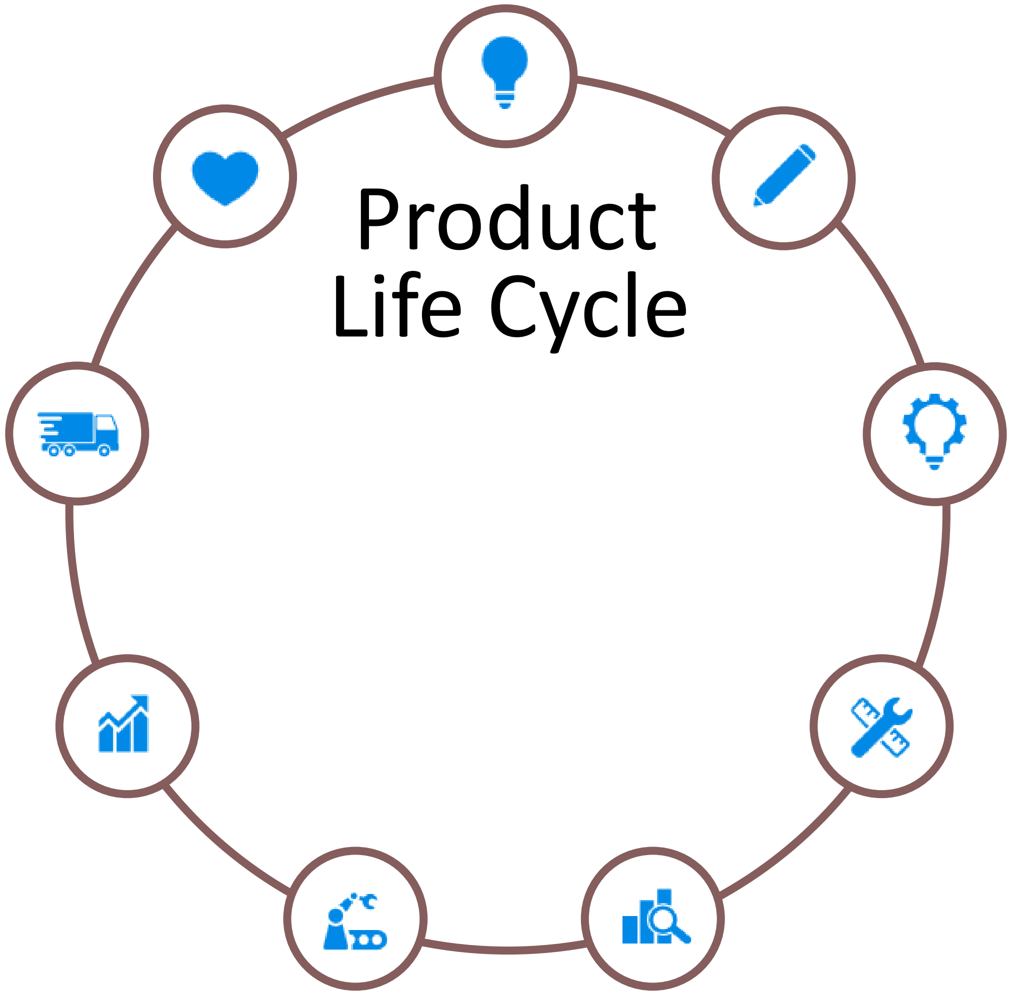
- Design process of innovative products
- Functional design concepts
- Architectural design concepts
- Illustrate the concepts with a use case : an industrial plants surveillance system for risk management

Use case

Be an innovator : « Be able to... »

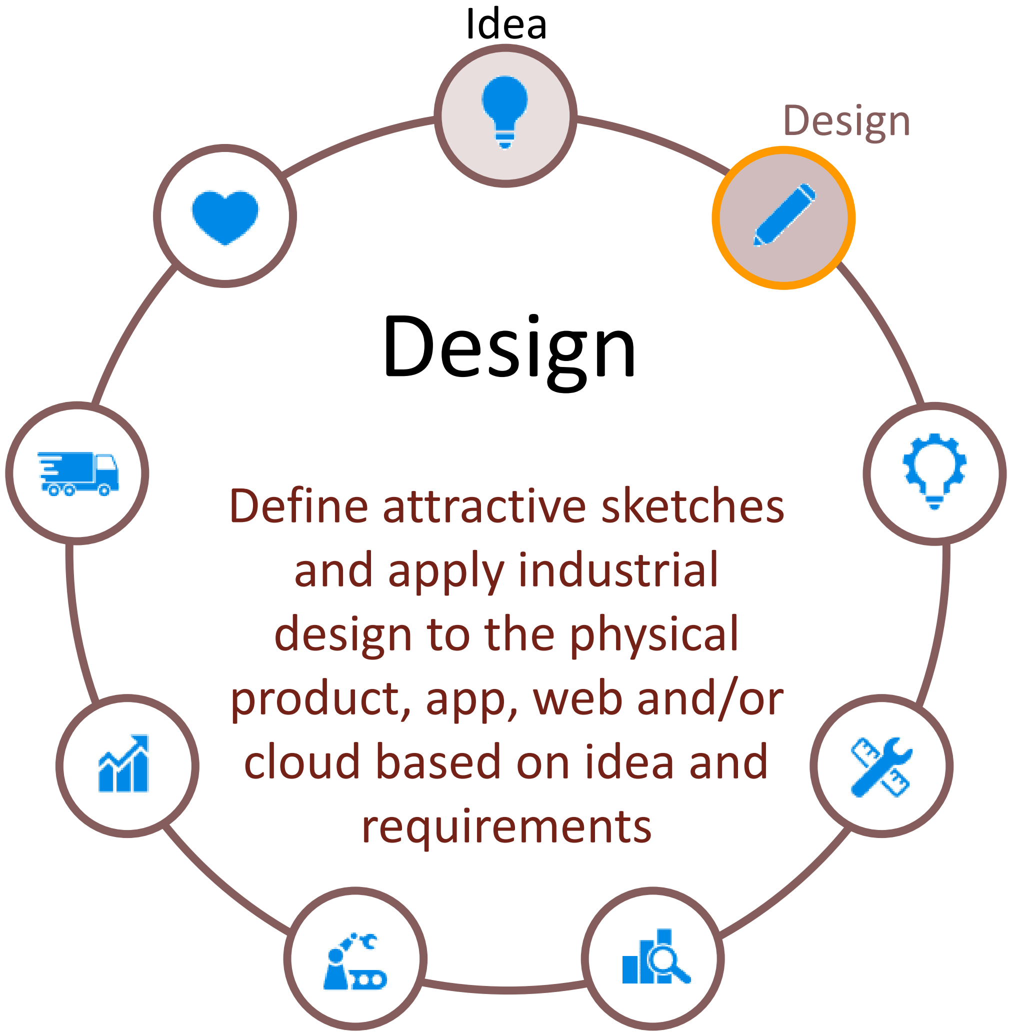
Design process of innovative products

Product lifecycle

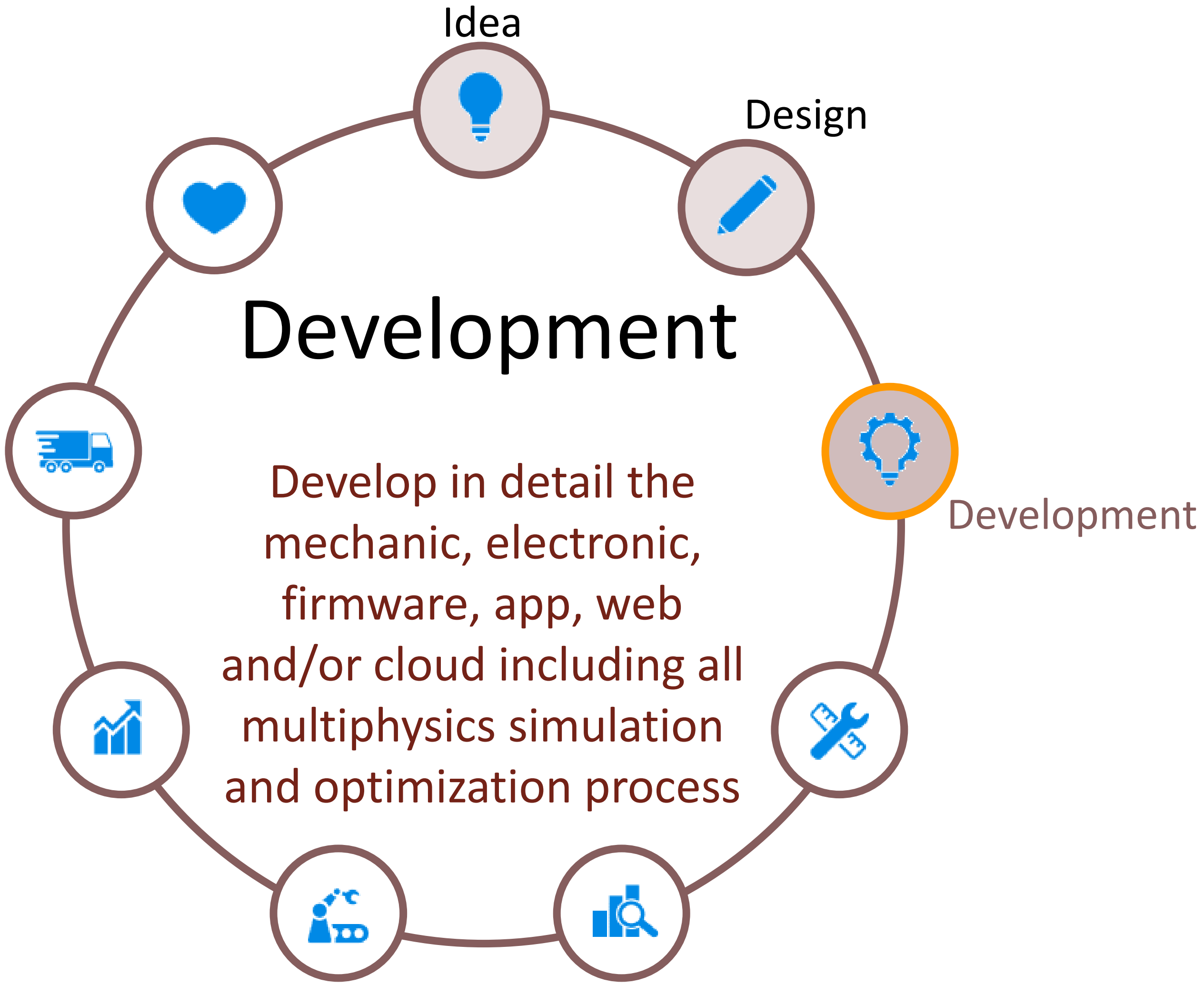


Product lifecycle

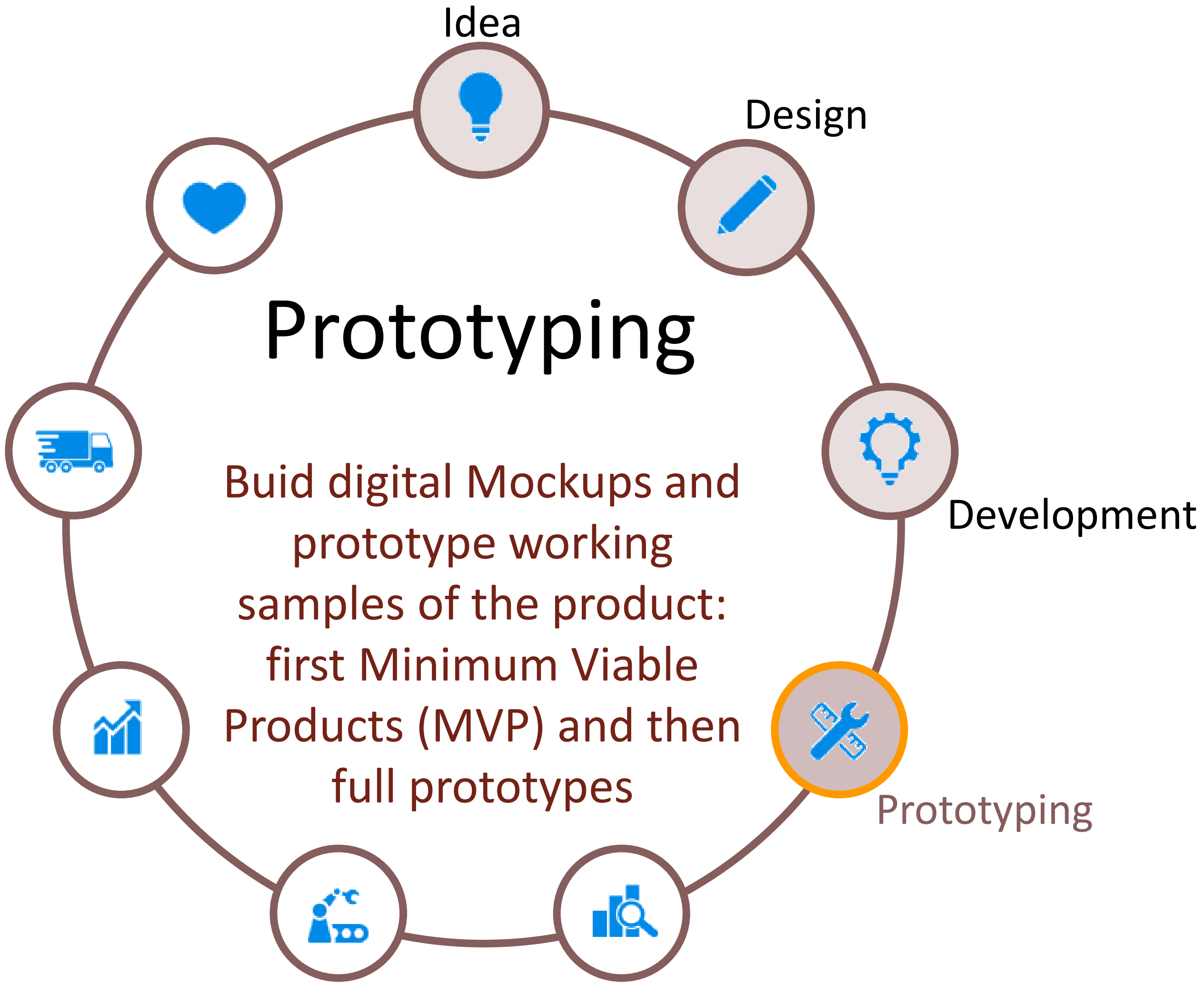
Product lifecycle



Product lifecycle

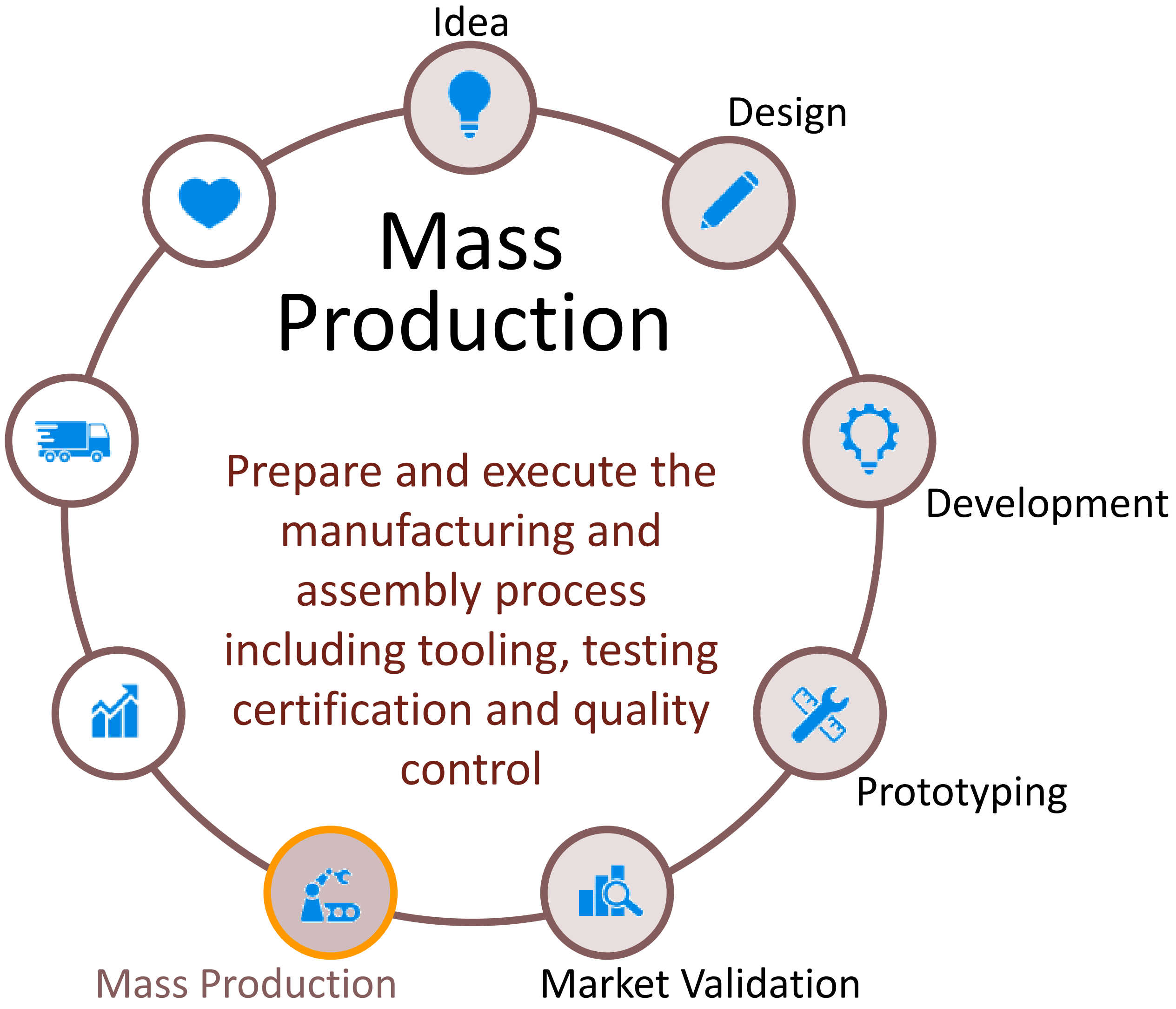


Product lifecycle



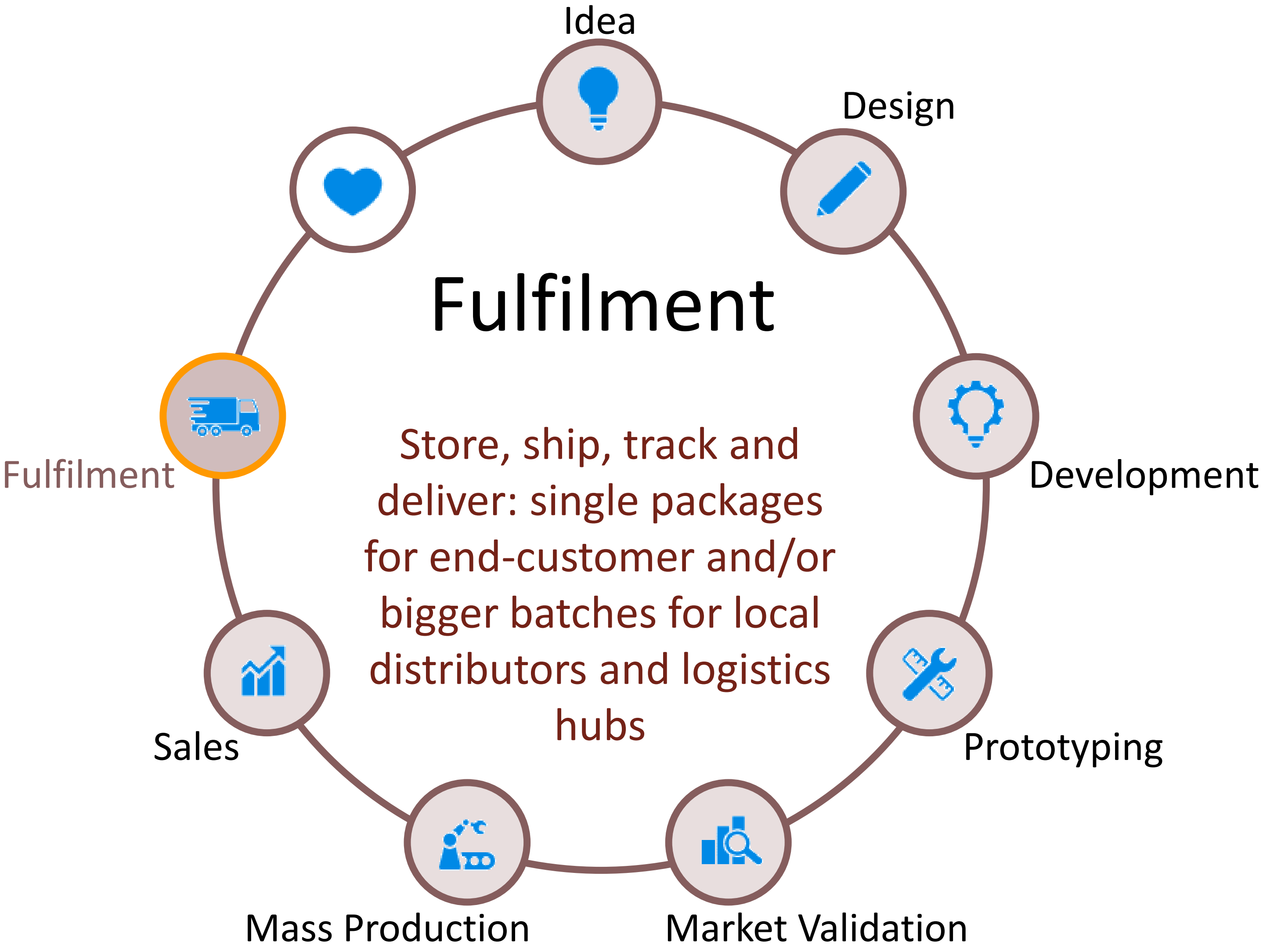
Product lifecycle

Product lifecycle

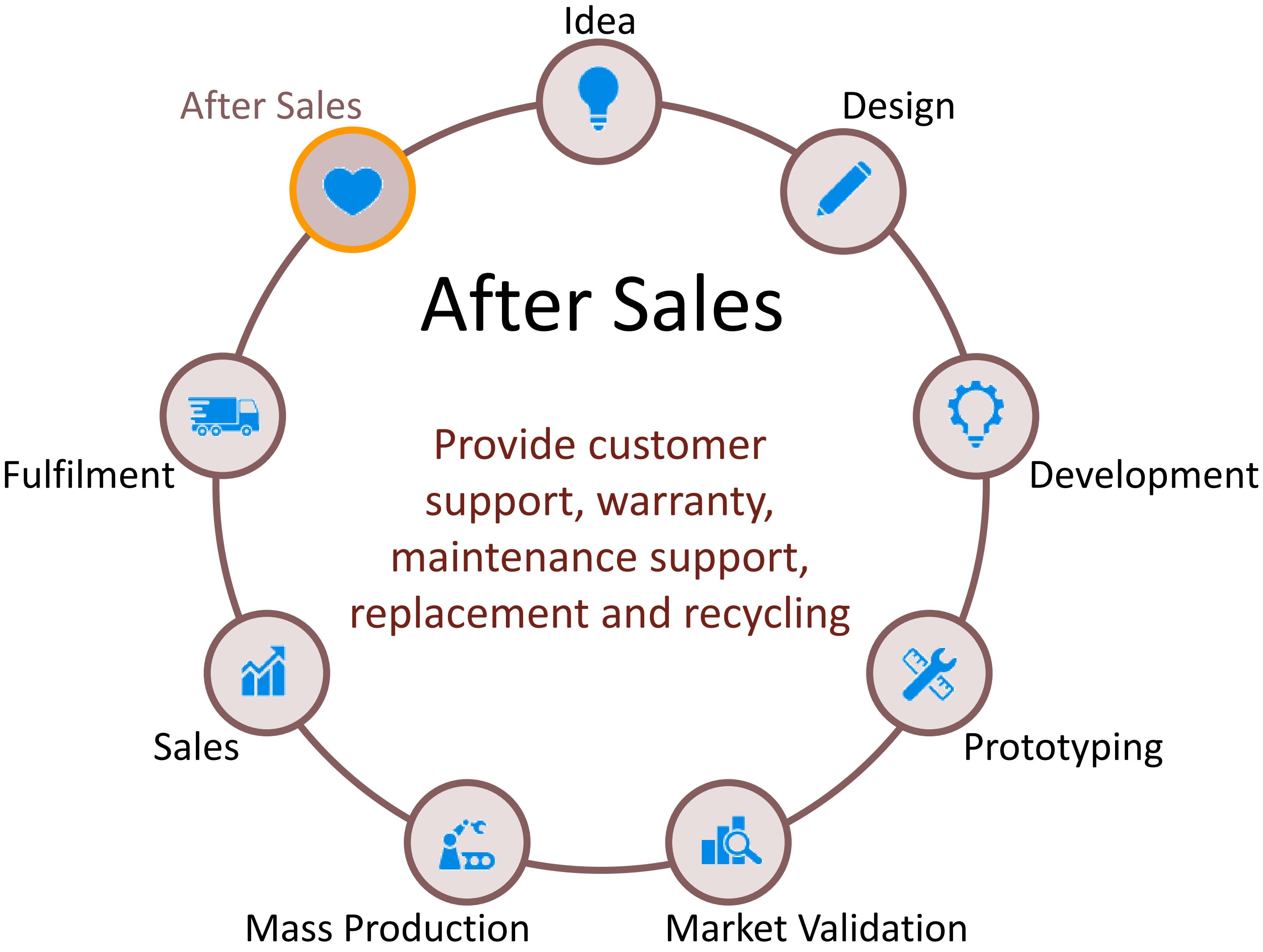


Product lifecycle

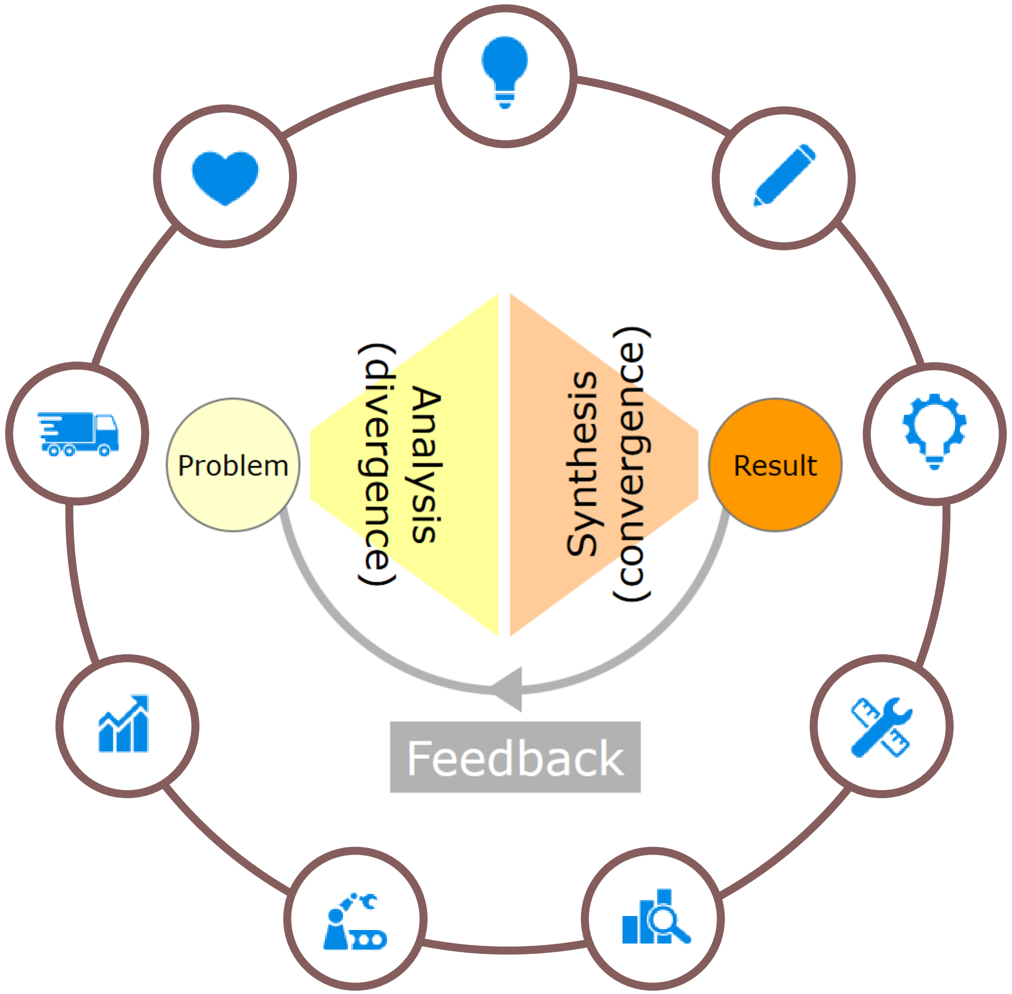
Product lifecycle



Product lifecycle



Product lifecycle



Product
Life Cycle

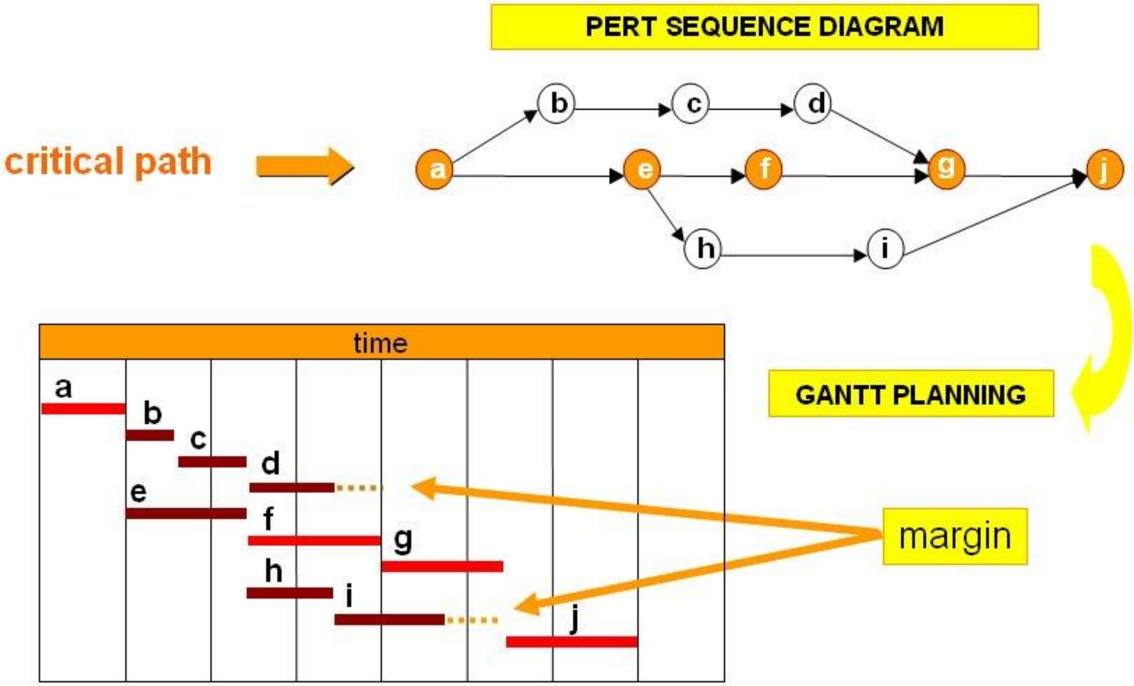
Project organization

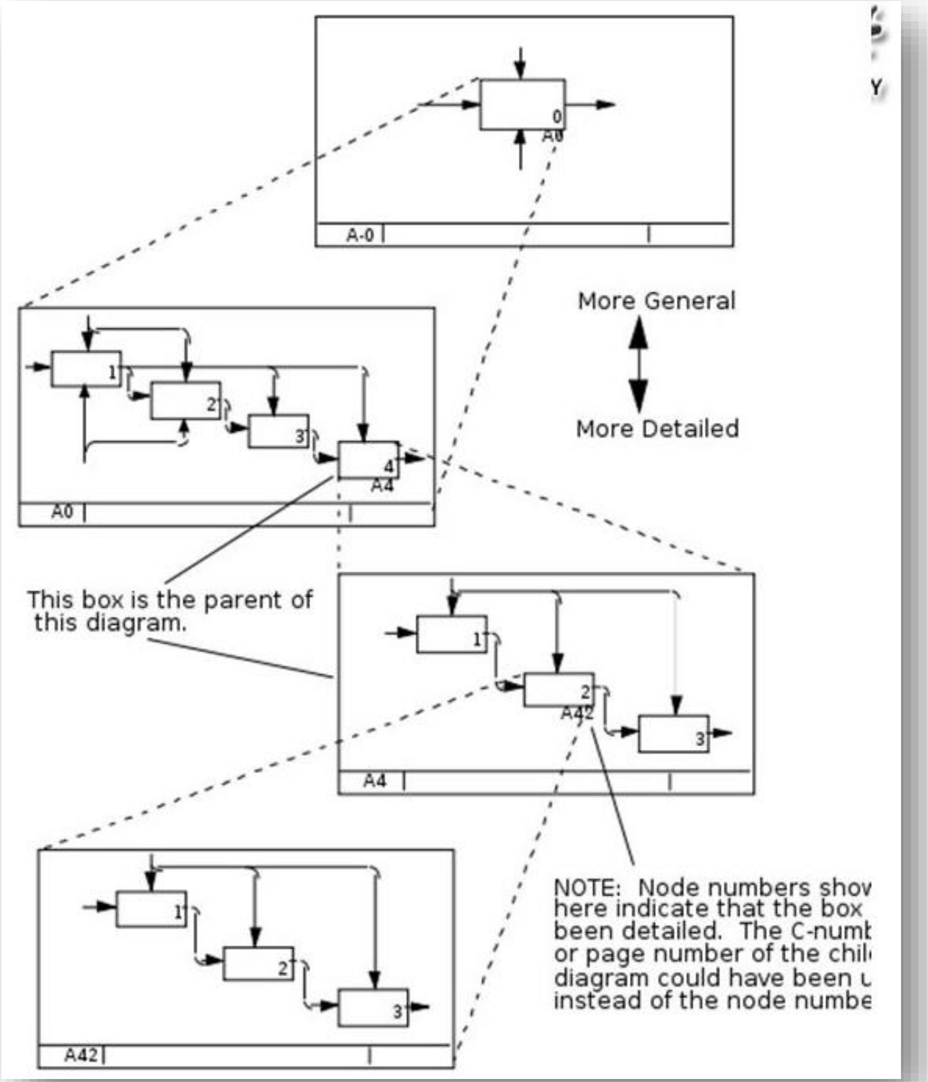
Project organisation

SADT (Structured Analysis and Design Techniques):

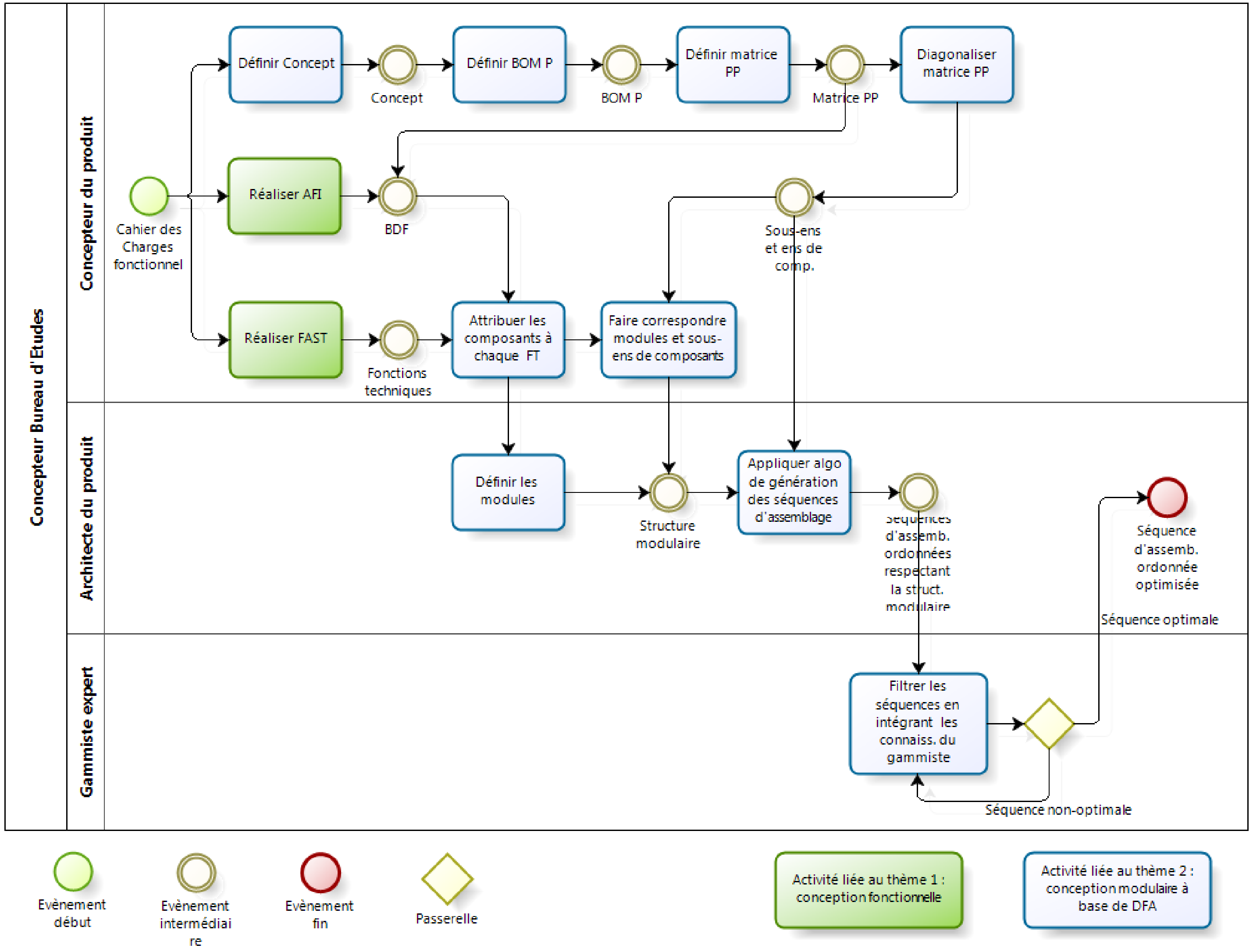
- Definition of tasks to be performed, Organization of deliverables, Definition of requested design methods, First listing of resources, Etc.

PERT and GANTT diagrams

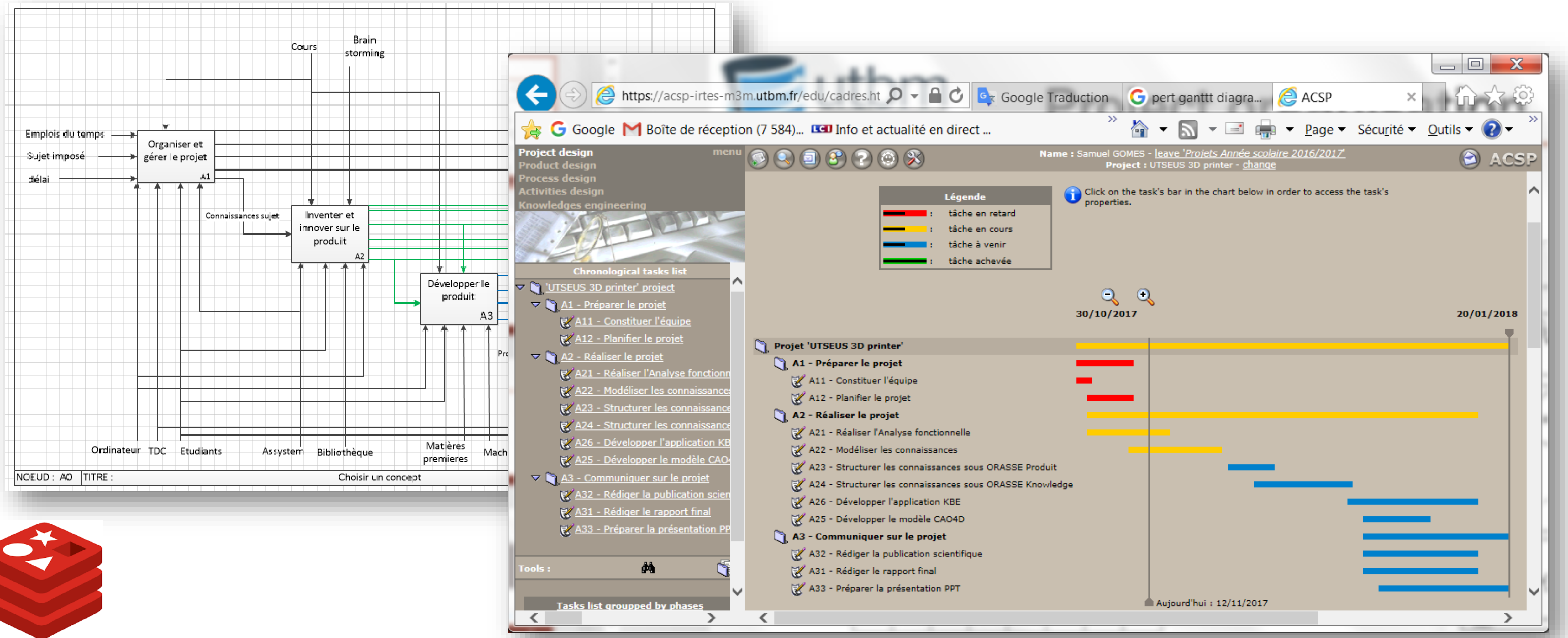




Project organisation



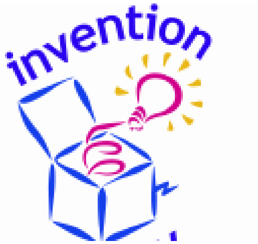
Project organisation

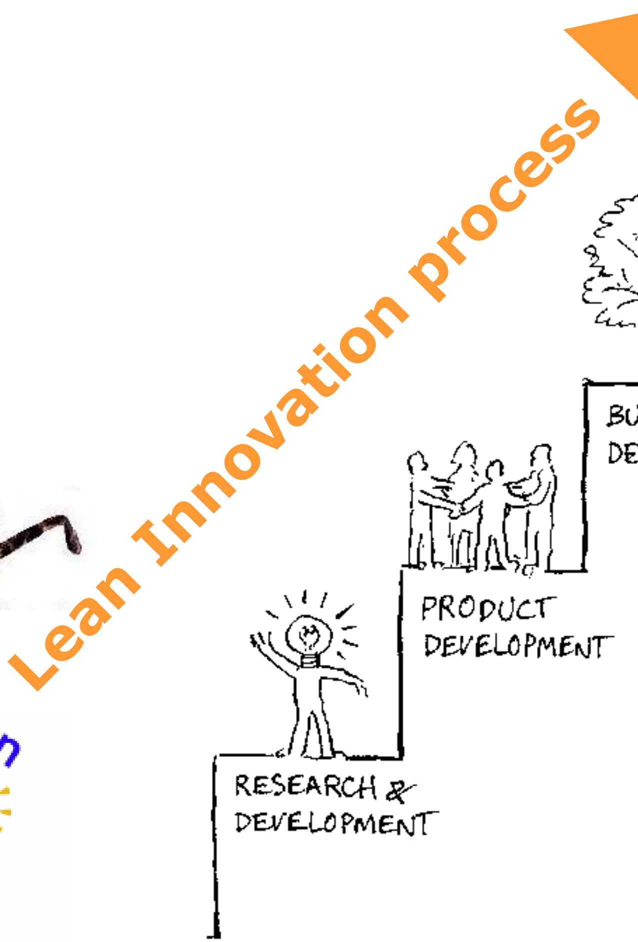


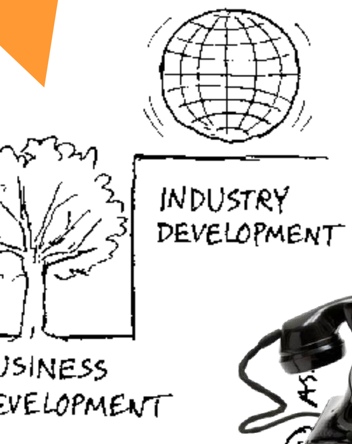
Use case

Needs, fonctions and ideas

Invention versus Innovation





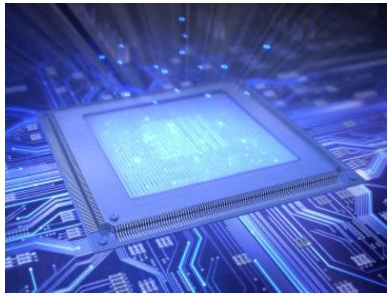


Innovation

Towards Product-Service innovation

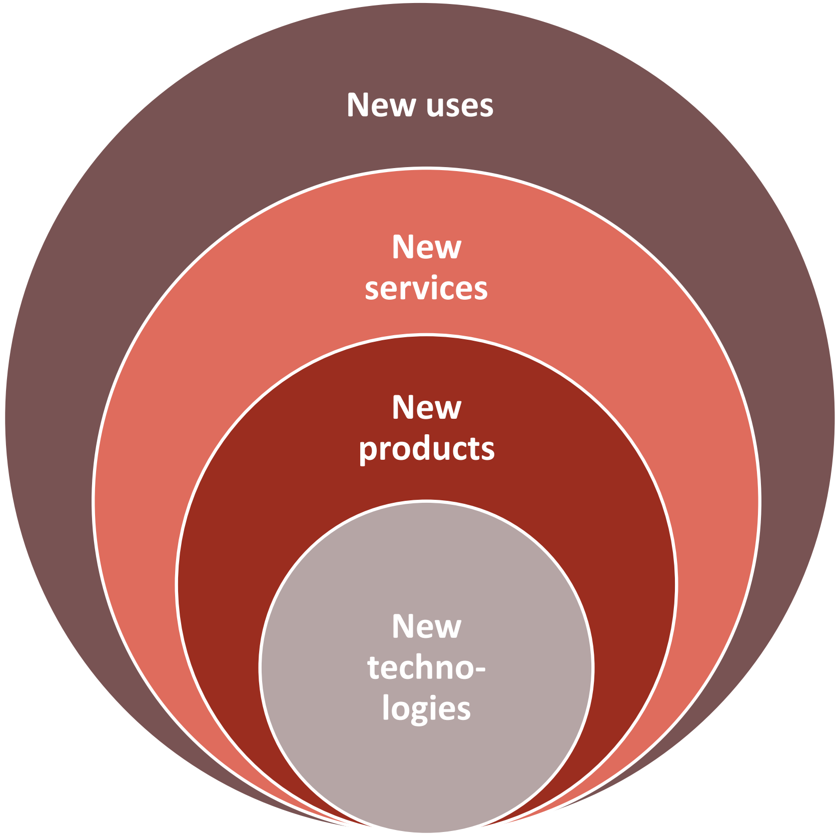
Today, innovation leads to change the identity of objects and, in the same time, redefine the technologies, the business models, the uses models of a Product/Service.

New Techno.



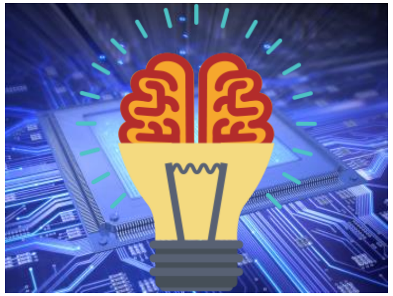
New values

New uses



New services

New products



Information gathering

State of art, benchmarking, patents review, survey, interviews…

TECHNOLOGY

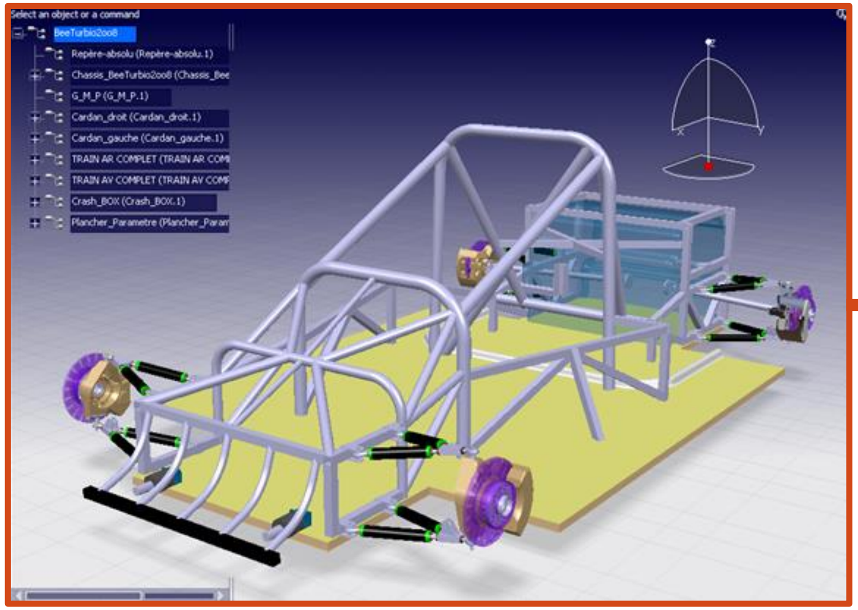
USES

MANUFACTURING

COMMUNICATION

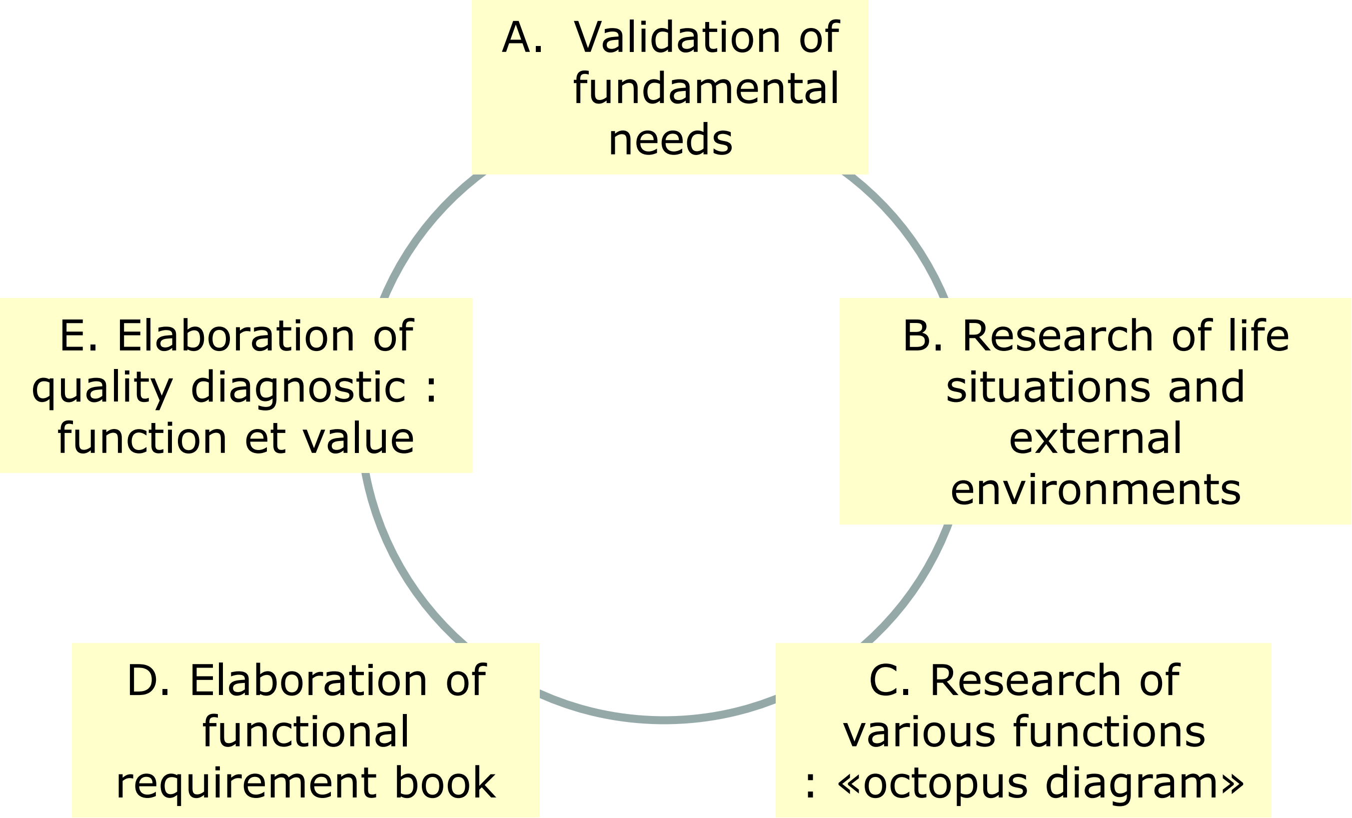
ENVIRONMENT

Mech. engineers focus on geometry

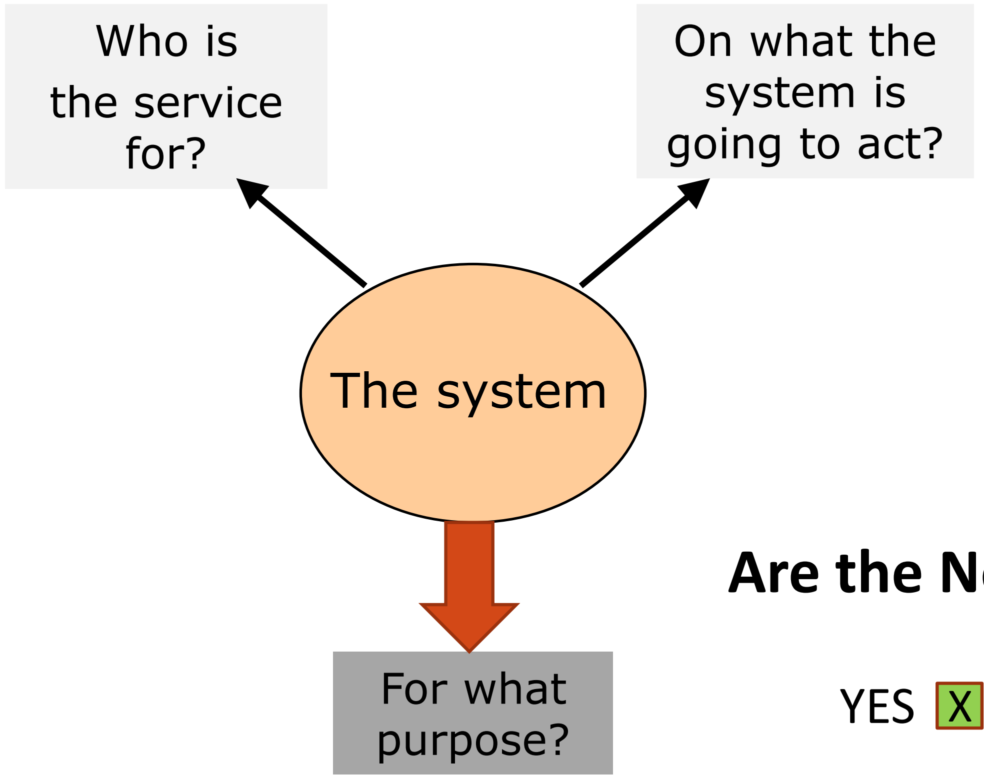


- Functional Design
- Architecture design
- Parametric design
- Geometric design
- Design optimization

Functional analysis methodology



A- Validation of fundamental needs



Are the Needs validated ?

YES ☒ NO ☐

Use case

Industrial plants mobile surveillance system for risk management

- Ability to move on water, on land and in the air
- Ability to make some environmental measurements and analysis
- Autonomous system
- Communicating system

Use case

State of art, benchmarking…

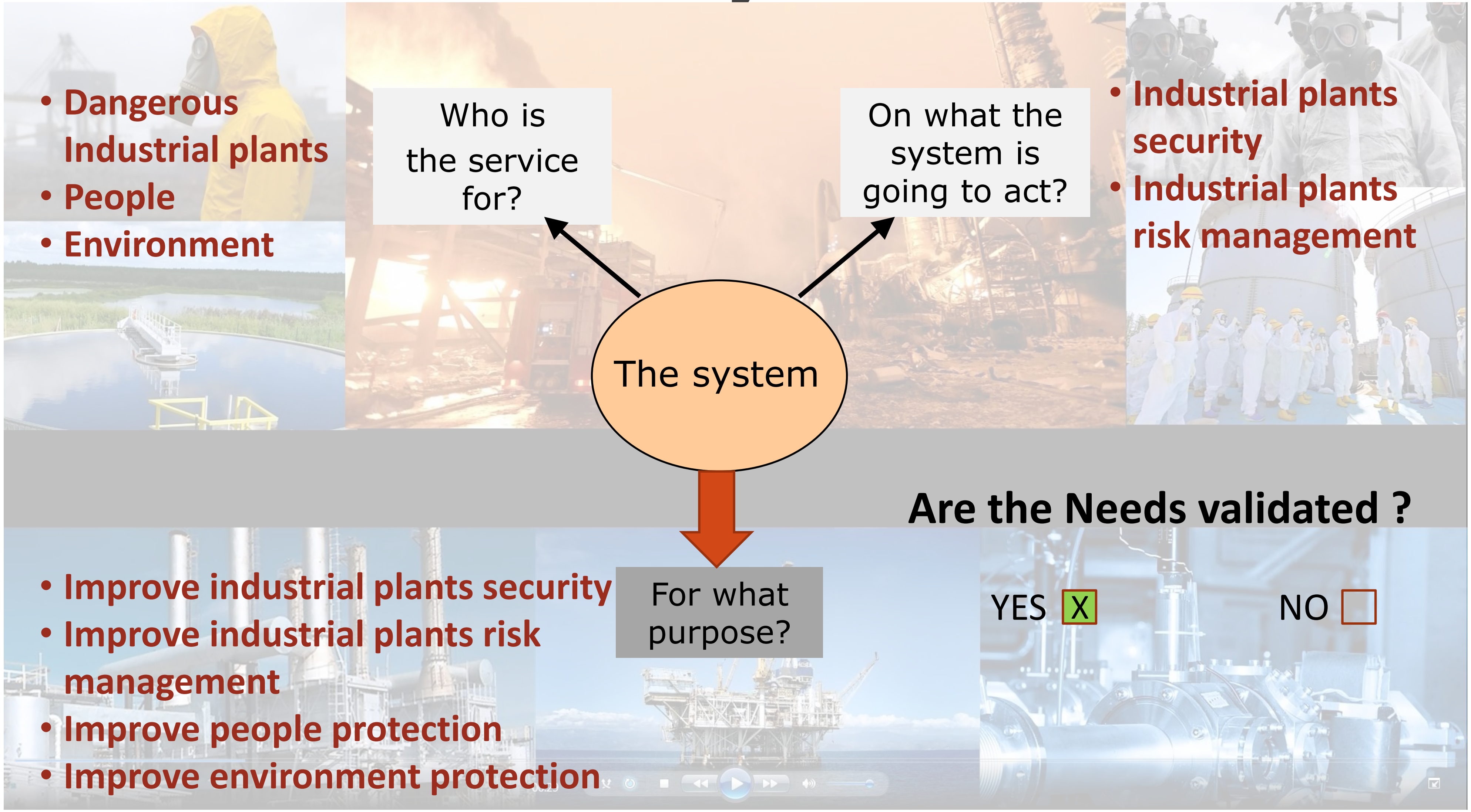
- Suspension system
- Wheel Axis Rotation: Switching from Land / Water Mode to Air Mode
- Integrate this mechanism into the design ?

- Drones, competing systems
- Direction (Automobile, Naval ...)
- Suspension (Pneumatic, hydraulic ...)
- Propellers
- Engines
- Batteries
- Floats

http://www.moreinspiration.com/

Use case

Functional analysis: Needs validation



Use case

B. Life situations and external environments

- Identify the various life situations in which the product will be found throughout its life cycle: Manufacturing, Distribution, Consumption (Acquisition, Storage, Use), Maintenance, Elimination / Recycling, etc.

- For each life situation it is necessary to identify the various elements from the product's environment (external components from the environment): industrial equipments, ground, water, air, satellites, sensors network, human supervisor, etc.

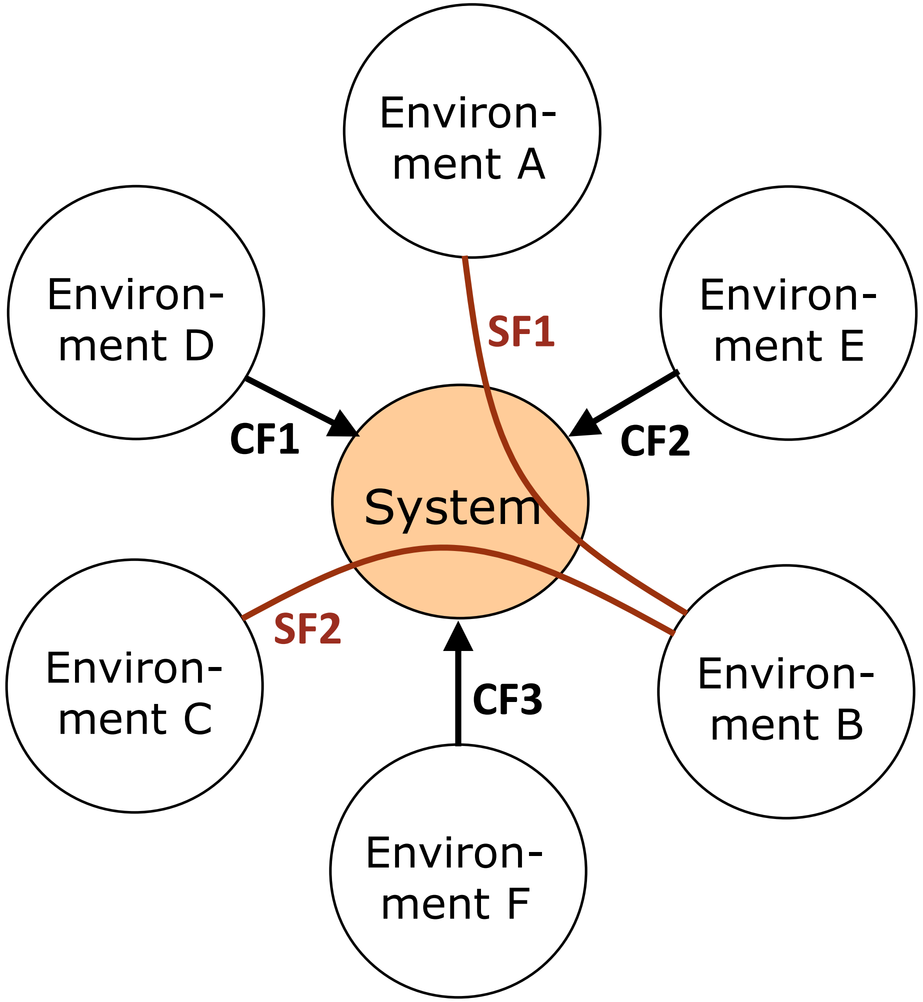
- Check their stability over time (evolution of external environments, standards, etc.)

C. Research of functions: «octopus diagram»

In each life situation, basic functions are described (Service and Constraint Functions):

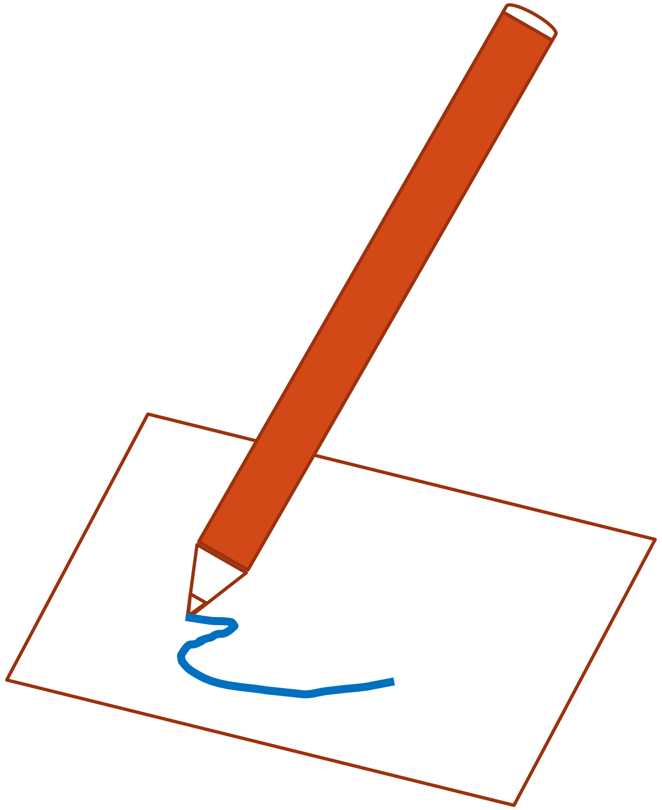
- **Service Function (SFi)**: *THE SYSTEM MUST* "infinitive verb + 2-3 elements of the environment“

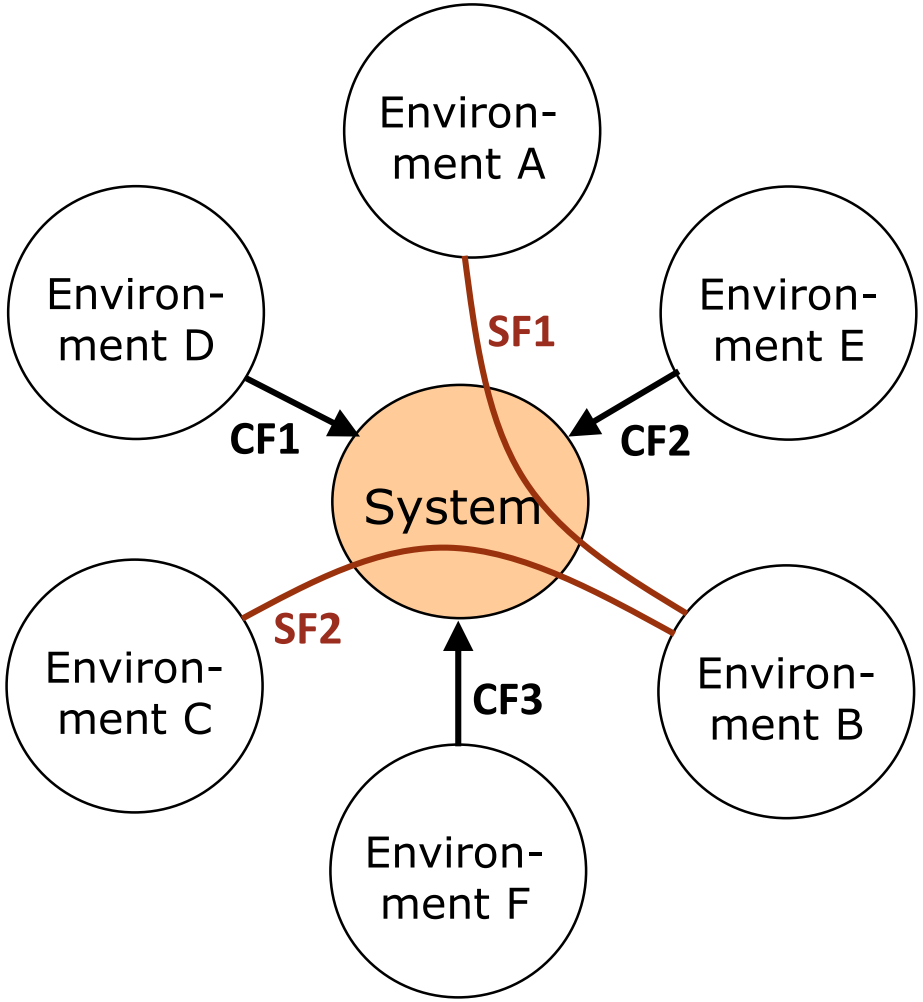
- **Constraint Function (CFj)**: *THE SYSTEM MUST* "infinitive verb + 1 element of the environment"



C. Research of functions: «octopus diagram»

Let’s perform together an example:
Stypen





C. Research of functions: «octopus diagram»

The next step is to perform a function validation by answering the following 5 questions:

- Why the function? (we search the origin, the cause): Because ...
- What is the function? (we look for the purpose, the purpose): For ...
- What can make the function evolve ?
- What can make the function disappear?
- Validated function: **YES** or NO

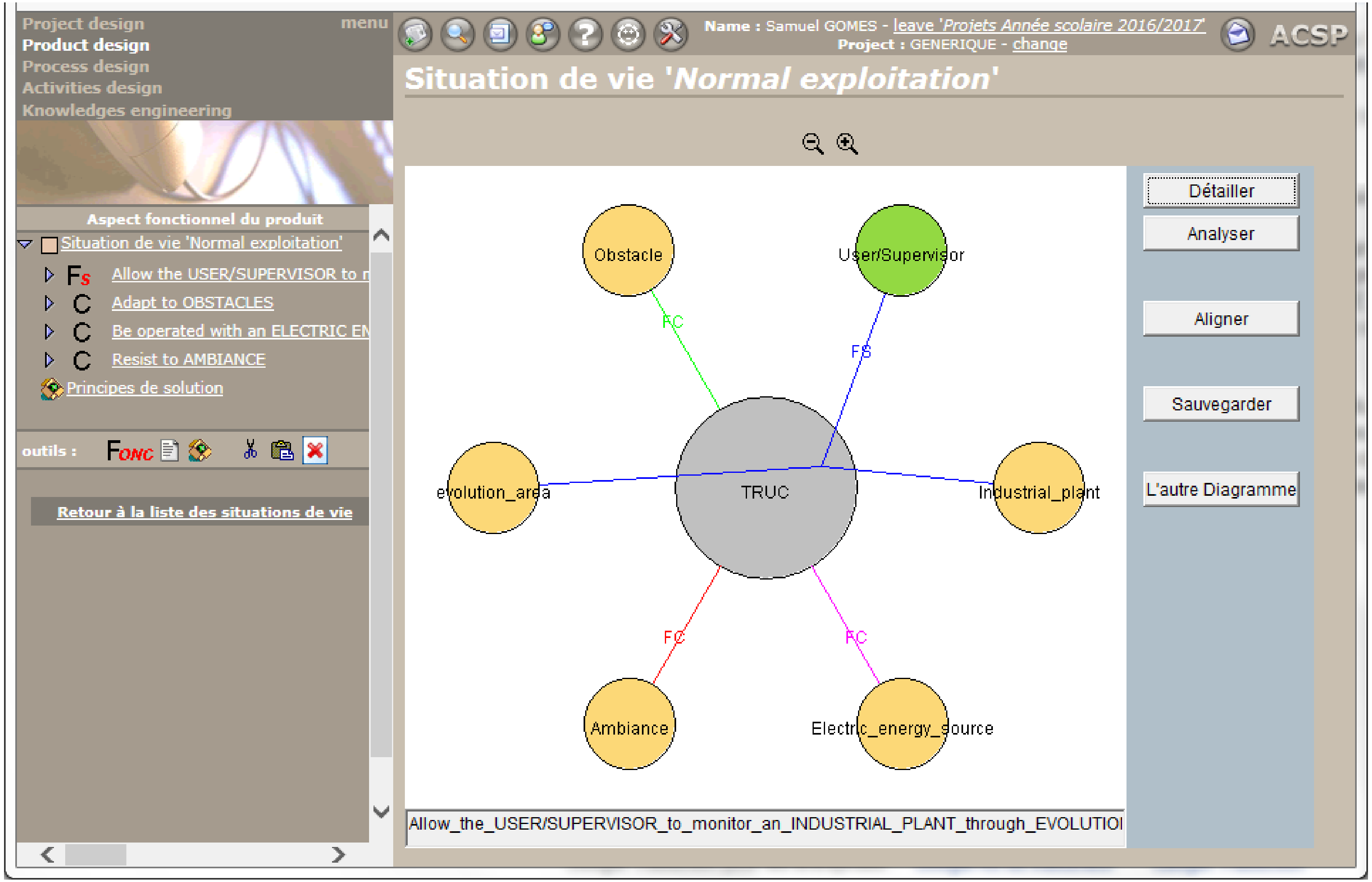
Finally, it is a matter of quantifying (valuing using value criteria) in terms of Time, Energy, Material, Information, Cost, and then ranking the functions thus defined.

- quantification of SFi or CFj: characterization of the verb and characterization of various environments,
- hierarchy of functions and value criteria using flexibility levels (0-3)

C. Research of functions: «octopus diagram»

Life situation : Normal use

- SF1: Allow the USER/SUPERVISOR to monitor an INDUSTRIAL PLANT through EVOLUTION AREAS
- CF1: Adapt to OBSTACLES
- CF2: Be operated with an ELECTRIC ENERGY SOURCE
- CF3: Resist to AMBIANCE

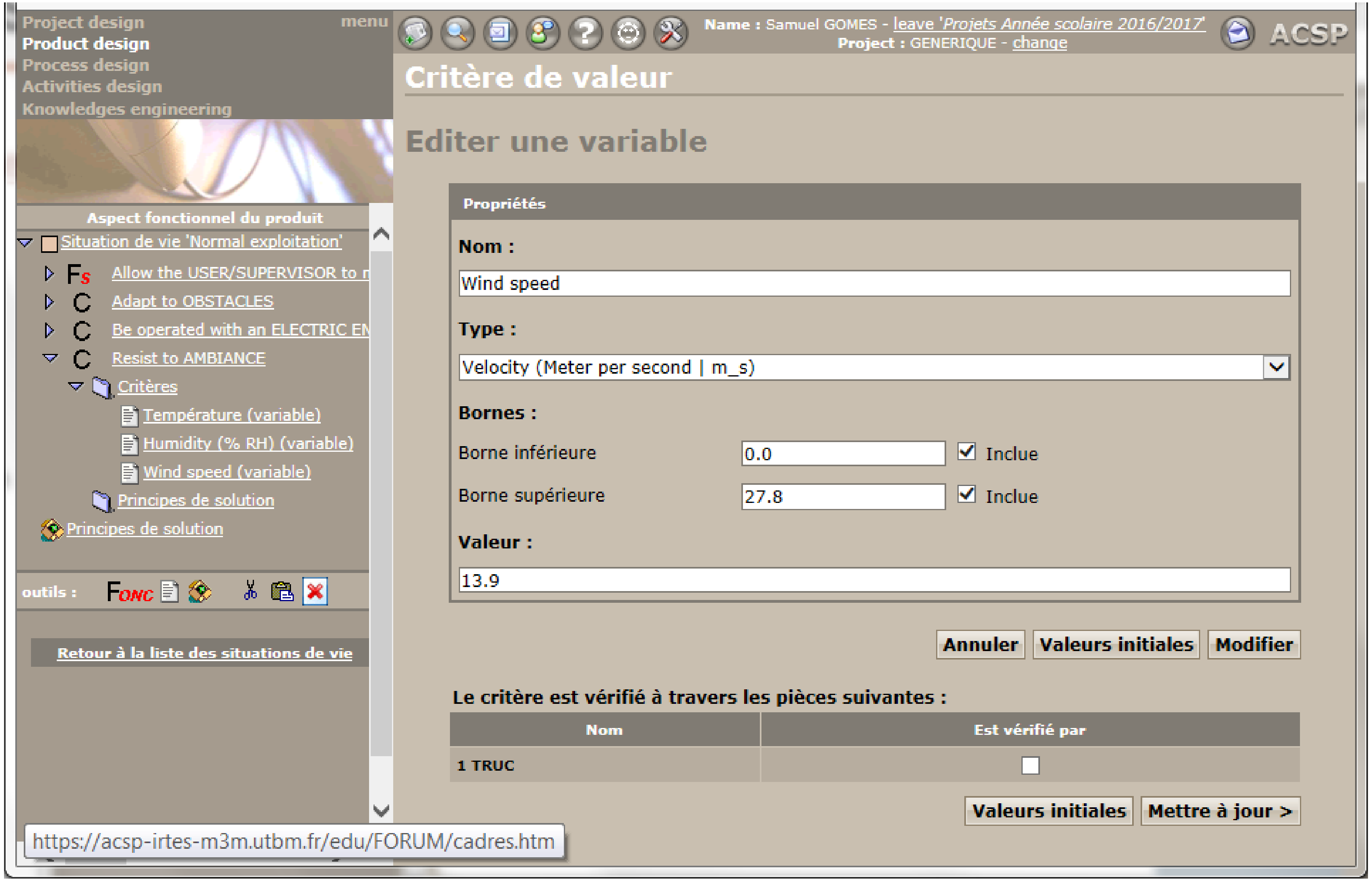


Use case

C. Research of value criteria for each function

Life situation : Normal use

- CF3: Resist to AMBIANCE
  - Temperature: -30°C < T < +80°C
  - Humidity: 0% < RH < 100%
  - Wind speed: 0km/h < S < 100km/h
  - etc.



Use case

DSM application to Requirements

Besoin	Niveau		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	Total
Evoluer en milieu terrestre	Sec/Humide/moue/Glissant	R1	1	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1	13
Altitude de vol	Alti min =0m max=100m	R2	0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	1	5
Humidité de l'air	0%RH à 80%RH	R3	1	0	1	1	0	1	1	1	1	1	1	0	1	0	1	0	11
Vitesse du vent	0Km/h	R4	1	1	1	1	0	1	0	1	1	1	1	1	0	1	1	1	13
Présence de fumée	Oui	R5	1	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	5
Evoluer sur l'eau	Calme à légèrement agitée	R6	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	0	11
Température	de -10°C à 40°C	R7	1	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	5
Résistance à l'eau	Etanche	R8	1	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	5
Type de Fonctionnement	Autonome ou piloté par l'utilisateur	R9	1	1	1	1	1	0	1	0	1	0	0	1	0	0	0	0	8
Stabilité dans les trois milieux	En phase de mesure/déplacement	R10	1	0	1	1	0	1	0	0	0	1	1	1	0	0	1	0	8
Réactivité de la direction	Moyenne	R11	1	0	1	1	0	1	0	0	0	1	1	1	0	0	0	0	7
Autonomie des batteries	30 min	R12	1	0	0	1	0	1	0	0	1	1	1	1	1	0	0	0	8
Recharge des batteries	1h30	R13	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	3
Encombrement	50cm à 80cm	R14	1	0	0	1	0	1	0	0	0	0	0	0	0	1	1	0	5
Franchir des obstacles	3cm	R15	1	0	1	1	0	1	0	0	0	1	0	0	0	1	1	0	7
Résister aux chocs	Forts	R16	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	4

Use case

DSM application to Functions

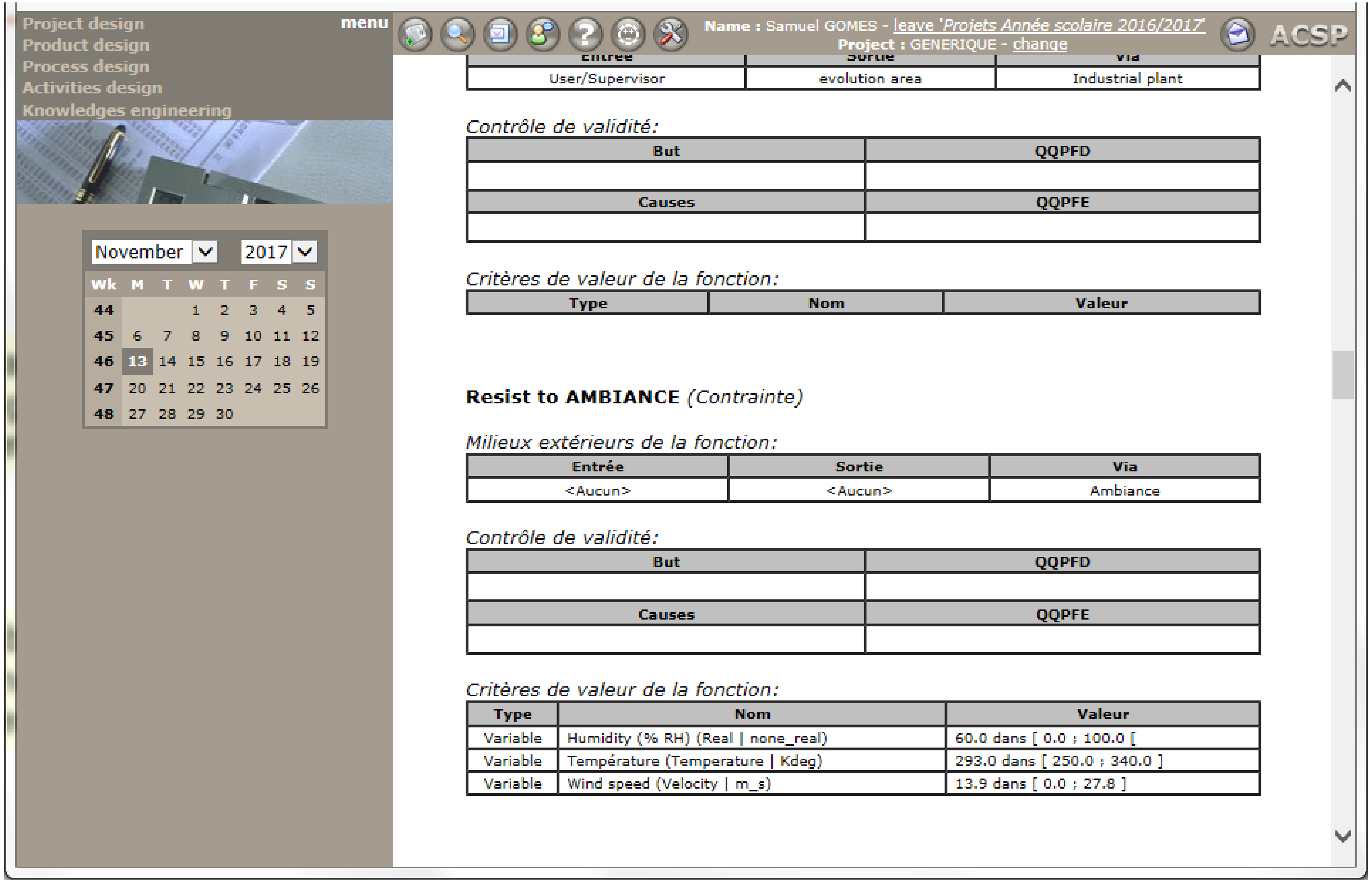
			FP1	FC1	FC2	FC3	FC4	FC5	FC6	FC7	FC8	FC9	Total
Utilisation	Permettre à l'utilisateur de surveiller un site industriel dans les trois milieux	**FP1**	1	1	1	1	0	0	0	0	0	0	4
	Résister aux environnements extérieurs	**FC1**	1	1	0	1	0	0	0	0	0	0	3
	Être alimenté en énergie	**FC2**	1	0	1	1	0	0	0	0	0	0	3
	S'adapter aux obstacles	**FC3**	1	1	1	1	0	0	0	0	0	0	4
Fabrication maquette/prototype	Être réalisable dans les ateliers de l'UTBM	**FC4**	0	0	0	0	1	1	0	0	0	0	2
	Respecter le budget imposé par l'école	**FC5**	0	0	0	0	1	1	0	0	0	0	2
Maintenance	Être clair et intuitif	**FC6**	0	0	0	0	0	0	1	1	0	1	3
	Être démontable avec un outillage simple	**FC7**	0	0	0	0	0	0	1	1	1	1	4
	Être le moins couteux possible	**FC8**	0	0	0	0	0	0	0	1	1	1	3
	Proposer des pièces facilement remplaçable	**FC9**	0	0	0	0	0	0	1	1	1	1	4

Use case

D. Generate the Requirement book

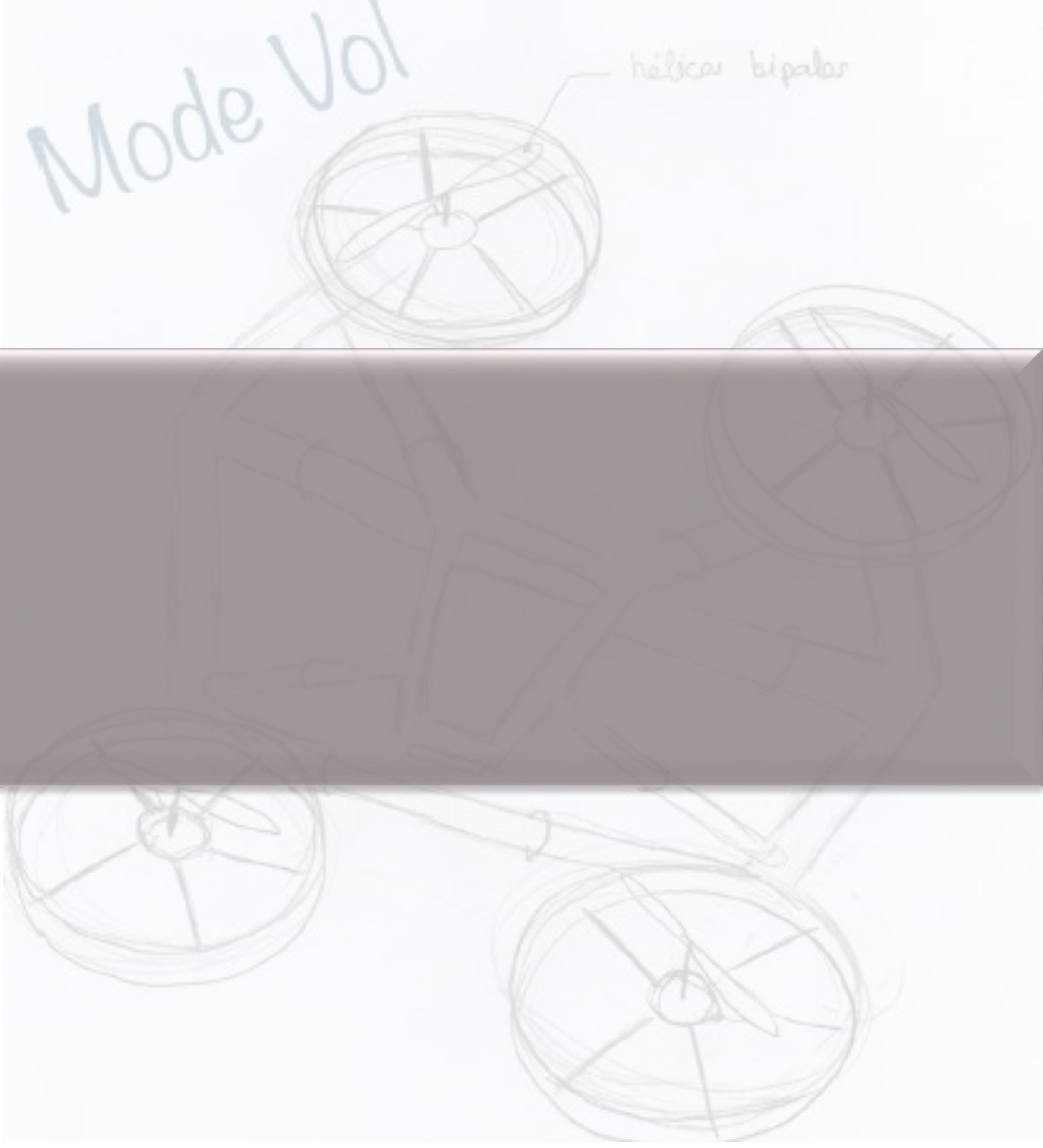
For each life situation

- All functions (DSM: sorted list of functions, clusters of functions)
  - All value criteria (DSM: sorted list of value criteria, clusters of value criteria)



Use case

Design

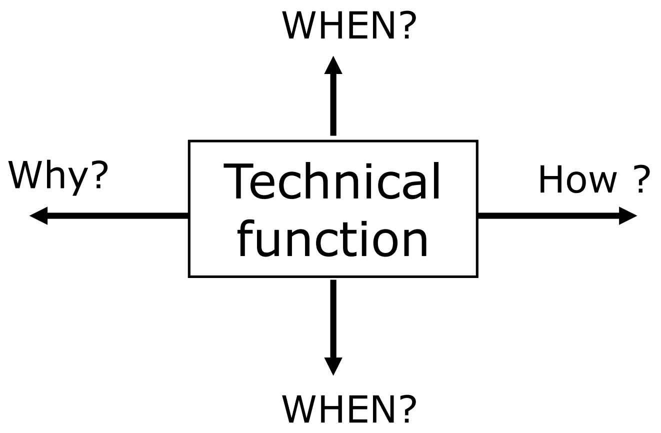


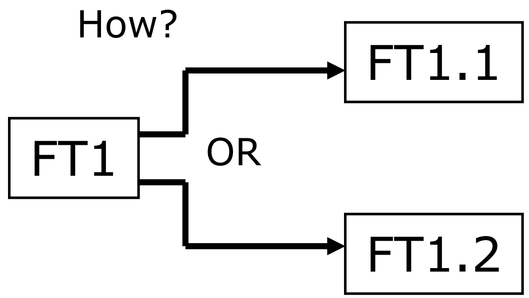
FAST: Function Analysis System Technique

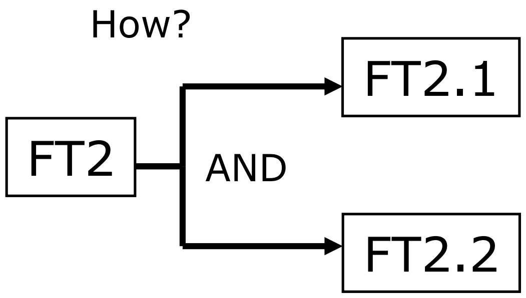
- FAST is a graphical communication tool between project stakeholders. FAST focuses on the relationships between functions towards product modules/components.
- Objective: establish a tree of technical functions (tree of solutions) whose final elements constitute principles of solution which can be integrated in the final design
- FAST method helps to organize technical functions of a product, defined from Sfi and CFj. FAST helps to represent the logic of the relationships between functions, by repetition of "Why? - How? - When? » asked at each stage of the analysis.
- FAST produces a diagram that helps designers to explain and justify technical solutions

FAST: Function Analysis System Technique

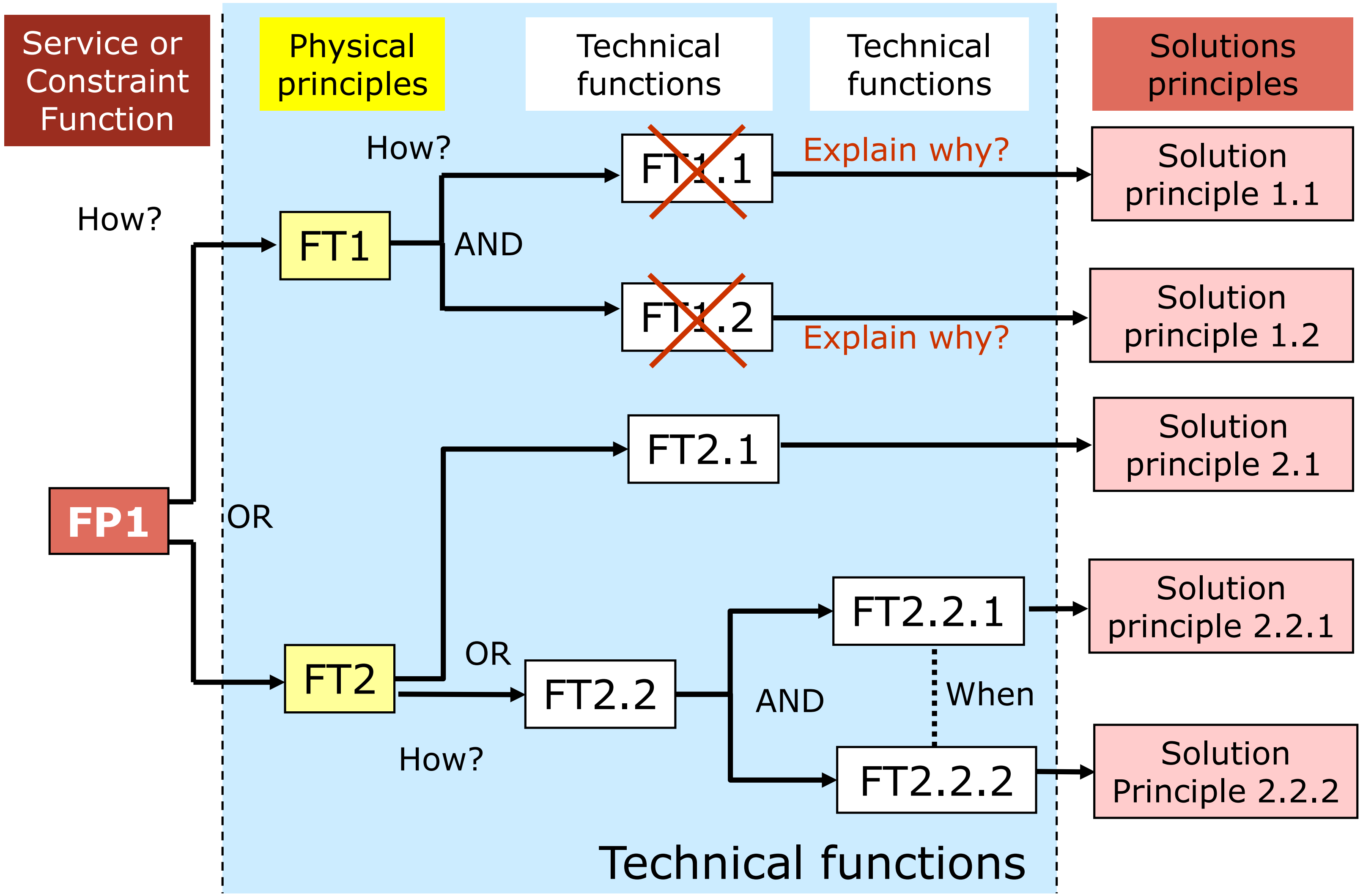
The following formalism is used to establish FAST diagram







FAST: Function Analysis System Technique



Service or Constraint Function	1rst Solution principle	2nd Solution principle	3rd Solution principle	4th Solution principle
SF1	Solution principle 1.1 + Solution principle 1.2	Solution principle 2.1	Solution principle 2.2.1 + Solution principle 2.2.2	
SF2	…	…	…	…
CF1	…	…		
CF2	…	…	…	…
…	…	…	…	

1rst concepts generation (compatibility)

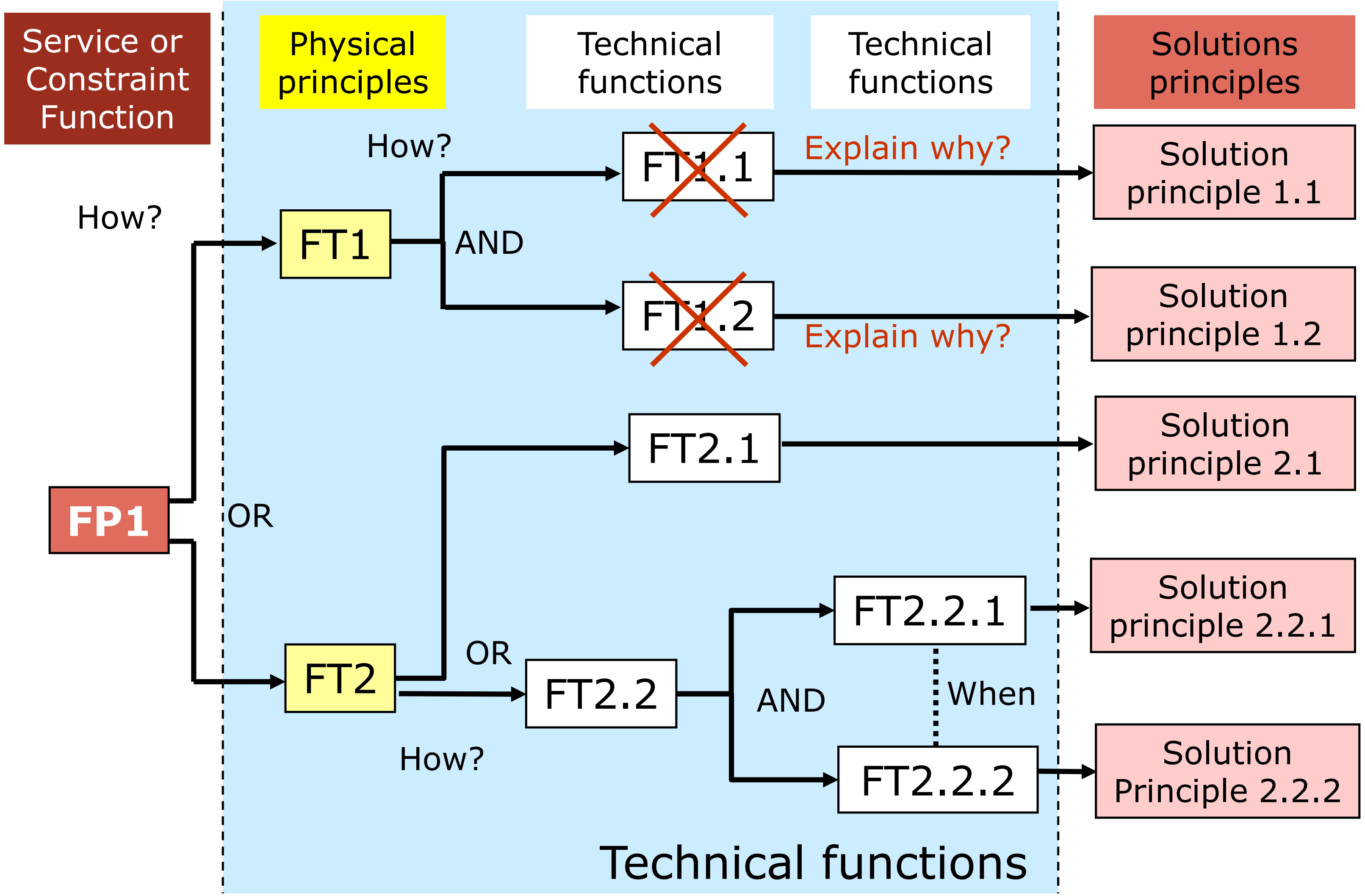
Service or Constraint Function	1rst Solution principle	2nd Solution principle	3rd Solution principle	4th Solution principle
SF1	Solution principle 1.1 + Solution principle 1.2	Solution principle 2.1	Solution principle 2.2.1 + Solution principle 2.2.2	
SF2	…	…	…	…
CF1	…	…		
CF2	…	…	…	…
…	…	…	…	

Preconcept 1

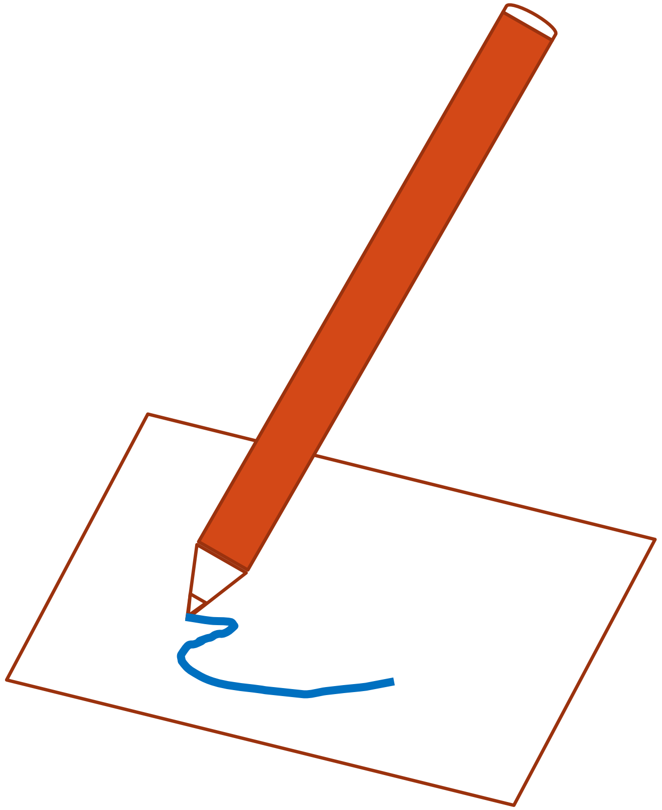
Service or Constraint Function	1rst Solution principle	2nd Solution principle	3rd Solution principle	4th Solution principle
SF1	Solution principle 1.1 + Solution principle 1.2	Solution principle 2.1	Solution principle 2.2.1 + Solution principle 2.2.2	
SF2	…	…	…	…
CF1	…	…		
CF2	…	…	…	…
…	…	…	…	

Preconcept 2

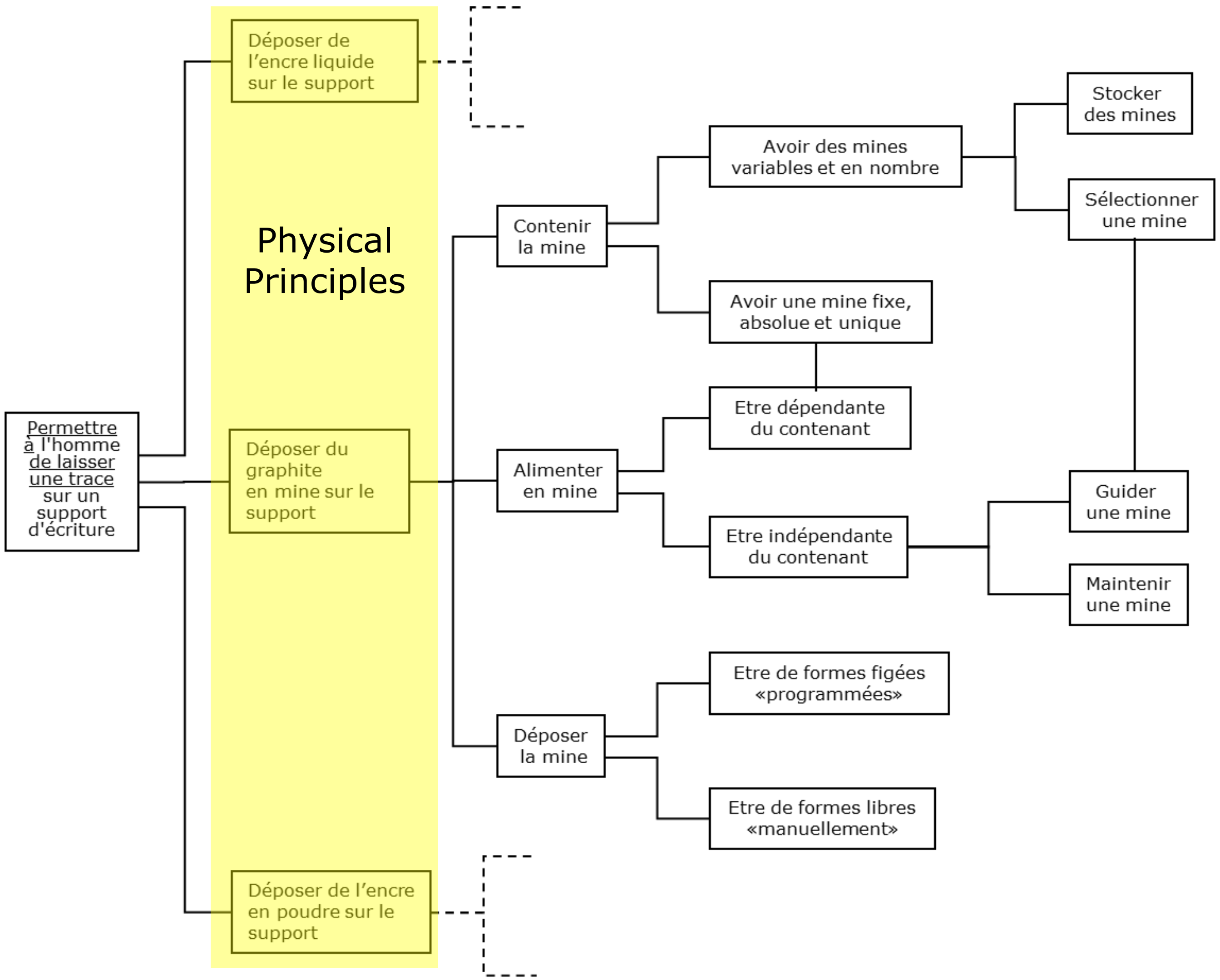
FAST: Function Analysis System Technique



Let's perform together an example: Stypen



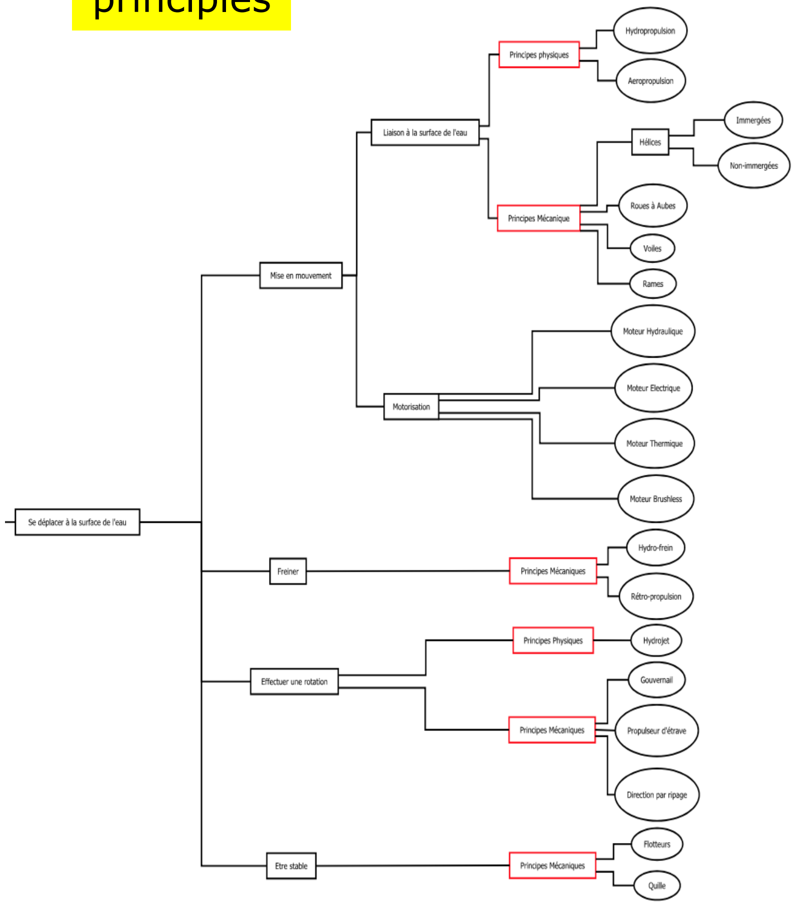
FAST: Function Analysis System Technique

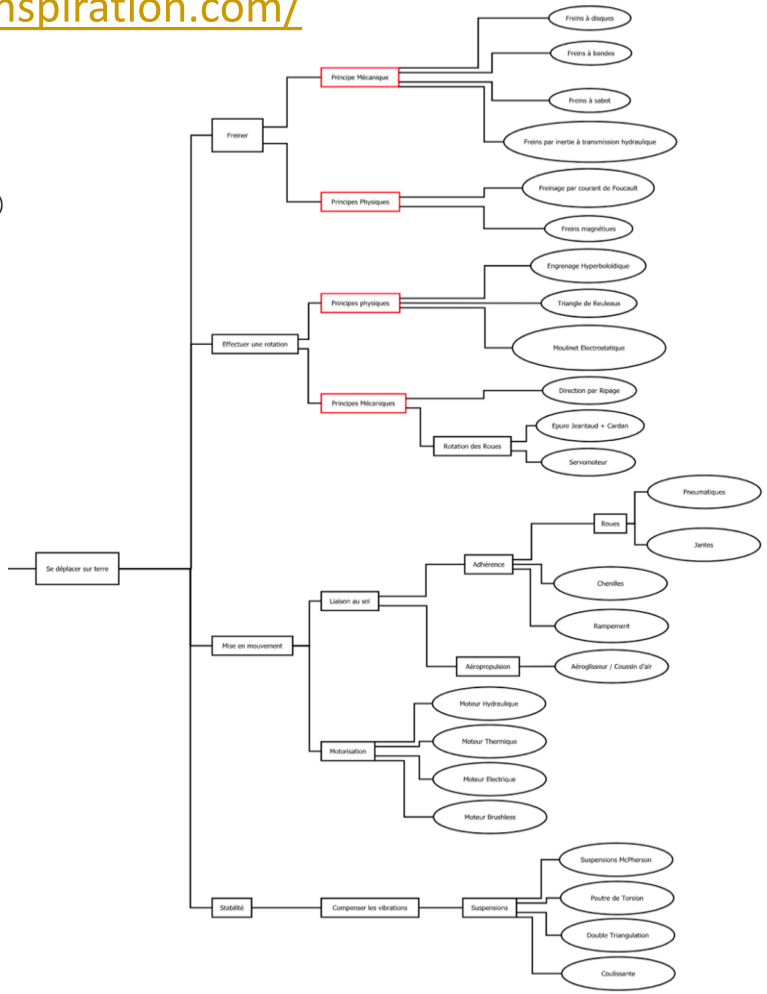


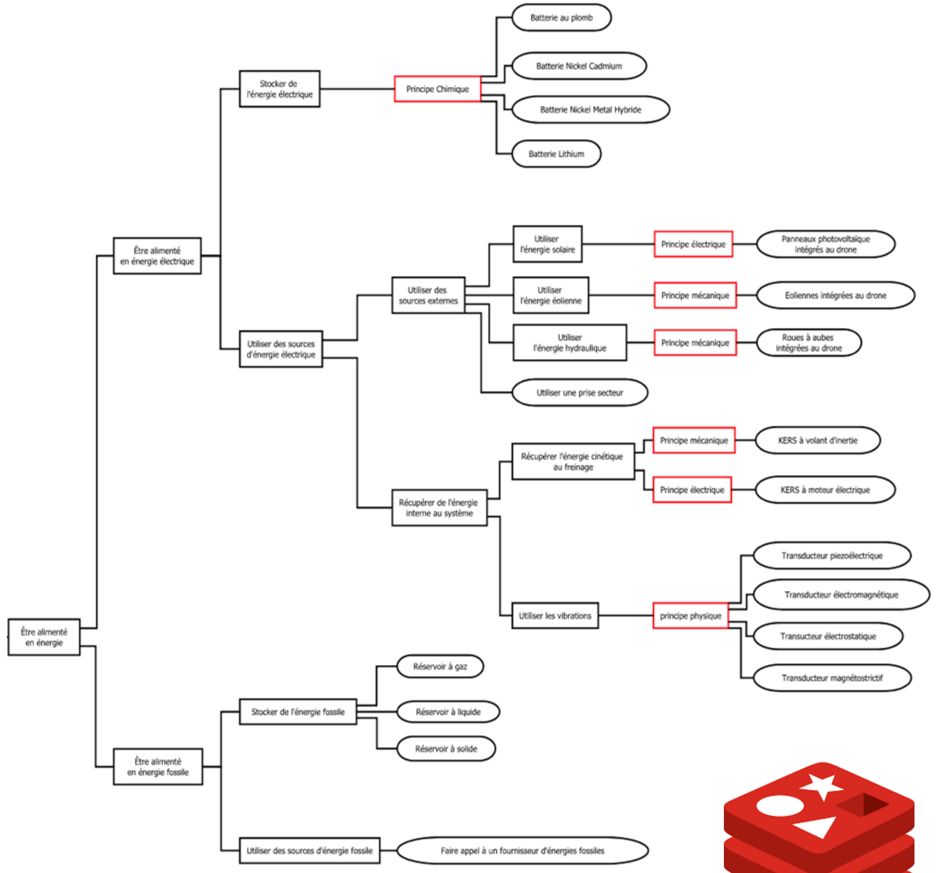
FAST: Function Analysis System Technique

Physical principles

http://www.productioninspiration.com/







Use case

First pre-concepts design and quotation

	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6	Concept 7
Permettre à l'utilisateur de surveiller un site industriel dans les trois milieux	2	2	2	2	2	2	2
Résister aux environnements extérieurs	1	2	1	2	2	2	1
Être alimenté en énergie	1	0	1	2	2	2	1
S'adapter aux obstacles	0	1	0	1	1	1	2
Être réalisable dans les ateliers de l'UTBM	1	2	1	2	1	2	1
Respecter le budget imposé par l'école	2	2	1	1	2	2	2
Être clair et intuitif	1	2	0	2	2	2	2
Être démontable avec un outillage simple	1	2	1	2	2	2	2
Être le moins couteux possible	0	1	1	1	2	1	1
Proposer des pièces facilement remplaçable	1	1	1	2	1	1	1
Total	15,5	23,5	14,5	27,5	27	26,5	24,5

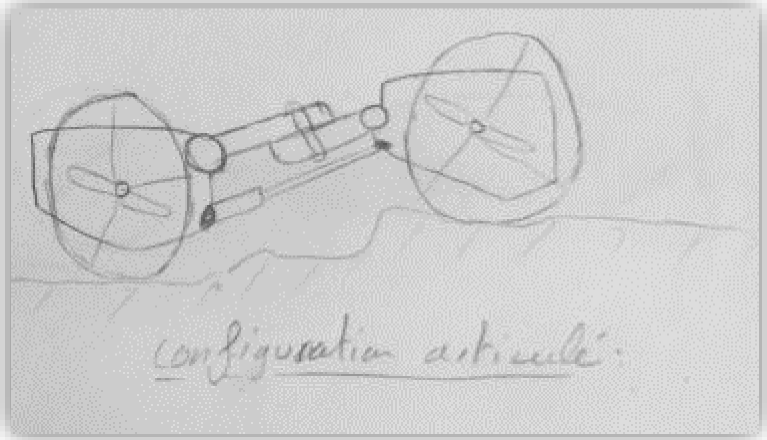
Classer les Pré-Concepts notés

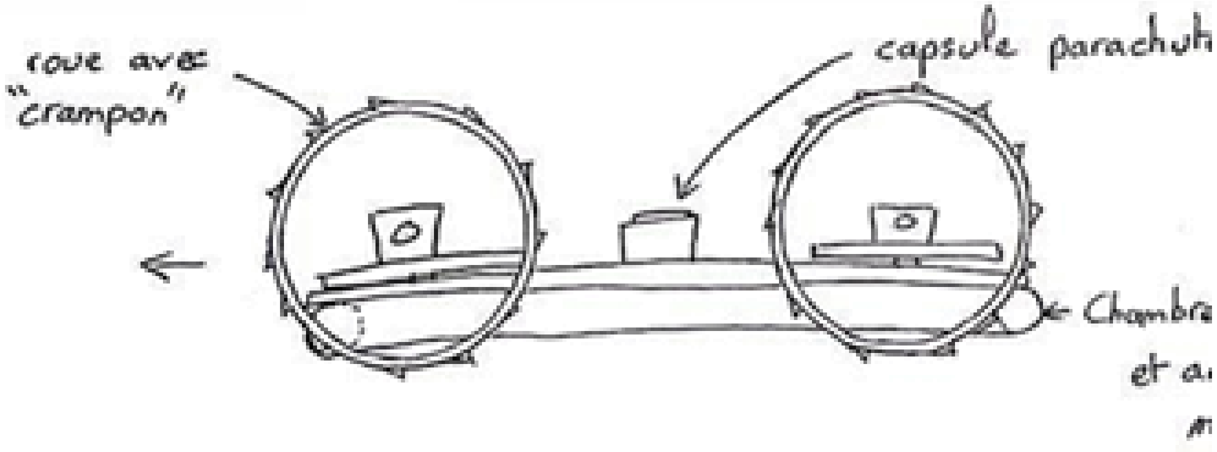
Classement	
Concept 4	27,5
Concept 5	27
Concept 6	26,5
Concept 7	24,5
Concept 2	23,5
Concept 1	15,5
Concept 3	14,5

Use case

Final concept design and optimization

- Direction cylinders
- Vertical articulations
- Shape of the floats
- Floats under pressure
- Hollow shell & PCB storage
- Tires





Use case

Conclusion

New design practice

Functional design and architecture design need to be performed before geometrical design

Parametric design and design optimization should be next steps

This approach is applied in many projects at UTBM

- Functional Design
- Architecture design
- Parametric design
- Geometric design
- Design optimization

Questions ?