EC07-FISE-Indus

Industrialization

Instructions

- This course will be taught entirely in English
- If you have any problems with any terms, ask me!!
- Acronyms are described at the bottom of the pages. I use them because you will encounter them during your career.
- I'm going to show you some videos (not all of them) during this lecture because they illustrate the process better than words.
- Questions are possible during lecture (but not too many) or between sessions
- There will be more slides in the presentation than during the course, you will have to read them before/after the course as you wish (recommended for the final evaluation).

Syllabus extract

Compétences	Etre capable de : - Choisir et valider un procédé de fabrication à partir d'un cahier des charges incluant les principes du développement durable - Valoriser les coûts de production d'un produit - Gérer un projet d'industrialisation									
Contenu de cours	Industrialisation (7,5hC, 3hTD, 6,5hTP) : 6hCM - CD 1,5CM - SH - Historique, définitions et démarche générale de l'industrialisation - La conduite de projet d'industrialisation : L'industrialisation en lien avec les autres fonctions dans l'entreprise (Bureau d'études, Marketing, logistique, Outillage, Production, Qualité, Achats) Transformation de la matière nécessitant des outillages spécifiques (Fonderie, Injection et extrusion plastique, métal, compression thermodurcissable, des poudres, découpe en bande, emboutissage, filage) Utilisation d'assemblages automatisés, intégration de soudures, de marquages, de cartes électroniques et adjonction de conditionnement Le fonctionnement des machines numériques et les risques liés à leur utilisation L'adaptabilité des processus d'assemblages dans les processus d'industrialisation L'intégration des outils numériques (IoT) dans les processus d'industrialisation - L'élaboration des coûts d'industrialisation : Make or Buy ? La prise en compte de la localisation dans les processus d'industrialisation et de transferts de production. La prise en compte de la taille des séries - Les normes environnementales dans le cycle de vie produit TD1 : Comprendre et réaliser une stratégie de localisation industrielle d'un produit (TD - CD) TD2 : Profil environnemental du produit (PEP) - (TD - SH) TP1 : Industrialiser la fabrication d'un chariot de manutention (TP -MA) TP2 : Business Plan et décision de site de fabrication en prenant en compte les aspects économiques et environnementaux (TP - CD)									
Responsable	Philippe RAGOT									
Evaluation	DS	TP	Projet	Cours	Soutenances	Autre				
Nombre d'évaluations	1	2	0	0	0	0				
Coefficient de l'évaluation	5	3	0	0	0	0				
Détail de l'évaluation	1 DS type QCM et 2 TP évalués									

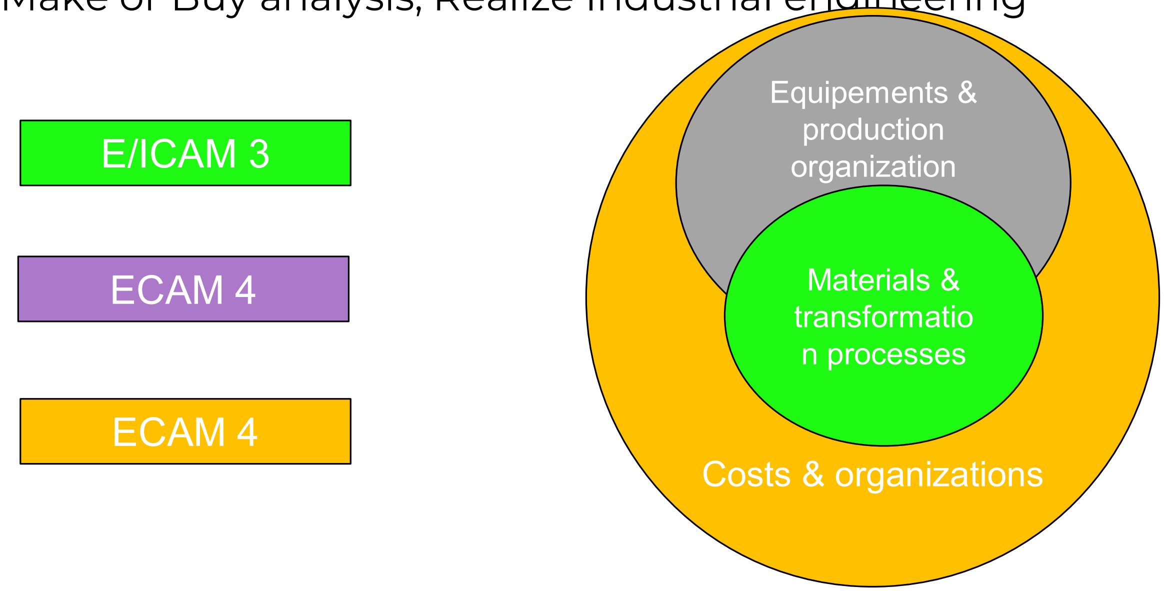
Structure of the EC:

- With Me: 4 Courses + 1TD + 1 Practice (Evaluated)
- With Mr Hassayoune: 1 Course + 1TD : "Sustainable development in Industrialization"
- With Mr ARNAUD: 1 Practice (Evaluated)
- 1 DS QCM evaluation

Objectives

Following your “Industrial Processes” training, you will continue to develop your skills in order to be able to:

- Understand “Industrialization” & the related positions
- Select and validate a manufacturing process based on specification sheet
- Estimate a production cost, Perform Make or Buy analysis, Realize Industrial engineering business plan
- Manage an industrialization project



Industrial engineering

1. **History, definitions and general process to industrial engineering**
2. **Industrial engineering in connection with other functions within the company**
3. **Assembly, treatments and tests in production**
4. **Equipment associated to processes, investment**
5. **Process Plan - Costing – Make or Buy – Business Plan**
6. **Industrial Engineering project, profitability**

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4. Equipment associa
5. Process Plan - Cost
6. Industrial Engineer

Why Industrial engineering ?

Why suddenly in the middle of the night someone woke up from a nightmare and said**: "I need industrialization!!"**

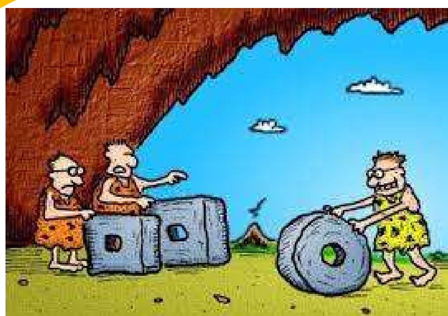
Industrialization: when ?

Industrialization: who is doing ?

Industrialization: what for ?

Industrialization: how much?

Some time ago… but in the end, it's always about customer satisfaction



Some time ago…

A customer demand was there

But…

Craft production

Production process was improved

How can I deliver what my Market is ready to pay for ?

The customer comfort demand increased

Industrial mass production was invented

The customer Quality demand increased

Costs competitiveness

Low tech ?

How can I do more with less ?

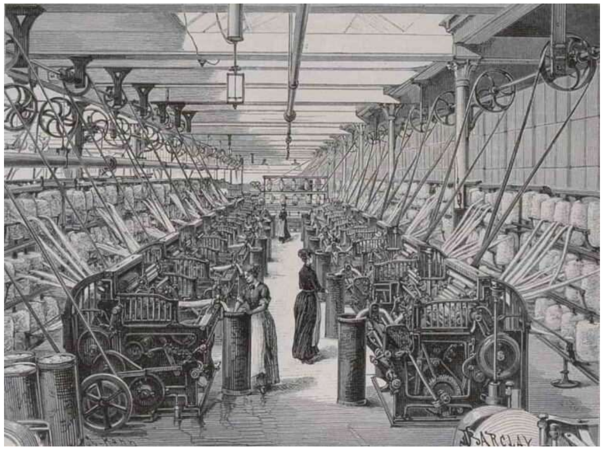
INDUSTRIALIZATION

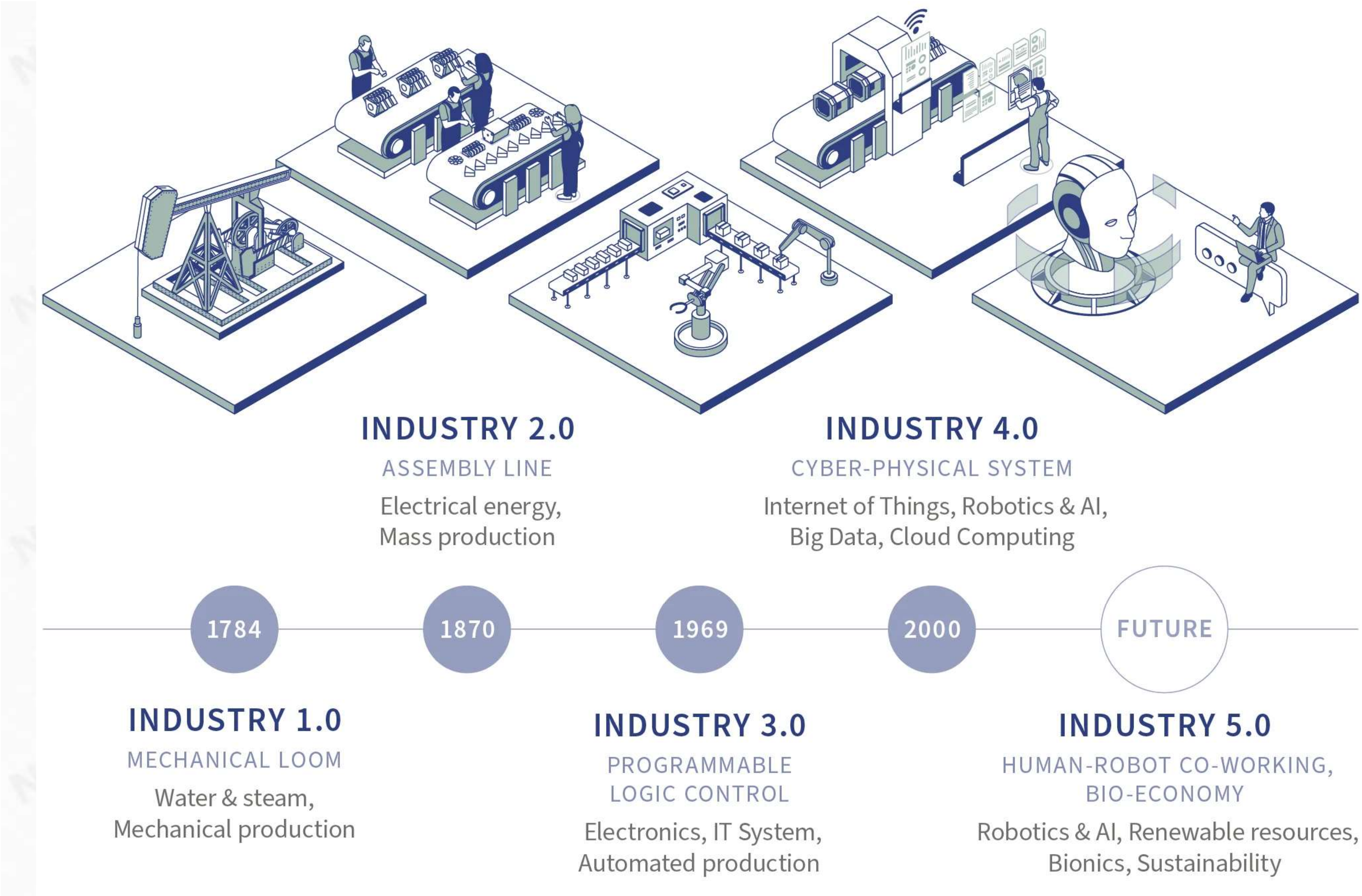
Why Industrial engineering ?

Operational Performance Must-Haves	Strategic Positioning Nice-to-Win
To fulfill Customer demand : • Manufacturing volumes • Production costs • Quality • Time	• Competitiveness • Differentiation • Sustainability • Eco Responsibility • Localization • …

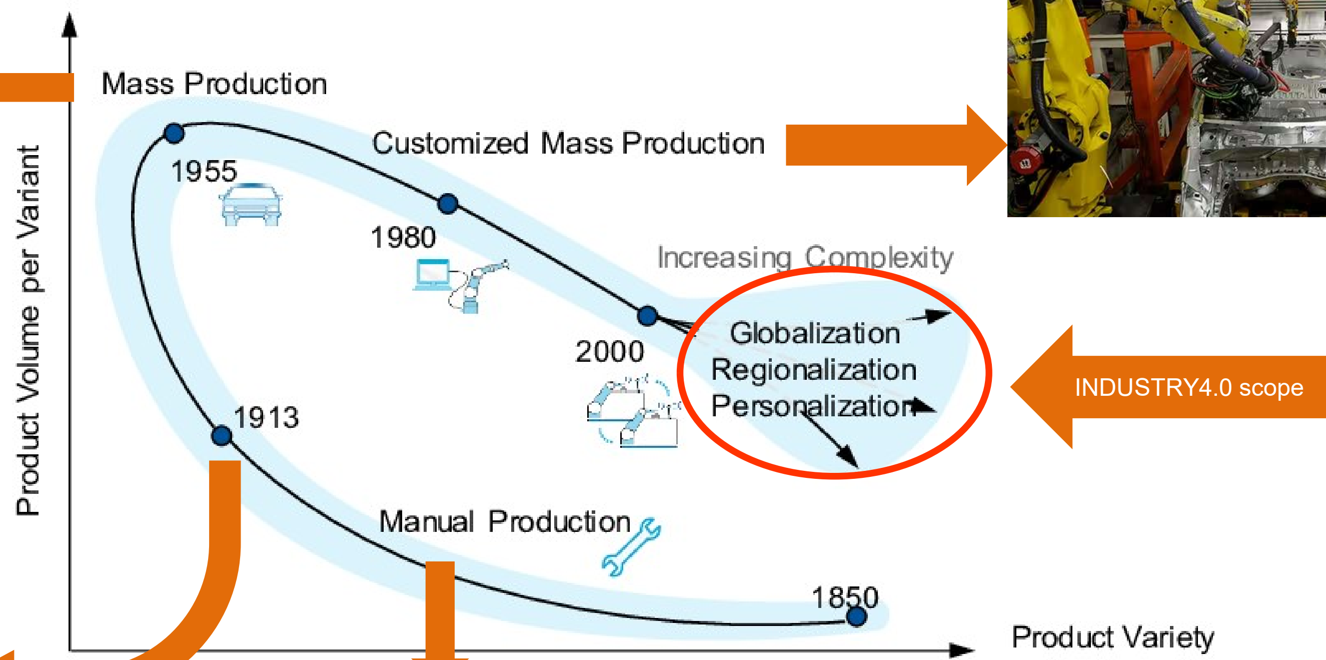
History - Industrial Revolutions & Production Systems Evolution

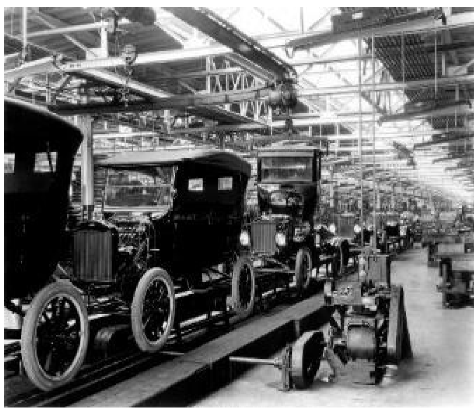
- **End XVIIIth**: Industrialization in England & Belgium
- **Beginning XIXth**: Industrialization in France
- **Second half XIXth**: Industrialization in Germany & USA
- **Beginning XXth**: Taylorism, Fordism in USA (division of labor, line balancing, wages per unit, low-skilled operators)
- **1960s (Japan)**: Process enrichment: Just-in-Time, Kanban, TPM → Lean manufacturing
- **1980s**: Industrial IT, Robots, CNC, Computer-Aided Manufacturing, flexible machines
- **End 1990s**: China: “Factory of the World” (low-cost, low-quality production)
- **2011 (Germany)**: Concept of Industry 4.0 (response to China, focus on cyber-physical systems, IoT, data)

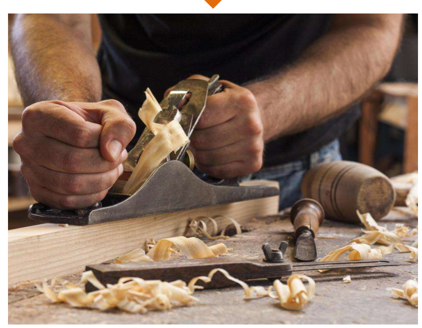



INDUSTRY 2.0
ASSEMBLY LINE
Electrical energy,
Mass production
INDUSTRY 4.0
CYBER-PHYSICAL SYSTEM
Internet of Things, Robotics & AI,
Big Data, Cloud Computing
1784
1870
1969
2000
FUTURE
INDUSTRY 1.0
MECHANICAL LOOM
Water & steam,
Mechanical production
INDUSTRY 3.0
PROGRAMMABLE
LOGIC CONTROL
Electronics, IT System,
Automated production
INDUSTRY 5.0
HUMAN-ROBOT CO-WORKING,
BIO-ECONOMY
Robotics & AI, Renewable resources,
Bionics, Sustainability

From 1st industrial revolution to INDUSTRY4.0







Industrial evolution over the time

	Production	Operators' skills	Communication	Scope of com	Time unit
First industrial revolution (1780 - 1870)	Unit production or small batches	Craftsmen	Human to human	Whole workshop with few people	Week / Month / more
Second industrial revolution (1910 - 1940)	Large volumes of standard products	Very limited	Human to human	Each working station	Week / Month
Third industrial revolution (1970 - 1990)	Small to large batches of standard products	Either no operator or skilled operators / technicians	From ERP --> Human → machines → Human → ERP	Standalone machines or lines	Hour / Day
Fourth industrial revolution (2005 - ...)	Unit to medium batches of customized products	Either no operator or skilled operators/ technicians	Carried by products → Smart machines connected to ERP	Whole value added chain	Millisecond / Minute

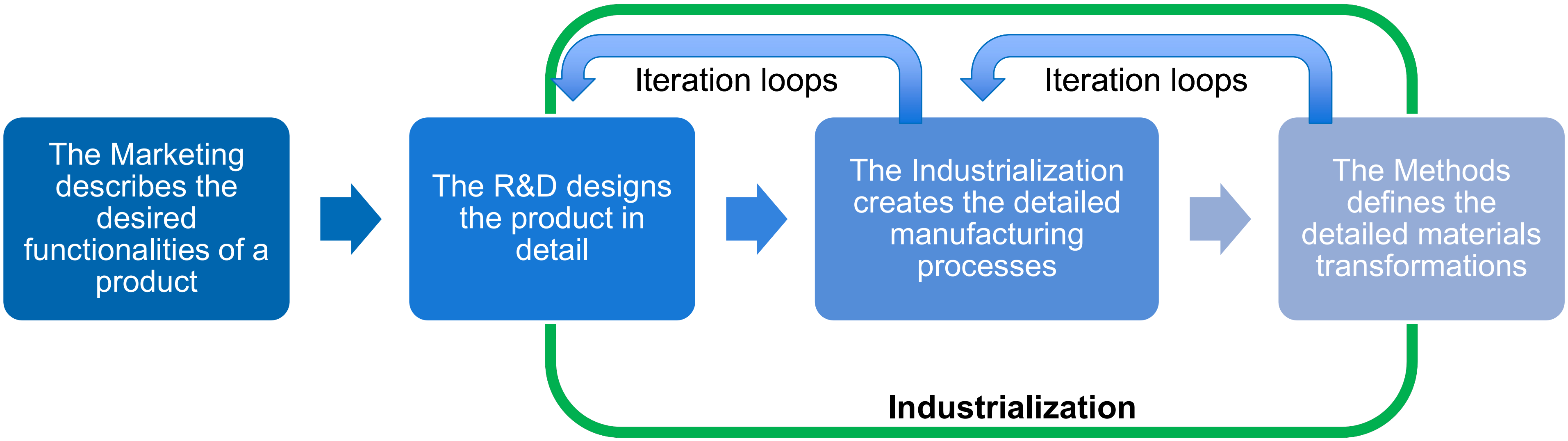
High mix – Low volumes, MTO (Make To Order)

Smart connected machines

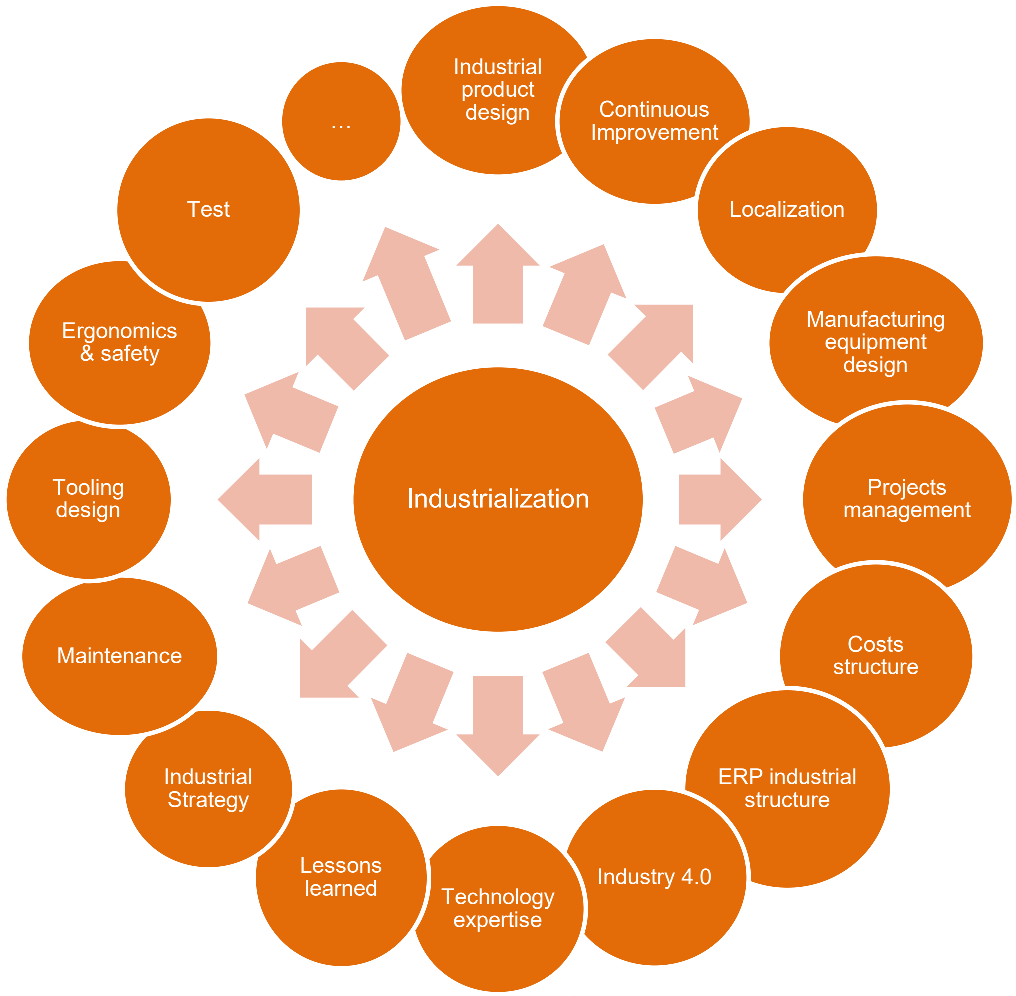
ERP: Enterprise Resource planning

Where stands “industrialization” in the product creation process

Reminder



Activities commonly managed by Industrialization



Definition & terms

Industrialization (US) Industrialisation (UK)

Turning economies from craft and agriculture into factory-based mass production.

Manufacturing Engineering

How to make things: design and improve machines, tools, and processes.

Industrial Engineering

How to make things work better: optimize people, machines, and systems for efficiency.

Engineering

Using science and math to solve real-world problems and build solutions.

Production Engineering

How to run production: plan, control, and manage the workflow in factories.

Methods

The “best way” to do a task, written down and standardized for repeatability.

Definition from Wikipedia: Nowadays

Industrial Engineering is an engineering profession that is concerned with the optimization of complex processes, systems, or organizations by developing, improving and implementing integrated systems of people, money, knowledge, information and equipment. Industrial engineering is central to manufacturing operations.

Industrial Engineers use specialized knowledge and skills in the mathematical, physical and social sciences, together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results obtained from systems and processes. There are several industrial engineering principles followed in the manufacturing industry to ensure the effective flow of the systems, processes and operations. This includes Lean Manufacturing, Six Sigma, Information Systems, Process Capability and DMAIC. These principles allow the creation of new systems, processes or situations for the useful coordination of labor, materials and machines and also improve the quality and productivity of systems, physical or social. Depending on the sub-specialties involved, industrial engineering may also overlap with, operations research, systems engineering, manufacturing engineering, production engineering, supply chain engineering, management science, management engineering, financial engineering, ergonomics or human factors engineering, safety engineering, logistics engineering or others, depending on the viewpoint or motives of the user.

DMAIC: Define Measure Analyze Improve Control

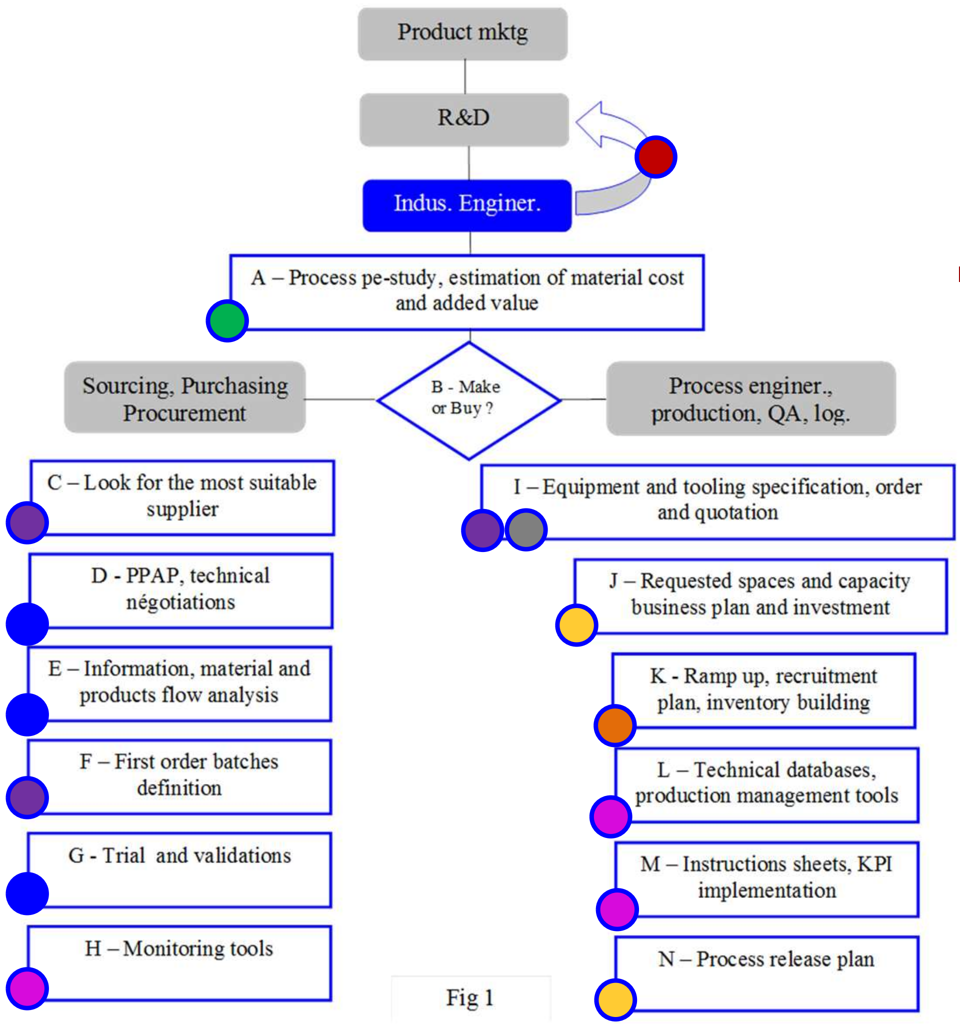


Fig 1

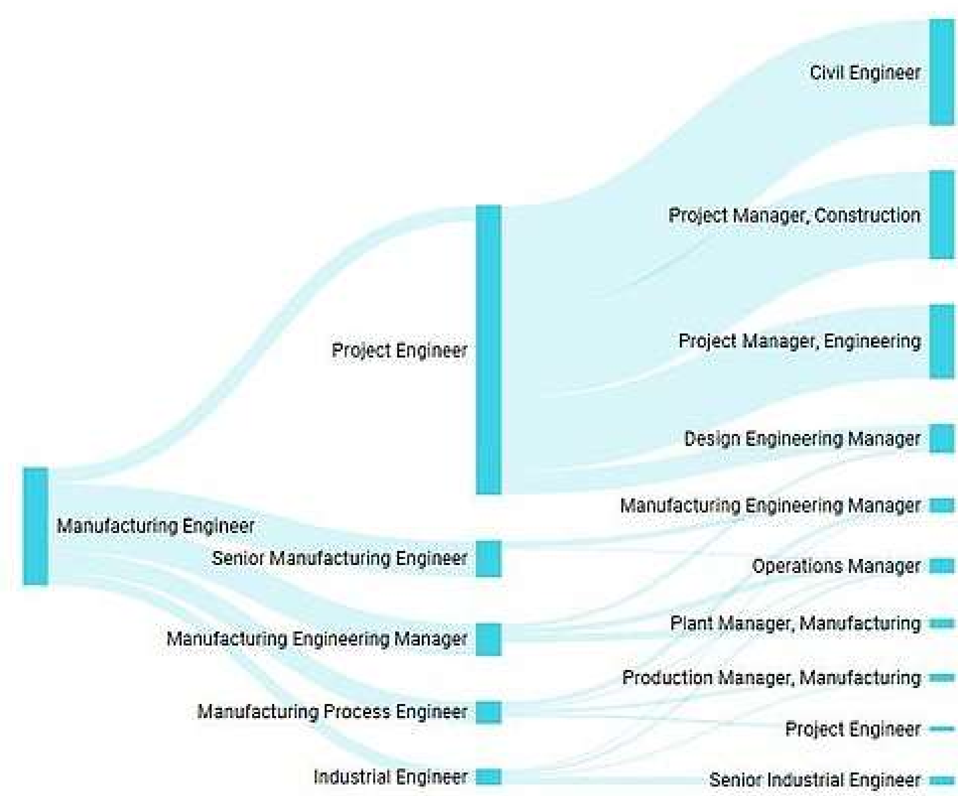
Typical steps

- American Institute of Industrial Engineers, 1975 ;

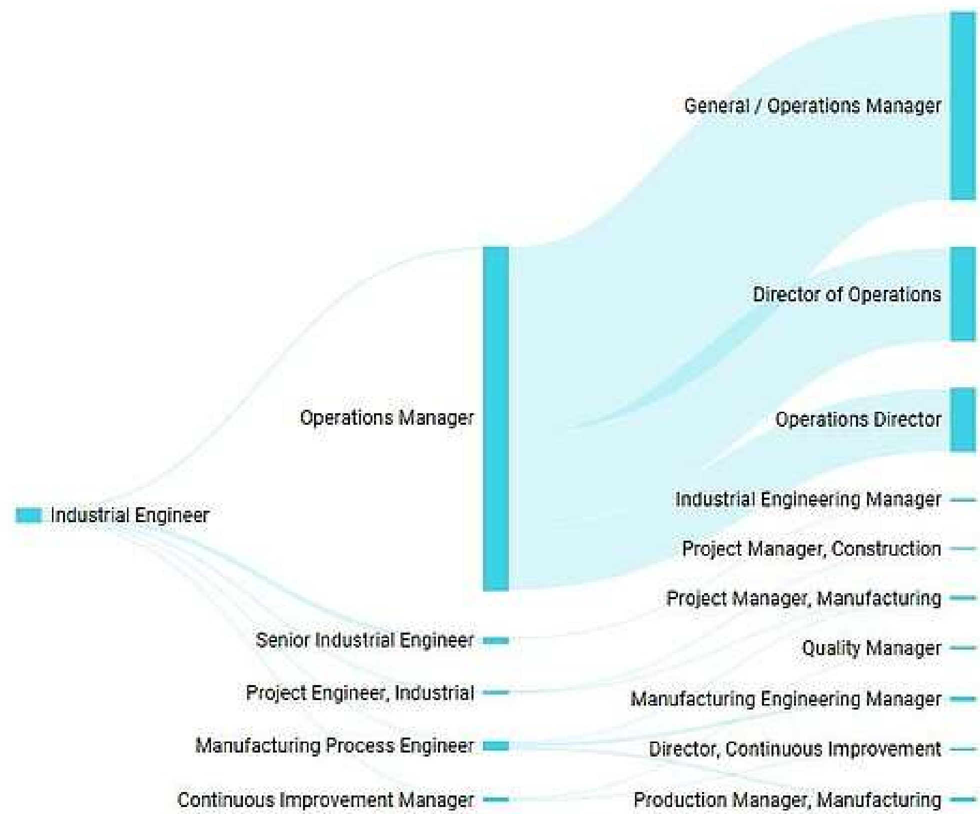
"Industrial engineering is concerned with the design, improvement, and installation of integrated systems of people, materials, equipment, and energy. It draws upon specialized knowledge and skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems"

Career path for Industrialization engineers

Common Career Paths for Manufacturing Engineer



Common Career Paths for Industrial Engineer



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Industrial engineering in connection with other functions within the company

The purpose of this chapter is to highlight the diversity of activities handled by Industrialization positions.

It will show you that technology is just one part of an Industrialization Engineer's work, building relationships is equally important.

Finally, it will give you a sense of the wide range of activities the industry offers today, in the near future, and throughout your career, depending on your ambitions and career goals.

Position of Industrialization in the global organization of a company

As Industrialization's main roles are to « prepare » product to be manufactured and to define manufacturing equipment, we observe 3 typical situations:

1. Industrialization is part of the R&D department
2. Industrialization is part of the Production organization
3. Industrialization is a standalone department

These 3 situations are related to the size of the company, its history and the emphasis that is intended to put on the deliverables.

Situation 1 will re-enforce the influence of manufacturing into the product design (high manufacturability & quality first => costs by design). But disconnected from production day to day realities. Commonly found in Automotive and fast changing products (Electronic).

Situation 2 will strengthen the competencies available in production facilities, enhance continuous improvement activities and cost driven productions. But this enable poor product manufacturability and creates late product design modifications. Commonly found in stable production cycle with long life products and few design changes.

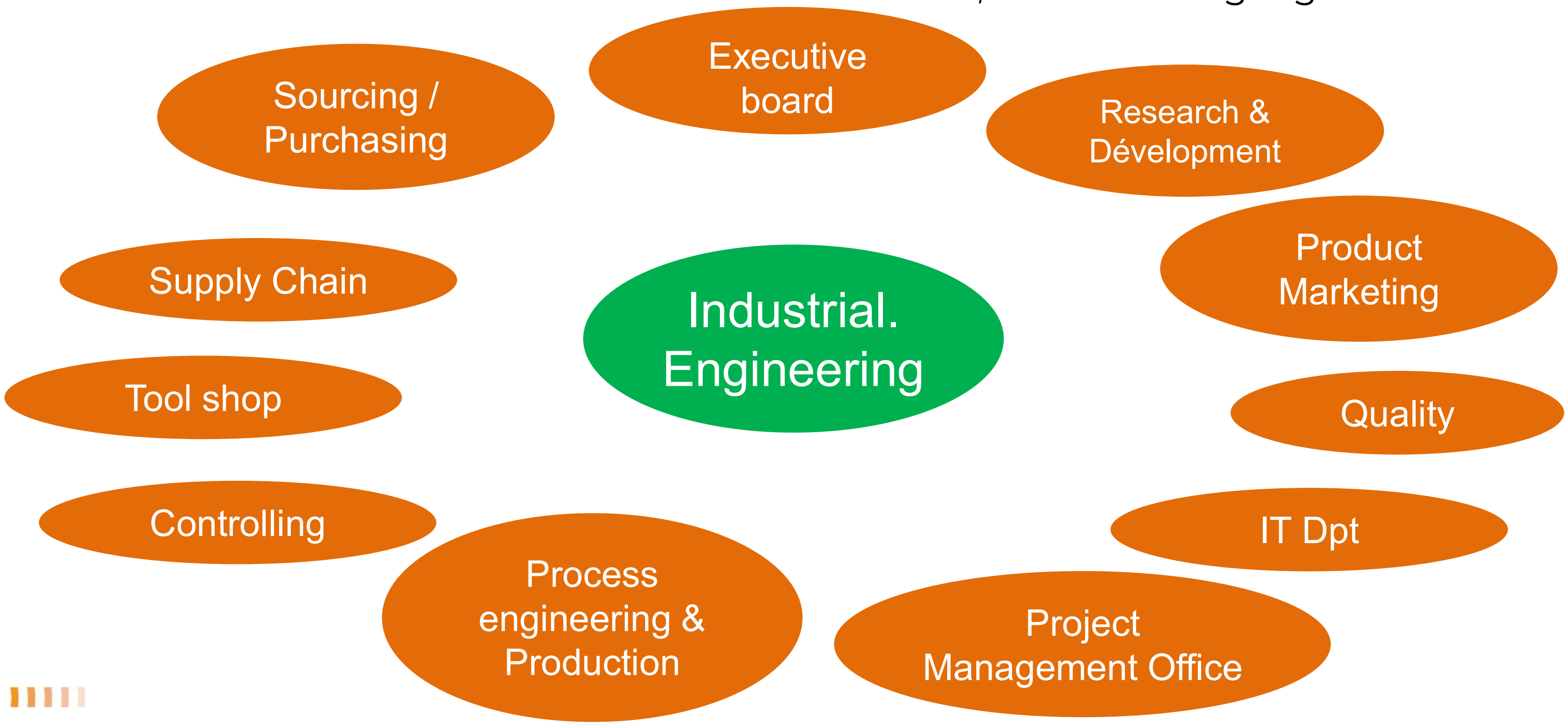
Situation 3 is a compromise of both previous organizations. This is existing in large organizations.

There is a 3bis organization where industrialization is split in 2: one located in R&D focusing on product manufacturability + one located in operations focusing on production means (Called Manufacturing Engineering) => this the most efficient solution, but also the most expensive in terms of resources.

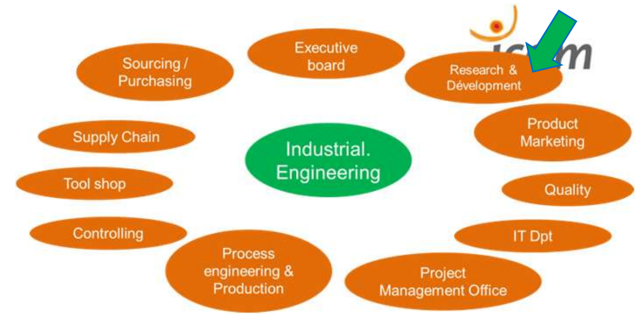
There is no good or bad solution, just the one corresponding to the Market demand !

Relationship of Industrial Engineering within the company

Industrialization is, in essence, a department with a high degree of relationship, there is almost no department that does not interface with industrialization, but I have highlighted the most important.



Interactions with R&D



- Product architecture design, aesthetics and 3D design
- Components design and specs in 2D
- CTQ Critical to Quality parameters to be monitored
- Electrical & electronic drawings, PCBA layout
- Prototyping and tests

R&D

Feasibility technic & economic.

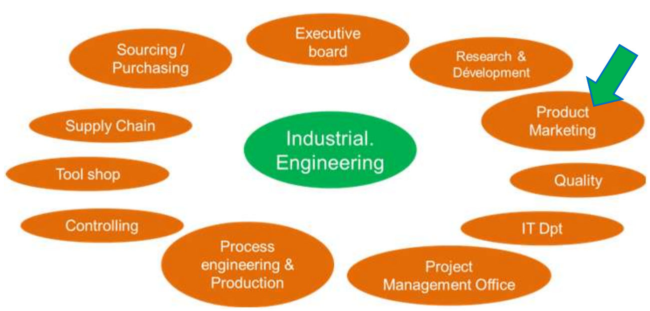
Technical solutions for product challenged by technical solutions for process

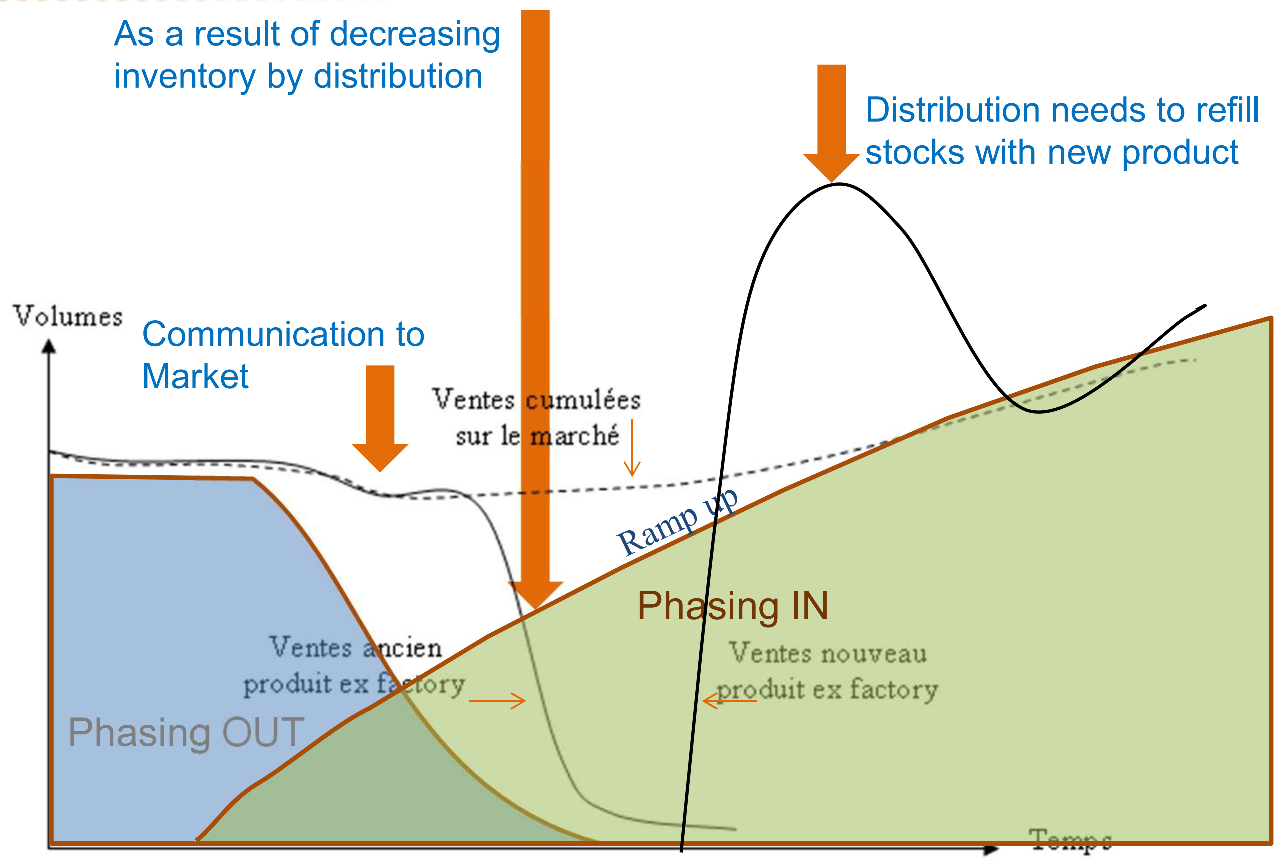
Industrialization

Interactions with Marketing during new product launch

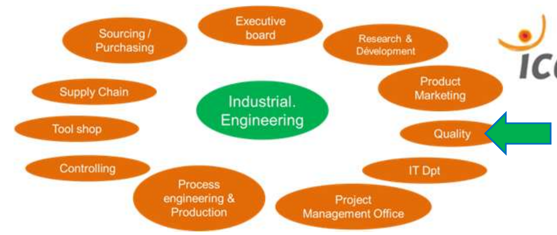
These curves represent the Phase IN / Phase OUT of products when properly managed:

- Smooth production transitions with minimal volume fluctuations
- No dead stock
- Satisfied customers





Interactions with Quality



Industrial engineering has an active role in the Quality Management and some expertise support activities

Process FMEA

Measurement System Analyze and tests in production = Capabilities

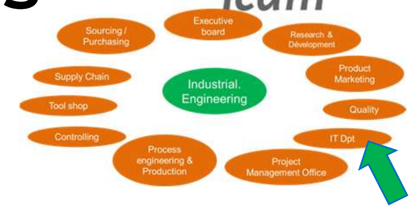
Equipment and process release / validation process

Machines / process capabilities, PPAP (Production Part Approval Process)

Key Quality indicators identification & monitoring

FMEA: Failure Modes & Effects Analysis

Interactions with Information Technologies

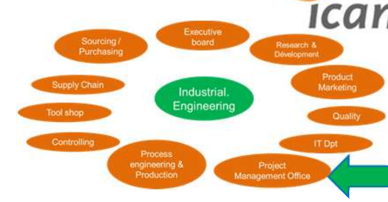


Industrialization is a key user or data provider:

- ERP industrial data structure (Product, Process Plan, Standard time, cost's structure, hourly rates, ...)
- Computer Aided Tools: PDM, PLM, CAD, CAM,...
- MES Manufacturing Execution Systems
- Industry 4.0 related tools
- Maintenance software
- Machines identifications & inventory
- Spare parts management
- Multiple project / planning IT tools
- SPC analyze tools
- Machines operating software
- Test software
- ...

An UpToDate Industrialization department can't operate without IT

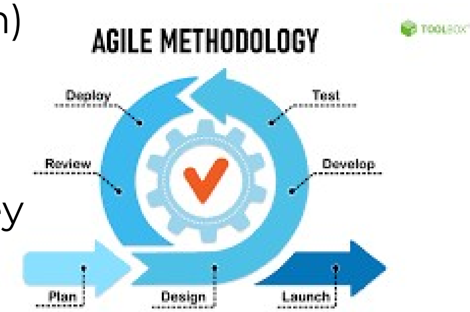
Interactions with Project Management Office (PMO)



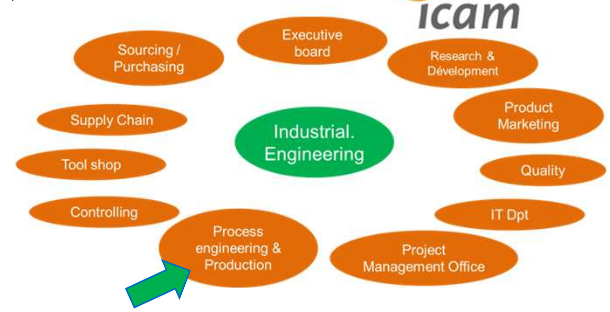
As PMO is coordinating the projects within a company, Industrialization is Leading projects of :

- New product launches
- Product end of life
- Continuous Improvements
- Localization
- Insourcing
- Outsourcing
- Technical expert analyze
- Competency development (technology, project management, CI, Lean)
- Capitalization
- …

Proposing new projects, reporting ongoing activities & achievements (Key Project Indicators) , mitigating risks

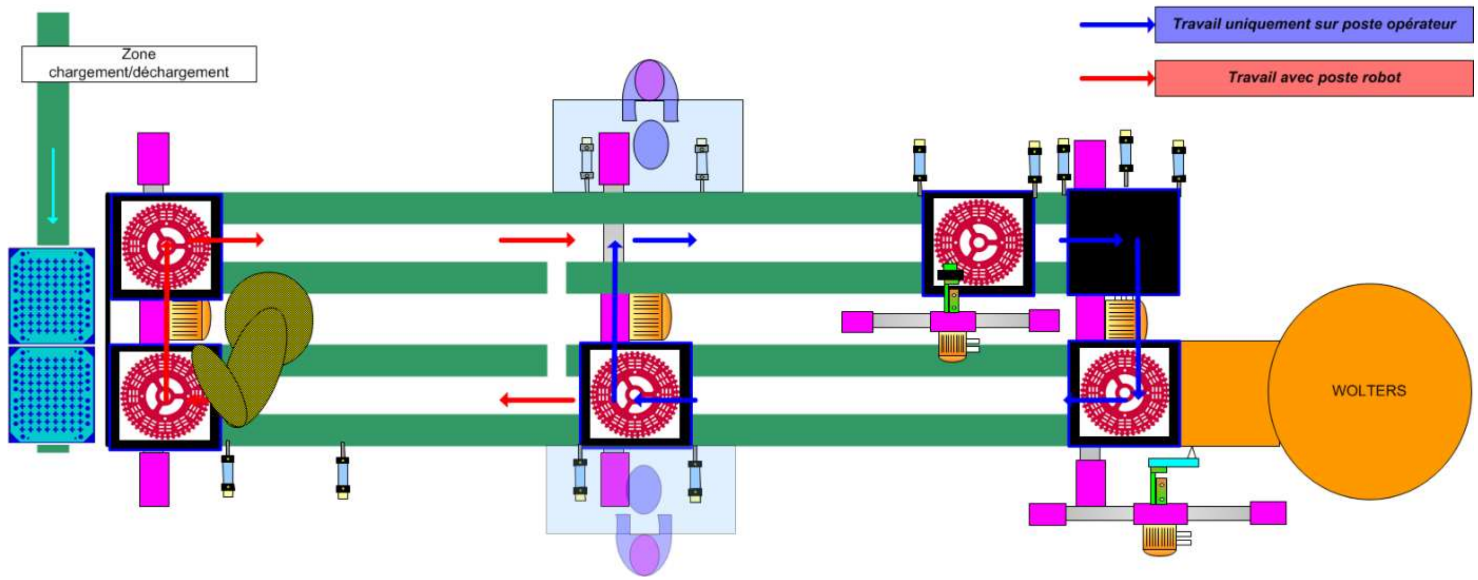


Interactions with Process Engineering & Production

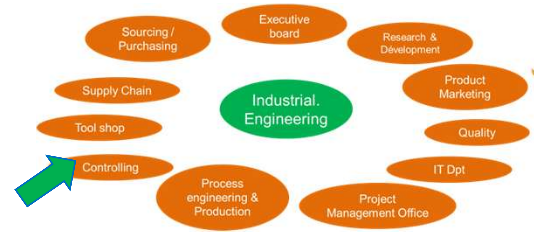


- Detailed manufacturing processes definitions
- Standard times definition (MTM)
- Machines Standard
- Lean
- Ergonomics, safety concerns
- Layout, Lean organization
- Recruitments & training
- Internal material flows
- Maintenance
- Data & KPI monitoring

MTM:
Mean Time Measurements



Interactions with Controling



<u>Estimate / simulate several cases of:</u>

- Profitability
- Return On Investment
- Investments (depreciated)
- Expenses
- Currency exchange effects
- Depreciations rules
- Ramp up figures
- Financial risks
- Direct labor costs
- Indirect labor costs
- Logistic costs
- Multiple taxes

INVESTMENT	AMOUNT	Life span
Industrial equipment		8
Tools		4
Other		4

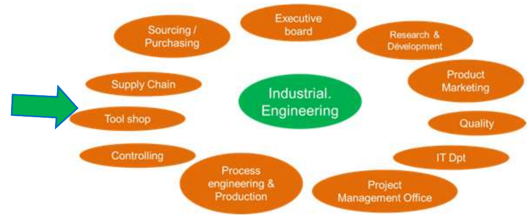
ASSUMPTIONS	
Life time of project	8
Income tax rate	25%
Discount rate	6.0%

PROFITABILITY EVALUATION

PAYBACK (in years)	10.00
NPV (Net Present Value)	0

YEAR	0	1	2	3	4	5	6	7	8
CASH FLOW OF INVESTMENT & WORK.CAP.	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Equipment (-) & resale of asset (+)	0								
Tool (-) & resale of asset (+)	0								
Other (-) & resale of asset (+)	0								
Income tax savings of equipment		0	0	0	0	0	0	0	0
Income tax savings of tools		0	0	0	0	0	0	0	0
Income tax savings of other investment		0	0	0	0	0	0	0	0
Δ of working capital (Increase [-] ; Decrease [+])									
OPERATING INFLOWS	0	0	0	0	0	0	0	0	0
Additional turnover (+)									
Savings material consumption (+)									
Savings labour costs (+)									
Savings prod° overhead (+)									
Others (+)									
OPERATING OUTFLOWS	0	0	0	0	0	0	0	0	0
Developpement and testing (-)									
Other launch costs (-)									
Material consumption (-)									
Labour costs (-)									
Prod° overhead (-)									
Others (-)									
OPERATING INFLOWS - OUTFLOWS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Income Tax on Operating (Inflows - Outflows)	0	0	0	0	0	0	0	0	0
ANNUAL CASH FLOW	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CUMULATIVE CASH FLOWS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ANNUAL DISCOUNTED CASH FLOW	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CUMULATIVE DISCOUNTED CASH FLOWS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Interactions with Tool shop (ie: Injection & stamping)



SMED: Single Minute Exchange Die

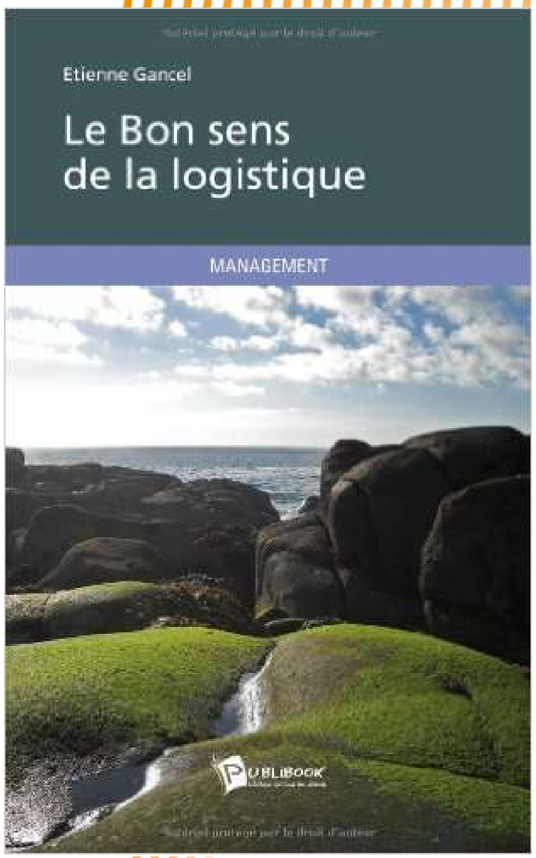
Number of cavities per tool
number of tools

Cost & Lead time to get tools

Interfaces tools / machines
Technical standards

Quick changeover requirements (SMED)

Interactions with Supply Chain



Raw material, components, semi-finished, finished goods flows

Prepare Make or Buy (Lead time, transportation, custom, stock management)

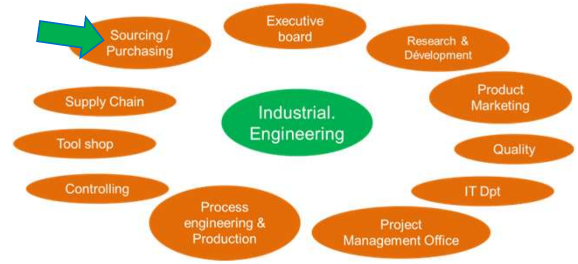
ERP interactions with industrial IT (INDUSTRY 4.0), procurement & replenishment parameters

Storage management (FiFO, LiFO) material obsolescence, material codification

Delivery per reference (OTD) or per purchase orders (OTIF)

ERP: Enterprise Resources Planning
FiFO: First In First Out
LiFO: Last in First Out
OTD: On Time Delivery
OTIF: On Time In Full
IT: Information Technology

Interactions with Sourcing (Direct & indirect)



Perform together the Make or Buy study (Capacity, technical ability, costs comparisons)

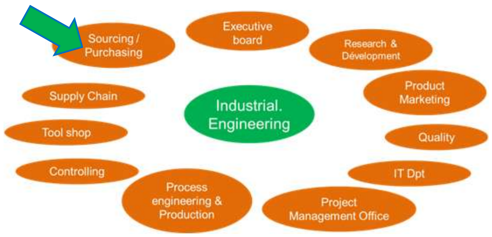
Insourcing or outsourcing simulation & execution

Investment (technical negotiations regarding equipment, installations, tools)

Service Level Agreement (SLA) and After Sale Service agreement (Maintenance)

Definition:
Direct sourcing = everything that is part of the product (Bill Of Material) => raw material, parts, stickers, …
Indirect sourcing = everything else => Tools, maintenance costs, external consultant, machinery,…

Tips about Procurement / Sourcing / Purchasing



Procurement, purchasing, and sourcing are often used interchangeably. Yet these three common industry terms actually are very different things. While they're all important to the procurement function, they each serve different purposes and require different strategies, processes, and resources within the organization.

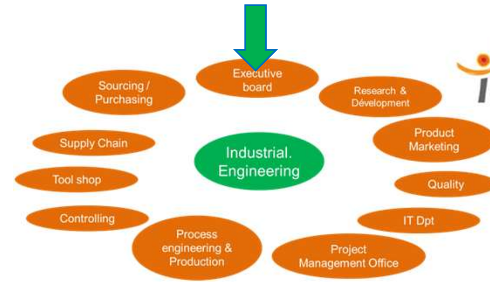
Procurement is the overall process of obtaining goods and services for your organization. It incorporates all the tasks involved in the search for—and purchase of—the materials and resources a company requires to do its business.

Sourcing activities are those at the very beginning of the procurement lifecycle. They involve everything up until the actual purchase of a good or service.

While sourcing is finding items, **Purchasing** is buying them—and all the steps in which that entails, from raising a purchase order to acquiring the product and arranging payment.

Source: https://www.fairmarkit.com/blog/procurement-purchasing-and-sourcing-how-they-differ

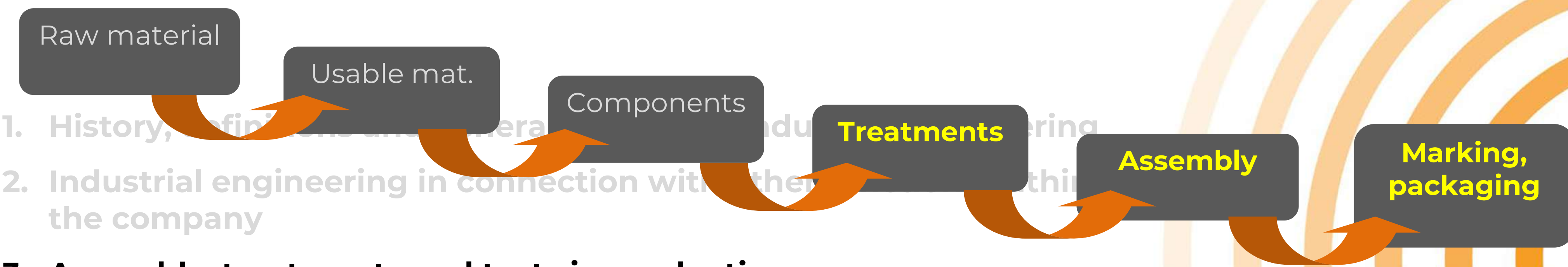
Interactions with Executive Board



Strategic decisions taking like:

- Business Hypothesis, sensitivity to external fluctuations
- Risks
- Manufacturing locations
- Manufacturing transfers
- Internalization / externalization
- Acquisitions
- Closing…

Industrial engineering



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3. **Assembly, treatments and tests in production**
4. Equipment associated to processes, investment
5. Process Plan - Costing – Make or Buy – Business Plan
6. Industrial Engineering project, profitability

Assembly, treatments and tests in production

The purpose of this chapter is to provide you with an overview of most common processes used in industries today.

This is a continuation of what you've learned last year in the "EC-05-Procédés industriels"

It covers several fields like Automotive, Telecom, Pharma, Food, Appliance, Electronics, railway, Aero, ...

But not that much like buildings, bridges and roadways

Heat treatments

Heat treatments consist of a certain number of combined operations of heating and cooling for the purpose of:

1. To improve the characteristics of the materials and make them more favorable to a given use, with the following modifications:
    - Increased breaking strength and elastic limit Rem, Re, A % by giving the element better hold.
    - Increased hardness, enabling parts to better resist wear and tear or impact.
2. To regenerate a metal that has a coarse grain/rough texture (refining the grains, homogenize the structure) case of materials having undergone forging.
3. To remove the internal tensions (work hardening) of the materials before undergoing cold plastic deformation (stamping, flow forming)

English	French
Annealing	Recuit
Quenching (Deep or superficial)	Trempe
Tempering	Revenu
Ageing	Maturation
Nitridation / Carbonitridation	Nitruration azote / Carbonitruration
Staining	Cémentation
Chromizing	Chromatisation

Surface treatments

The purpose of surface treatments is not to change the part performances but to improve or change:

- Protection
- Aesthetic
- Decoration
- Mechanical performance (limited)
- Electrical performance

Some examples for Metal:

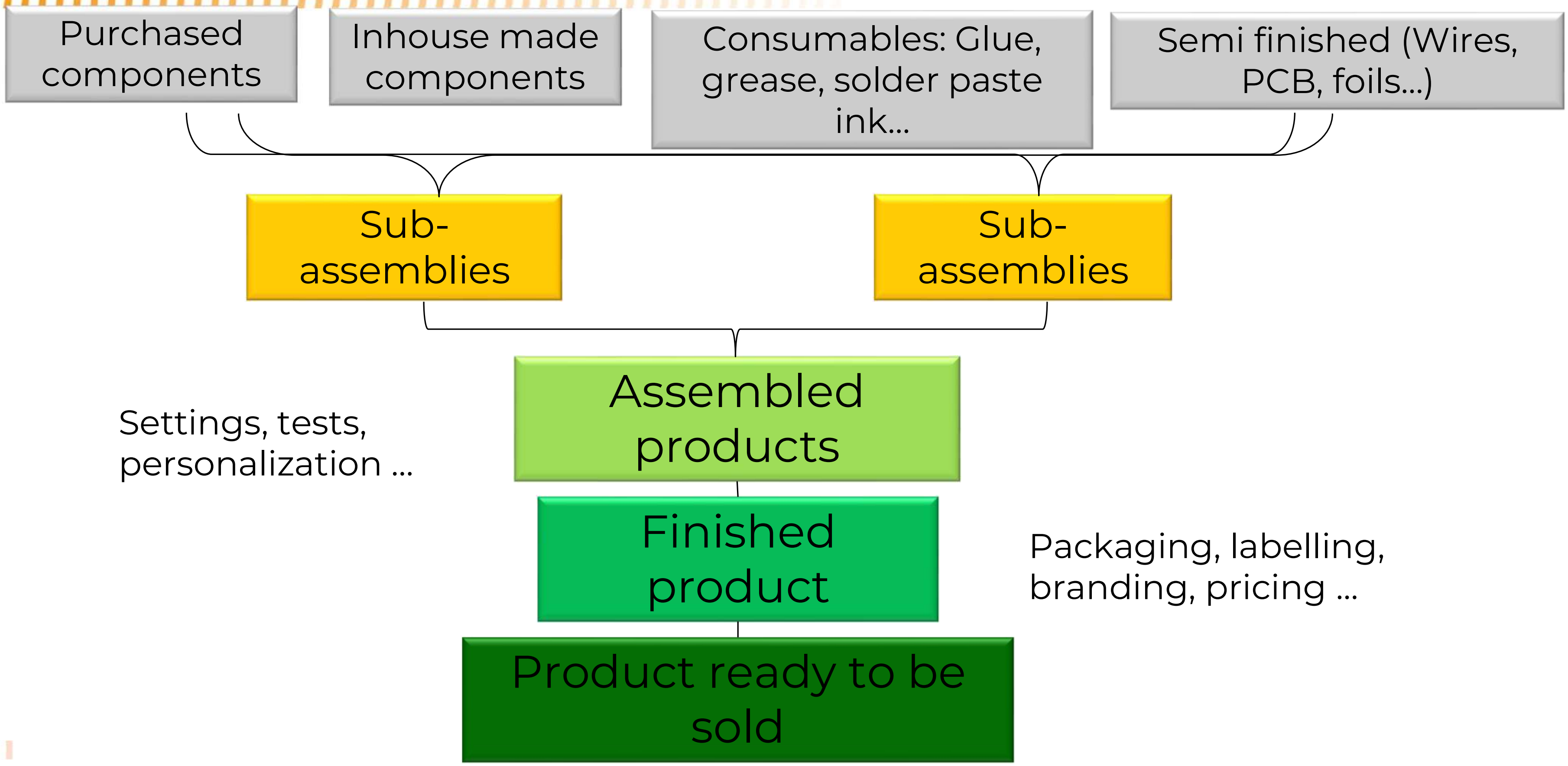
- Zinc plating
- Nickel plating
- Chrome plating
- Silver plating
- Burnishing
- Phosphating
- Painting (cataphoresis - powder)
- Polishing

Some examples for Plastic:
Most of these treatments are for deburring or preparation for painting/plating:

- Sandblasting
- shot blasting (grenaillage)
- Plasma
- Corona
- Flaming
- Painting
- Chrome plating
- ...

Basics of assembly

Reminder



Assembly by welding

Definition: “to join two pieces of metal together permanently by melting the parts that touch”.

Not to be mixed with “Brazing”: Brazing is a joining process traditionally applied to metals (but also to ceramics) in which molten filler metal (the braze alloy) flows into the joint (electronic field).

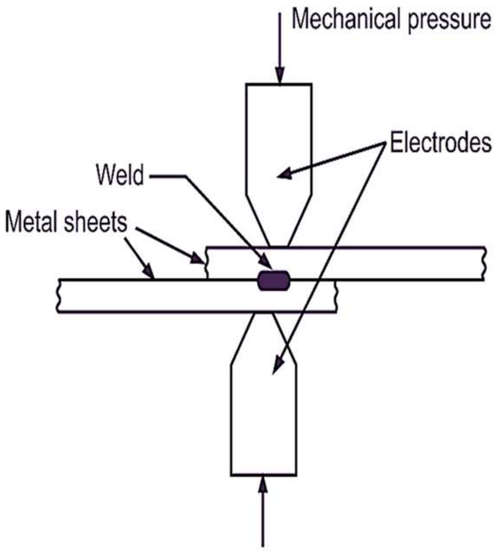
By extension, it applies to other materials than metal: ie Plastics.

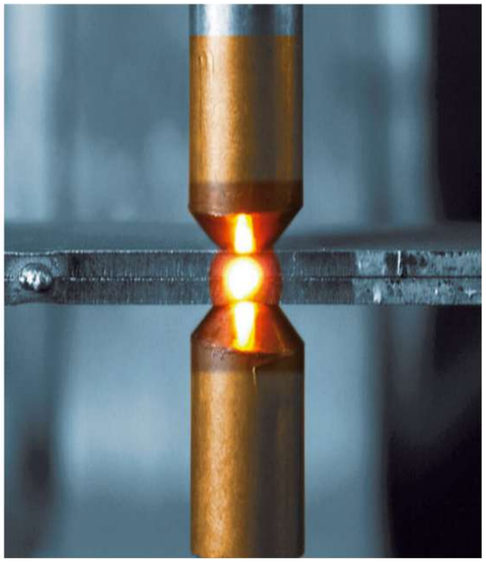
Resistive, point to point

•A high current, low voltage, flows between the 2 parts to be assembled

•The heated point melts the material of the 2 part

•No addition of extra material



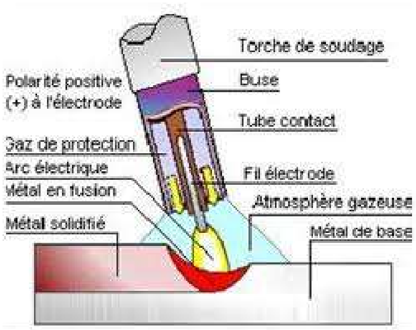


Assembly by welding

MIG: Metal Inert Gaz

Gas metal arc welding (GMAW), also known as MIG (metal inert gas) welding or MAG (metal active gas) welding, is a process in which an electric arc forms between an electrode and a metal workpiece, heating the metals and causing them to melt, and be joined. The weld area is generally protected from atmospheric contamination by use of an inert shielding or cover gas (argon or helium)

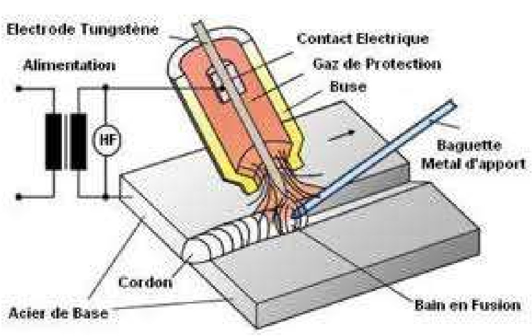
- Some metal is added to the melting point by the electrode (3rd metal)



TIG: Tungsten Inert Gas

Tungsten Inert Gas (TIG) welding, also known as Gas Tungsten Arc Welding (GTAW) is an arc welding process that produces the weld with a non-consumable tungsten electrode. Tungsten inert gas (TIG) welding became an overnight success in the 1940s for joining magnesium and aluminum. Using an inert gas shield instead of a slag to protect the weld pool, the process was a highly attractive replacement for gas and manual metal arc welding. TIG has played a major role in the acceptance of aluminum for high quality welding and structural applications.

- No extra metal added by electrode

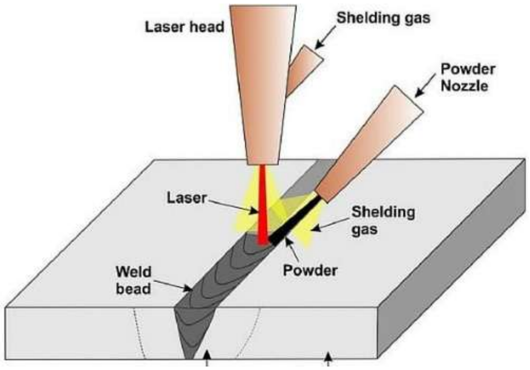


Assembly by welding

Laser welding

Laser welding is a process used to join together metals or thermoplastics using a laser beam to form a weld. Being such a concentrated heat source, in thin materials laser welding can be carried out at high welding speeds of metres per minute, and in thicker materials can produce narrow, deep welds between square-edged parts

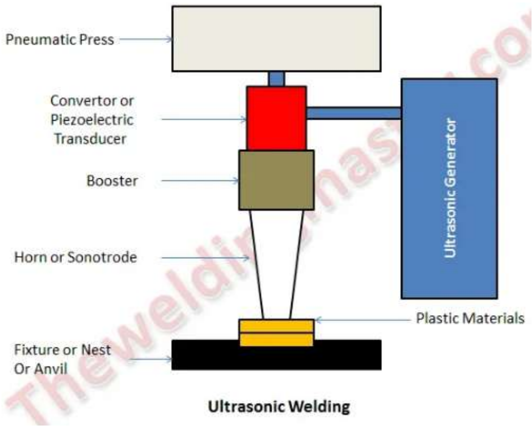
- Powder material addition



Ultrasonic welding

Ultrasonic Welding (USW) is a welding technique that uses ultrasonic vibration of high frequency to weld the two pieces together. It is most commonly used to weld thermoplastic materials and dissimilar materials. Metal with a thin section can also be welded with USW.

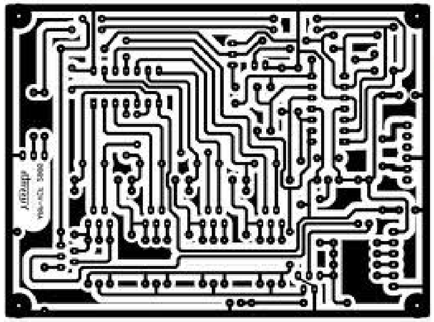
A high frequency (20 kHz to 40 kHz) ultrasonic vibration is used to join two plastic pieces together. The high-frequency vibration generates heat energy at the interface of the two pieces and melts the material. The melted material fused with each other to form a strong weld on cooling and solidification.
The typical frequency used is 15, 20, 30, 35, or 40 kHz.
•No addition of material



Assembly by welding

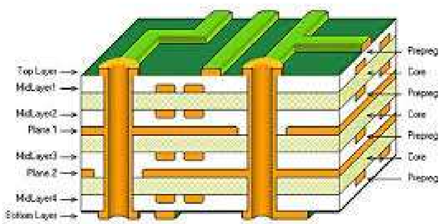
Type	Metal	Plastic	Notes	Typical Application
Resistive	Yes	No	Adjust electrods section according to each metal	Body welding automotive
MIG	Yes	No	Some metal is added to the melting point by the electrode (3rd metal)	High productivity or large area to be weld. Buildings, navy, automotive.
TIG	Yes	No	Some metal is added to the melting point by the stick. Possibility to weld without extra material.	Mostly piping, food piping, Nuclear, high-quality welding. Thin material welding.
Laser	Yes	Yes	Take care with ray reflection on shiny metal. Accurate welding	Medical, large domains of application.
Ultrasonic	Yes	Yes	Specific parts design and transducor required	Medical, electronic, toys, …

Electronic PCB assembly SMD / SMT

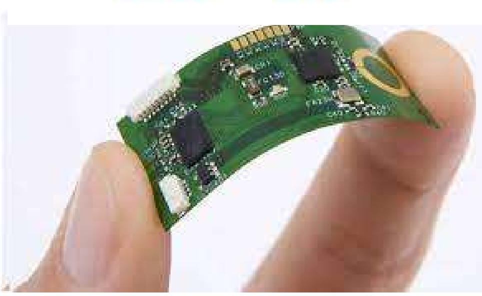


Today this technology is applied in 90% of applications, as long as the power is not « high ».
Telecom, automotive, gaming, computers, medical, industry…

One side PCB



On multi layer PCB



On flexible PCB

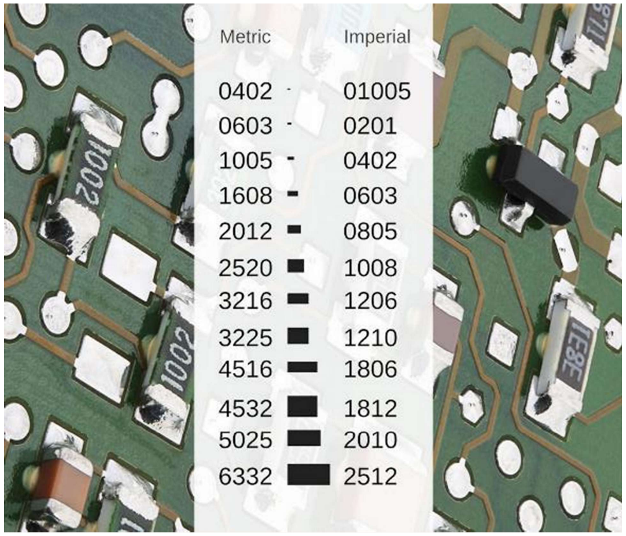
Chip shooter: https://www.youtube.com/watch?v=nMYSneJN55c
SMD: Surface Mounting Devices
SMT: Surface Mounting Technology

SMT reflow process single or double side

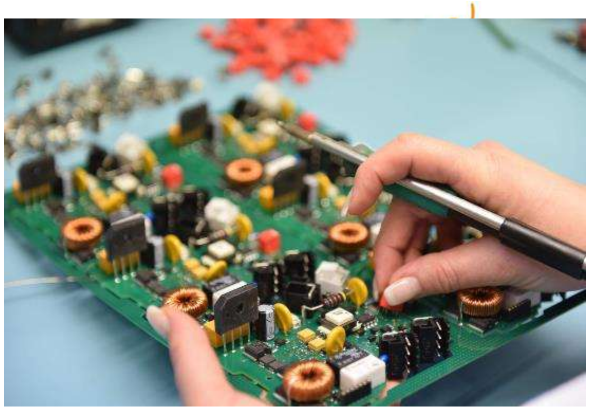
Description of the reflow process: https://www.youtube.com/watch?v=eOUf59iut3s
Oven : https://www.youtube.com/watch?v=LCmia0Wsmqg
Full SMD assembly proces: https://www.youtube.com/watch?v=HRvADApuyzA

SMD package sizes

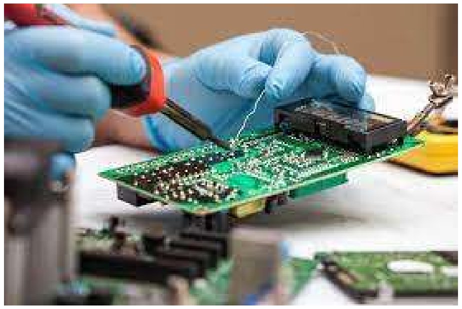
Size	Metric			
	Resistor Case Code	Approx. Length (mm)	Approx. Width (mm)	Power (W)
	0402	0.4	0.2	0.031
	0603	0.6	0.3	1 / 20 (0.05)
	1005	1.0	0.5	1 / 16 (0.062)
	1608	1.6	0.8	1 / 10 (0.10)
	2012	2.0	1.25	1 / 8 (0.125)
	3216	3.2	1.6	1 / 4 (0.25)
	3225	3.2	2.5	1 / 2 (0.5)
	4532	4.5	3.2	3 / 4 (0.75)
	5025	5.0	2.5	3 / 4 (0.75)
	6332	6.3	3.2	1



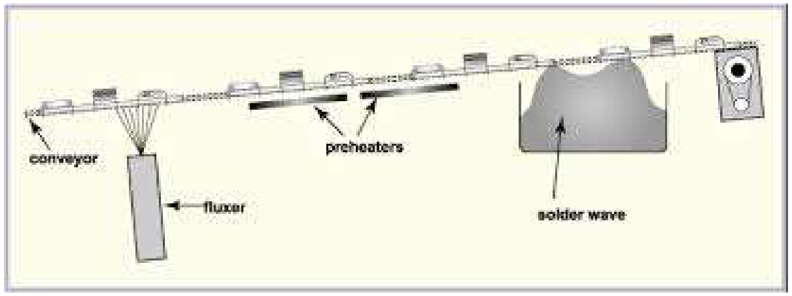
Electronic PCB assembly THT



This technology is requested each time some high power is need (Power supplies) or some mechanical force are applied (Connectors) or "big" components are needed (Capacitors, transistors…)



Manual soldering



Wave soldering

Selective soldering

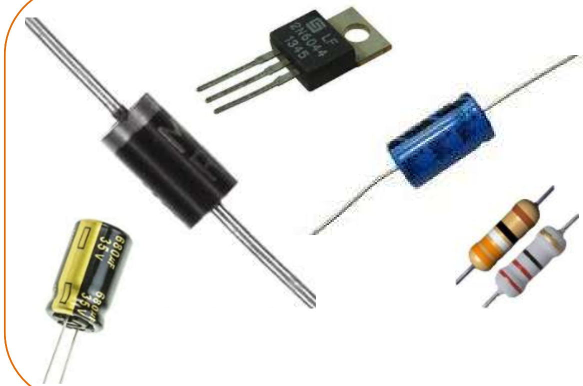
THT wave soldering: https://www.youtube.com/watch?v=f4DZqvKg3ug
THT manual or selective soldering: https://www.youtube.com/watch?v=-z_0HhPrXBs
THT: Through Holes Technology

Electronic PCB Assembly mix THT & SMD

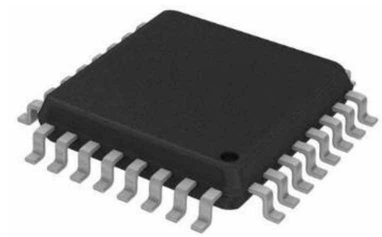
- Very often, both technologies are combined:
- SMD for most components (Cheap & fast process, compact surface)
- THT only for few parts (More expensive process, more space)

THT or SMD ? Why ?

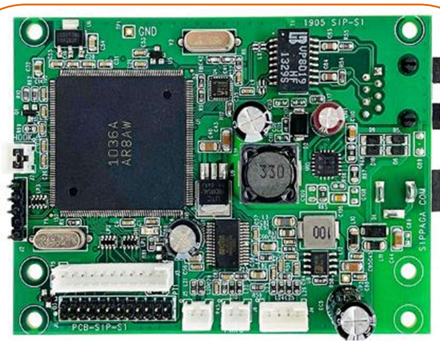
Electronic components vocabulary



SMD


IC : Integrated Circuit


PCB = Printed Circuit Board


PCBA = Printed Circuit Board Assembled


Antic PCB !

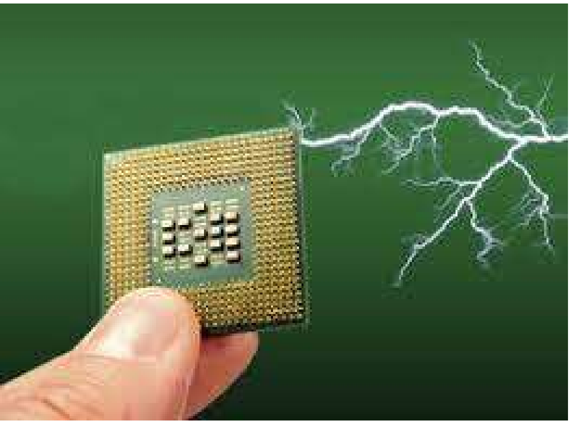
Electronic devices assembly

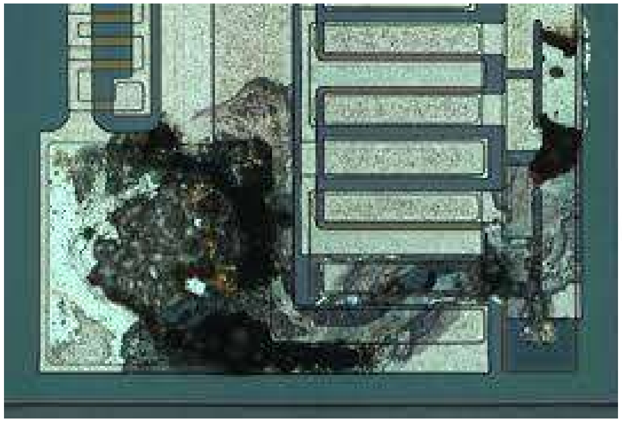
Once the PCBA is ready it will be mounted into the final product with some specific constraints:

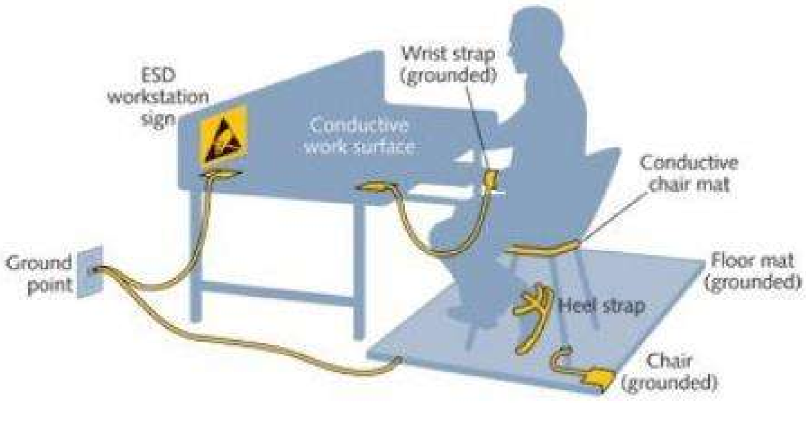
- ESD protections
- Mechanical stress prevention
- Dust or contamination protections

ESD protections

ESD is the plague (la peste) or the scourge (le fléau) of electronic industry.
The smaller the components are the more sensitive to ESD they are.
Microcontrollers and all active components are subject to be destroyed or damaged by ESD.
The biggest risks in that the component is damaged, but still operating (Potential problem not detected during production test) but the product has a reduced lifetime. The only solution is PREVENTION.







ESD Friendly Workspace

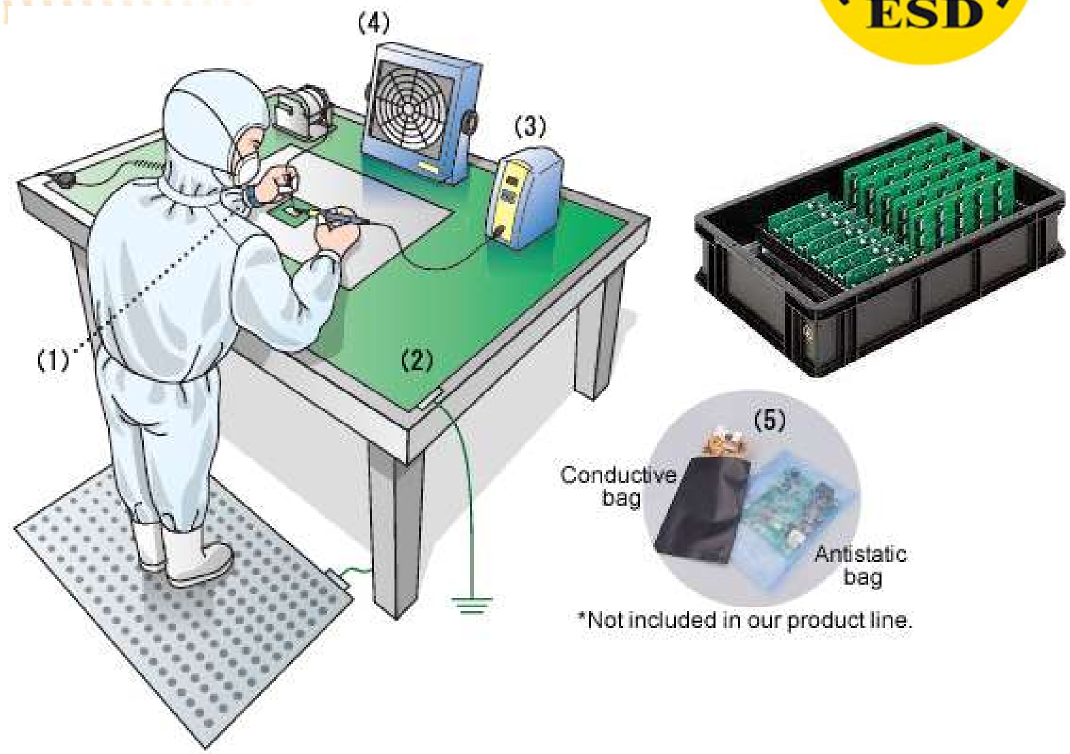
ESD = ElectroStatic Discharge

ESD protections

The <u>entire electronic PCBA flow</u> must be considered:

- Components storage & handling
- PCBA manufacturing
- Tests
- Repair stations
- Storage
- Transport
- Assembly into the final product

The final product must be designed so that the usage isn't ESD sensitive (R&D's job!)

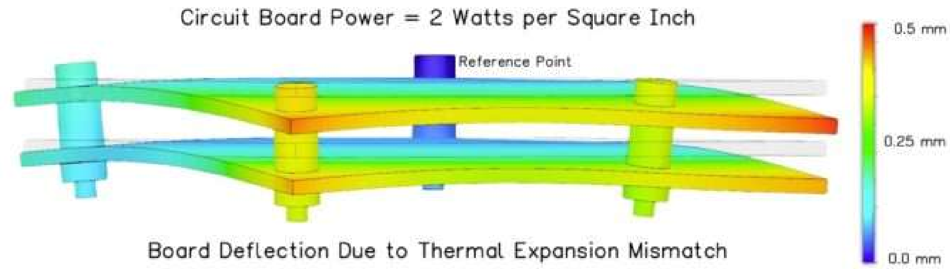


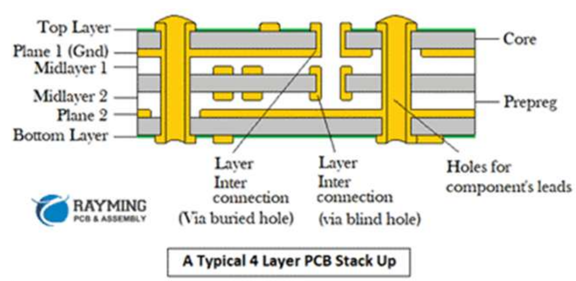
PCBA mechanical Stress

A PCBA is made of PCB (multilayer 1,6mm, 0,8mm or thinner) on which components are soldered.
There are multiple causes to bend or twist the PCBA:

- Dilatation / shrinking of PCB
- Stress during components placement
- Stress during manufacturing process
- Stress during storage
- Stress during assembly into the final product
- Stress during usage

All these stress might cause defaults in solder joints, breaking components, breaking bounding inside components, breaking PCB external or internal lines.
There is only one solution: no stress !





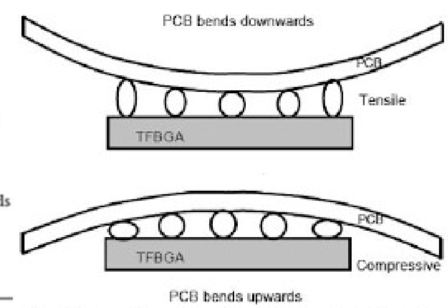
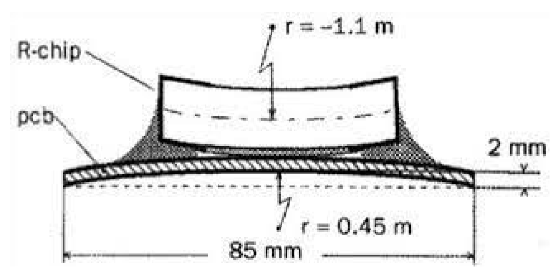
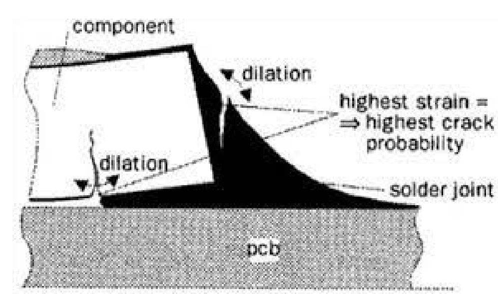


Fig. 2 Stress in solder joint during PCB bending



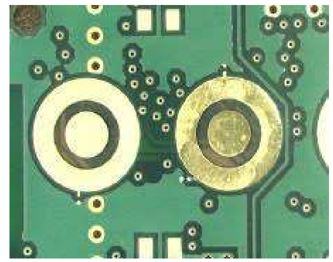
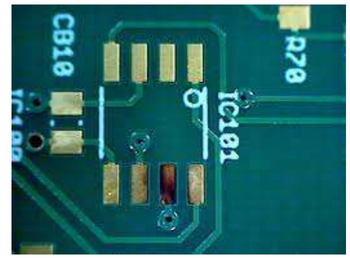


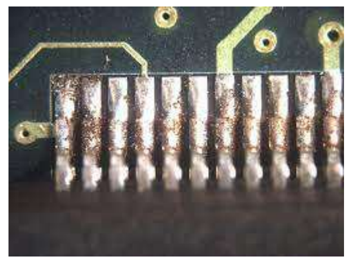
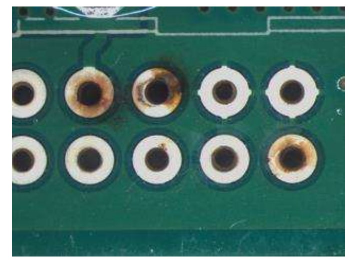
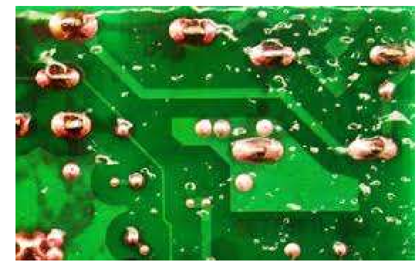
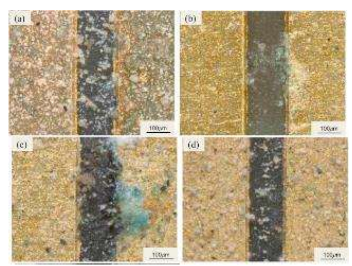
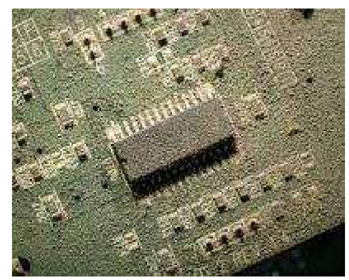
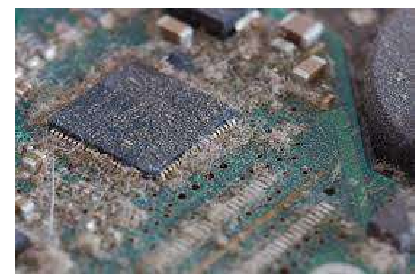
Dust or contamination of Electronic PCB

There are multiple source of contamination of an electronic device.
The consequences are:

- Defaults
- Intermittent defaults (Bad contacts)
- Reduced performances
- Short circuits (Ionic contamination)

A PCB is made of cupper with different surface treatments and protections.
Any failure in the process will create oxidation or ionic contamination, in addition dust will create dielectric failure or poor contacts.
Solutions: Prevent from dust &/or clean PCBA

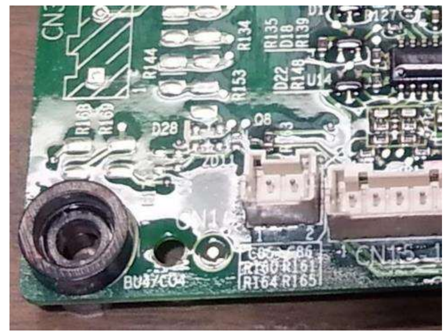








Solutions for Dust & ESD

In extreme usage conditions, some specific processes are applied to the PCBA or the final product (Aerospace, Military application, electronic devices located into the motor compartment of a car, alarm sirens).

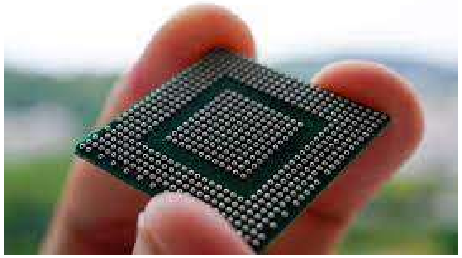
Conformal coating:
A specific varnish is applied to the PCBA, except connectors, or contact areas.
This varnish stabilize « for ever » the dielectric, protects from dust or water (under a certain level)
Expensive process, not easy to repair.

Potting:
A resin is filling the PCBA and its container.
This resin stabilize « for ever » the dielectric, protects from dust or water.
Expensive process, impossible to repair.



On top of the « climatic » protections, both processes also protect from Hacking (PCB modifications)

PCBA & electronic test



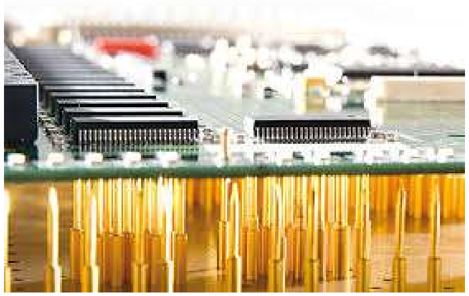
Due to the huge quantity of components assembled, it’s mandatory to test each PCBA at different steps of the process. There are many technical solutions according to the complexity of the board, the tolerance of defaults from the market, the added value of the product. A SpaceX PCBA won't be tested like a Toy sold 5 € !

Test possibilities are – from basic to complex:

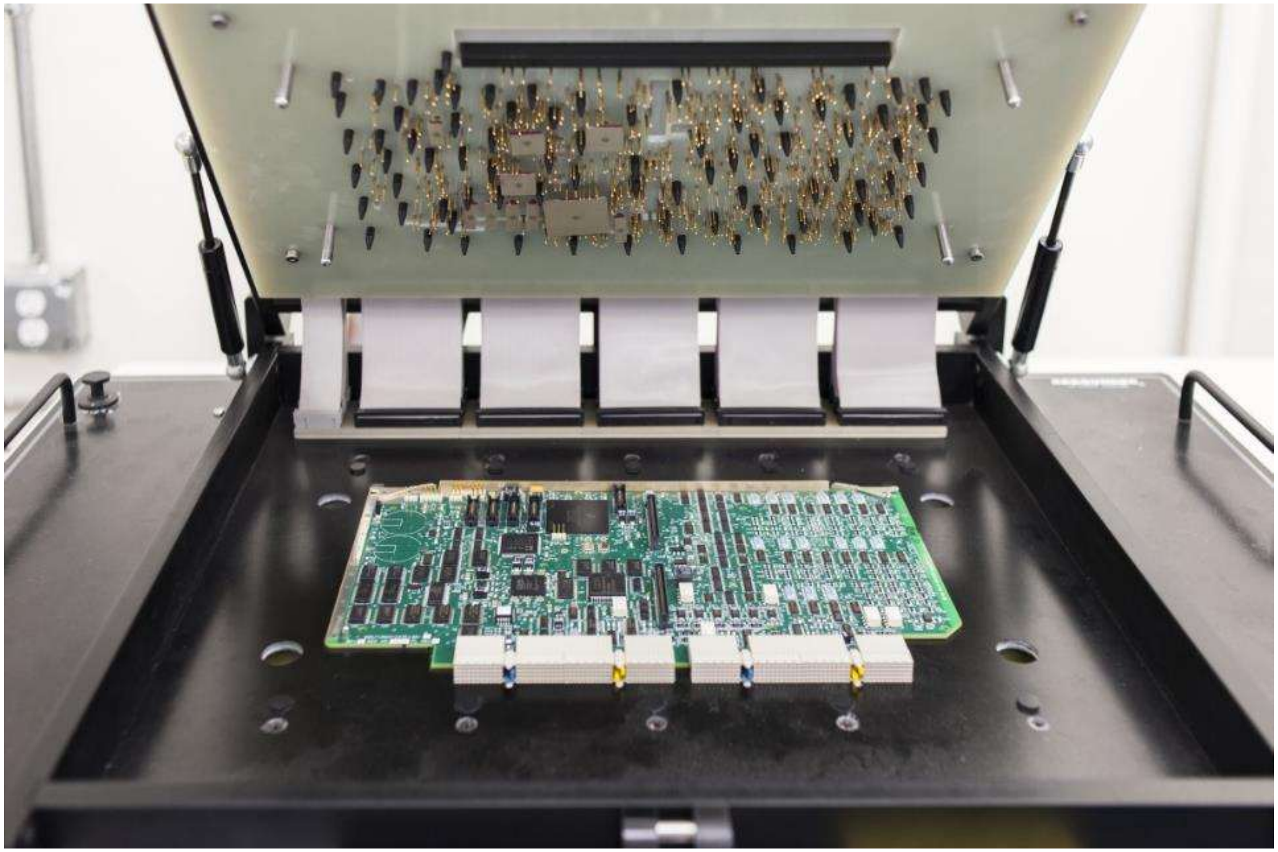
- Functional test of the finished product
- Functional test of the PCBA
- Visual inspection by operator
- Visual inspection by artificial vision basic
- Visual inspection by artificial vision with IA
- Flying probes tester (low volumes manufacturing)
- ICT: In Circuit Tester
- JTAG / Boundary SCAN (high digital contain PCBA: Telecom, Servers, Computers, MEMS)
- X-RAY Scanner
- Burning tests (High added value PCBAs: Telecom (not cellphones), Military, Aero
- Most of time, several of these tests are performed for the same product at different steps of the process.

ICT: https://www.youtube.com/watch?v=NWqR_fJaMHE
Flying probe tester: https://www.youtube.com/watch?v=fjmjYVNuLEE
BGA X-RAY inspection: https://www.youtube.com/watch?v=ywzMSWIhAlw
Boundary Scan: https://www.youtube.com/watch?v=Y_dfg8h_yEY

JTAG: Joint Test Action Group
BGA: Ball Grid Array



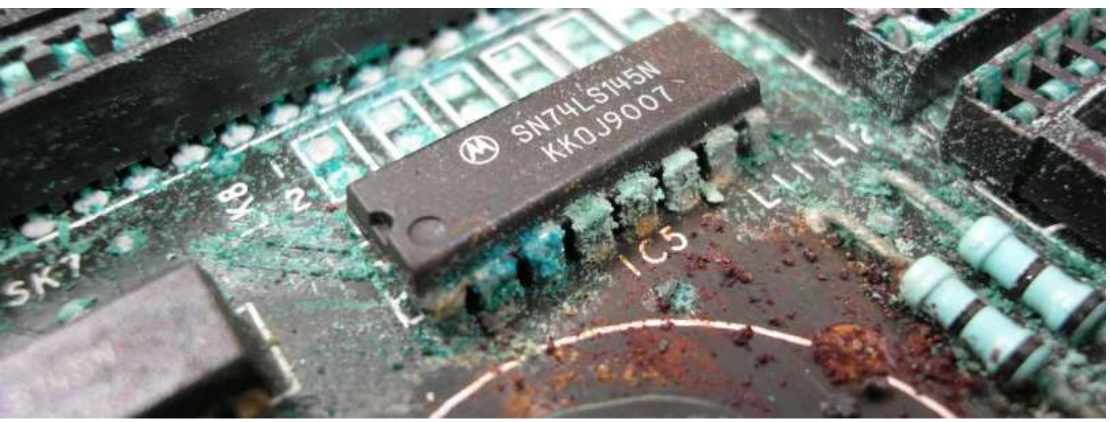
Example of PCBA Bed of nails (ICT or Functional tests)

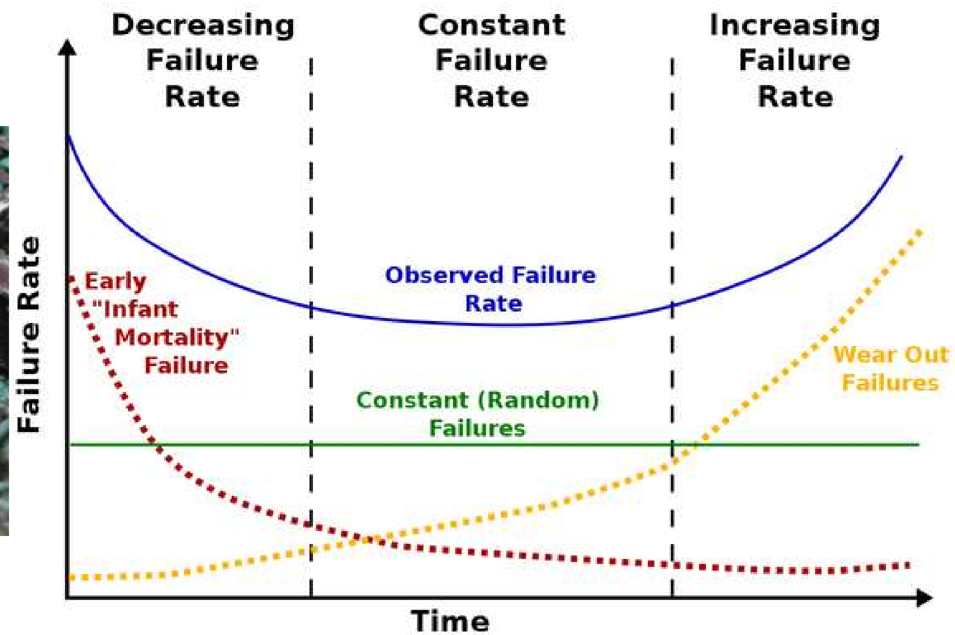


Example of burning tests (Destructive or nondestructive)

Forcing the “infant mortality” failures to appear before product selling (non-destructive)
Endurance / life tests to determine the expected life duration (destructive)

- Cycle of Temperatures / Humidity / Salt
- High voltage / dielectric test





Mechanical Assemblies

There are much solutions to assemble multiple parts !!

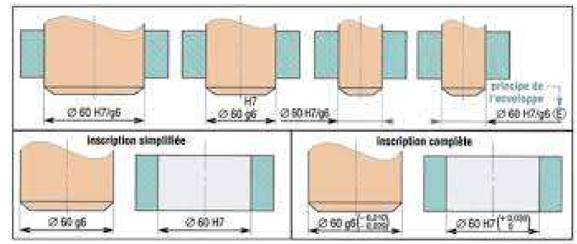
The best one is to have NOTHING to ASSEMBLE !

As Engineers, always step back and question your team :

« Why do I have 2 parts to assemble, wasn’t it possible to make it in one part ? »

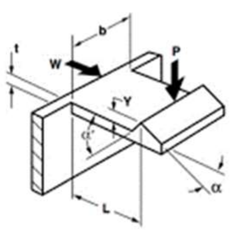
If the final answer, “is I need to assemble”: next page…

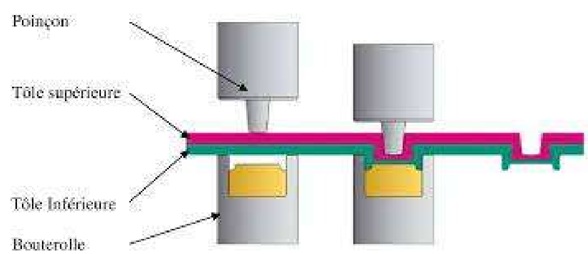
Mechanical Assemblies



List of possibilities:

- Clips
- Clamp
- Screws
- Rivets
- Glue
- Welding
- Forced (H7G6)
- Deformation (Tox,...)



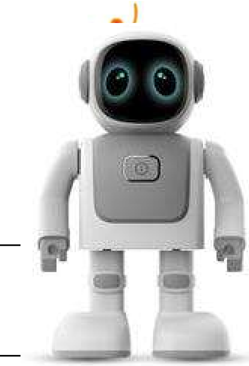


Assembly: Manual vs Automatic

Manual Assembly

Suitable/recommended when:

- The assembly requires complex movements (difficult to reproduce with machines)
- Flexible components (difficult to handle with machines)
- Small production volume (Dedicated machines can't be depreciated)
- Short product lifetime or frequent updates (Dedicated machines can't be depreciated)
- Very big products (Ships, airplanes, …) but…
- In low-cost country, with low labor costs



Automatic Assembly

Suitable/recommended when:

- Product designed for (Easy to handle with machines)
- High volume of repeatable production
- Harsh working conditions (Pénibles) Repetitive, high/low temperature, effort, risks
- Long lifecycle of product (Possibility to depreciate machines) > 5years
- Shapes easing prehension by robots
- Orientation shapes or perfect symmetry
- Short takt Time (i.e. < 1 min)

Manual assembly

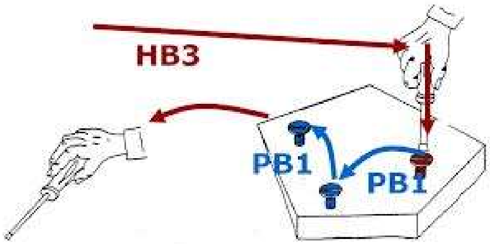
1 – Define detailed succession of operations to perform

2 – Rough estimation of operation times needed

3 – Ergonomic of working stations, including placing components and tools, dimensions

4 – Check operations balancing and precise material flows

5 – Define Poka-yoke & standards and write instructions sheets



Manual assembly

Automatic Assembly

1 – Define detailed succession of operations to perform

2 – Chose the right means to load and maintain parts in right direction

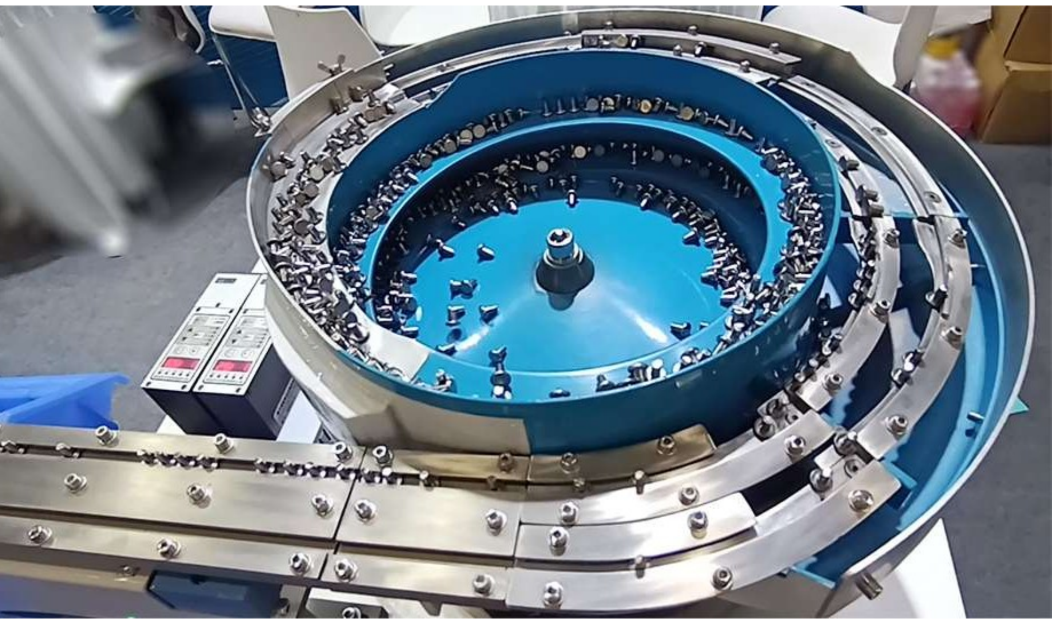
3 – Constraints review that will lead architecture and layout of line

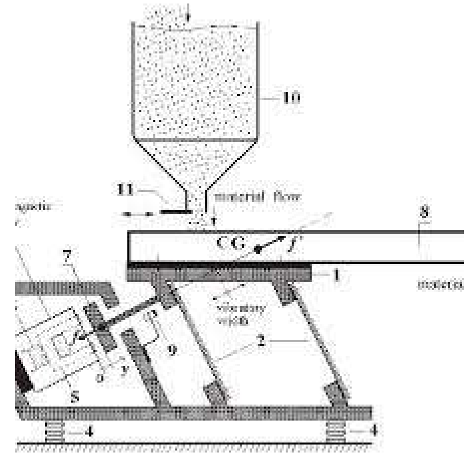
4 – Specifications chart for material and information flows

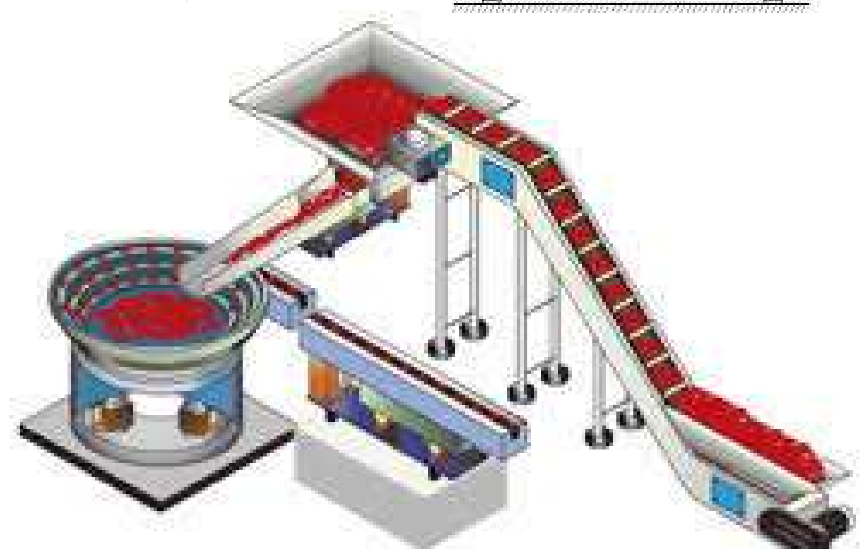
5 – Design, programing, building, set up and validation

Very often ; Special machines / assembly lines involved, robots, artificial vision, connected stations and machines → Make to order by last differentiation
Investment from **100 k€ to 3000 k€**

Components supply systems : feeders (2k€ to 200 k€)







Vibratory feeding systems, principle

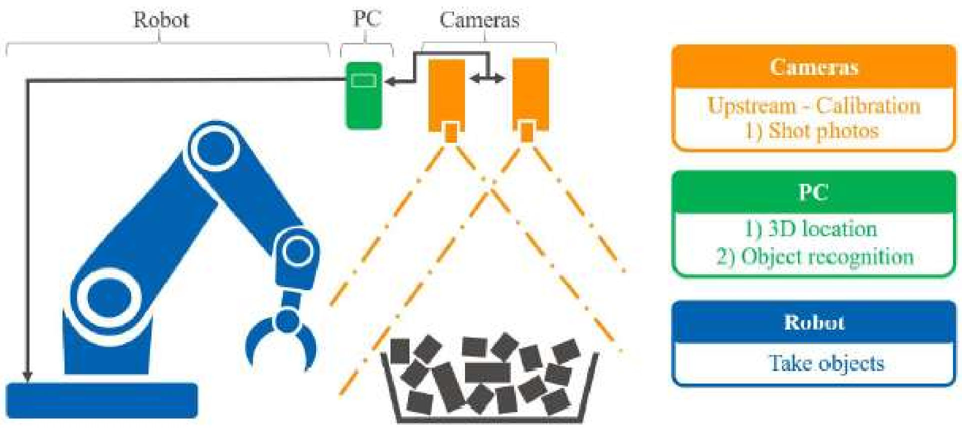
Purpose: Bring very small up to medium size parts from bulks to positioned & available for picking by operator or robot. Commonly used in industry.

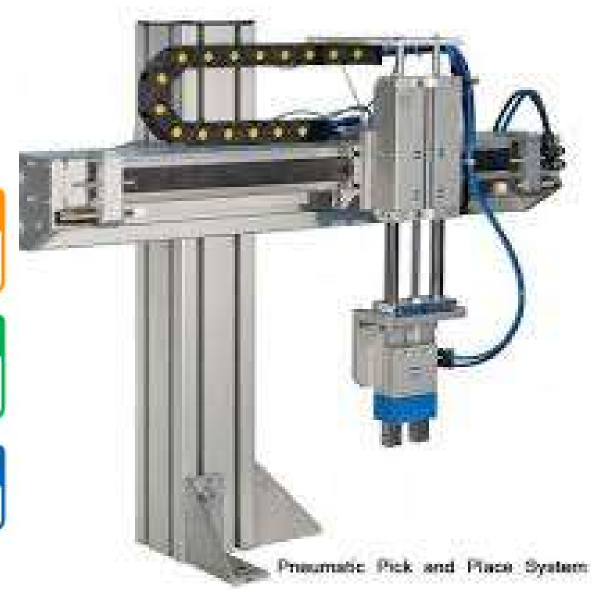
Drawback: expensive, noisy, complex to setup & maintain.

Vibrating bowl principles: https://www.youtube.com/watch?v=BPK9lGPo89o

Components supply systems

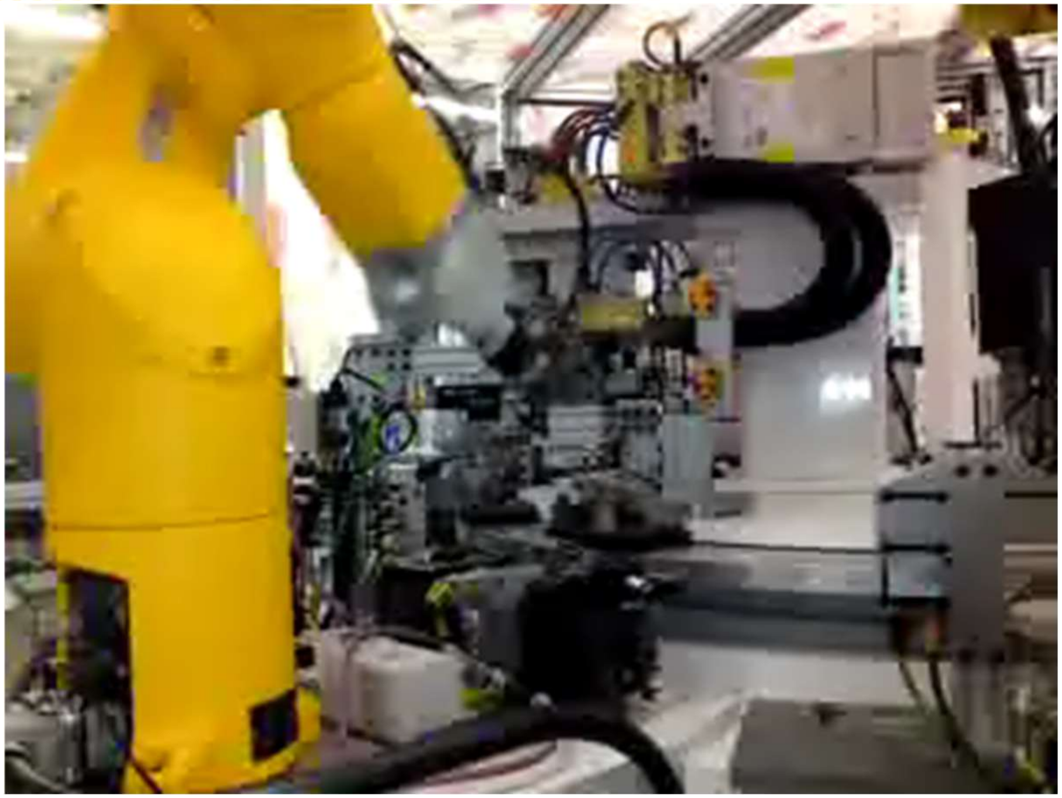
Pick and place (5 k€ to 50+ k€)





Up to 200 k€ as soon as artificial vision is used)

Components supply & ass'y systems



Most used robots

- Very good accuracy and repeatability
- Very fast when small
- Robust and economic

SCARA robots : Two parallel cylindric axis on each end of a moving arm

Most used robots

Polar robots : At least 6 rotative axis allowing X,Y,Z position of the tool and A,B,C rotations of it

- Very large applications scope
- From bottom table or ceiling
- Fast and strong

We have one in lab02

Most used robots

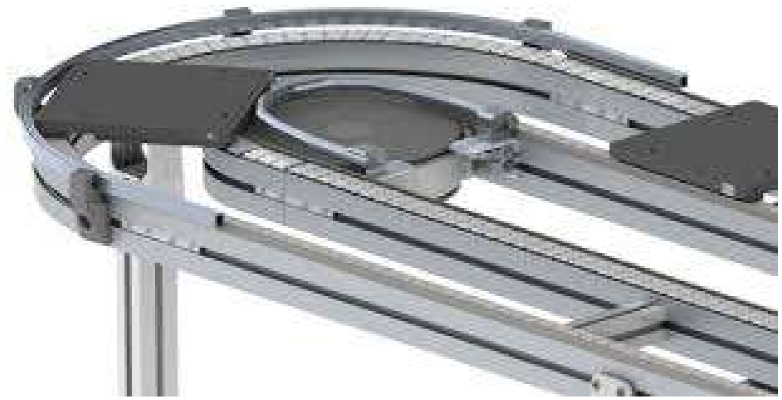
Cobots : At least 6 rotative axis allowing X,Y,Z position of the tool and A,B,C rotations of it.

The aim of a Cobot is to allow the Operator & Robot to operate simultaneously in the same area, without specific protections

- Same movements as polar robots
- No need safety protections around
- Direct programing by learning
- Slow and expensive

We have one in lab02 and one in lab03

Components supply systems : conveyors

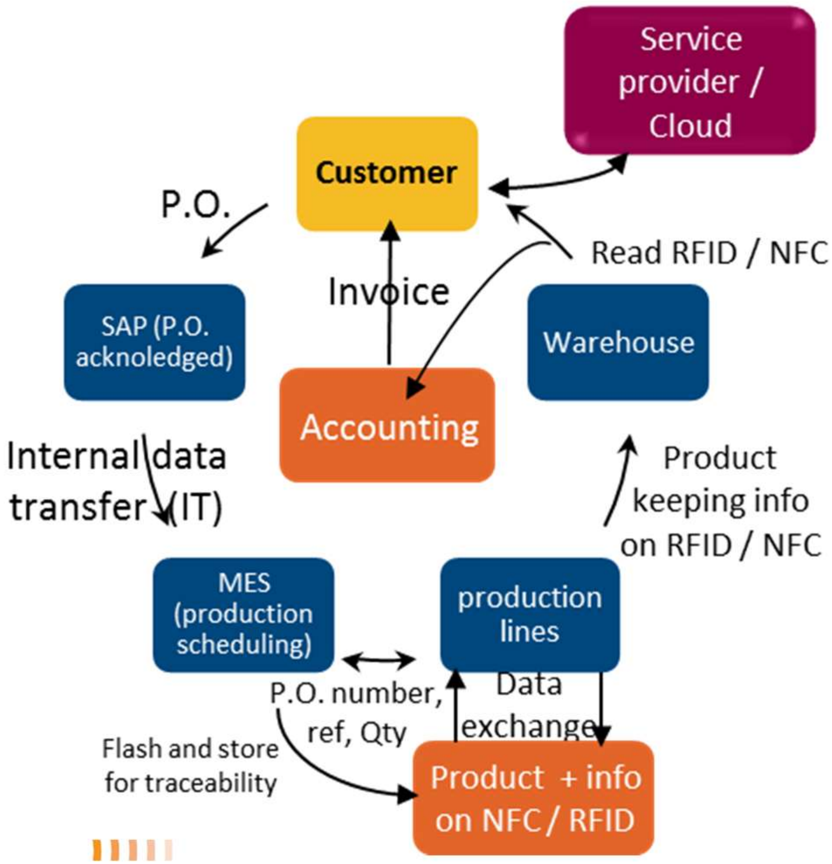


Purpose is to transport parts or semi finished between stations.
Stations can be automatized or manual.
Conveyor is NOT lean because it limits the flexibility of workstations

Mixed solutions

In many cases, there is a mix of manual stations, automatized stations, standalone workstations or workstations connected by conveyors.

MTO, High mix – Low volume management



Industry 4.0 is offering possibilities to speed up data flows. Then brings a fast info flowing from customer demands up to manufacturing facilities upstream and downstream.

In this context, two types of production flows can be distinguished:

MTO: Make to Order here production starts only after a customer order.	≠	MTS: Make to stock where production is based on forecasts

Today is a reality for Kitchen providers for example.

like customized kitchen designs manufactured only after a customer order.	standard kitchen elements produced in advance and stored

MTO vs MTS

Make To Stock = PUSH

- The production facility receive some sales previsions by the Sales departments (multiples countries for example)
- These cumulative volumes are aggregated, and a production plan is defined
- Operations execute the production plan.

Field of application:

- Smartphone
- Furniture (Ikea)

Risks:

- Wrong sales forecasts (Too much or not enough)
- Some market events that jeopardize the sold volumes (COVID, War, competitor, climate,...)
- Long reaction time in the case of high fluctuation of demand

Make To Order = PULL

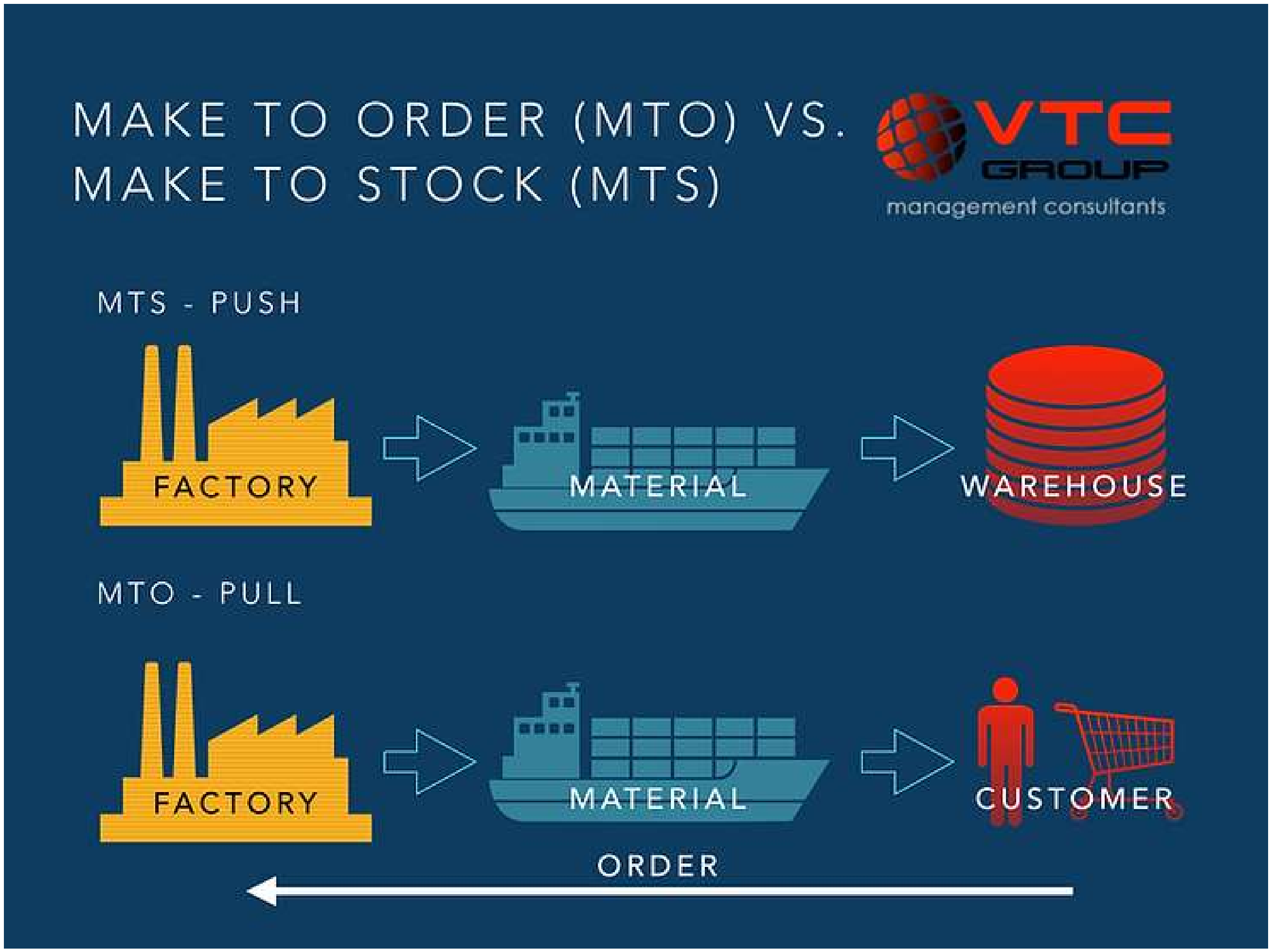
- Every single product is pre-ordered by customer
- In most cases, the product is customized to the customer demand
- No production launch without pre-payment

Field application:

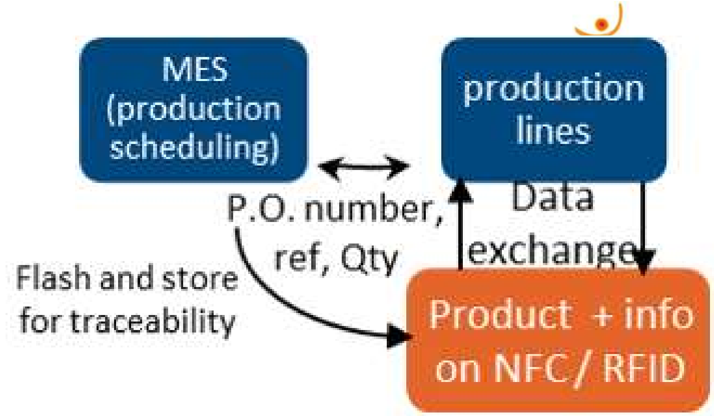
- Automotive
- Machining
- Kitchens

Risks:

- Delivery time: missing components, quality problems
- Transportation time & costs
- No costs effects on volumes (No costs down in case of high volumes)


MAKE TO ORDER (MTO) VS.
MAKE TO STOCK (MTS)
VTC GROUP
management consultants
MTS - PUSH
FACTORY
MATERIAL
WAREHOUSE
MTO - PULL
FACTORY
MATERIAL
CUSTOMER
ORDER

Connected products: IoT



Product memory can store :

- References of customer who ordered and specify it
- Corresponding B.O.M.
- Corresponding Process Plan
- Traceability data, tests results, critical parameters

Product can communicate (radio, Bluetooth, NFC, …):

- Processing sequence to handling robots and conveyors system
- Operations to make to each machine or Pick to Light workstation
- Accumulated data along the process (measurement results, accumulated cost, …), downloaded from machines or manual workstations

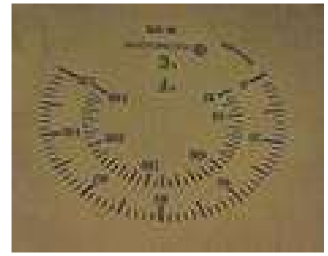
BOM: Bill Of Material

Note ; when no memory capacity into the product, data matrix can be used as well, associated to an external database.

Deeper study → Mastère Spécialisé ETNO (Icam Strasbourg)

Marking

Every product must be « marked » for multiple purposes:
- Customer identification (Product reference, serial number)
- Legal Marking (Food industry, Pharma, …)
- Industrial purpose identification
- Traceability
- Branding
- Decoration
- Pricing
- Usage indications
- …



Each marking must follow some specificatio
- Size
- Colors
- Resistance to abrasion, to chemicals
- Accuracy

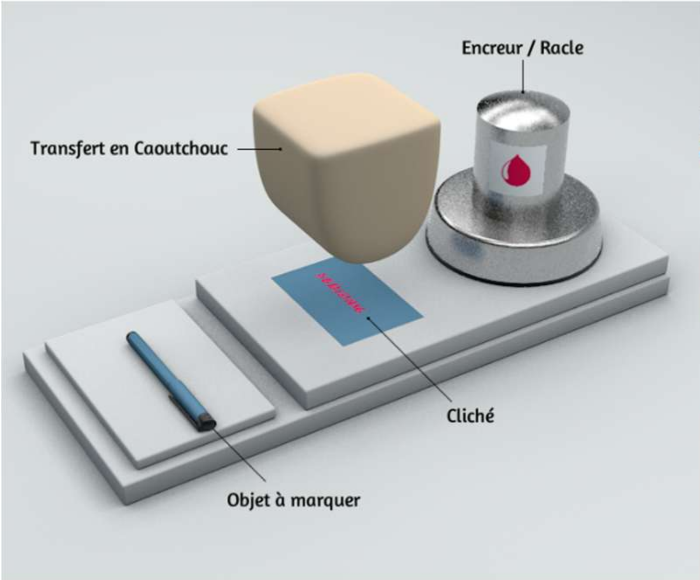
Marking (manual / semi auto)

By ink transfer (pad printing)

- Good quality
- Odd surface possible
- High volumes, “low costs”
- Automatization possible

Drawback:

- Only one color per shot
- Ink is dusty process
- Ink can be non sustainable
- Lot of ink wasted
- No marking flexibility = one cliché per type of marking
- No possibility of incremental values (serial numbers)



Tampoprinting – Pad printing: https://www.youtube.com/watch?v=aZFfcA8v88U

Marking

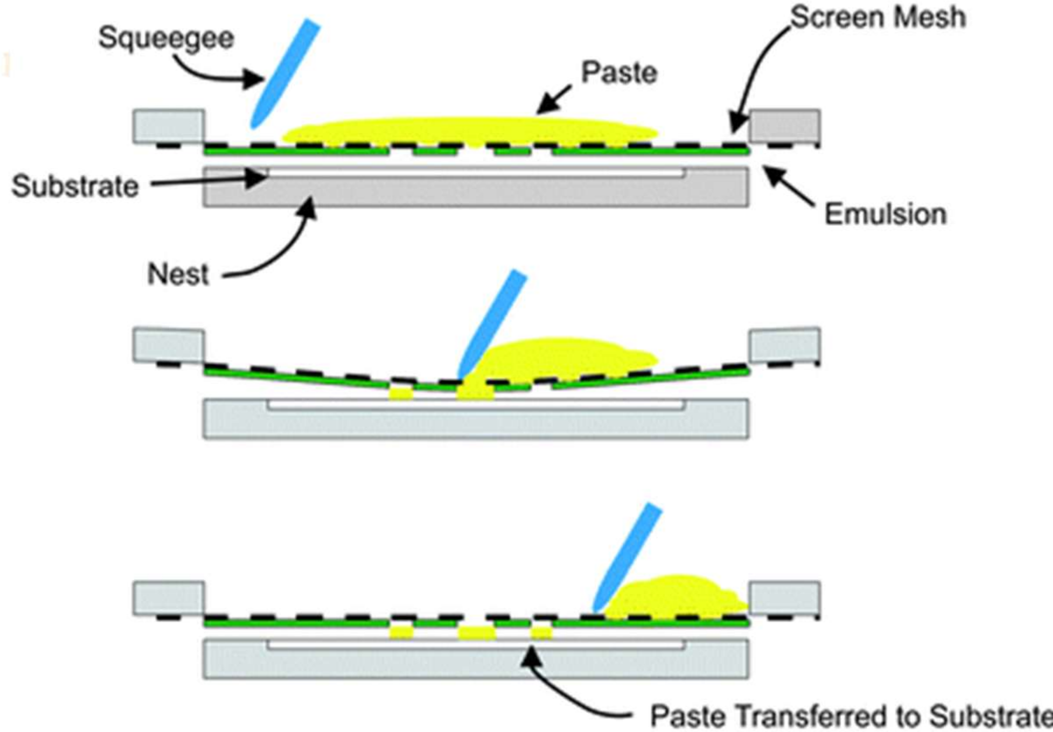
By ink transfer (Silk printing), this is the most common process in packaging.

- Good quality
- High volumes “low cost”
- Automatization possible

Drawback:

- Curing (UV, heating mandatory)
- Only one color per shot
- Ink is dusty process
- Ink can be non sustainable
- Lot of ink wasted
- No marking flexibility = one cliché per type of marking
- No possibility of incremental values (serial numbers)

Also used in Electronic SMD



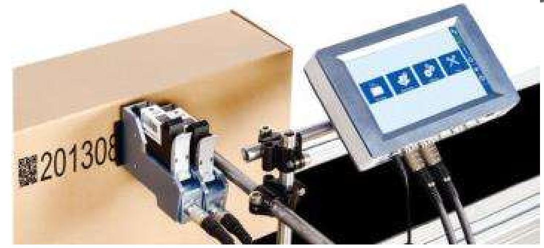
Serigraphy marking:
https://www.youtube.com/shorts/G3A8CeOs-zI

Marking (flexible)

By ink jet (2 to 200 k€)
- Multicolor
- Image fully flexible
- From low (€) to high quality (€€€)
- not only flat surface
- multi materials

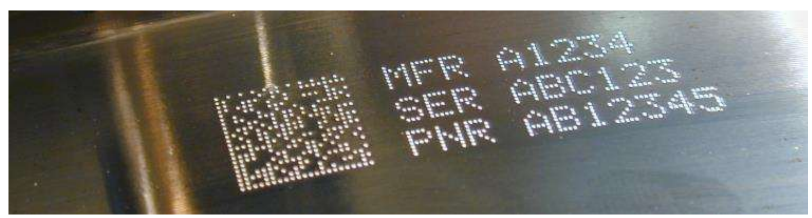
By laser (50 to 150 k€)
- limited to one color (with nuances)
- Image fully flexible
- Not only flat surface
- multi materials (non reflexive)
- UV or IR laser.

By engraving (20 to 50 k€)
- Mechanical marking (impacts)
- Mainly metal marking



Inkjet marking €: https://www.youtube.com/watch?v=OGr6kK9YYCE
Inkjet marking €€€: https://www.youtube.com/watch?v=6fKuV5dFbEk

Laser marking: https://www.youtube.com/watch?v=QsqUueoV1f4

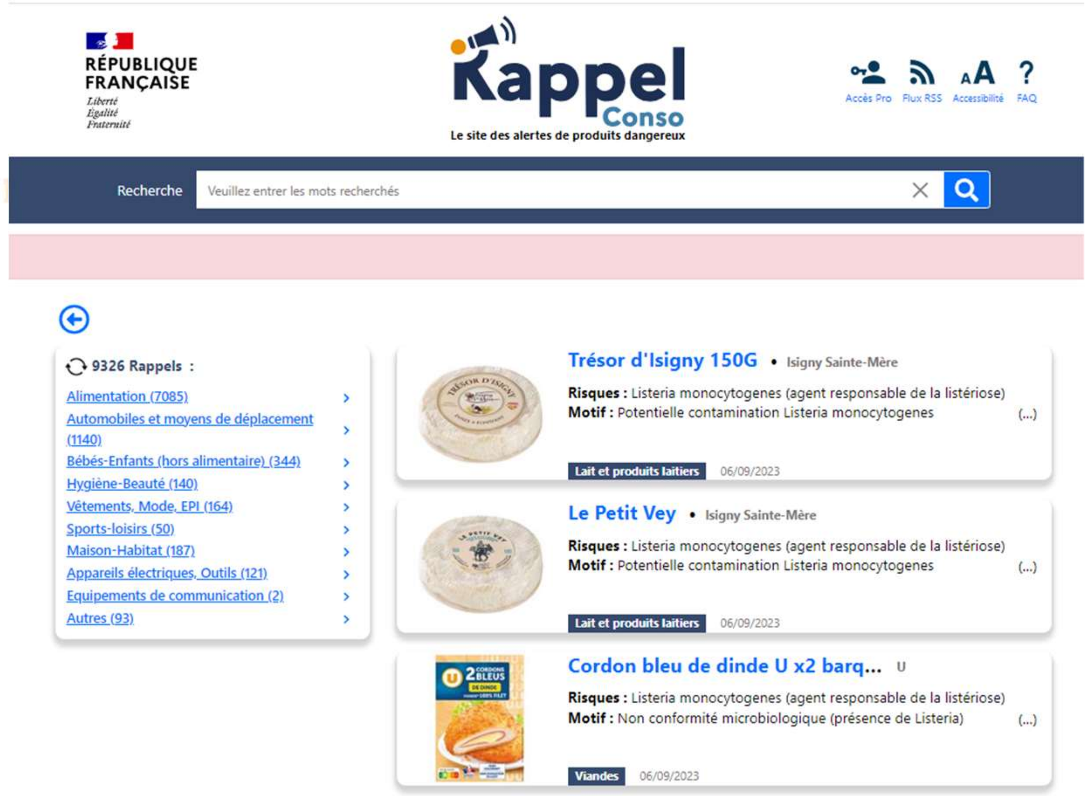


Engraving: https://www.youtube.com/watch?v=knoP0ryKJ1c

Traceability: what for?

Traceability is the possibility to identify Products through the manufacturing flow, logistic warehouses, distribution centers and at the user.

It allows the possibility to make statics or investigations on several parameters (Product, Process, parts, …)



It allows “recall”, sorting of products, or the possibility to know “where the product is” or “a batch of product is”.

It enables to narrow the list of products to be recalled in terms of major Quality issue : like food industry (health risk), automotive (breakdown issue), Appliance, Buildings (Steel or concrete problems).

Traceability can be performed by:

- “Passive” ID: date code making, Serial number marking, Barcode, Pixel code
- “Active” ID: RF-ID, Flash Mem, SD, any type of MEM able to store data

Traceability: How does it work ?

Traceability means being able to know « as much as possible » what is inside the product and where does it come from?

Globalization has complexified identification of origin of « materials »

Story (fictive):

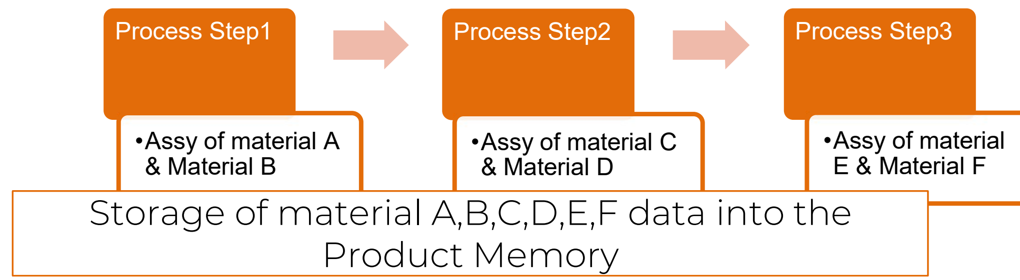
In a « chocolate bar »: There is, at least, cacao, milk, sugar, aluminum package. Most of time those components are multisource => 3 suppliers for cacao, 20 for milk and 10 for sugar and one for aluminum.

If my supplier of cacao is informing the factory that its cacao production was defective « last week »: What should I do ?

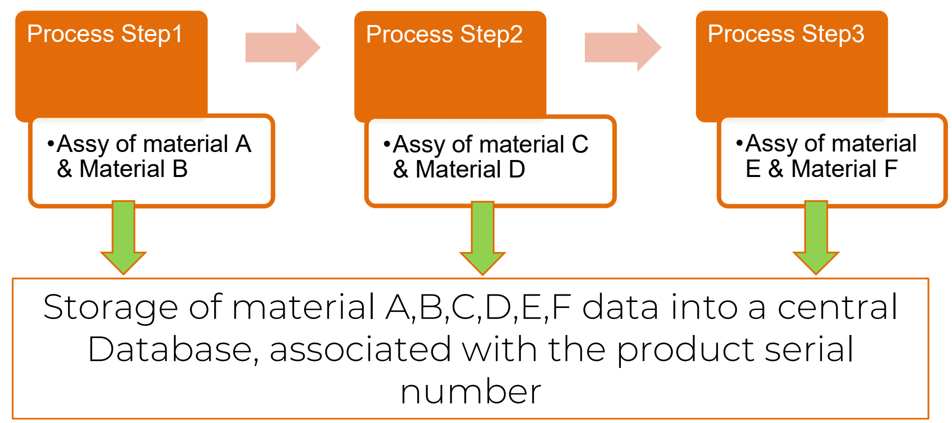
Multiple cases are possible:

1. Nothing: nobody will see it!
2. Stop all my production: destroy all cacao stocks, all ongoing production all finished products inside my factory, all products in stock in the selling points and recall all products at customers by doing a massive media communication = Economic disaster
3. I have an accurate traceability; I'll contain the problem due to a robust process in place.

Product with Active memory



Product without memory



Traceability: how much does it cost?

The money spent to implement a traceability system must be balanced with the threats and/or the legal requirements.

Pharma, food industry, aero, telecoms and many other industries MUST trace many data from their own processes, but also from their suppliers. So, it's not a question of money.

Many other industries like automotive, appliance, entertainment have no specific requirements for traceability. It's their own decision to implement such a system and to decide what, how and how long to store data. Nevertheless, it's their interest to do it.

The decision might be:

* A strategic decision when Shareholders decide to implement – no discussion

- An economic decision (curative) to implement AFTER a big recall costing huge amount of money
- An economic decision (preventive) to implement anticipating a potential recall, avoiding then the direct economic impact + the poor image delivered to customers.

The technical solution: You have to question yourself and the different stakeholders (QUALITY, IT, Controlling, Marketing & sales, ...):

- What could be the costs of a recall or quality incident?
- What are the probability that it happens ? (FMEA)

With these costs / risks: you can define a budget envelop.

Is your product able to store data ? Does it increase the cost of the product?
What volume of data can you store into the product ? When yes, you must install from the beginning of the process writers that will load data into the product.
What are the necessary data to be stored: => strong discussion and arbitration necessary !!
When your product can't store data, you must place at the beginning of the process, a unique ID on the product. Install readers at all the necessary stations and store data into a database (Called Historian in many industries) for a certain period of time.

Whatever is the solution, it's costing huge amount of money (Hardware + Software, read write and store) 100k€ to M€ !!

Tests in production

In almost all manufacturing industries some “tests”, “controls” or “inspections” are performed at multiple steps of the manufacturing process.

Visual inspections, by human or machine (presence of component, shape conformity, aspect and marking)

Dimensional measurement

Response to input measurement (electrical, digital, pneumatic, movement, effort…)

Hardness, deformation

Weight, static and dynamic balancing

Cycle time

Consolidation of different measurements

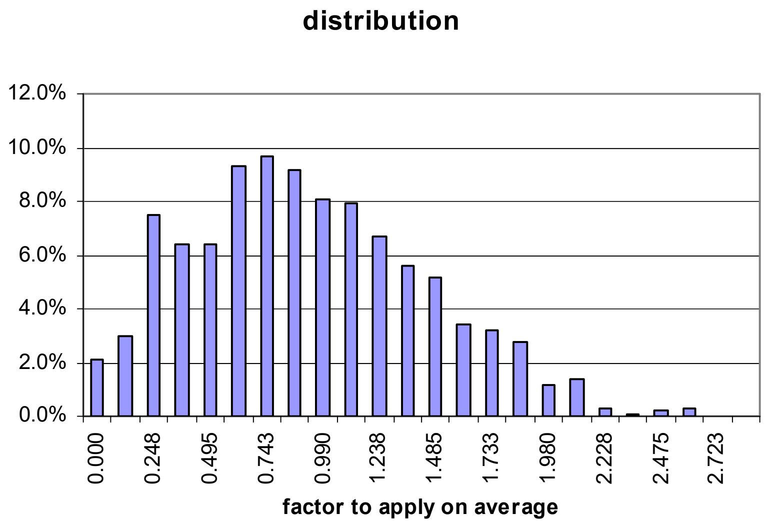
Functional tests

…

These tests are performed:

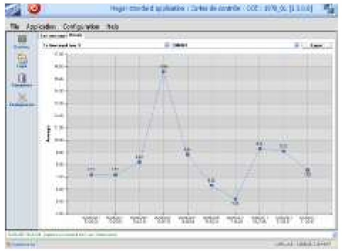
By measurement (value)

By attribute (go/nogo)



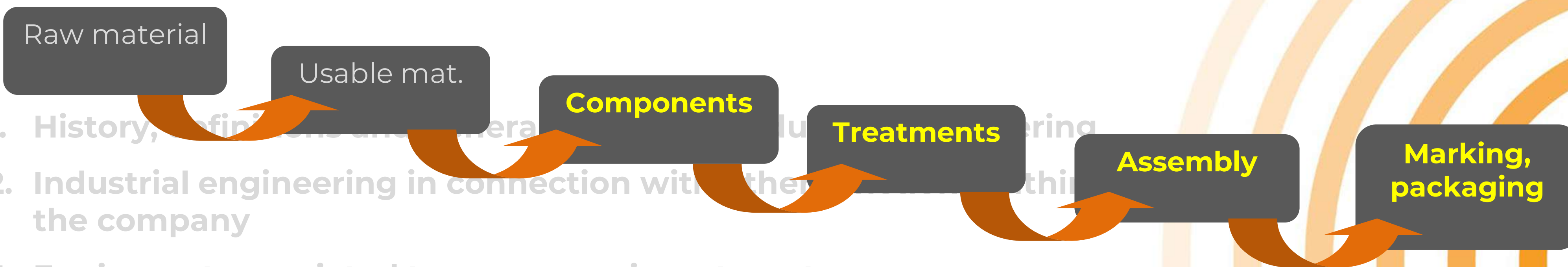
Tests in production

- SPC are often applied for improvements



Visual tests (presence of component, shape conformity, aspect and marking)	Camera and associated software for numerical image analysis
Dimensional measurement	Lasers and associated sensors, optical numerical ruler, caliper
Response to input measurement (electrical, digital, pneumatic, movement, effort…) Hardness, deformation Weight, static and dynamic balancing	Piezo sensors, inductive or capacitive sensors, switches
Cycle time	Parts counters, time counters
Aggregation of measurements	Flash memory, RFID, shift register

Industrial engineering



1. History, ... era ... du ... ering
2. Industrial engineering in connection with the ... thi ... the company
3. Equipment associated to processes, investment
4. **Assembly, treatments and tests in production**
5. Process Plan - Costing – Make or Buy – Business Plan
6. Industrial Engineering project, profitability

Equipment associated to processes, investment

This chapter is dedicated to machines, it provides very approximate cost figures and areas of implementation. This is not a decision table but guides you in the questions you need to ask yourself and your stakeholders in order to be able to make the right decisions and convince your shareholders, technical point of view.

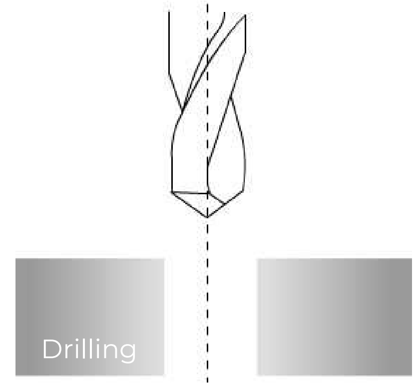
Machining

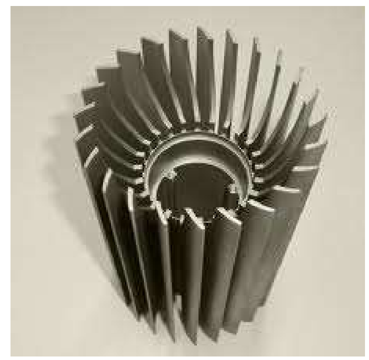
• Drilling (Basic, Low investment)
The part is fixed a rotative tool is drilling the part vertically.

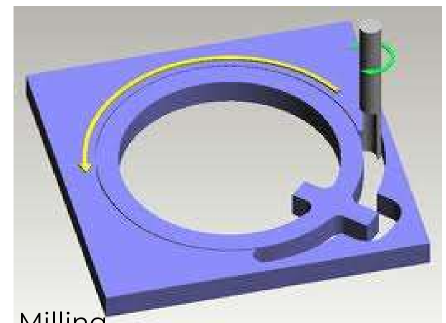
• Lathing - turning (30k€ to 1M€/unit) – fr:Tournage
The tool is fixed on a moving horizontal drawer. The part is turning. Material is removed circularly.
https://www.youtube.com/watch?v=WrsDUA6PKoM

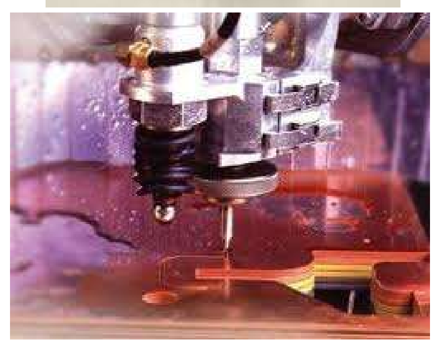
• Milling (50k€ to 2M€/unit) – fr:Fraisage
The part is fixed, a tool is rotating, moving X,Y,Z and removing material in all directions.
https://www.youtube.com/watch?v=i-PgeWbDgq4

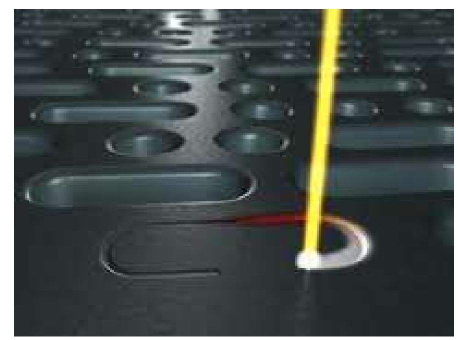
• EDM (*electrical discharge machining*) – fr: Electro-érosion (100 to 200k€/unit)
• Water jet, electrical arc, laser (100 to 500k€/unit)
https://www.youtube.com/watch?v=MMyhv6OIJkc











Machining

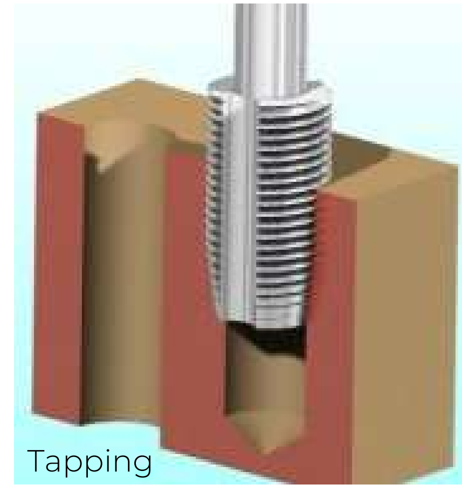
• Tapping (usually associated with drilling, lathing, milling) fr:tarraudage
https://www.youtube.com/watch?v=qk-8t77cjdU

• Lapping (30 up to 1M€) fr: surfaçage, polissage
https://www.youtube.com/watch?v=Z6togIVqC4M

• Gear cutting (special machines or associated to milling) (expensive !)

• Grinding (20 to 100k€) fr: affûtage, meulage
https://www.youtube.com/shorts/oawztg_4wi4

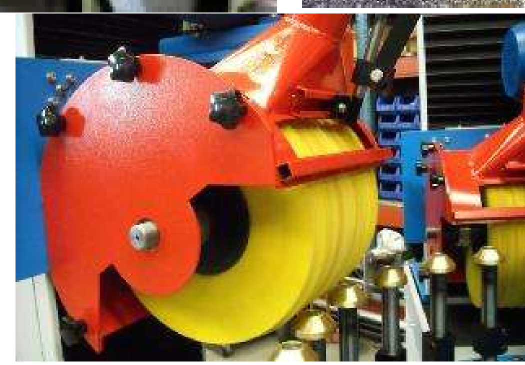
• Polishing (low-cost equipment, can be robotized)



Tapping

Lapping

Gear cutting



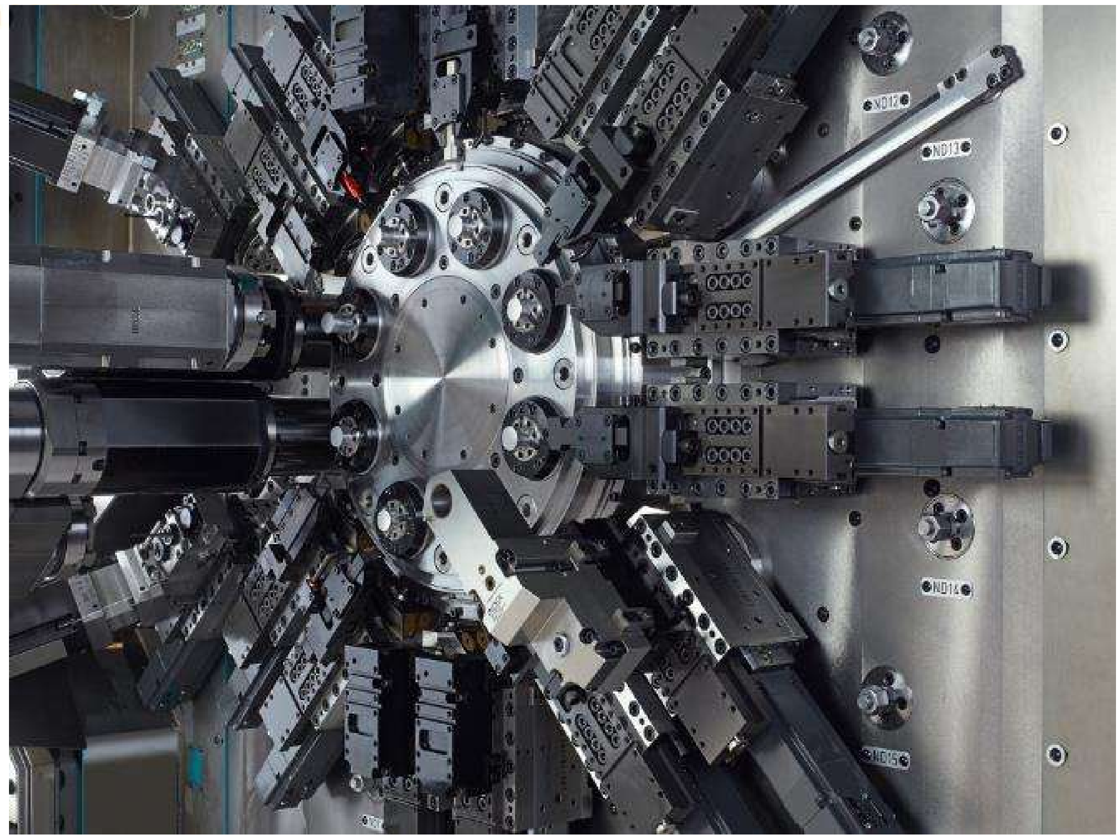
Auto lathing (100k€ to 1M€)

- High volume manufacturing to cover machines investment costs
- Covers many designs
- Most of time, parts are subcontracted to specialized suppliers (no investment)

Multi spindle auto lathing (> 500k€)

- For very large production batches
- Less accurate than simple mobile spindle auto lathe, but good enough
- Sometimes insourced, but seldom

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



Auto lathing by turning tools around wire (> 50k€)

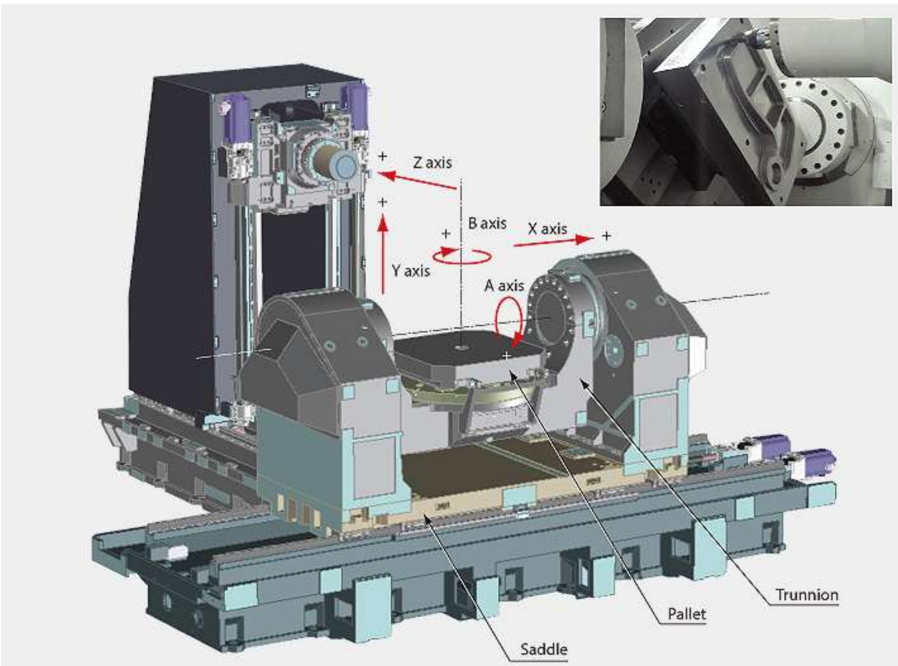
For very long parts, compared to diameter

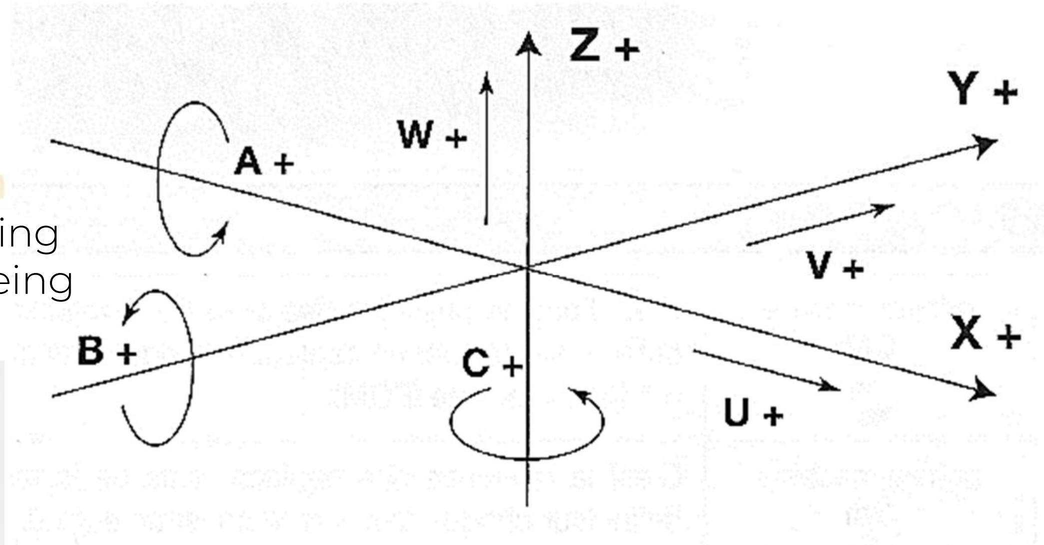
Milling center

- Tools store and automatized tool exchanger → Complex machining operations
- Compulsory as soon as accuracy is required for some designs
- Can include ; milling, drilling, lathing, tapping, gears shaping…
- Small and middle size batches only
- Investment: above 100 k€

Milling center choice (ie: DATRON)

Number of axis to move the workpiece (Z axis being parallel to milling tool main rotation axis, X axis being the longest perpendicular axis to Z)





- Capacity ; X, Y, Z (in mm)
- Power and spindle maximum rotation speed
- Workpiece loading system
- Tools places in automatic dispenser

Milling center

Drilling center (often combined with milling)

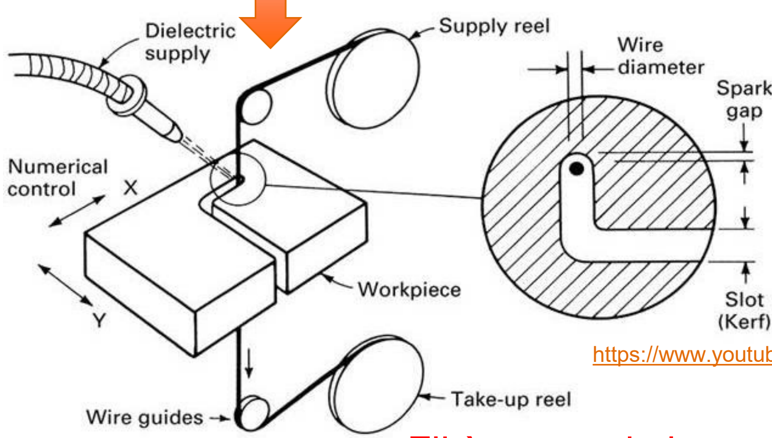
- When many holes / tapping in the same part
- High lubricant flow → high speed
- Cost =< 100 k€

- Milling/ Drilling center: https://www.youtube.com/watch?v=rkfVI9ZBVGI

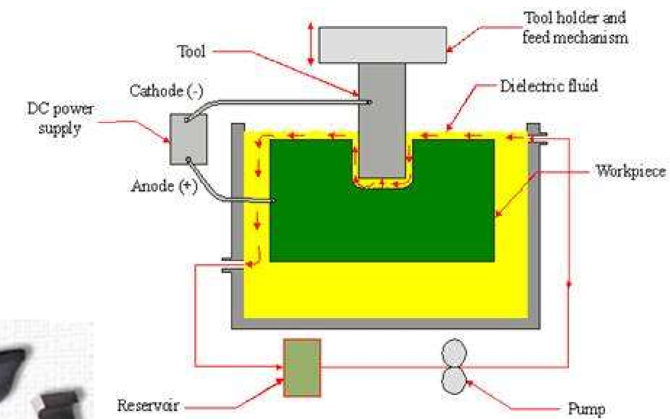
EDM (*electrical discharge machining*)
fr: Electro-érosion

Mostly used to produce tools for stamping, molds for injection, punch or dies on <u>hard materials</u>. It's a very slow process (0,2 to 10mm per minute). A high current flows from an electrode or a wire to the part and creates sparks that « remove » material.

- Electrode erosion: the electrode enters progressively into the material
- Wire erosion (0,05 to 0,2 mm wire): material is cut according to the wire movement.



https://www.youtube.com/watch?v=liFRg0UPaiE



https://www.youtube.com/watch?v=L1D5DLWWMp8

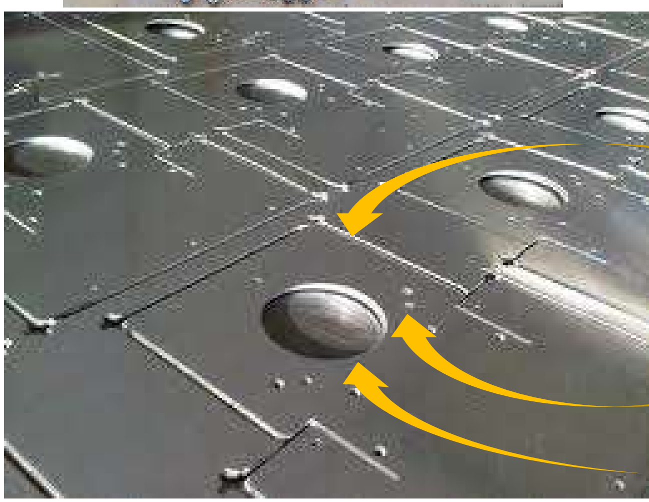
« Fil à couper le beurre »

Cutting with a numeric machine

Investment several 100 k€

Interchangeable punches & dies

CNC Press

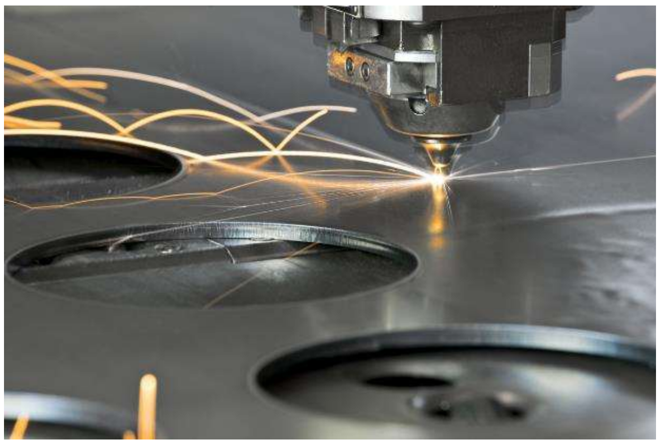


Trumatic Punching : https://www.youtube.com/watch?v=s2wOIP7JMMg

Laser or plasma cutting

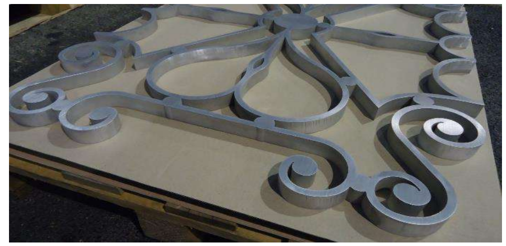
Up to several cm depth

Investment 100 k€ to 500 k€



Plasma:
https://www.youtube.com/watch?v=DNoGzyEGWi0
Laser: https://www.youtube.com/watch?v=3dVT4cNjI8M

Water jet cutting



Water or water + sand is propelled under high pressure on the material to be cut.

Propulsion speed > 1000 m.s

0.05 mm < Jet diameter < 0.5 mm

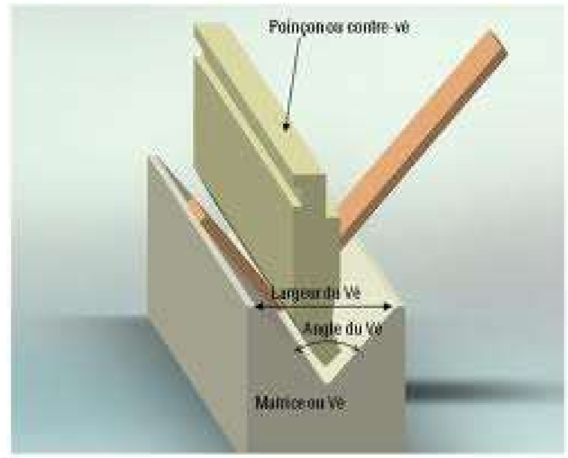
Cut thickness up to 100 mm, according to material

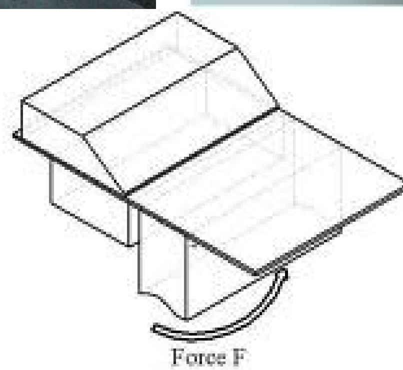
Used for many material: Stone, Metal, wood, plastic, foam. As long as the requested accuracy is not high.

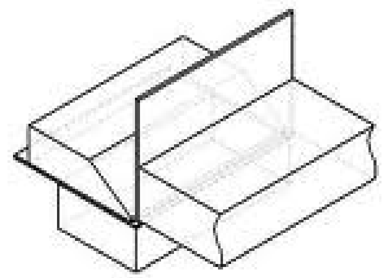
Investment: 50k€

Water Jet cutting: https://www.youtube.com/watch?v=FXk76rWYdEs

Metal Sheet bending







- Blades tools
- Manual loading (most of the cases)
- Up to couple of meters width
- Investment ; < 100 k€

Thermoplastic injection

https://www.youtube.com/watch?v=b1U9W4iNDiQ

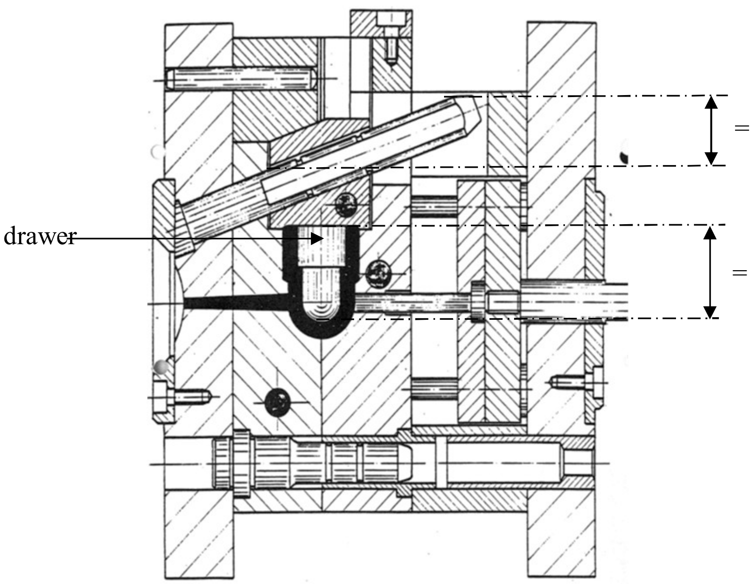
Injection press costs: 40 to 300 k€ investment per press : size dependent
Plus, peripheral equipment:

- Thermo regulator (s) # 10 k€ per press
- Runner picker # 20 k€ per press (or 2 presses)
- Regranulation process # 5k€ per press
- Drying, coloring, feeding installation 300 to 1000 k€ for the entire workshop
- Water cooling / depolluting station 300 to 1000 k€ for the entire workshop
- Preheating station (molds) # 20 k€ for several presses

+

- Molds !! The mold can be more expensive than the machine, related to its complexity

Thermoplastic injection



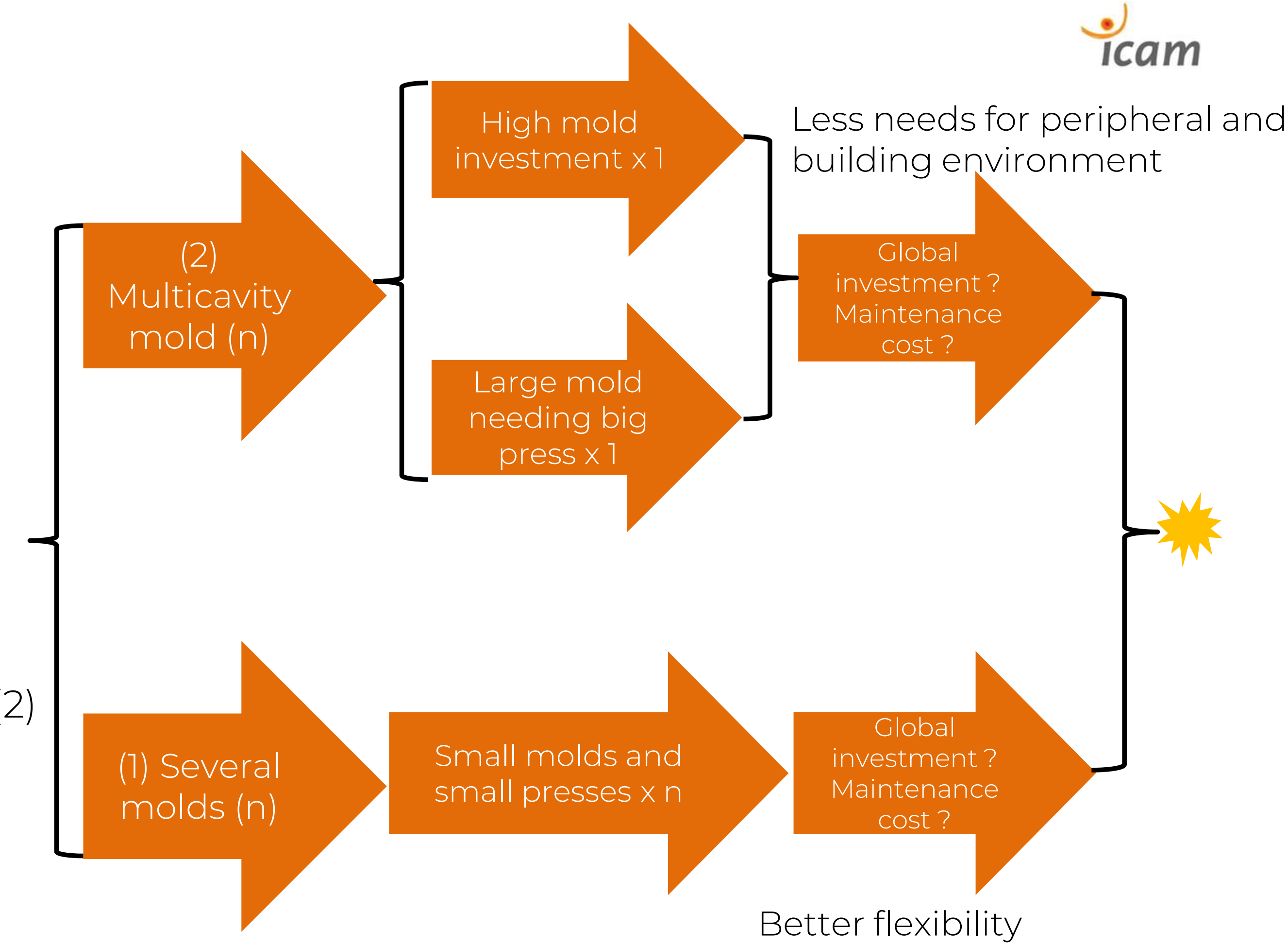
Production Molds cost: from 10 k€ (very simple, two cavities), to 300 k€ (big ones with complex unmolding movements). Procurement lead time: several months !

An aluminum prototype mold (very short lifetime): 1-5k€

Mold selection

Problem: you need to produce more parts volume than the capacity of one mold.
Possibilities (And/or):

- Increase the working hours (Extra time, extra shifts)
- Duplicate mold (1)
- Duplicate cavities in one mold (2)

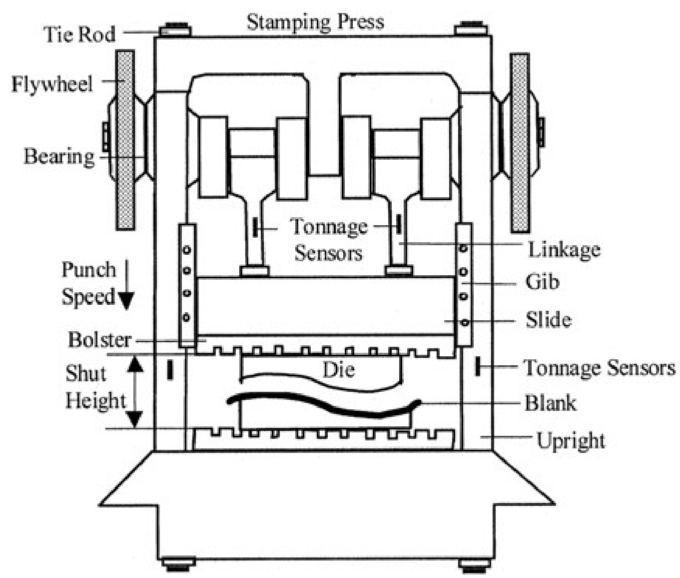


Metal stamping

Punching, bending, forming mechanical presses, from 0.5 ton to 1000 tons and more

Cost from 5000 € to more than 1 M€ : unit

Bruderer press: https://www.youtube.com/watch?v=eDAEeXcwjOg



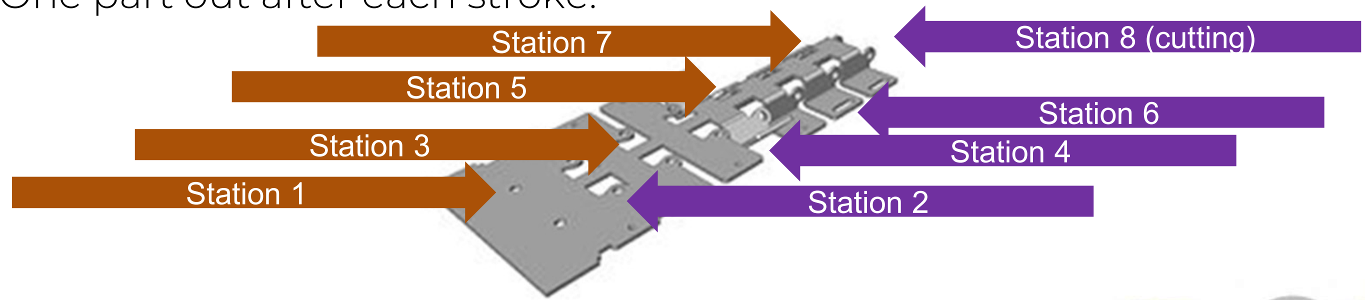
Metal stamping: Peripheral equipment

Feeding equipment

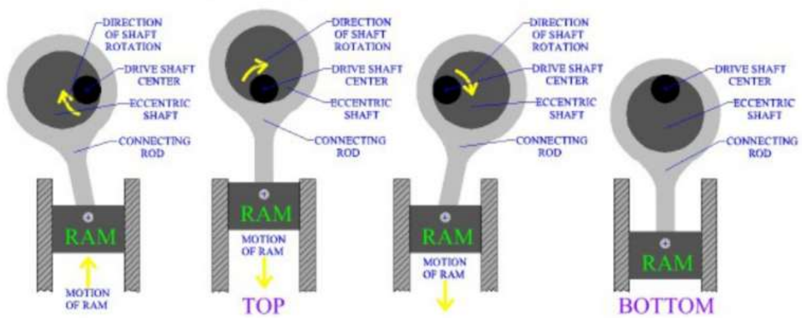
Straightener

Stamping Tools and press selection

- Simple stamping tools → Part is completed after one stroke only
- Stepping tools → Several strokes needed to get a complete part which is transferred to the next station in the tool each stroke. It requires accurate indexing of the stripe at each station. One part out after each stroke.



- Press force depends on total section to cut x K factor x Rm (refer to ECAM3 course)
- Don't forget to add necessary pressure for bending operations inside the tool and consider material thickness



Deep stamping press (fr: emboutissage)

Hydraulic press used for deep stamping

Low speed, but long loading / unloading stages, anyway

Very high power → 200 k€ to 1000 k€

Some « management » decisions

In your career, you'll often be confronted to the following dilemma:

Should we invest in new machines ?

Should we replace old machines ?

Should we buy secondhand machines ?

Should we subcontract the parts ? But being owner of the tools ?

Should we lease the machine ?

In the following pages, I'll guide you through the questions you should answer by yourself or with the different stakeholders in order to "facilitate" the answer. I'll have to take the decision, but must most often to convince others about the interest of your proposition (not only your convictions)

IMPORTANT: the same technical problematic, considered in 2 different companies will most probably result in 2 different decisions !

We are not considering only technics and this not pure math !!

Decision taking for investment. Checklist of questions

What is my company strategy regarding the machine/process I want to invest? Innovative / conservative, diversified / limited, integrated / fabless. Let's imagine I'd like to acquire an injection press to make badges of employees at Crédit Lyonnais : crazy? Or not.

What is the financial situation of my company: wealthy, very profitable, high cash flow or not ? Profitable & wealthy will more probably invest, when others will lease the machine or prefer to externalize the activity.

Are the competencies already available inhouse? Is there a will to acquire the skills? Whatever are the motivations, if the skills won't be available, it's not recommended to acquire the machine, better to externalize.

What competitors are doing? Should I copy or differentiate? Is there a competitive advantage to do it inhouse? Can I have a better reactivity, or will I do things he can't do?

We have an old machine, when should we replace it ? Question all the previous points, maybe answers changed from the past decision to invest and today. In the case the investment is still necessary: when? 5y?10y? Wait the machine is "dead"? In fact, it's necessary to make a cost study based the consolidation of the maintenance costs, the productivity of the old machine, compared with the investment, depreciation and productivity of the new machine (considering that the maintenance costs may increase overtime).

Should I insource something that is currently externalized: Think about masks and Doliprane few months ago..

Such questions must be answered BEFORE any technical or financial detailed study that could lead you to waste your time !!

Industrial engineering

1. History, defin... l engineering
2. Industrial eng... ctions within the company
3. Assembly, tre...
4. Equipment a...
5. **Process Plan - Costing – Make or Buy – Business Plan**
6. Industrial Engineering project, profitability

BOM & Process Plan

Every product is made of 2 things: **Materials** and **Transformation activities**

Materials contained in a product are listed into a file/document named BOM: Bill Of Material. Fr: Nomenclature

BOM can be composed of:

- Raw materials (Metal, plastic granulates, sand, grease, water,...)
- Components (Screws, PCB, capacitor, tire, ...)
- Semi-finished products (PCBA, motor, gear-box,...)
- Accessories (Packaging, stickers, pallets,...)

Every item is "described" enough to enable Sourcing to <u>BUY</u> it.

Each of these items are "attributes" like:

- Reference
- One or multiple suppliers
- Price
- Delivery lead-time
- Conditioning
- Drawings
- Specifications
- ...
- This list can be very long (Imagine a car ! 30,000 parts)

Transformations activities to elaborate the product are described into a file/document named: Process Plan. Fr: Gamme

Process Plan is the description of the necessary actions to be performed to "transform" the BOM to become a "product" to be sold.

- Actions done by operators
- Actions done by machines
- "other actions": logistic, repair, quality inspection,...

Every action is "described" enough to enable Operations to MAKE it

Each of these actions are described like:

- Technical description with chronology
- Time necessary to realize detailed operations
- Qualification and associated hourly rate of operator
- Machine requested and hourly rate
- Tools necessary and hourly rate
- Direct & indirect costs
- ...
- This list can be very long (Imagine a train ! 20,000 operations for 1 wagon)

BOM & Process Plan structure

Most of time BOM & Process Plan are stored in one or two databases:

- ERP: Enterprise Resource Planning containing all Process Plan & BOM data (References, prices, hourly rates, sourcing data,...)
- PLM: Product Lifecycle Management containing Engineering date like technical product & process data (parts drawings, specifications, construction drawings,...)

BOM & Process Plan are not only lists (flat lists) but structures corresponding to the real product process.

How BOM & Process Plan are created ?

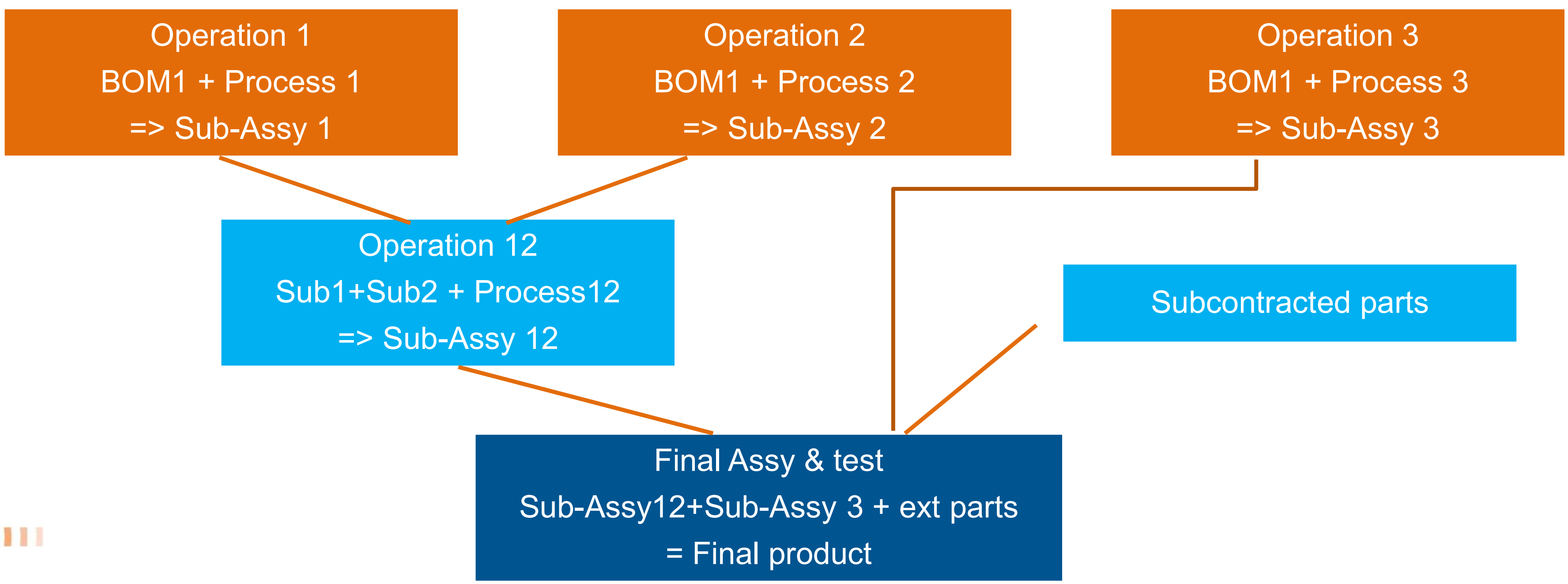
1. Engineering (R&D) is providing the finished product description (Single parts drawings 2D &3D, assembled product 3D, and some recommendations on how to assemble & test it. => They provide the BOM (flat)

2. Industrialization is defining « How » to manufacture the single parts & « how » to assemble & test the final product in every details => They provide the PROCESS PLAN and the STRUCTURE of BOM

Nota: the same product manufactured in 2 different plants, will have the same BOM but 2 different PROCESS PLAN and STRUCTURE (different machines, different ways of manufacturing, different flows…)

Structure of BOM & Process Plan

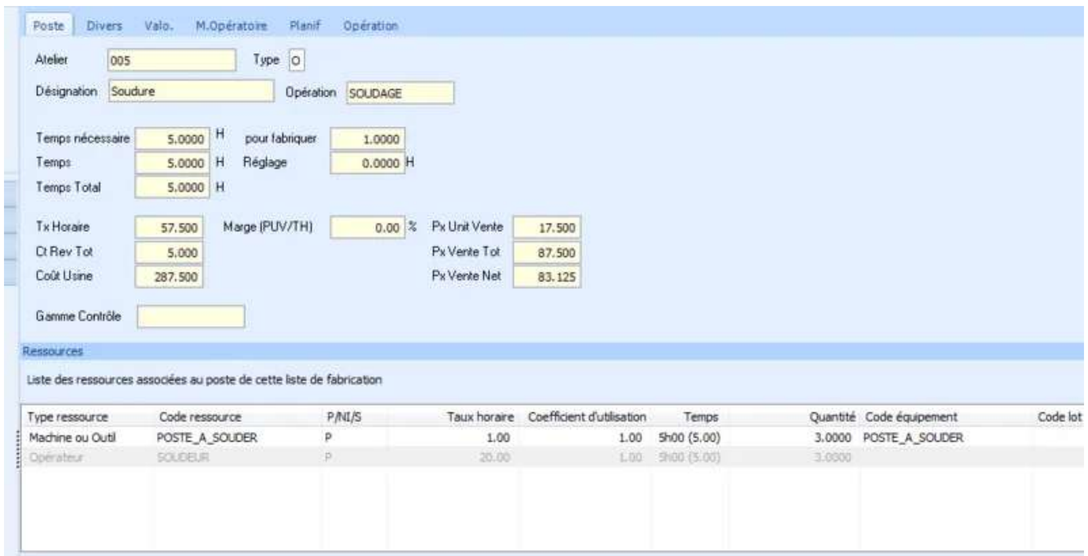
To fit to the real manufacturing process steps, BOM & Process Plan are the image of the real process. Each manufacturing steps has its own BOM & Process Plan. They are called HIERARCHY or STRUCTURE. Such structure is fully described in an ERP.



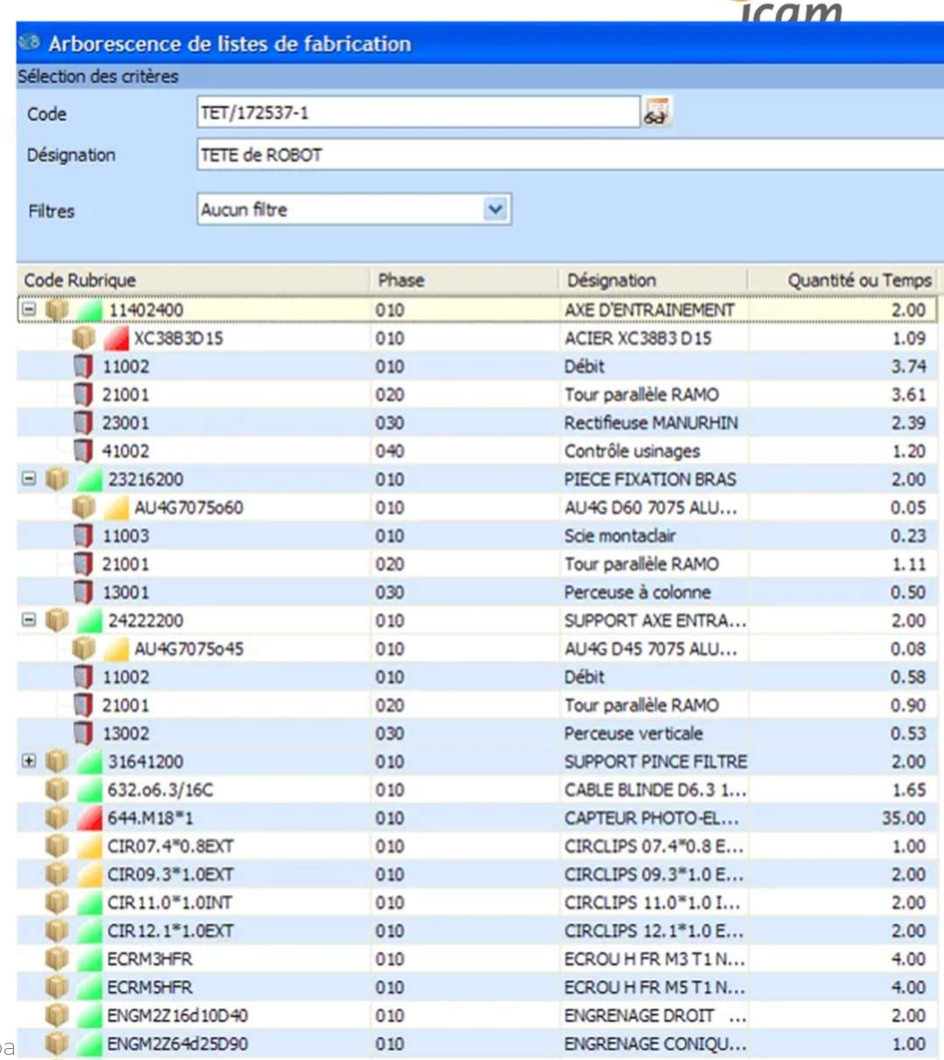
Structured BOM & Process Plan into an ERP

On the right view, you can observe the raw materials (Metal), the process to be realized, the machines to be used. And the components to be purchased.

On the bottom view: The necessary time for the operation, the hourly rate, …



Type ressource	Code ressource	P/NI/S	Taux horaire	Coefficient d'utilisation	Temps	Quantité	Code équipement	Code lot
Machine ou Outil	POSTE_A_SOUDER	P	1.00	1.00	5h00 (5.00)	3.0000	POSTE_A_SOUDER	
Opérateur	SOUDEUR	P	20.00	1.00	5h00 (5.00)	3.0000		



Code Rubrique	Phase	Désignation	Quantité ou Temps
11402400	010	AXE D'ENTRAINEMENT	2.00
XC38B3D15	010	ACIER XC38B3 D15	1.09
11002	010	Débit	3.74
21001	020	Tour parallèle RAMO	3.61
23001	030	Rectifieuse MANURHIN	2.39
41002	040	Contrôle usinages	1.20
23216200	010	PIECE FIXATION BRAS	2.00
AU4G7075o60	010	AU4G D60 7075 ALU…	0.05
11003	010	Scie montaclair	0.23
21001	020	Tour parallèle RAMO	1.11
13001	030	Perceuse à colonne	0.50
24222200	010	SUPPORT AXE ENTRA…	2.00
AU4G7075o45	010	AU4G D45 7075 ALU…	0.08
11002	010	Débit	0.58
21001	020	Tour parallèle RAMO	0.90
13002	030	Perceuse verticale	0.53
31641200	010	SUPPORT PINCE FILTRE	2.00
632.06.3/16C	010	CABLE BLINDE D6.3 1…	1.65
644.M18*1	010	CAPTEUR PHOTO-EL…	35.00
CIR07.4*0.8EXT	010	CIRCLIPS 07.4*0.8 E…	1.00
CIR09.3*1.0EXT	010	CIRCLIPS 09.3*1.0 E…	2.00
CIR11.0*1.0INT	010	CIRCLIPS 11.0*1.0 I…	2.00
CIR12.1*1.0EXT	010	CIRCLIPS 12.1*1.0 E…	2.00
ECRM3HFR	010	ECROU H FR M3 T1 N…	4.00
ECRM5HFR	010	ECROU H FR M5 T1 N…	4.00
ENGM2Z16d10D40	010	ENGRENAGE DROIT …	2.00
ENGM2Z64d25D90	010	ENGRENAGE CONIQU…	1.00

Global Profit & Loss of a company

This table is a Standard table to present the global performance of a company.

Gross turnover = the total amount of the company sales

Net turnover = the Gross Turnover – the discount you made to your customers

Gross Operating margin = Net Turnover – All the money spent to produce: “Manufacturing costs”

Operating margin = Gross Operating margin – all other company costs

Operating Margin represents the “profitability” of the company.

It’s NOT the net result (that includes tax & other financial figures income and outcome)

Accounting items	and orders of magnitude
Gross turnover	100 to 115
Trade discounts	
Net turnover	100
Material costs	
Direct labor	
Indirect labor	
Consumables	
Other indirect manufacturing costs	
Depreciation	
Gross operating margin	20 to 50
Commercial Supply Chain	
Research and development	
Marketing	
Commercial costs	
Administration and overheads	
Operating margin	**10 to 15**

Product cost structure: manufacturing costs

Manufacturing Costs (fr: PRIX de REVIENT) include:

- Purchased materials is the sum of all components from the BOM
  - 1 product = 1 unit; 2 products = 2 units
- Direct labors is the sum of all time*hourly rate of the Process Plan
  - 1 product = 1 unit; 2 products = 2 units
- Indirect labors is the value of salaries of people necessary to make production running but not directly mounting the products (see on the right)
  - 1 product = 1 unit; 2 products <= 2 units
- Consumables are some materials that are purchased to enable the production running, but not belonging to the product (Machines' oil, hand towels,...)
- Other indirect manufacturing costs are consultants' fees, training costs, small non-depreciated tools, office supplies consumed by the direct and indirect staff defined above, rentals
- Depreciations is an amount representing the money the company sets aside to renew investments already made when they become obsolete.

1	**Purchased Materials**		50
2	**Direct labor**		15
3	**Indirect labor**		15
4		Production management	6
5		Maintenance technicians	4
6		Production handlers	2
7		Other support activities	3
8	**Consumables**		3
9	**Other indirect manufacturing costs**		5
10		Energy	3
11		Spare parts	1
12		Other indirect costs	1
13	**Depreciation**		12
14		Common buildings and facilities	2
15		Production machinery and equipment	7
16		Tools	3
	Total Manufacturing cost		100

Manufacturing cost (or « Cost of sales »)

= Net turnover – Gross margin

= Material cost + Added value in production

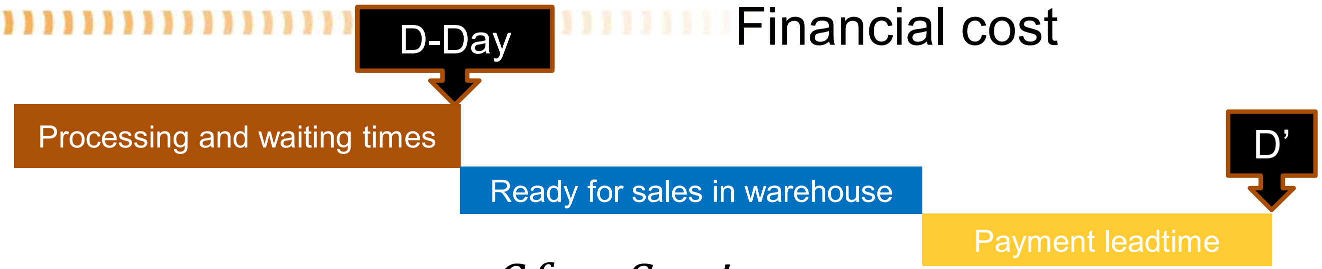
Postes comptables	et ordres de grandeur
Chiffre d'affaire brut	100 à 115
Remises commerciales	
Chiffre d'affaire net	**100**
Achats matières	
Main d'œuvre directe	
Main d'œuvre indirecte	
Consommables	
Autres coûts indirects de production	
Amortissements	
Marge brute d'exploitation	20 à 30
Logistique commerciale	
Recherche et développement	
Marketing	
Coûts commerciaux	
Administration et frais généraux	
Marge opérationnelle	10 à 15

Material cost

- Raw material or components purchased, for their purchasing price, plus transportation, custom duties and losses value.
- Minus resold materials (scraps, runners, recycled, …), for their selling price (without VAT)
- Plus stock ownership costs for materials.

Cost of inventory ownership: finished products

Financial cost



$$Cf = Sv \,.\, i$$

Sv = Stock value = Yearly turnover x (D’ – D) / 365

I = interest rate applicable to working capital, or expected for return on investment

Often 2 to 5 % of total inventory value per annum

Ie: A company having a turnover of 1M€, some payment conditions at 45 days and some average storage leadtime of 25 days. 2,60% for I.

Cf=1M*(45+25)/365 * 2,6% = 80k€

This value represents the money “lost” due to internal Finished products inventory and leadtime to get paid by customers.

Actions: Sell as fast as possible the products ! Make sure your customers are paying fast.

Cost of inventory ownership: purchased materials

Obsolescence costs, variations of costs values:

- Material you purchased that you won't use anymore (can be destroyed or sold)
- Material you purchased that can't be used anymore (Batteries, food, …)
- Material you purchased at a certain value with an actual value higher or lower
- Material stored since long time that you « could use one day » but that you started to depreciate (about 20% per year)
- Material "lost"

Some inventory must be done eve

Cost = Acquisition cost – Residual value

→money "lost" on your purchased material.

Cost of inventory ownership: m² costs

The higher the stock is, the higher these costs are.

This are physical costs like :

- Building
- Shelves
- Offices
- IT System
- Lighting
- Heating
- Cooling
- Humidity control
- Forklifts
- Access roads
- .....

Cost of inventory ownership: overall (From 10% to 25% per annum)

€ Financial cost ; Purchased material and other direct costs paid at D date, invoiced later at D' date → Usually around 0.4% of total inventory value

€ Obsolescence cost ; Total cost when stock is lost, according to given occurrence probability relating to quality risks, products lapsing or unsold products for unexpected reason → 2 % to 15 %, depending on products

€ Physical costs relating to storage means ; including subcontracted activities cost (e.g. cleaning) → 0.5 % to 3%, depending on stock value.

€ Insurance cost to cover damage risks by water, fire, theft... → 2% to 5% (if you store sand, the risk is not the same as Iphone 14 !)

€ Salary cost of people in charge of material handling and storage management (eventually subcontracted) → 2% to 5%, depending on stock value.

This is the reason why many Lean projects are focusing on reducing stocks !

Transportation and custom costs: some figures

- One 44 ft container → 1450 € on Europe – Asia way. 3600 € for return way
- One 22' container cost only 30% less
- One 44 ft container Europe – South America, or return → 2600 €
- Entry custom taxes in Brazil ; 18%, but less from Mercosur countries
- Entry custom taxes in India ; 12%
- Entry custom taxes in China ; 8%, but 5% only from Asian countries
- VAT usually recovered when re-export

Figures subject to change according to recent events !!!

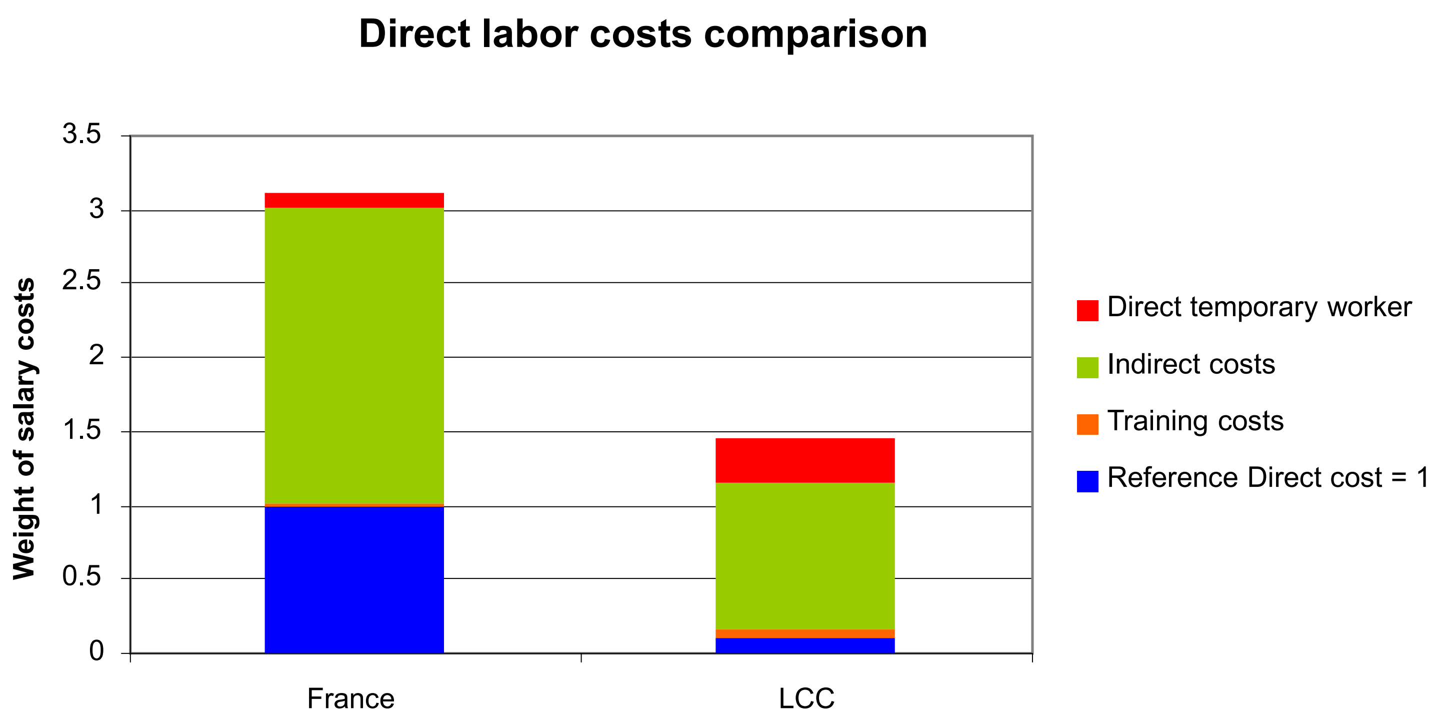
Wage and direct salary costs

What does it include ?

- Net wage given to employee
- Paid holidays and public holidays
- Social burden tax paid by employer
- Bonus and accessories free of tax
- Transportation cost or participation to transport
- Food or subsidy to food expenses
- Housing or housing allowance
- Allocated company car (top managers and sales force)
- Absenteeism cost

Rules, practices costs, ratio, differs from countries to countries

In Low-Cost Countries, direct labor cost not on stake, more indirect costs



Indirect salary costs

Which people ?

- Direct management in Production
- Maintenance technicians and engineers
- Quality inspectors
- Storekeepers and materials handlers
- Production engineering people
- ….. And others whose headcount isn't directly linked with volumes, but are neither dedicated to products development, nor logistic, sales & marketing, general management

With the same cost structure as direct wages (Taxes, holidays, …)

Consumables

What does it include ?

- Electricity, water, gas, used for processing
- Tissues, soap, oil, and materials to clean and maintain production means
- …. All other purchased items that are not part of the product nomenclature, but are still more or less directly related to production volumes

Other indirect expenses for production

What does it include ?

Training and traveling expenses for production staff

Heating, conditioning, gardening, security cost for production building

Insurances

…. And other cost whose are not linked with volumes, but facilitate the production activities

Depreciations

What is that ?

- Money that is put aside, every year, to accumulate after X years, enough capital that allows to replace worn equipment or to be spent for maintenance (Details in the EC08-Maintenance).
- X between 1 to 3, as far as IT equipment & software is concerned
- X between 1 to 5, for specific tooling -> 4 years is commonly used
- X between 5 to 10, for machines -> 8 years is commonly used
- X between 15 to 30, as far as building is concerned -> 20 years is common

- Either linear (same amount each year), or decreasing (same percentage of remaining capital to depreciate, every year)

Some details here for France: https://www.l-expert-comptable.com/a/52013-la-duree-d-amortissement-d-une-immobilisation.html

Depreciations

1/3 of the booking value N-1

Depreciation on 8 years for 100 k€ machine				
Linear depreciation		Year	**Degressive depreciation**	
Yearly deprec.	Booking value		Yearly deprec.	Booking value
12 500 €	87 500 €	1	33 333 €	66 667 €
12 500 €	75 000 €	2	22 222 €	44 444 €
12 500 €	62 500 €	3	14 815 €	29 630 €
12 500 €	50 000 €	4	9 877 €	19 753 €
12 500 €	37 500 €	5	6 584 €	13 169 €
12 500 €	25 000 €	6	4 390 €	8 779 €
12 500 €	12 500 €	7	4 390 €	4 390 €
12 500 €	0 €	8	4 390 €	0 €

Other engineering project costs to consider

- Traveling and living cost of engineers when setting up new process abroad
- Traveling and living expenses to involved foreign production engineers in upstream stages of the project, in order they take ownership before local setting up
- Equipment transportation cost
- Instructions for use and technical documentation translation regarding equipment not locally sourced, plus safety compliance and certification fees
- Custom duties for imported equipment and materials
- Local certification of process and products by official bodies
- Training expenses for production people including maintenance

Costs comparison (synthesis)

I. <u>Whatever the case:</u>
- Organic increase of business
- Winning a new market
- Take the best Make vs Buy decision
- Decide where to localize production

Cost calculation to take into consideration is not the same and several options are there, in each case.

II. <u>Key questions to ask:</u>
- Do we have the appropriate machines / tools locally, or do we need to invest new ones?
- Who should be the tools owner ? (IP protection, risk to not recover, locked market)
- Which part or the costs (fixed) will remain internally, even if I externalize production ?
- Is the material cheaper here or there, including logistic and taxes costs ?
- What is the consolidated profit at Group level, where do we have interest to make profit ? (Allocation of benefits, transfer prices; where will we need cash later ?)
- Where are the competencies located?

Manufacturing location ?

The role of industrialization is to propose alternative options for manufacturing locations, considering multiple parameters:

Where to place my manufacturing activities ?

- I can do it in my Plant A (ex: France)
- I can do it in my Plant B (ex: Poland)
- I can ask to an external supplier to make it for me (ex: Apple)

Manufacturing location ?

Make / Here

- Investment and competences ? ⟷ Operations control and business continuity ?
- Labor cost and evolution here ? ⟷ Labor cost and evolution there ?
- Structure cost here ? ⟷ Structure cost there ?
- Energy and maintenance costs ? ⟷ Energy and maintenance costs ?
- Warehousing cost ? ⟷ Stock ownership and transportation cost ?
- Confidentiality ⟷ Risk of counterfeiting

Buy / There

Industrial engineering

1. History, definitions and ge… …ngineering
2. Industrial engineering in c… …ons within the company
3. Assembly, treatments and…
4. Equipment associated to p…
5. Process Plan - Costing – Make or Buy – Business Plan
6. **Industrial Engineering project, profitability**

Project leader profile*

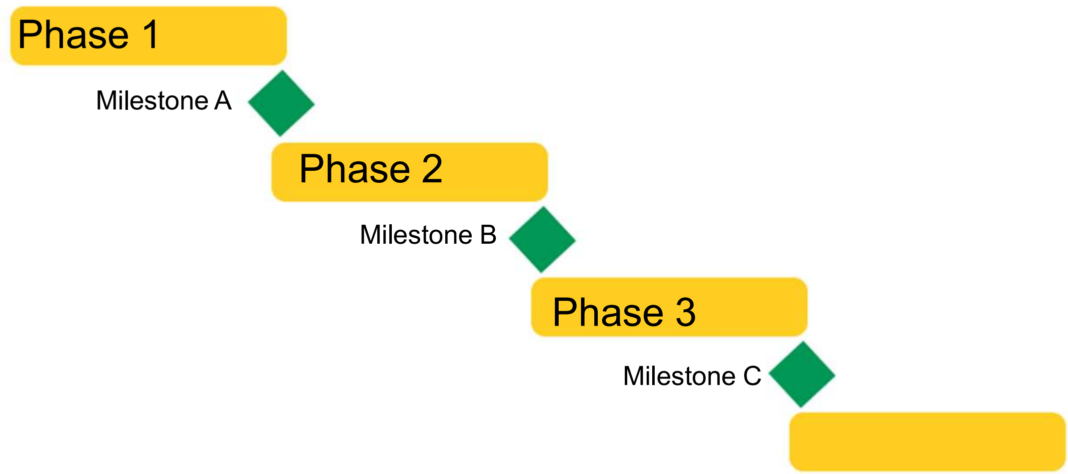
- Very good communicator
- Not necessarily an expert of product or process
- Having good understanding of skills related to the project
- Charism (indirect management), ability to convince
- Rigorous
- Able to synthetize, prioritize, motivate the team
- Open minded to new ideas

* A project leader is NOT necessary a Product Owner or Scrum Master

Milestones & phases

- A Milestone is a short moment during which the core team is investigating and validating (or not) the expected deliverables.

- A phase is a period of time (1 week to one month or more) during which the team (Core team, extended team, experts, ...) are producing the expected deliverables of the project. This production is respecting the defined sequence and assignation of tasks.

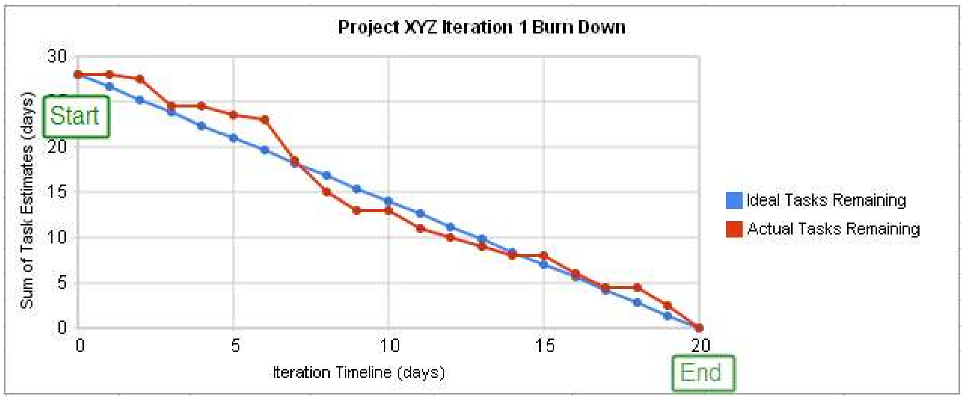


Is it compatible with Agile or Waterfall?

Project sequenced by Milestones

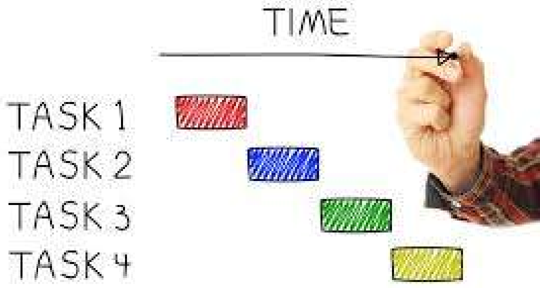
Each activity must be S.M.A.R.T.

- **S**pecific
- **M**easurable
- **A**chievable
- **R**ealistic
- **T**imely defined

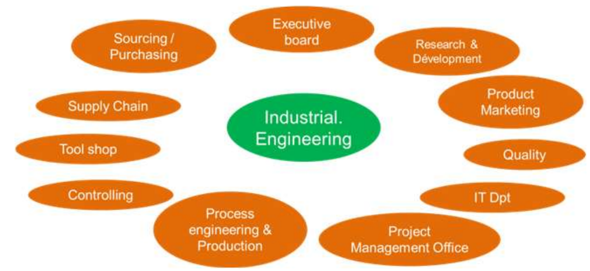


Benefits of Milestone sequenced project:

- Real time control of project progress, then quick reactivity (before it's too late !)
- Managed by backlog of tasks
- Load balanced between members at every phase
- Possibility to divide "big" projects into sub-projects
- Easy visualization by a GANTT & Burndown Chart

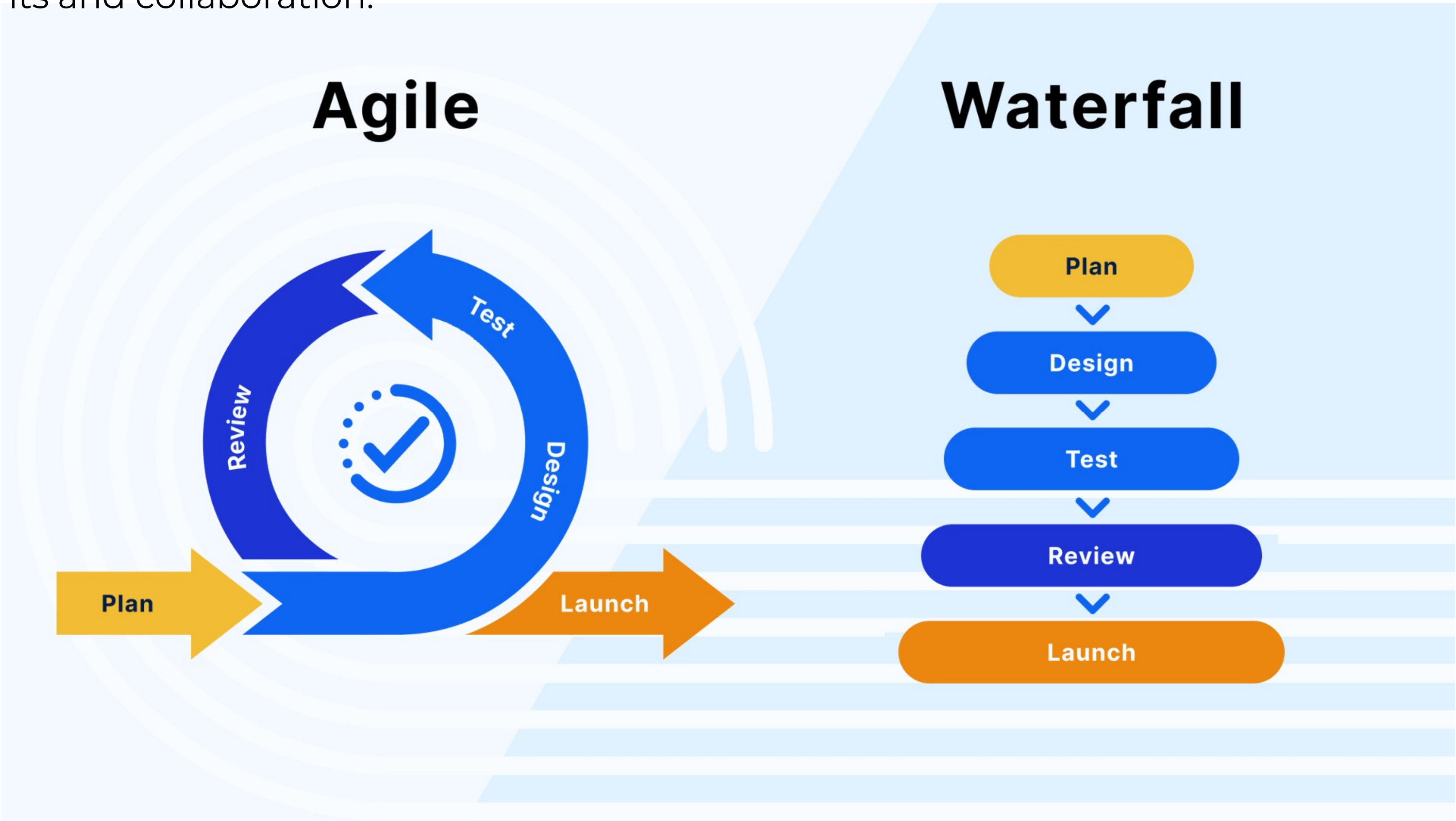


Project team management



- Ideally, project team should be composed of **multidisciplinary Engineers**. In small teams, prefer “Generalists” Engineers (better agility and flexibility)
- Core team members should be dedicated to the project; extended team & experts are part time affected to the project.
- The reporting to the project leader is “transversal” in most cases and members can be located multisite.
- Project management tools must be set up according to the size of the project & the team location (Agile or Waterfall applies).
- Regular team meetings must be setup, middle and short-term action plan need to be built & communicated between project milestones
- Risk management must be set-up (Identification & mitigation, using FMEA)
- Formal Milestones reviews must take place and relevant KPIs communicated to the stakeholders and shareholders
- A formal capitalization must take place regularly and at the end of the project
- The team is released at the end of the project and every members is receiving new assignment

The **Waterfall** model is a rigid, linear project approach where each phase must be fully completed before moving on to the next one. In contrast, the **Agile** method is a flexible, iterative approach that breaks a project into short phases, allowing for continuous adjustments and collaboration.



Industrial Project Inputs

Manufacturing specification chart (fr: Cahier des charges):

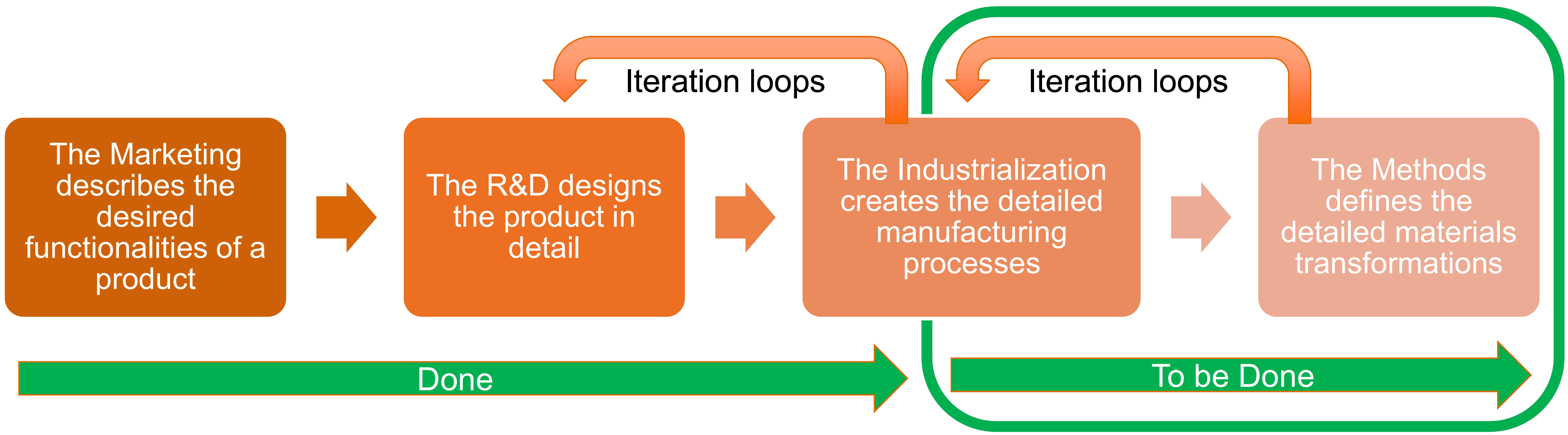
- Products range (products variations like colors, high-end, low-end)
- Bill Of Materials, for each product variant
- Expected volumes per product variant
- Designs, schemes, technical specifications for products & components.
- Goals: Production cost for given volumes, and deadline for first deliveries.

Note: quality metrics are difficult to define at early stages of the project (at least some targets are defined).

Quality issues, discovered during the project can impact, either the deadline, the cost, or the production volumes.

Industrial engineering project management

At this phase of the project:
- The product design is done
- It considered the manufacturing recommendations done by Industrialization
- The R&D team will be reduced
- The effort is concentrated on Industrialization team



Industrial engineering project management

Target: provide the appropriate means and production organization in order to:

- Respect manufacturing costs target (€)
- Meet deadlines regarding market launches (Time)
- Ensure covering sales forecasted manufacturing volumes (Quality & Quantity)

Typical project Milestones: (fit to many industries product launch)

- Phase1: Product design freeze and target cost definition
- Phase2: Marketing plan, Functionality specifications chart
- Phase3: Process pre-study release and draft cost estimation
- Phase4: Process freeze, release investment and first materials purchase
- Phase5: Process validation on pre-production
- Phase6: Ready for sale product validation and safety stock building

Phase1: Product design freeze and target cost definition

SMART:

- Specific for each component of the product (Drawings, tolerances)
- Measurables released by Marketing on each reference (Cost, timing & volumes per reference)
- Achievable thanks to prototypes validation
- Realistic as Manufacturing Engineering agreed on design base (through lessons learned with experts)
- Time is a critical topic as process design is not yet done ! But key milestones can be defined.

Benefits:

- Ensure investment will keep as it will be agreed by Top Mgt
- Allow some R&D representatives to leave project team
- Possibility to define sub projects within a big one, with new team members

Phase2: Marketing plan, Functionality specifications chart

SMART:

- Specific for each market area (volumes per commercial reference, commercial launch date, finished goods inventory location = where do we intend to sell what, …)
- Measurable by KPI on finished goods inventory progress (ramp up measurables)
- Achievable due to production capacity commitment
- Realistic as in line with equipment and facilities set up plan
- Time controlled & secured by a Gant Chart

Benefits:

- Ensure Sales team can commit on realistic dates and quantities
- Allow Marketing representatives to leave project team (Handover to sales team)
- Possibility to define sub projects by market area (and or countries)

Phase3: Process pre-study release and draft cost estimation (optional, needed for very new process introduction)

SMART:

- Specific for new processes
- Measurable: specific qualification activities implemented
- Achievable: is the purpose of the step: verify the ability to do the new process and confirm hypotheses
- Realistic as it remains into the project targets (Time, Costs, Deliverables)
- Time in line with project target

Benefits:

- Validate assumption of new processes
- Confirm or adjust the budget figures (Investment, tools, standard time)

Phase4: Process freeze, release investment and first materials purchase

SMART:

- Specific for every step of the process
- Measurable in €, T and product quality during prototyping
- Achievable as it’s matching project target
- Realistic as it meets budget constraints
- Time in line with project target

Benefits:

- Engage most of the project budget ! With confidence
- Allow to finalize business plan with accuracy
- Allow incremental investment spending, per sales points, per product variant or per volume increase.

Phase5: Process validation on pre-production

SMART:

- Specific for each production step (machine, workstation)
- Measurable by Overall Equipment Efficiency performance and quality figures
- Achievable on pre-production batch through minimum one day production per reference of product
- Realistic as it reflects what will be observed in mass production
- Time respects the global project timing

Benefits:

- Ensure no big surprise in mass productions, minor problems will be mastered and solved
- Allow to release final payment of equipment suppliers
- Possibility to organize operators' training during this period of time

Phase6: Ready for sale product validation and safety stock building

SMART:

- Specific for each product reference
- Measurable in stored quantities are ready for sales at every defined location (Sales points, countries)
- Achievable as it consists in main project target
- Realistic as it reflects finished goods storage conditions as well as downstream supply chain
- Time respecting project target

Benefits:

- Ensure actual availability for sales
- Gives confidence to Sales forces
- Possibility to test response of Production to non-planned of demand (Market fluctuations)

Role of project leader

What to prepare to « convince » your “top management” to validate your project ?

or

What to prepare to « convince » your “investors” to finance your project ?

What to prepare to « convince »

Bases

- ✓ Context of the project
- ✓ Project introduction, in line with Company strategy
- ✓ Alternative options (Anticipate!)
- ✓ Hypotheses considered for business plan
- ✓ Investment, headcount, supply chain involved for proposed options
- ✓ Business plan on 3 to 8 years, depending on expected lifetime of operations/product
- ✓ Payback of investment, Net Present Value at the end of the period
- ✓ Sensitivity of results according to alternatives or hypotheses (What if…)
- ✓ Project organization: Team, Leader, time schedule, expertise needed
- ✓ Details of analysis not presented but ready to be shown to answer any specific question (backup)

Planning

Project: From decision to go live

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Closing — Monitoring & controlling — Execution

- ✓ Bill of materials for each reference
- ✓ Manufacturing Process Plan details
- ✓ Request For Quotation: vendors for materials, subcontracted activities, equipment
- ✓ Purchasing and servicing contracts
- ✓ Green light to invest
- ✓ Procurement of equipment
- ✓ Manufacturing site and product certification according to relevant standards (ISO, VDE, …)
- ✓ Site preparation, IT software and databases installation
- ✓ Additional staff recruitment
- ✓ Staff training and product – process validation
- ✓ Safety stock building
- ✓ Project completion and feedback for capitalization (lessons learned)
- ✓ Mass production to orders

Project: Possible road blockers

Product:
- Redesign in case of qualification test failed
- Late additional reference or specification late changed

Context:
- Bankrupt of one selected supplier
- Unexpected currency fluctuation
- Social crisis blocking one site
- Sanitary crisis
- War

Process:
- Equipment not meeting expected performance
- Broken equipment during transportation, installation o
- Equipment quarantined by customs
- Longer training ramp up

Material:
- non respect of timing
- Wrong delivery or poor quality

There is no chance that a project happens like planed !!

Business plan: Definition (Explored during the TD)

A business plan is a documented strategy for a business that highlights its goals and its plans for achieving them. It outlines a company's go-to-market plan, financial projections, market research, business purpose, and mission statement. Key staff who are responsible for achieving the goals may also be included in the business plan along with a timeline.

Since its contents revolve around how businesses succeed, break even, and turn a profit, a business plan is used as a tool for sourcing capital. This document is a way of showing potential investors or lenders how their capital will be put to work and how it will help the business thrive. All banks, investors, and venture capital firms will want to see a business plan before handing over their money, and investors typically expect a 10% ROI or more from the capital they invest in a business.

In the next slides, we will focus on the financial aspects in relationship with manufacturing aspects.

Industrial Business plan

- Purpose is to simulate several options in order to convince investors about project profitability.
- All options must be strongly documented in order to trace modifications after project launch (And adjust BP when necessary).
- Number of considered variants must be reasonable (not 10 cases). Eventually, best case and worst-case hypothesis must be considered separately. And variations should be contextualized (Competitors, Epidemic, War, higher/lower volumes, manufacturing locations)
- Consider figures’ evolution year after year, (inflation, volumes, selling prices, …)
- Depreciations (fr: amortissements) are calculated into the template
- Consider inventory ownership cost variance versus reference situation.

Business plan example

(Explanation in the following pages)

Output result

Inputs & variables

Hypothesis	
Interest rate (%)	2,00%
Linear depreciation for building (years)	20
Linear depreciation for machines (years)	8
Linear depreciation for tools (years)	4
Tax rate on result (%)	33,00%
Stock depreciation rate p.a. (%)	15,00%
Salary increment rate / year (% on top inflation)	3,00%

Business plan for ………

Payback ; 0,64 years for total investment of 830000 € and ROI of 16 % after 5 years

Better option than placing capital with interest after 0,3 years

Net present value after 4 years ; 1610 k€, after 8 years ; 1942 k€

	Start	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment in building	0 €	0	0	0	0	0	0	0	0	0	0
Investment in machines	680 000 €	680000	595000	510000	425000	340000	255000	170000	85000	0	0
Investment in specific tools	150 000 €	150000	112500	75000	37500	0	0	0	0	0	0
FRANCE		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Unit seling price and / Sales yearly volumes	**9,00 €**	80 000	150 000	210 000	250 000	280 000	300 000	300 000	300 000	300 000	300 000
Net sales incomes		€720 000	€1 350 000	€1 890 000	€2 250 000	€2 520 000	€2 700 000	€2 700 000	€2 700 000	€2 700 000	€2 700 000
Material cost	2,002 €	€160 160	€300 300	€420 420	€500 500	€560 560	€600 600	€600 600	€600 600	€600 600	€600 600
Direct labour salary cost	0,194 €	€15 986	€29 973	€41 962	€49 955	€55 950	€59 946	€59 946	€59 946	€59 946	€59 946
Indirect labour salary cost		€40 000	€41 200	€42 436	€43 709	€45 020	€46 371	€47 762	€49 195	€50 671	€52 191
Other indirect expenses, but depreciation		€20 000	€20 400	€20 808	€21 224	€21 649	€22 082	€22 523	€22 974	€23 433	€23 902
Differential transportation cost (<0€ when saving)		€0	€0	€0	€0	€0	€0	€0	€0	€0	€0
Inventory value		€25 427	€28 154	€30 047	€31 027	€30 786	€30 795	€30 795	€30 795	€30 795	€30 795
Allocated building maintenance cost		€3 000	€3 090	€3 183	€3 278	€3 377	€3 478	€3 582	€3 690	€3 800	€3 914
Stock ownership cost		€3 814	€4 223	€4 507	€4 654	€4 618	€4 619	€4 619	€4 619	€4 619	€4 619
Financial cost		€16 600	€16 600	€16 600	€16 600	€16 600	€16 600	€16 600	€16 600	€16 600	€16 600
Result	-830 000 €	€460 440	€934 214	€1 340 084	€1 610 079	€1 812 227	€1 946 304	€1 944 367	€1 942 376	€1 940 330	€1 938 228

Business plan explanation

Hypothesis	
Interest rate (%)	2.50%
Linear depreciation for building (years)	20
Linear depreciation for machines (years)	8
Linear depreciation for tools (years)	4
Tax rate on result (%)	33.00%
Stock depreciation rate p.a. (%)	10.00%
Salary increment rate / year (% on top inflation)	0.50%

Some hypotheses, to be prepared with controlling

Result / key outputs => decision making

Business plan for ………
Payback ; 1.42 years for total investment of 496000 €
Better option than placing capital with interest after 2.1 years
Net present value after 4 years ; 903 k€, after 8 years ; 2330 k€

Business plan (detail)

Making 2 or 3 BP with different figures and make live simulations that shows the sensitivity of results

All these parameters can be simulated according to several hypotheses:

- Change location
- Automatize or not
- Variation of sales
- Variation of sales price

	Start	Year 1	Year 2	Year 3	Year 4	Year 5
Investment in building	0 €	0	0	0	0	0
Investment in machines	680 000 €	680000	595000	510000	425000	340000
Investment in specific tools	150 000 €	150000	112500	75000	37500	0
FRANCE		Year 1	Year 2	Year 3	Year 4	Year 5
Unit seling price and / Sales yearly volumes	**9,00 €**	80 000	150 000	210 000	250 000	280 000
Net sales incomes		€720 000	€1 350 000	€1 890 000	€2 250 000	€2 520 000
Material cost	2,002 €	€160 160	€300 300	€420 420	€500 500	€560 560
Direct labour salary cost	0,194 €	€15 986	€29 973	€41 962	€49 955	€55 950
Indirect labour salary cost		€40 000	€41 200	€42 436	€43 709	€45 020
Other indirect expenses, but depreciation		€20 000	€20 400	€20 808	€21 224	€21 649
Differential transportation cost (<0€ when saving)		€0	€0	€0	€0	€0
Inventory value		€25 427	€28 154	€30 047	€31 027	€30 786
Allocated building maintenance cost		€3 000	€3 090	€3 183	€3 278	€3 377
Stock ownership cost		€3 814	€4 223	€4 507	€4 654	€4 618
Financial cost		€16 600	€16 600	€16 600	€16 600	€16 600
Result	-830 000 €	€460 440	€934 214	€1 340 084	€1 610 079	€1 812 227

Return on investment (ROI) – Cash result

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- If I own a certain Capital (ie: 1000€) Should I invest in industry or in Financial invests?

$$Payback\ (years) = \frac{Investment}{yearly\ earning}$$

	Inputs	
	Payback (years)	**4**
	Capital (€)	**1000**
	Interest rate	**4%**
		Safe placement @Bank
	Cash out / early earning	0
	Year 1	40,00
	Year 2	41,60
	Year 3	43,26
	Year 4	44,99
	Year 5	46,79
	Year 6	48,67
	Year 7	50,61
	Year 8	52,64
Cash result after 8 years:		**1368,57**

Case 1: I leave my money at the bank which gives me interest

Return on investment (ROI) – Cash result

- If I own a certain Capital (ie: 1000€) Should I invest in industry or in Financial invests?

$$Payback\ (years) = \frac{Investment}{yearly\ earning}$$

	Inputs		
	Payback (years)	**4**	
	Capital (€)	**1000**	
	Interest rate	**4%**	
		Safe placement @Bank	Investment **Fixed** revenue
	Cash out / early earning	0	-1000
	Year 1	40,00	250,00
	Year 2	41,60	250,00
	Year 3	43,26	250,00
	Year 4	44,99	250,00
	Year 5	46,79	250,00
	Year 6	48,67	250,00
	Year 7	50,61	250,00
	Year 8	52,64	250,00
Cash result after 8 years:		**1368,57**	**2000,00**

Case 2: I invest in Industry considering theorical figures

Return on investment (ROI) – Cash result

- **If I own a certain Capital (ie: 1000€) Should I invest in industry or in Financial invests?**

$$Payback\ (years) = \frac{Investment}{yearly\ earning}$$

	Inputs				
	Payback (years)	**4**			
	Capital (€)	**1000**			
	Interest rate	**4%**			
		Safe placement @Bank	Investment **Fixed** revenue	Investment **variable** revenue	
	Cash out / early earning	0	-1000	-1000	
	Year 1	40,00	250,00	250,00	Year1, as planned
	Year 2	41,60	250,00	175,00	Year2: COVID / -30% revenue
	Year 3	43,26	250,00	262,50	Year3: Great increase / +50% of Year2
	Year 4	44,99	250,00	200,00	Year4: War in UKRAINE / -20% revenue of initial plan
	Year 5	46,79	250,00	225,00	Year5: Still War / -10% revenue of initial plan
	Year 6	48,67	250,00	250,00	Year6: back to plan
	Year 7	50,61	250,00	275,00	Year7: 10% growth vs Y6
	Year 8	52,64	250,00	330,00	Year8: 20% growth vs Y7
Cash result after 8 years:		**1368,57**	**2000,00**	**1967,50**	

Case 3: Reality !

Return on investment (ROI) – Cash result

- If I own a certain Capital (ie: 1000€) Should I invest in industry or in Financial invests?

$$Payback\ (years) = \frac{Investment}{yearly\ earning}$$

	Inputs				
	Payback (years)	**4**			
	Capital (€)	**1000**			
	Interest rate	**4%**			
		Safe placement @Bank	Investment **Fixed** revenue	Investment **variable** revenue	
	Cash out / early earning	0	-1000	-1000	
	Year 1	40,00	250,00	250,00	Year1, as planned
	Year 2	41,60	250,00	175,00	Year2: COVID / -30% revenue
	Year 3	43,26	250,00	262,50	Year3: Great increase / +50% of Year2
	Year 4	44,99	250,00	200,00	Year4: War in UKRAINE / -20% revenue of initial plan
Cash result after 4 years:		**1169,86**	**1000,00**	**887,50**	

What about cash after 4 years ?

Use of SWOT : a decision tool

SWOT: Made in France?	
Strengths	**Weaknesses**
Technologies' mastering Low need of stocks Reactivity of logistic & manufacturing High degree of automation High Quality	Higher salary costs Annual quantity of hours 35h/5*220d Low industrial culture Low qualification of operators Risks taking not in the french culture Fondamental research limited by means
Opportunities	**Threats**
Industry 4.0 Exchange rates € / LCC money Transport costs Reduction of the salaries LCC/France	Industry priority decreasing (Before COVID & Ukraine war) Young generation not motivated by Industry Eastern Europe competition

Conclusion

This course was compact and introduced you many new subjects.
None of them were deep drilled.
In your career of Engineers, you’ll implement some of them, <u>but for sure not all</u>.
Now, you know it exists and as Engineers, you’ll be able to find the right information you need at the right time.

Feel free to investigate the fields you’re interested in.
<u>We will continue together with TDs and Practices</u>

Thank you for listening

Acronyms and financial terms glossary

P&L = Profit and losses = Compte d'exploitation

T.O. = Turnover = Chiffre d'affaire = C.A

Net TO = Chiffre d'affaire net (after deduction of exceptional discount)

C.O.S. = Cost of sales = Manufacturing cost = Coût de production

G.M. = Gross margin = Marge brute

Depreciation = either ; saving money to replace existing assets or loosing value of goods / amortissement des investissements; ou bien ; perte de valeur des marchandises dans le temps.

EBITDA = Earning before interest tax depreciation and amortization = Excédent Brut d'Exploitation.

EBIT = Earning before interest & tax = EBITDA – Depreciation / dotation aux amortissements

C.F. = Cash flow = EBITDA – Tax & financial interest = Résultat net d'exploitation + amortissements

Current assets = Inventory (= stocks) + Account receivables (= comptes débiteurs)

Current liabilities = Comptes créditeurs

W.C. = Working capital = Current assets – Current liabilities

D.I.O. = Days Inventory Outstanding = Valeur du stock exprimée en nombre de jours de couverture par rapport aux besoins moyens