Some information about Digital Manufacturing

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What is a (mechanical) manufacturing process?

It is a transformation involving

- **Materials**
  - Metals, plastics, wood, … as raw, semifinished or finished products
- **Energy**
  - In terms of forces and trajectories
- **Information**
  - To control forces and trajectories in order to “manage” the transformation

What is a transformation?

It is a modification of

- **geometry/shape**
  by adding/removing/forming the material
- **physical/chemical composition of the material**
  using heat, substances
- **relation between parts**
  by joining/assembling elements
- **location of parts**
  logistical transformation
- **aesthetical/surface proprierties**
  color, idrofoby, pattern/texture, …
- **etc.**

How to manage the information?

1) **Manually**

Human operator manages the transformation using its senses, know-how and experience

2) **Using a control system and**

based on enabling technologies (i.e. related to the process control)

of different nature

- mechanics (cams)
- hydraulics (pneumo-hydraulic logics)
- electronics/electromechanics (relais, transistors)
- digital electronics (computers, CNCs, PLCs,…)

The above principle can be applied to all type of transformations

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Manual vs. Automatic

Operator manages the machine

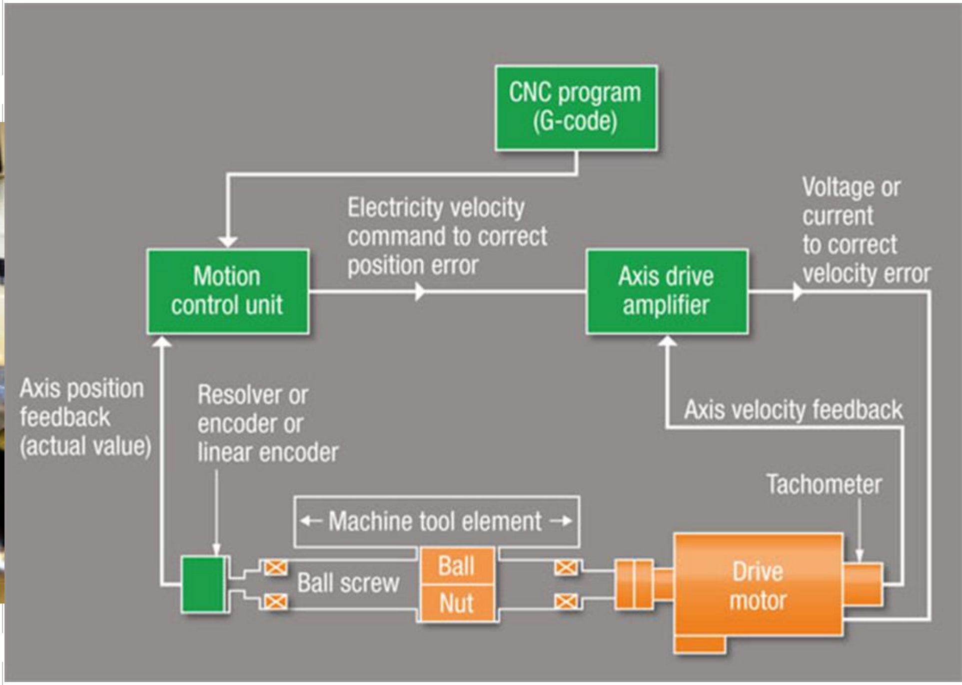
NC (Numerical Control, i.e. Computer) manages the machine

Manual vs. Automatic

Manual

Brain, sense, experience

Automatic



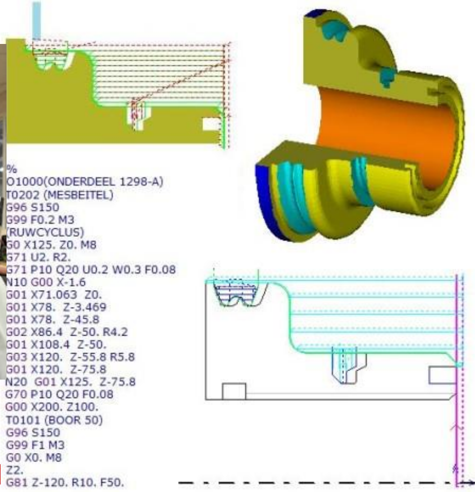
Computer, programmes, sensors, actuators

Manual vs. Automatic

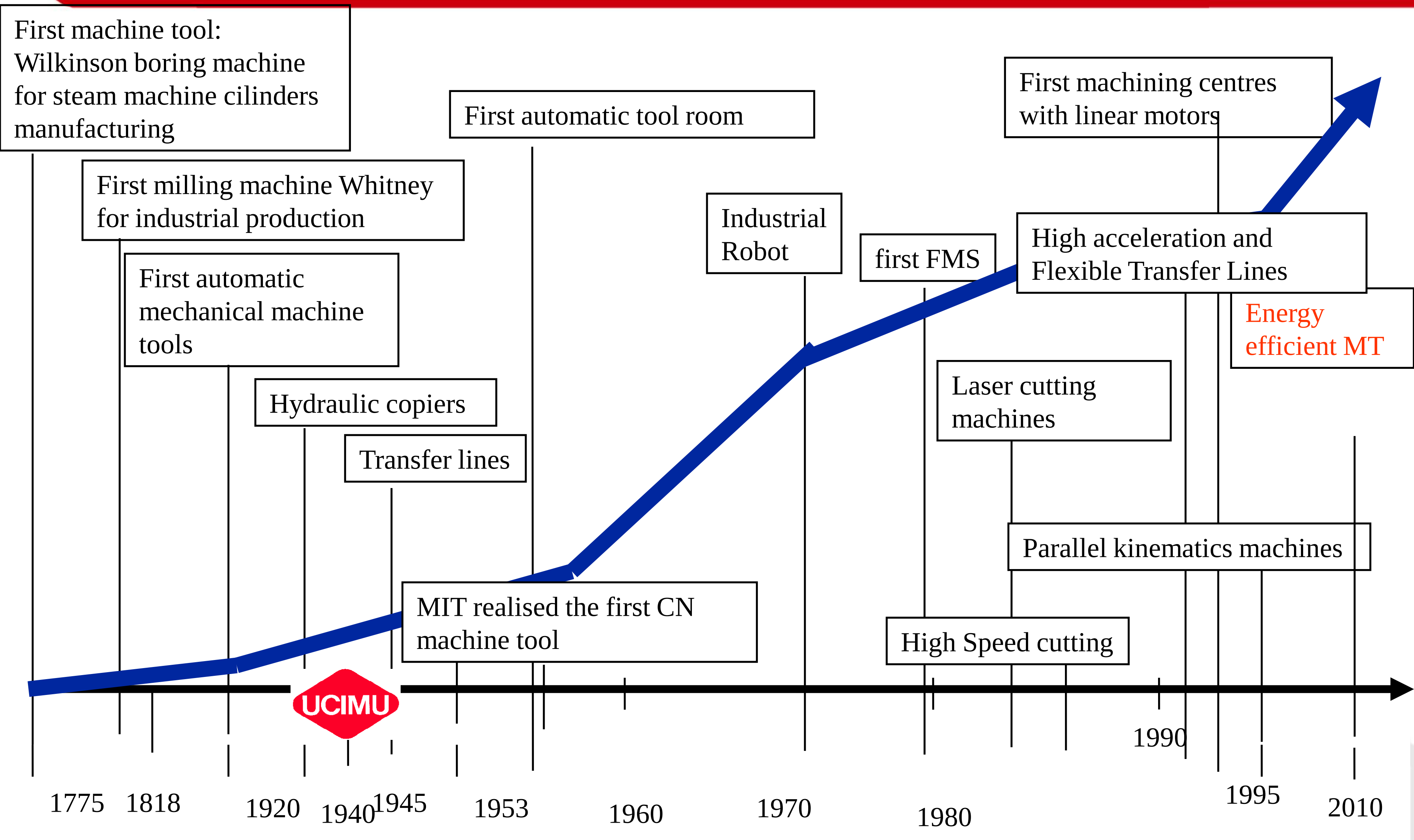
Operator manages machines functions

Operator programs a computer directly...

… or through another computer



Evolutive path of machine tools



Why automation in machine tools?

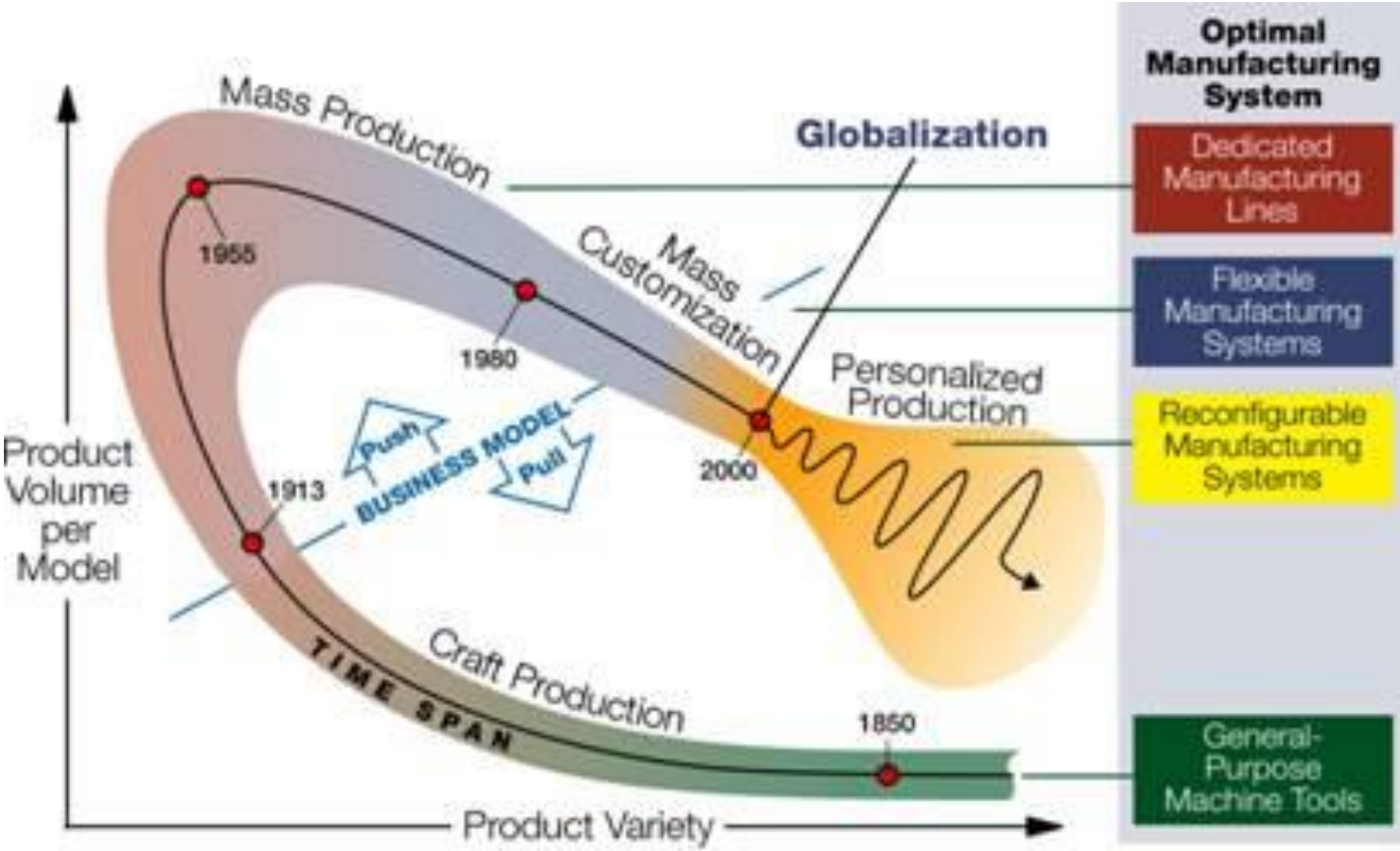
- **Some drivers:**
  - Increase production
  - Avoid repetitive/dangerous tasks
  - Increase precision
  - Increase quality
  - Avoid human factor influence
  - Allow more complex geometries/processes
  - Increase safety
  - Integrate machine and manufacturing environment
  - Control machine functions better

Traditional automation

- **Limits of traditional automation**
  - Need of deterministic and forecastable requests in term of
    - Product type
    - Manufacturing volume
  - Human factors
    - Repetitiveness of operations
    - No motivation/creativity
  - Mistakes and failures impact on the whole process chain
  - Set-up and reconfiguration
    - Expensive
    - Complex
    - Often need redesign of the production system

- **Flexibility of a manufacturing system**
  - In the field of engineering systems design, it refers to designs that can adapt when external changes occur
    - Machine flexibility - The different operation types a machine can perform.
    - Material handling flexibility - The ability to move the products within a manufacturing facility.
    - Operation flexibility - The ability to produce a product in different ways.
    - Process flexibility - The set of products the system can produce.
    - Product flexibility - The ability to add new products in the system.
    - Routing flexibility - The different routes (through machines and workshops) that can be used to produce a product in the system.
    - Volume flexibility - The ease to profitably increase or decrease the output of an existing system.
    - Expansion flexibility - The ability to build out the capacity of a system.
    - Program flexibility - The ability to run a system automatically.
    - Production flexibility - The number of products a system can currently produce.
    - Market flexibility - The ability of the system to adapt to market demands.

- **From flexible mfg to reconfigurable mfg**



- **Impact on manufacturing**
  - Mass customization poses a number of challenges to manufacturing systems
    - Not deterministic batches
    - Variability in demand
    - Lot 1 manufacturing
    - Variability in product design
    - Mix between standard and custom parts
    - Cost control
    - Rapid response
    - ….
  - These challenges cannot be faced in «traditional ways»

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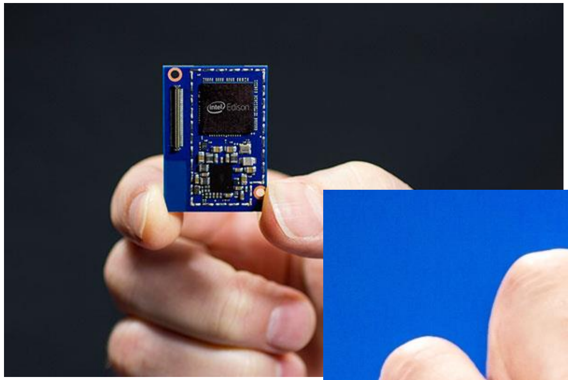
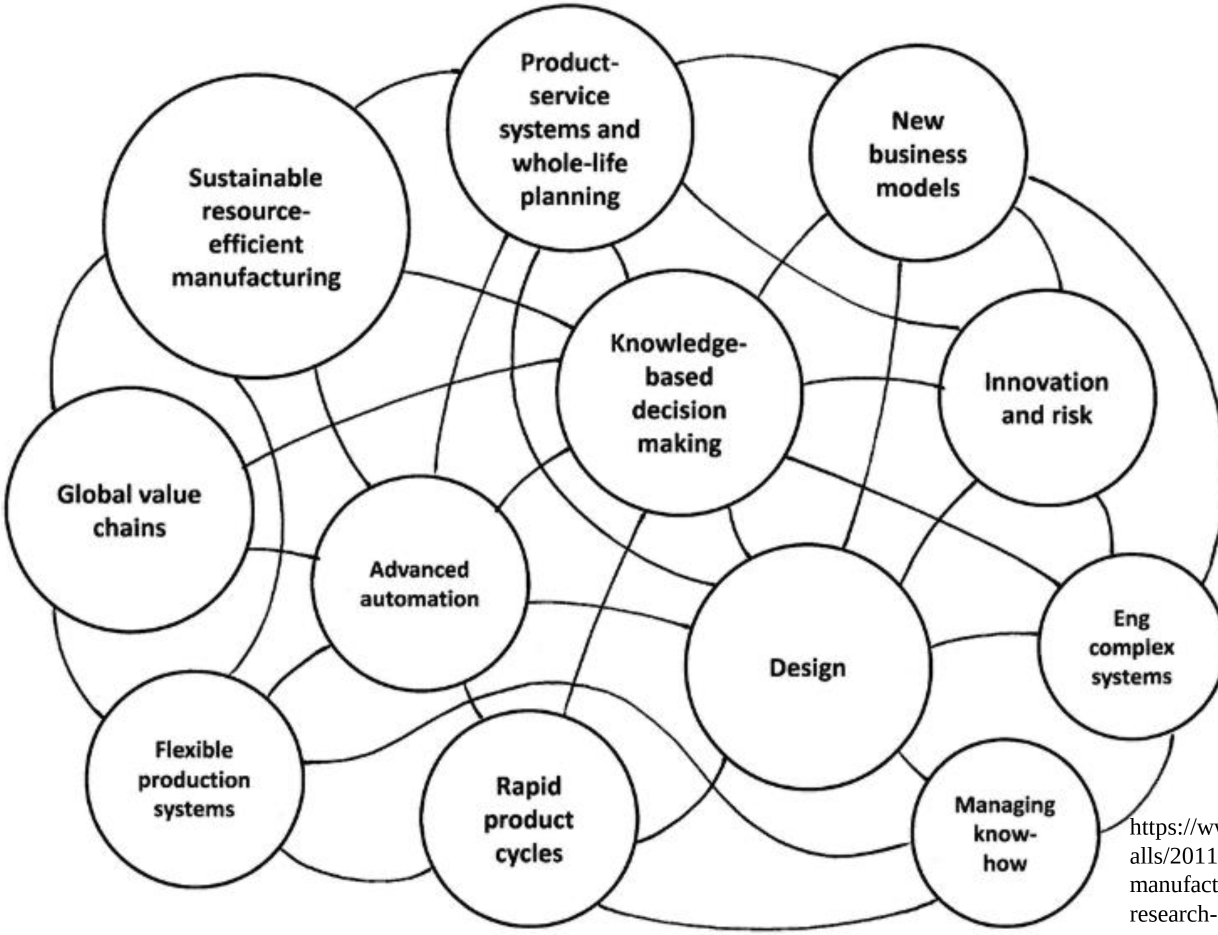
- **The role of Enabling Technologies**
  - **Advancements in many technologies, sometimes not peculiar (cross-contamination), allow a quick growth in manufacturing performance**
    - **Examples:**
      - **Materials**
      - **ICT/Electronics**
      - **Mathematics/Statistics**
      - **Simulation**
      - **…**

1950



Today

- The role of ICT in manufacturing



https://www.epsrc.ac.uk/files/funding/calls/2011/future-ict-enabled-manufacturing-cross-disciplinary-research-clusters/

What is «Industry 4.0»

- **Many «interpretations» of the concept are accepted**
  - For instance
    - It is an evolution of CIM (Computer Integrated Manufacturing)
      - Vision «ICT-centric»
      - Concept emerged in late 80s
      - Today allowed by Internet and power of modern computers
    - It is the «Intelligent Factory»
      - Based on the integration between manufacturing technologies and ICT (Information and Communication Technologies)
      - As stated in European Research Projects Programmes (7. Framework Program and Horizon 2020)
    - It is a manufacturing principle based on sustainability and lean manufacturing
    - It is the «fourth industrial revolution»
    - Italian approach:

"Industria 4.0 è l'interconnessione dei vari componenti del processo produttivo che genera valore, operante in tempo reale e in grado di circolare e gestire le informazioni legate alla generazione di valore aggiunto tra i vari componenti del sistema produttivo (macchine, esseri umani, prodotti e sistemi informatici)".

EXAMPLES OF
DIGITAL MANUFACTURING

Industry 4.0 and machine tools

- **Machine tools are real «cyber-physical systems»**
  - Thanks to the combination of computerized systems (NCs), automation, sensors, mechanics
- **This allows**
  - Flexibility
  - Reconfigurability
  - Integrability into more complex manufacturing systems
    - Already satisfying the requisites fixed by the German document

Examples of digital manufacturing

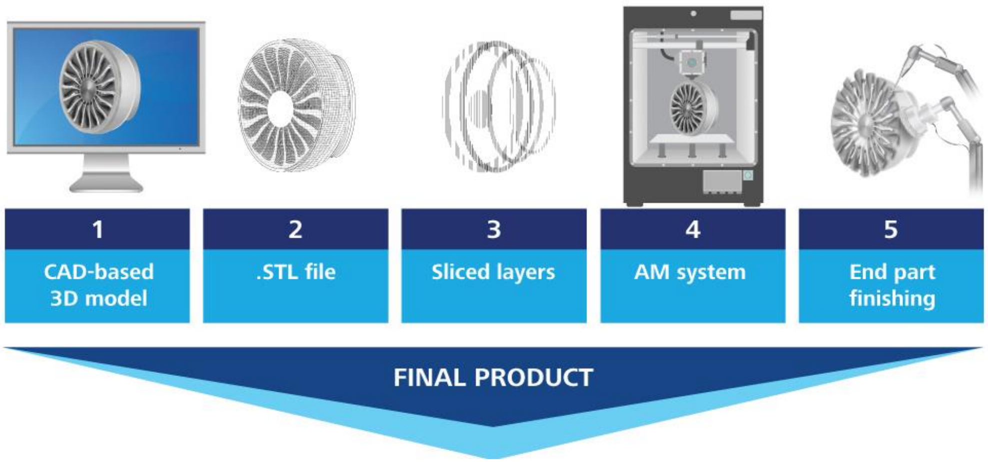
- **Laser-based Machine Tools**
  - Use a manufacturing system not based on “manual control archetypes”
    - based on a immaterial tool
    - allowing high performances in terms of geometries and materials
  - Require automated methodologies for control of processes and machining
  - Are suited to work in complex and integrated production systems
  - Base their flexibility on CAD software modelising the product and on CAM software to predefine the operations in a virtual way
  - Are characterized by an high level of sustainability
    - Environmental, thanks to energy efficiency of processes and scrap reductions
    - Social, because they don’t require heavy and dangerous tasks to the operator
    - Economic, thanks to the high added-value products manufacturing

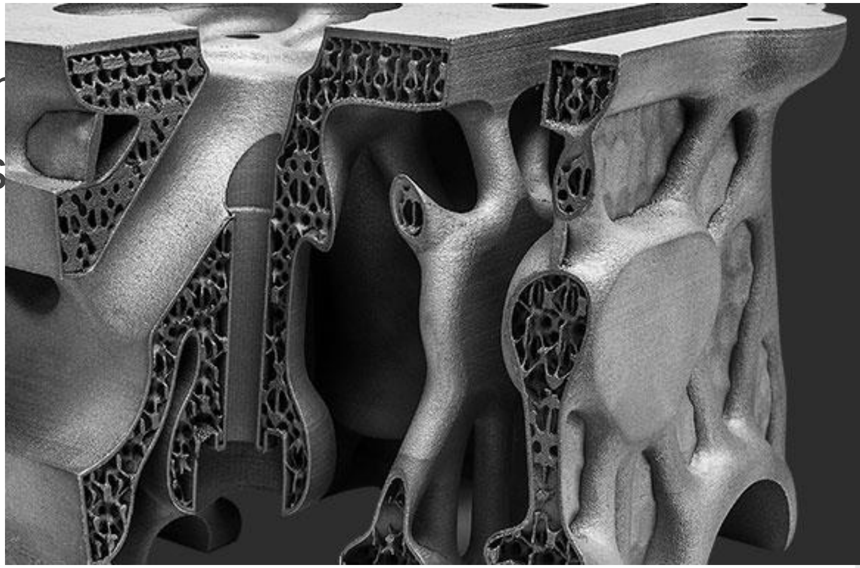
Examples of digital manufacturing

- **Human-robots cooperation**
  - Robots support human operator
    - Avoiding heavy/dangerous tasks
    - Sharing the same environment
    - Reacting and coordinating in accordance with operator’s behavior

Examples of digital manufacturing

- **Additive technologies allow manufacturing of parts almost impossible using other processes**





THANK YOU FOR YOUR ATTENTION

LAMIERA, fieramilano,
17-20/5/2017

31.BI-MU, fieramilano,
9-13/10/2018

ASSOCIAZIONE ITALIANA TECNOLOGIE ADDITIVE

Alcune informazioni sulle TECNOLOGIE ADDITIVE

Definizione tecnologie additive

- ISO/ASTM52921-1 “Standard Terminology for Additive Manufacturing-Coordinate Systems and Test Methodologies”):
  - *le tecnologie additive vanno intese come “quei processi che aggregano materiali al fine di creare oggetti partendo dai loro modelli matematici tridimensionali, solitamente per sovrapposizione di layer e procedendo in maniera opposta a quanto avviene nei processi sottrattivi (o ad asportazione di truciolo)”*

Altre definizioni

- “stampa 3D”
  - processi additivi che realizzano prodotti mediante la deposizione di materiale mediante una testa di stampa, ugelli od altre tecnologie di stampa)
- “prototipazione rapida”
  - ormai obsoleto dato che con le tecnologie additive vengono sempre più spesso realizzati parti funzionali (e non solo pezzi prototipali/dimostrativi)

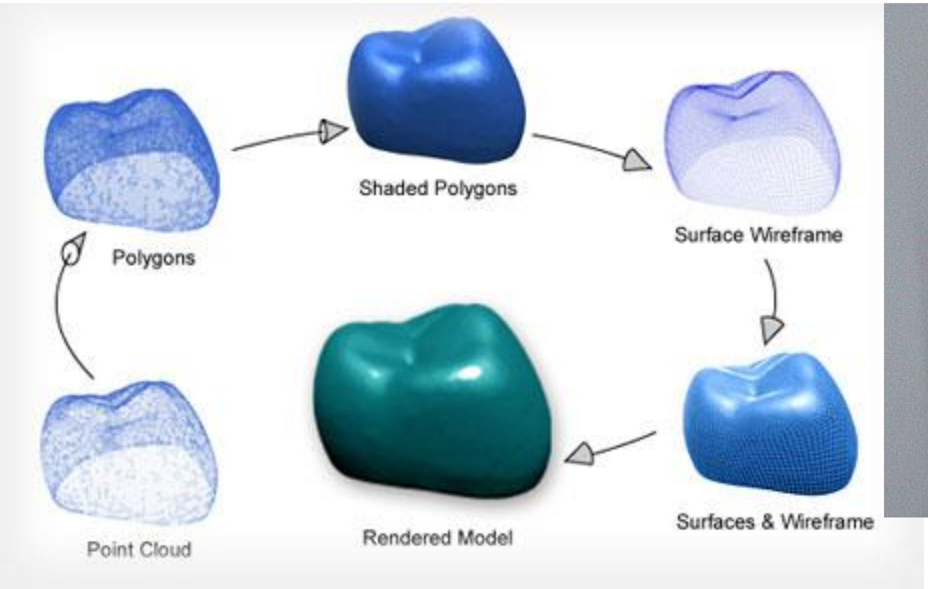
Fasi del ciclo produttivo

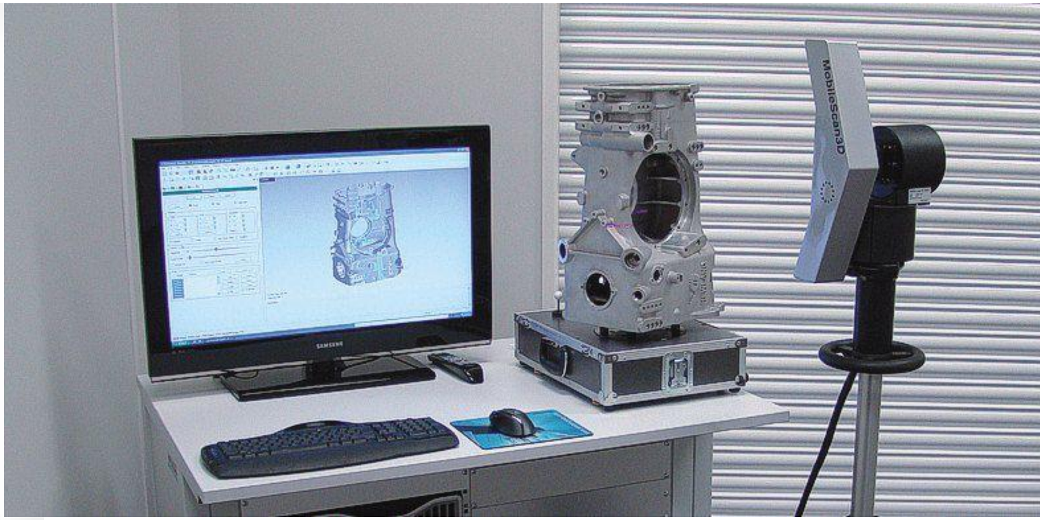
Figure 1. Additive manufacturing (AM) process flow

Graphic: Deloitte University Press | DUPress.com

Reverse engineering

- Si può partire da oggetti fisici opportunamente digitalizzati in «nuvole di punti» per diventare modelli CAD 3D

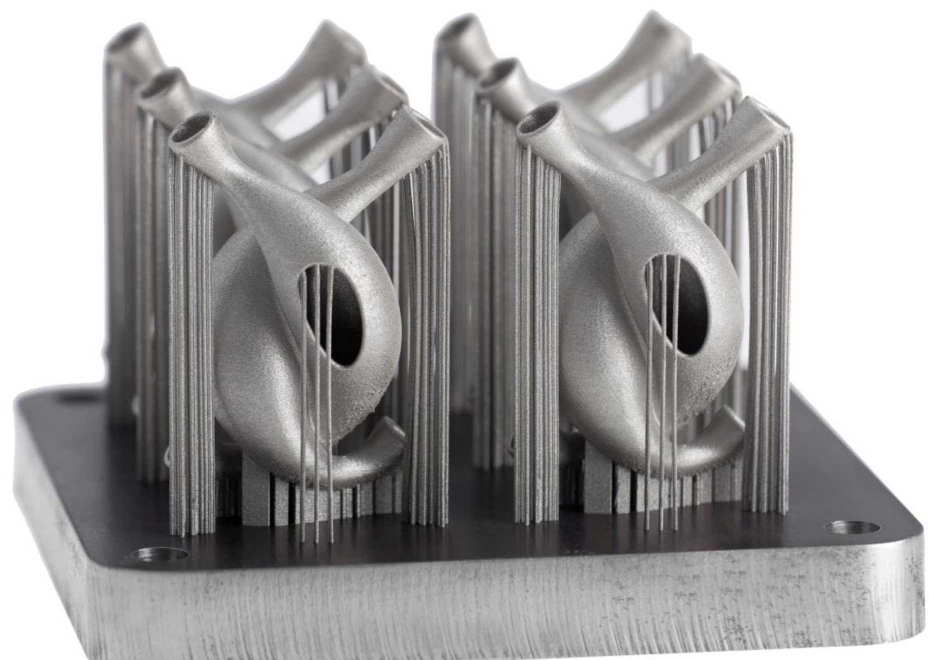




Cosa sono i supporti

- Sono delle «impalcature» che hanno il compito di sostenere il materiale grezzo prima che questo sia consolidato dal processo additivo
  - Si usano per parti a sbalzo o sottoquadri
  - Vanno previsti in fase di progettazione

Applicazione dei supporti



Fonte: Renishaw

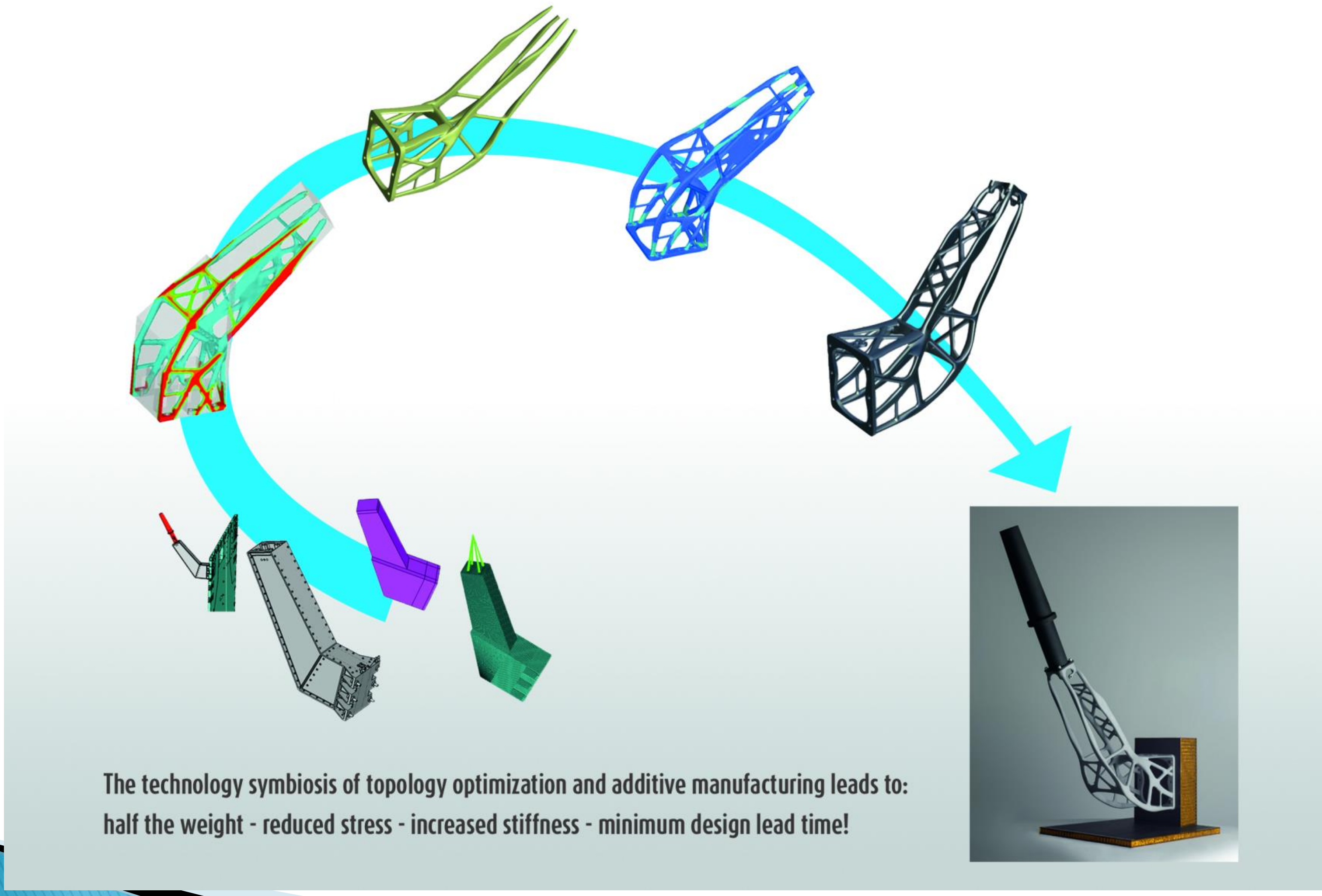
Aspetti di progettazione

- Per sfruttare efficientemente i vantaggi delle tecnologie additive, è necessario un nuovo approccio alla progettazione

Aspetti di progettazione

- Per fare questo, si utilizzano software che combinano la progettazione CAD con la modellizzazione FEM, al fine di ottimizzare le forme progettate, in funzione di
  - Obiettivi funzionali
    - Peso, rigidità, resistenza a fatica,…
  - Limiti tecnologici
    - Dimensioni, numero di supporti, collaudabilità,…
  - Aspetti di costo

Aspetti di progettazione



Aspetti di progettazione

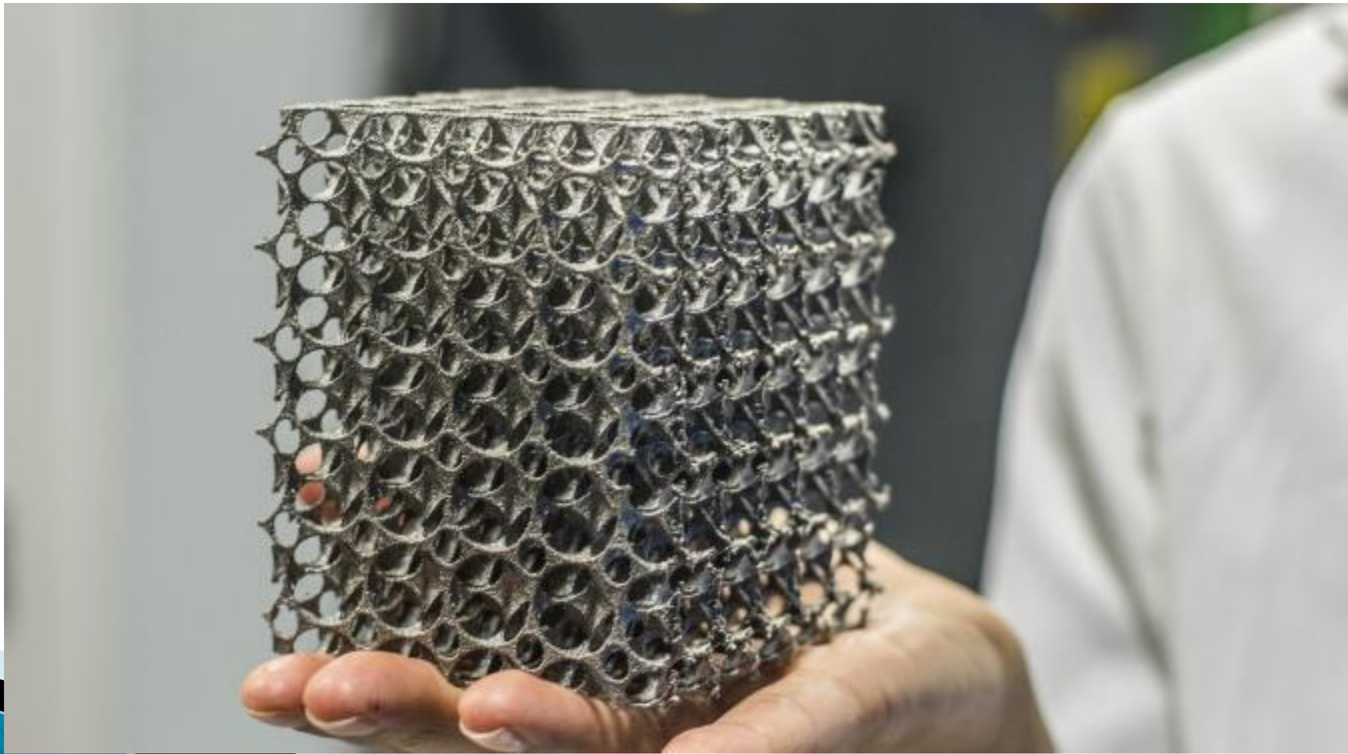
- Di conseguenza, il progettista non definisce più a priori la forma finale del pezzo
  - Definisce le condizioni al contorno
    - Vincoli, carichi, obiettivi funzionali, materiali
  - Valuta il risultato dato dal software in base a criteri prefissati
    - Costi, misurabilità, …
  - Eventualmente reitera il processo e apporta migliorie

Aspetti di progettazione

A	B	C	D
Basic Design	Lightweight Design	Lightweight Design with Shape Generator	Lightweight Design with Shape Generator
	Mass = 760g Displacement = 0.8 mm Minimum Safety Factor = 1.3	Mass = 640g Displacement = 0.5 mm Minimum Safety Factor = 1.4	Mass = 520g Displacement = 0.5 mm Minimum Safety Factor = 1.4

Aspetti di progettazione

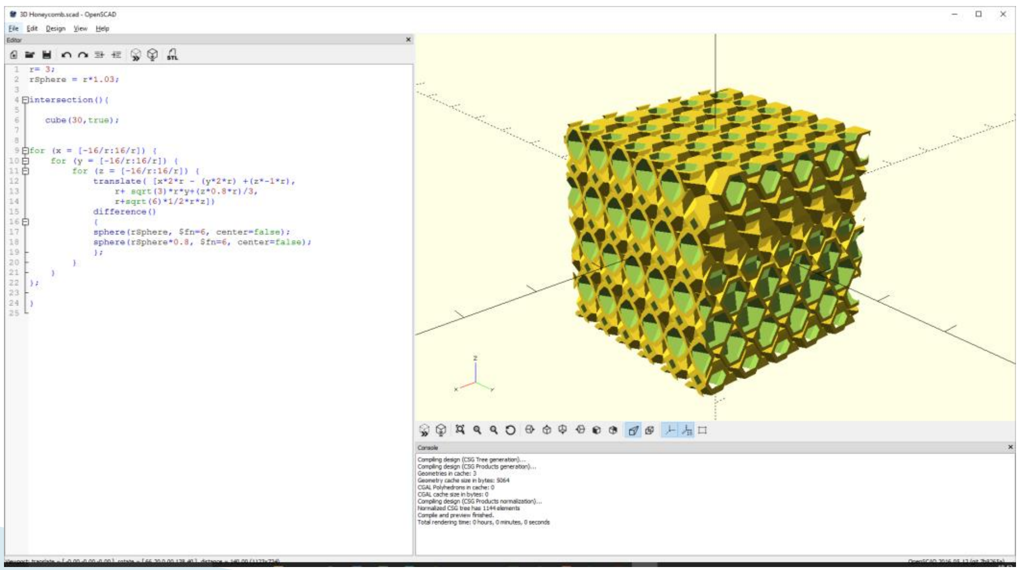
- Spesso la progettazione avviene scrivendo codice e non «disegnando
- Progettazione generativa



Aspetti di progettazione

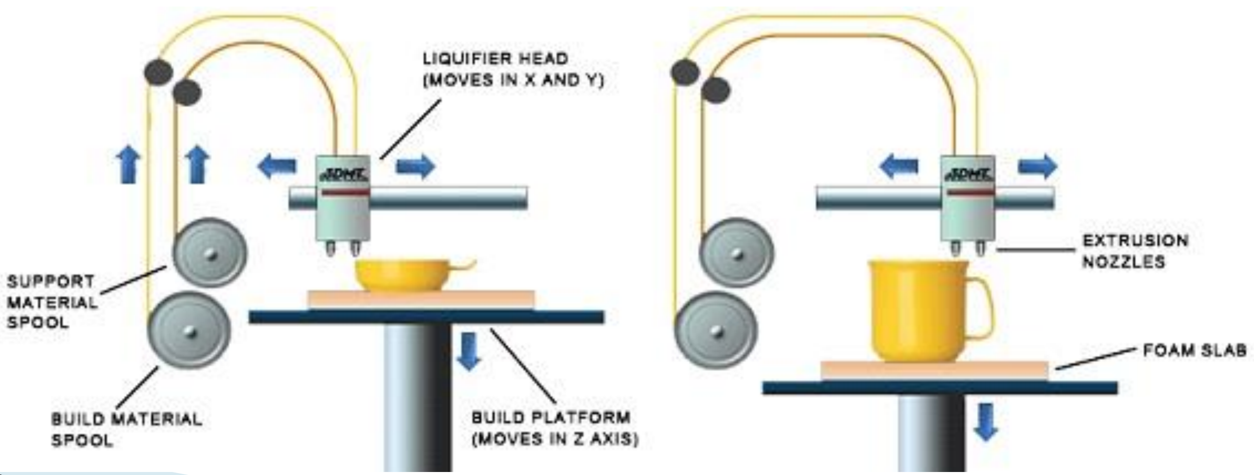
- Esempio di software free per progettazione generativa:
- OPEN SCAD
- www.openscad.org

```
r= 3;
rSphere = r*.99;

difference(){

    cube(150,true);


for (x = [-160/r:160/r]) {
     for (y = [-160/r:160/r]) {
          for (z = [-160/r:160/r]) {
               translate( [x*2*r - (y*2*r) +(z*-1*r),
                    r+ sqrt(3)*r*y+(z*0.8*r)/3,
                    r+sqrt(6)*1/2*r*z])
               sphere(rSphere, $fn=20, center=false);
          }
     }
};

}
```



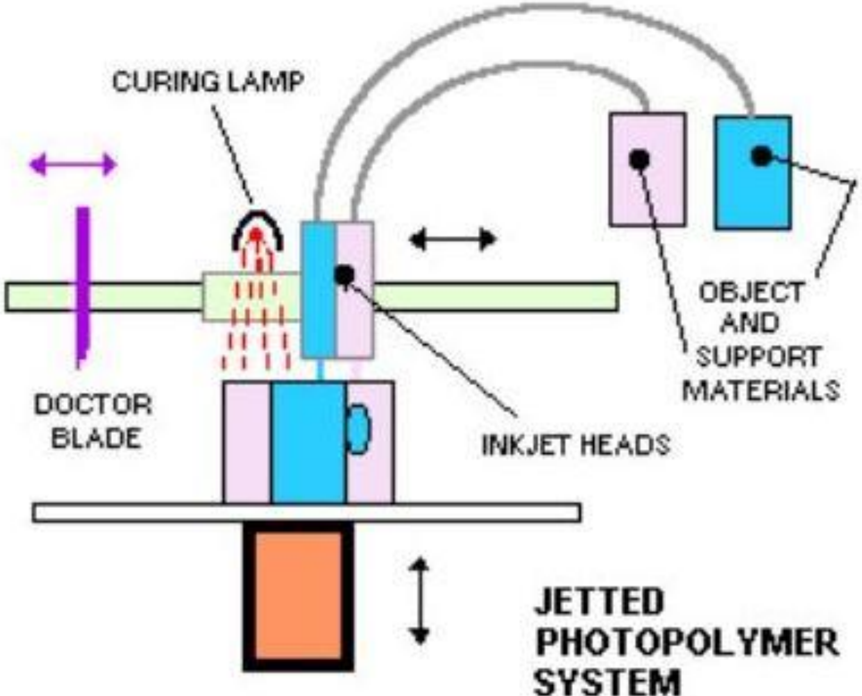
Tipi di processi per AM

- **Estrusione**
  - il materiale (solitamente polimero), portato allo stato pastoso, è distribuito selettivamente mediante un orifizio
    - tipicamente quello usato nelle macchine low-cost per la stampa 3D
    - Noto anche come FDM (Fused Deposition Modeling)



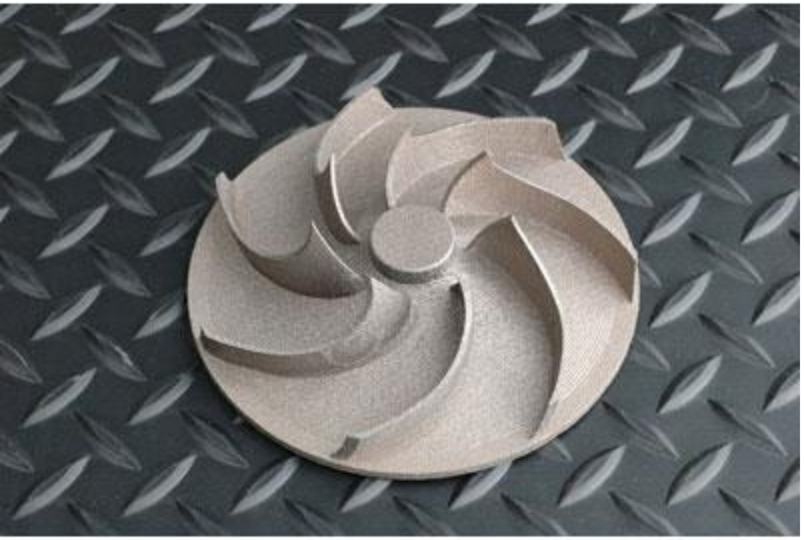
Tipi di processi per AM

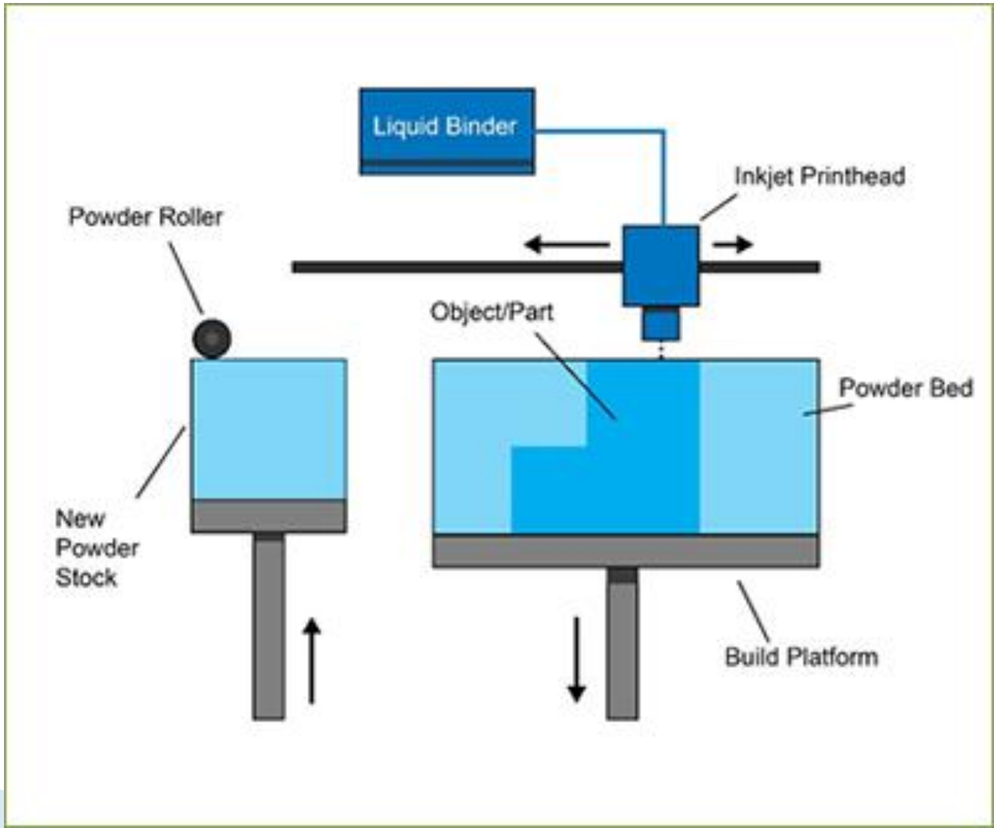
- **Jetting**
  - “goccioline” di materiale vengono spruzzate selettivamente per creare i layer (di polimeri, cera o metalli) e fatte solidificare per raffreddamento o con raggi UV



Tipi di processi per AM

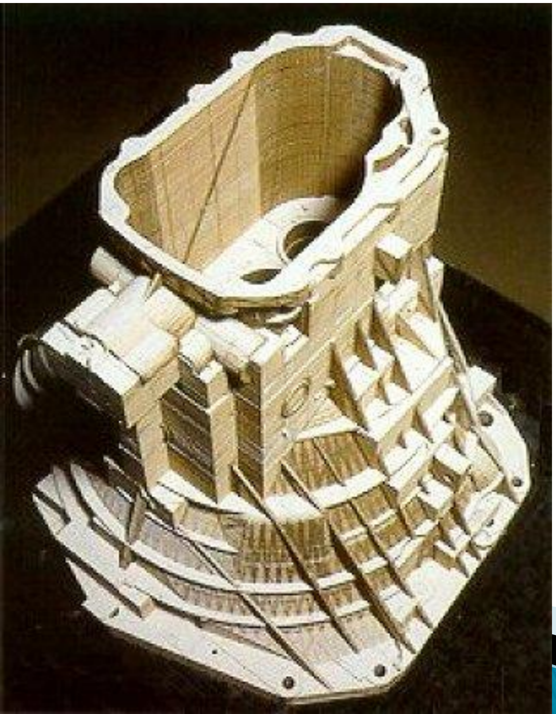
- **Binder jetting**
  - un agente legante allo stato liquido viene spruzzato su uno strato di polvere (polimerica, ceramica, terre da fonderia

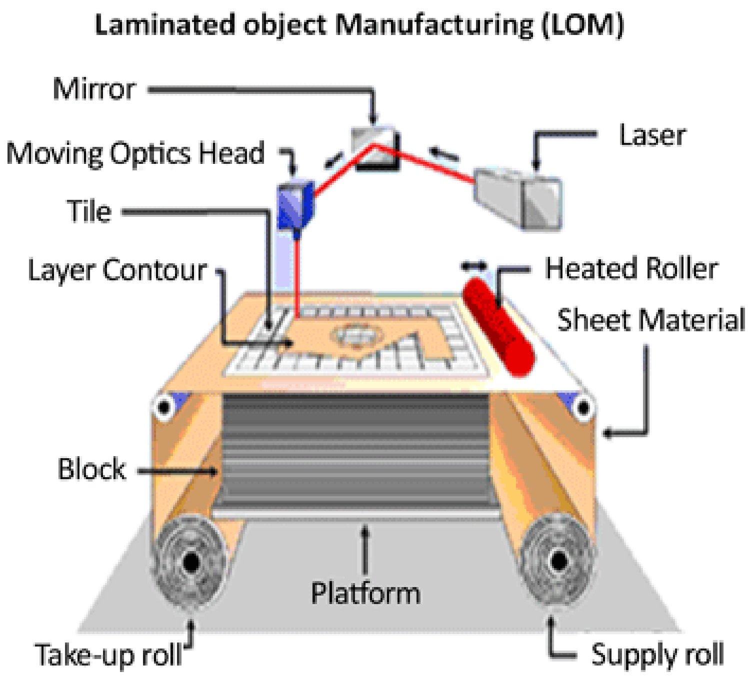




Tipi di processi per AM

- **Sheet lamination**
  - il manufatto creato mediante l'unione di fogli sagomati e uniti tra loro con vari metodi
    - Colle, ultrasuoni,…
    - solitamente di carta ma anche metallici





Tipi di processi per AM

- **Fotopolimerizzazione,**
  - solidificazione selettiva di un polimero liquido mediante radiazioni elettromagnetiche (fornite da un laser o similare)
    - in questa categoria rientra il noto processo di stereolitografia

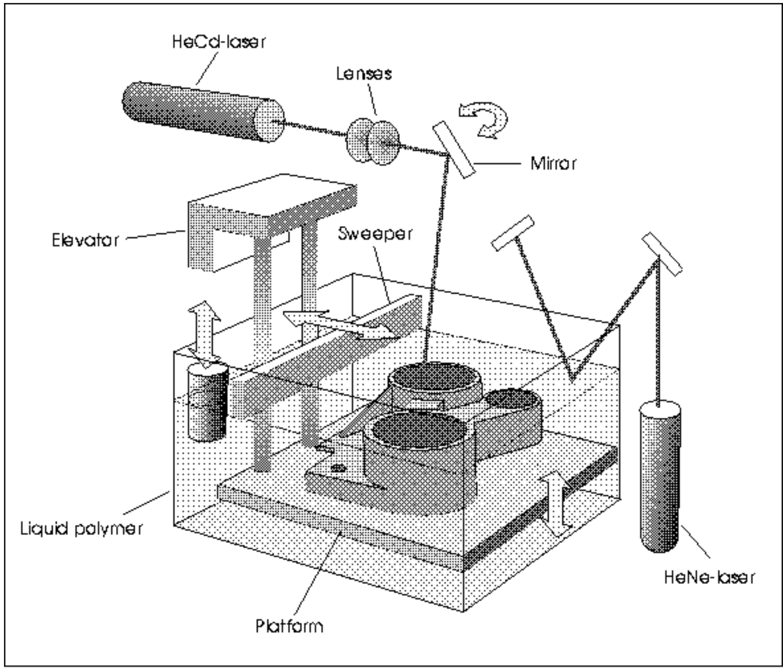
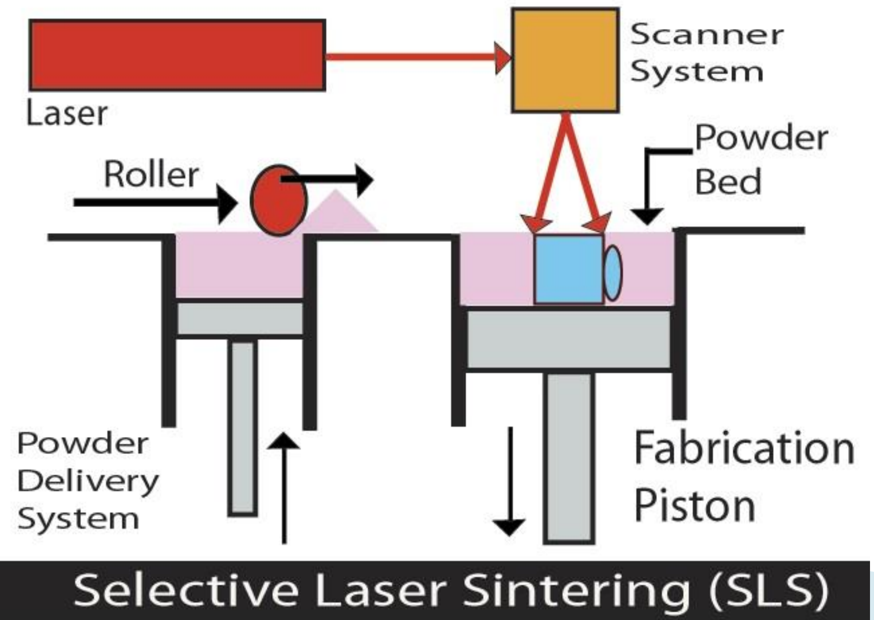


FIGURE 1. A schematic drawing of an SLA.

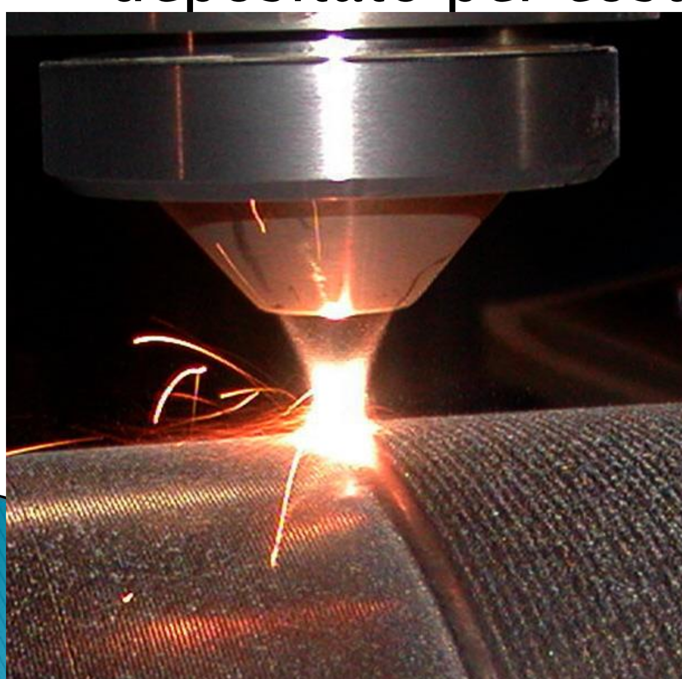
Tipi di processi per AM

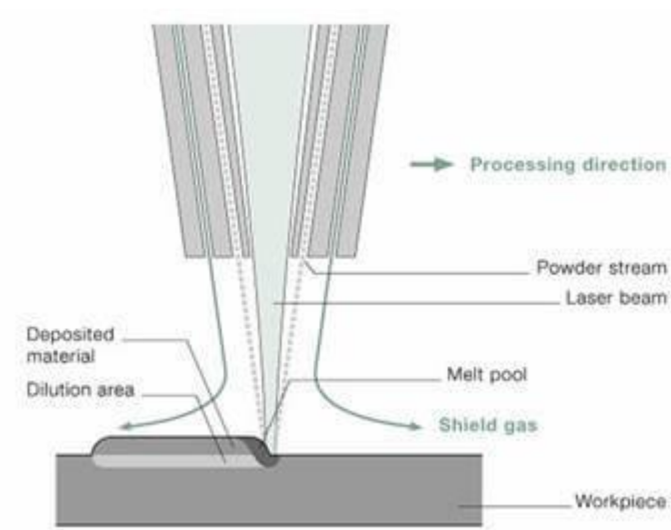
- **Power bed fusion /sintering**
  - un flusso di energia opportunamente concentrato, fornito solitamente da laser o fasci di elettroni, va a fondere o sinterizzare localmente uno strato di polvere (metallica o polimerica)



Tipi di processi per AM

- **Direct energy deposition,**
  - un flusso di energia, fornito da un laser, fonde il materiale (tipicamente sotto forma di polvere metallica, convogliata nella zona di lavoro da un apposito erogatore) nel momento in cui esso viene depositato per costituire il pezzo.

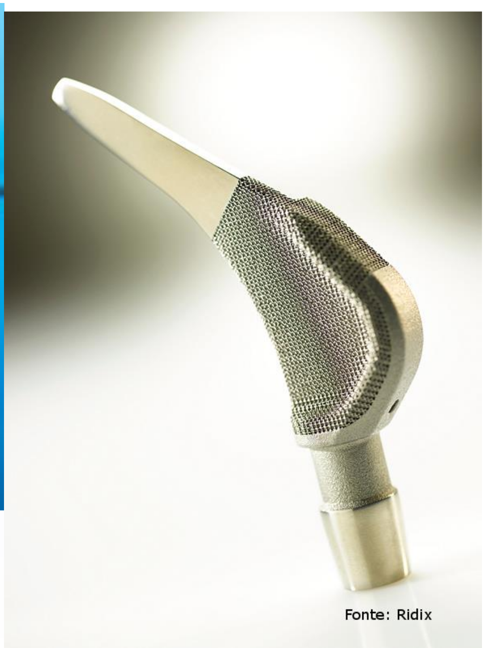


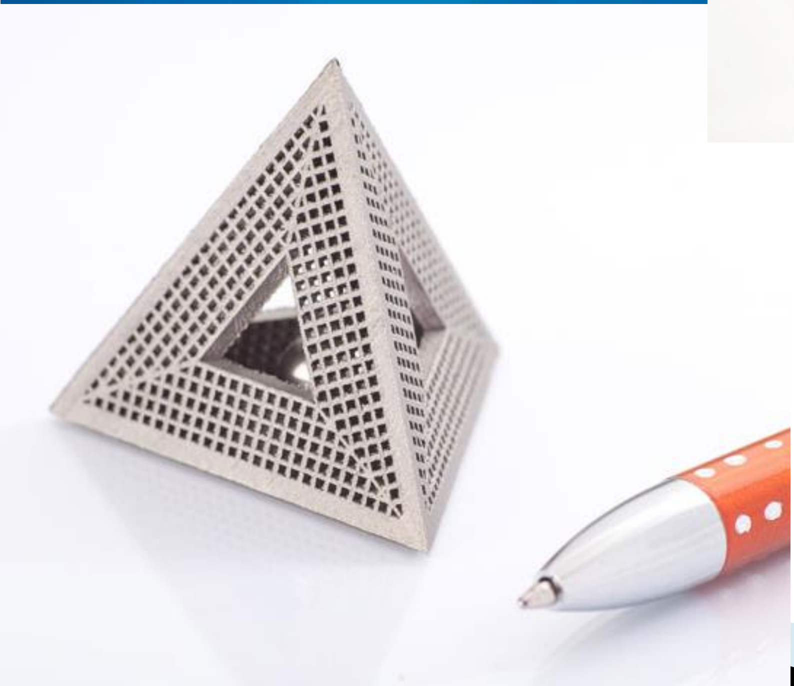


Alcuni vantaggi delle tecnologie additive

- Parti complesse
- Processi near net shape
- Mass customization
- Flessibilità di design e riconfigurazione
- Possibilità di ottimizzazione topologica
- Riduzione assemblaggi
- Ridotti tempi di set-up
- Pochi limiti alla progettazione
- Riduzione degli scarti

Esempi di parti





Esempi di parti

Fonte: Ridix

GRAZIE PER L'ATTENZIONE

AITA

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