https://www.youtube.com/watch?v=zIP-284Ond0

https://www.youtube.com/watch?v=k0poVtBhlsQ

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

3D Tech revolution

Riccardo Magni

What is Additive Manufacturing ?

ISO/ASTM definition:

"Process of **joining materials** to **make objects from 3D model data**, usually **layer upon layer**, as opposed to subtractive manufacturing methodologies, such as traditional machining."

Different terms used since AM started:

Different materials:
Polymers / Metals / Ceramics

Different technologies: SLA / SLS / 3D-Printers / FDM / DLP / DMLS / EBM / LMD / LC / …

What people need

KNOW ADDITIVE

THINK ADDITIVE

DESIGN ADDITIVE

New young designer, in deep knowlege of traditional technology, of additive and thinking in a new way

Market Application

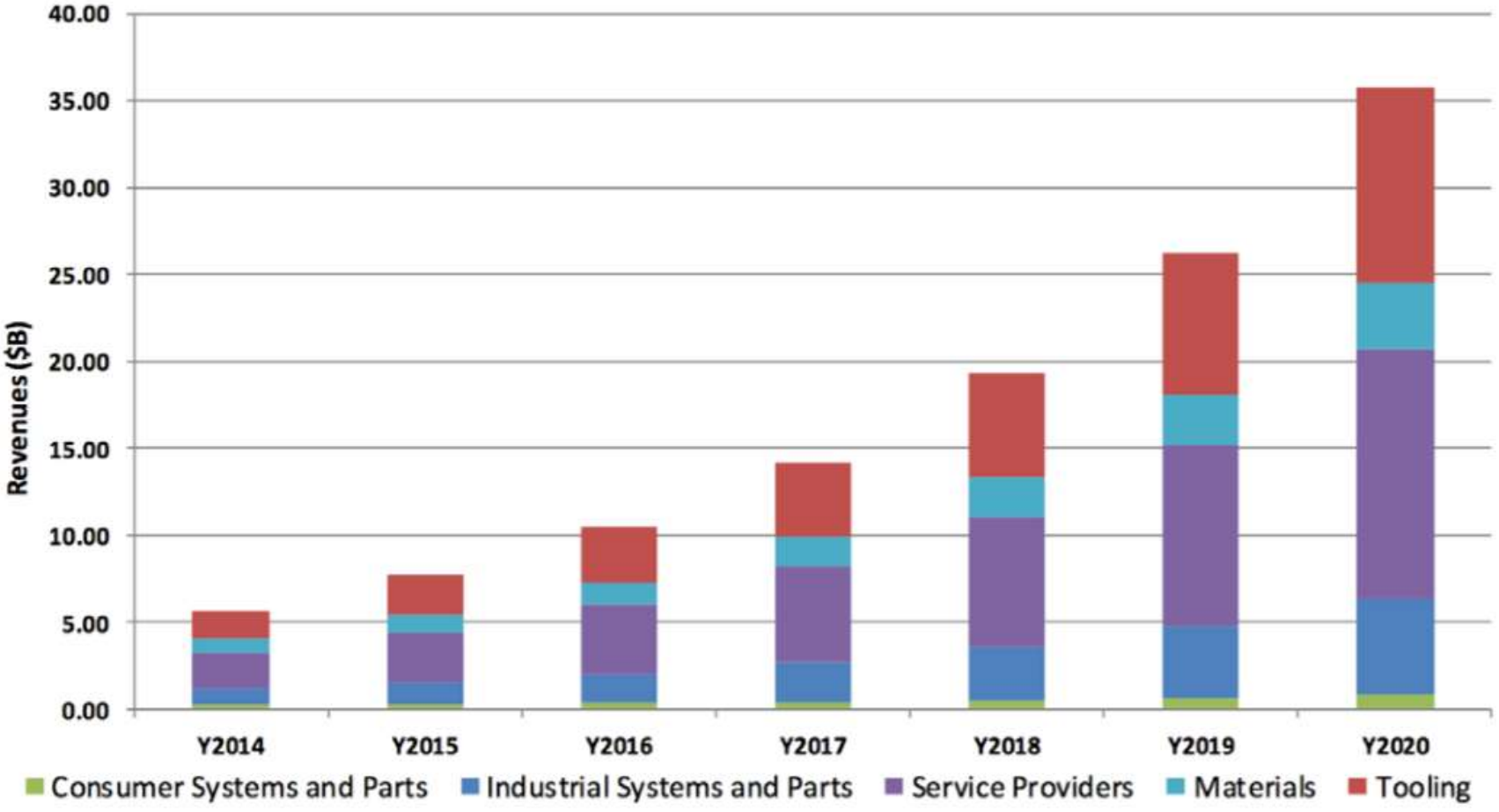
Markets Leveraging Additive Manufacturing

Aerospace & Defense | Medical Devices | High-Tech | Oil & Gas | Automotive | Consumer | Industrial Mfg.

Application Across Industries

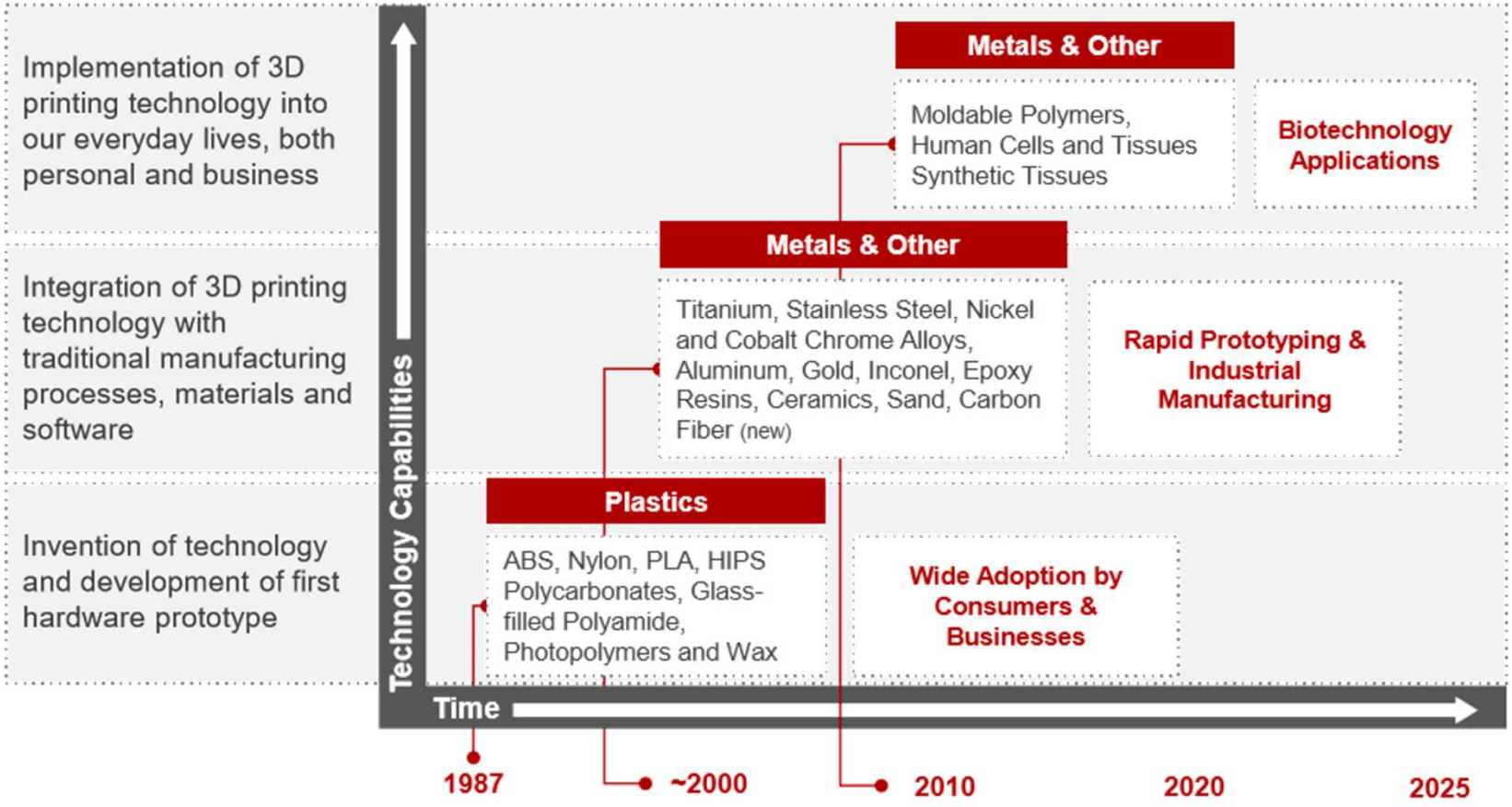
- High-design parts
- Rapid prototyping
- Fixtures
- Part consolidation
- Lightweight options
- Mass customization
- Reduced material cost
- Molds
- Short lead-time
- Tooling
- On demand production
- Reduce labor cost
- Replacement parts
- Complex geometries
- Micro scale modeling
- Small lot sizes

Revenue Forecast for the 3D Printing Industry from 2014 to 2020



Data Source: IHS Technology (January 2015)

The Impact of 3D Printing Technology



Technology / Metal

Powder Bed Fusion: Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), Selective Heat Sintering (SHS), Electron Beam Melting (EBM), and Electron Beam Welding* (EBAM, uses wire fed material)

Sample - Metal Additive Equipment Manufacturers

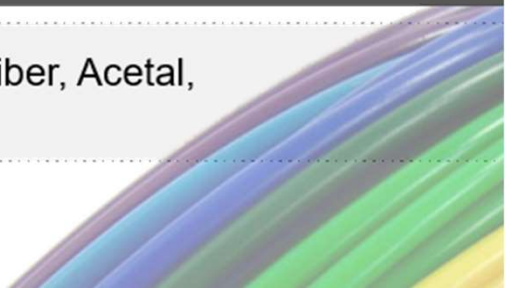
Metals: Titanium, Stainless Steel, Aluminum, Nickel Alloy, Precious Metals, Inconel, Cobalt Chrome and many others in development

Technology / Polymers

Vat Photopolymerization: Stereolithography (SLA), Digital Light Processing (DLP) Liquid photopolymers, Selective Laser Sintering (SLS) a photo-reactive resin are selectively cured with a UV laser or similar power source

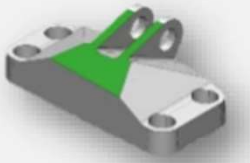
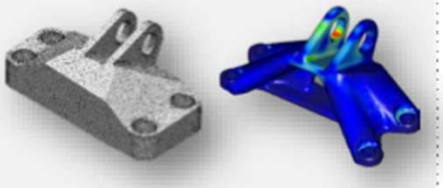
Sample – Polymer Additive Equipment Manufacturers

Polymers: ABS Plastic, Nylon, Polypropylene-like, Resin, Carbon Fiber, Acetal, Polycarbonate-like, and many others in development



Software / Design Tools

A wide variety of tools are used when designing for Additive. Some aide in the design, others analyze for structural conformity, while others optimize the topology of the object to be printed. Together they work to produce an STL file that is ready to print.

Design (CAD Interpretation)	**Analysis** (Finite Element Analysis)	**Optimization** (Topology / Layer Optimization)
		
• AutoCAD • SOLIDWORKS • CATIA • Siemens PLM	• Altair - OptiStruct • MSC Nastran • ANSYS	• Netfabb • Materialise • TOSCA

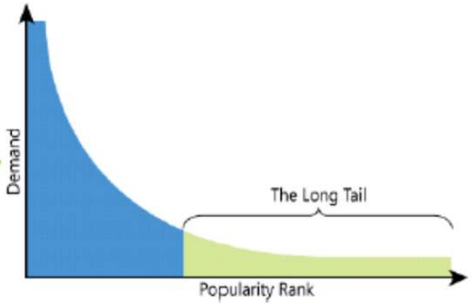
… DI CONSEGUENZA ANCHE I PARADIGMI PRODUTTIVI

Mass Production

- Lottizzazione
- Economie di scala
- Prodotti standard e maturi

Mass Customization

- Prodotto&servizio
- Flessibilità
- Produzione di piccola serie
- Prodotti unici

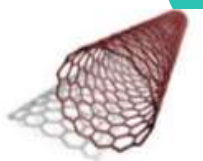


Fonte: Chris Anderson, "*The Long Tail: Why the Future of Business is Selling Less of More*", 2006

Combining several KETs for advanced AM products

SOCIETAL CHALLENGE

TRANSPORT



ADVANCED MATERIALS

NANOTECHNOLOGIES

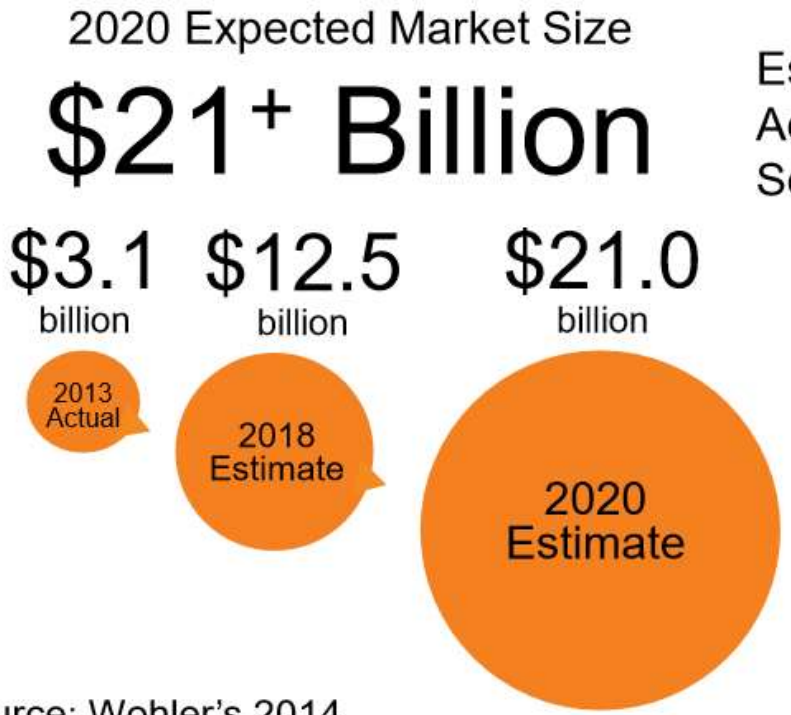
MICROELECTRONICS

PHOTONICS

ADVANCED MANUFACTURING

- ✓ CUSTOMIZATION FOR REAL END USER NEEDS
- ✓ NEW FUNCTIONAL DESIGNS FOR NEW VEHICLE CONCEPTS
- ✓ REDUCING COSTS INCREASING PERFORMANCE
- ✓ FAST RESPONSE TO HIGH DEMANDING SECTOR
- ✓ NEW TOOLS FOR NEW MINDED PROFESSIONALS
- ✓ NEW CONCEPT OPTIMISED INTRINCATED STRUCTURES TO FIT FUTURE USABLE SHAPES
- ✓ MANUFACTURING ON DEMAND

Market Size



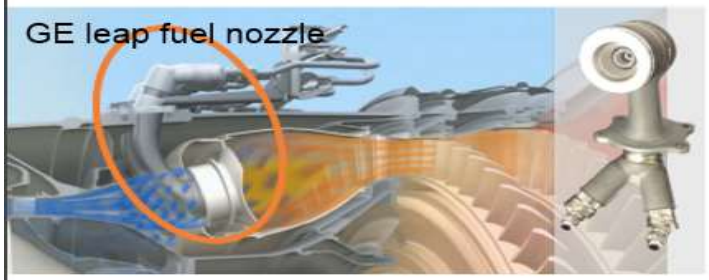
Estimated Global Market for Additive Manufacturing Products & Services

Source: Wohler's 2014

Polimeric additive manufacturing technologies

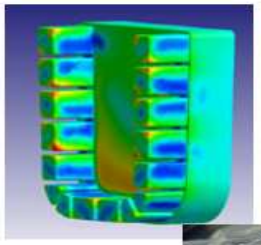
The diverse industrial uses of AM

GE leap fuel nozzle



Conventionally machined bracket (right) and redesigned bracket (right) using topology optimization, courtesy of Laser Zentrum Nord GmbH and Airbus

Airbus



Tooling: Linear Mold, Triform

Shoe cleats: NIKE

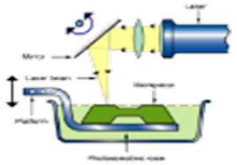
Skyfall

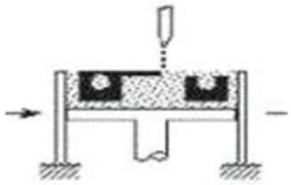
Custom airway stent: U. Michigan

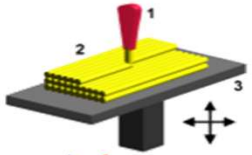
Modular products: Google Ara

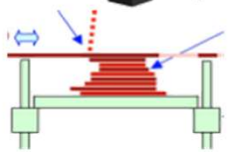
The 7 AM methods (from ASTM F42)

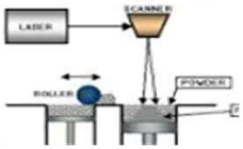
Low energy

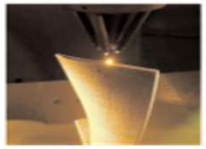








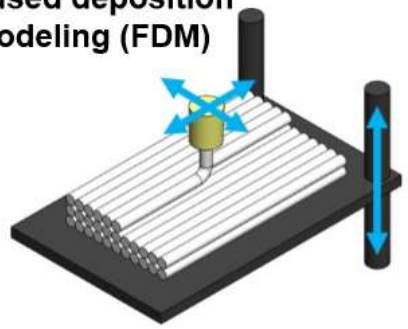




High energy

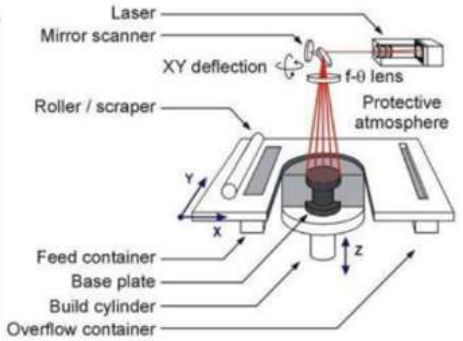
- **Vat photopolymerization (→ SLA)**: material is cured by light-activated polymerization.
- Material jetting (→ Objet): droplets of build material are jetted to form an object.
- Binder jetting (→ 3DP): liquid bonding agent is jetted to join powder materials.
- **Material extrusion (→ FDM)**: material is selectively dispensed through a nozzle and solidifies.
- Sheet lamination (→ LOM): sheets are bonded to form an object.
- **Powder bed fusion (→ SLS/SLM)**: energy (typically a laser or electron beam) is used to selectively fuse regions of a powder bed.
- Directed energy deposition (→ LENS): focused thermal energy is used to fuse materials by melting as deposition occurs.

Fused deposition modeling (FDM)

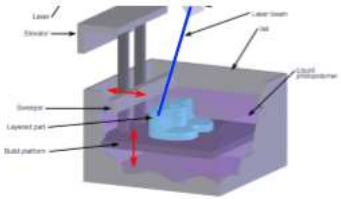


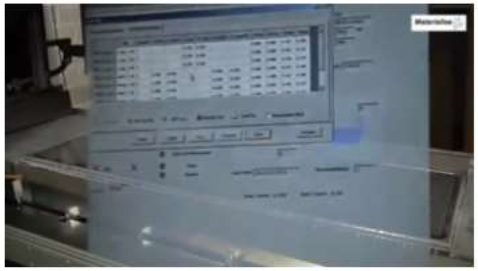
Northrop Grumman

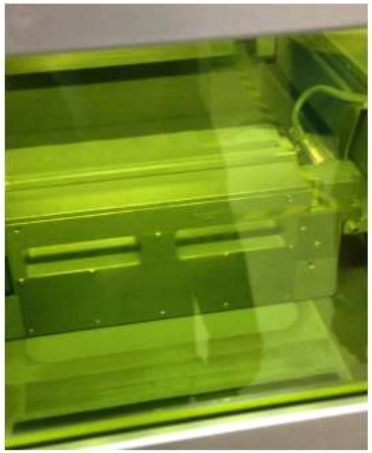
Selective laser sintering / melting (SLS/SLM)



Stereolithography (SLA)

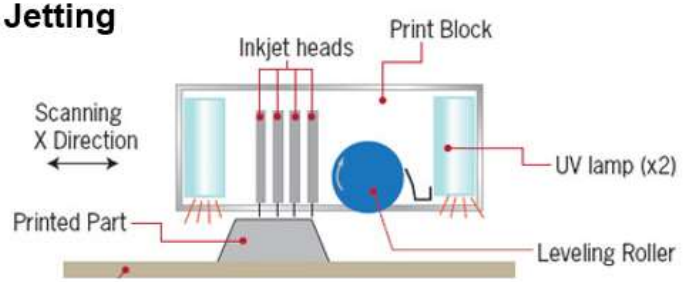


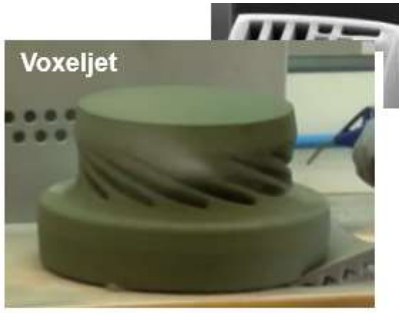




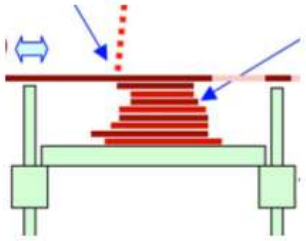
EOS/Materialise

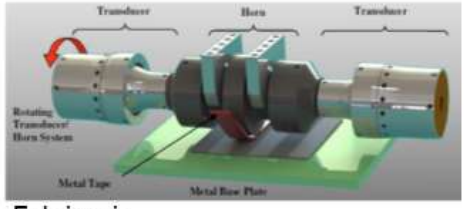
Material and Binder Jetting





Laminated Object Manufacturing (LOM)

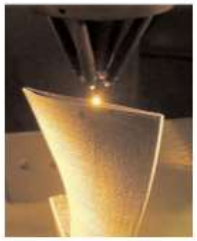




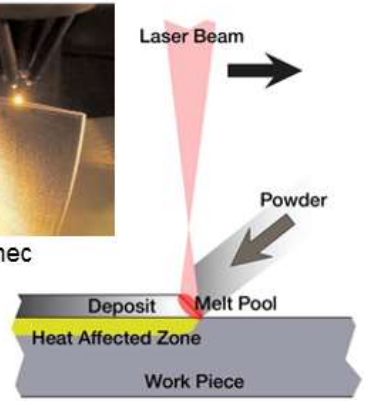
Fabrisonic

mCor

Directed Energy Deposition



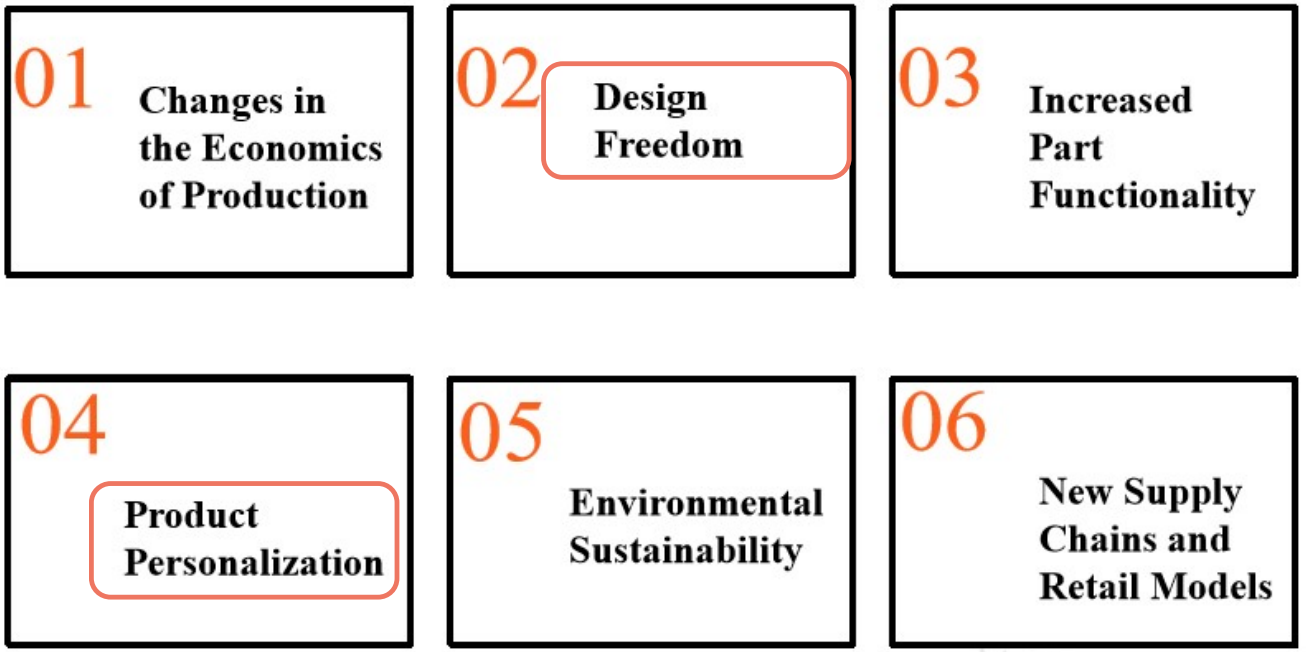
Optomec



Sciaky

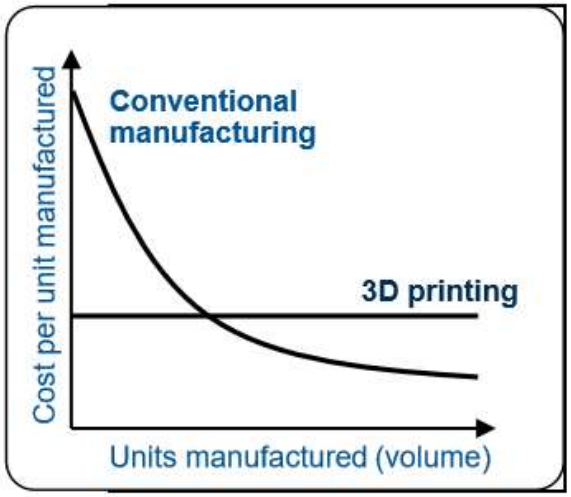
Processes	Machines	Build volume [mm]	Build rate [cm^3/h]	Layer thickness [mm]
FDM	Dimension 1200	254x254x305	20	0.25
Polyjet	Objet 30 Pro	294x192x148	56	0.016
B-jet	M Flex	400x250x250	1780	0.1
	Projet860Plus	508x381x229	968	0.1
SLS(P)	SPro60HD Base	381x330x437	1000	
SLM	EOS M400	400x400x400	105	0.03
	EOS M290	250x250x325	27	N/A
EBM	A2X	200x200x200	60	N/A

The Promise of 3D Printing for Manufacturing



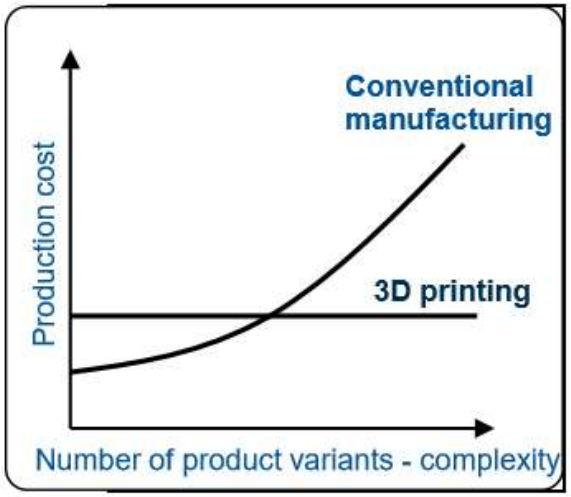
Changes in the Economics of Production

Economies of Scale



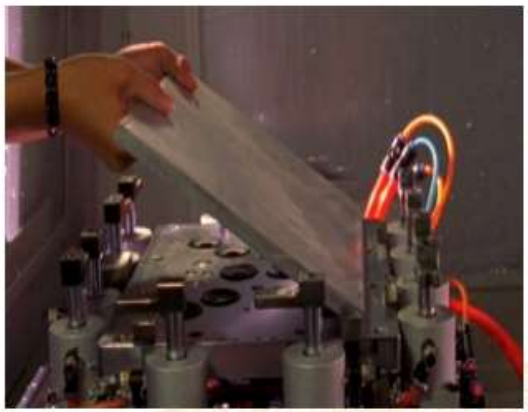
- **Marginal costs** do not change with **volume**
- 3D Printing reduces the **minimum efficient scale**
- Efficient alternative for **low-to-medium-sized production** runs

Economies of Scope

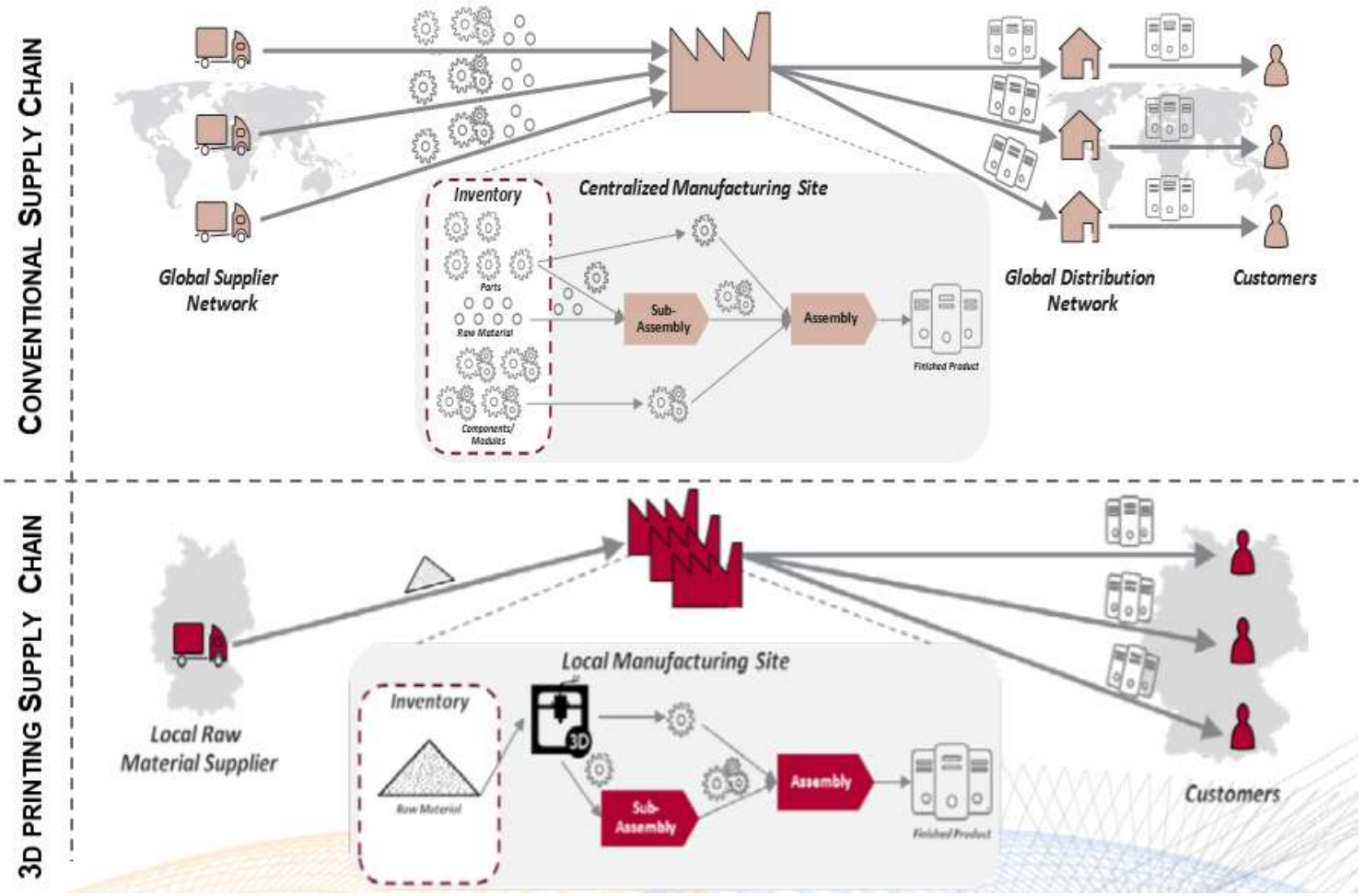


- Production of **multiple product variants** using the **same equipment, materials** and **processes**
- Manufacturing of **complex shapes** with no additional costs
- Enablement of efficient **product individualization/personalization**

3D Printing Provides Design Freedom



New Supply Chains and Retail Models

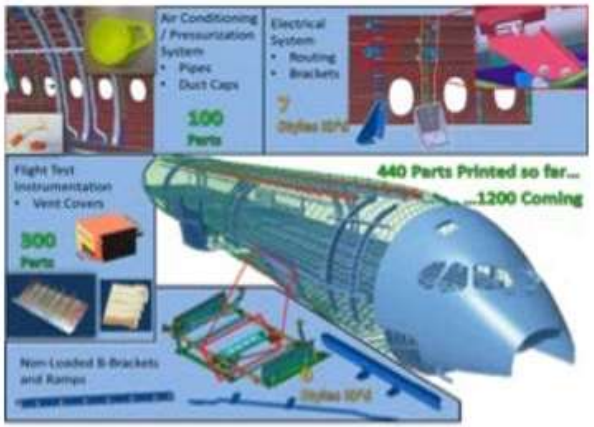


Airbus A350 XWB Program includes over 1000 3D printed flying parts

Airbus A350 XWB program contains more than 1000 flight parts 3D printed on Stratasys FDM Production Systems

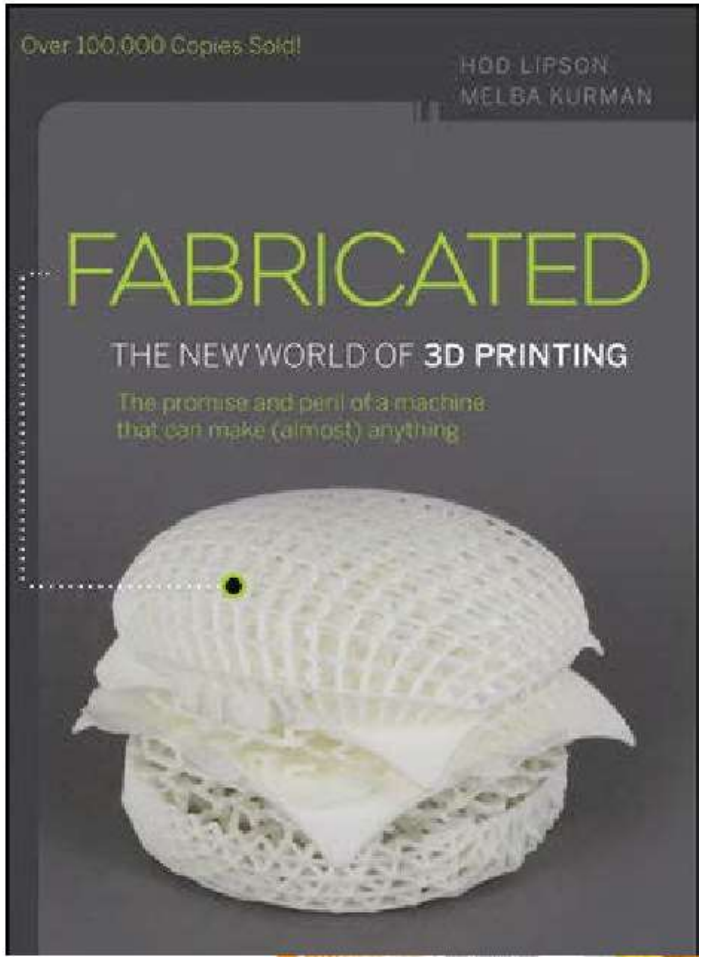
Increased supply chain flexibility and geometric freedom

Provided valuable weight reduction compared to traditional components



Novel Design Strategies

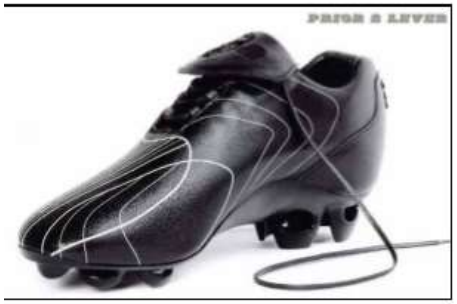
- Creative
- Design for Functionality, topology optimization
- Cellular structures
- Part Consolidation
- Compliant mechanisms
- Multiple materials, multi-functionality



Housewares, Clothing, Jewelry

Freedom of Creation

Prior 2 Lever



N-E-R-V-O-U-S System

Silver

Gold

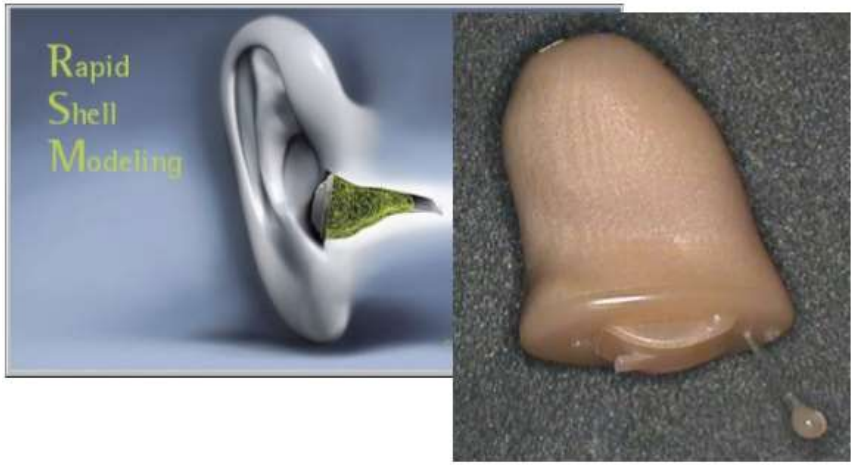
AM: Additive Manufacturing

Re-Engineering

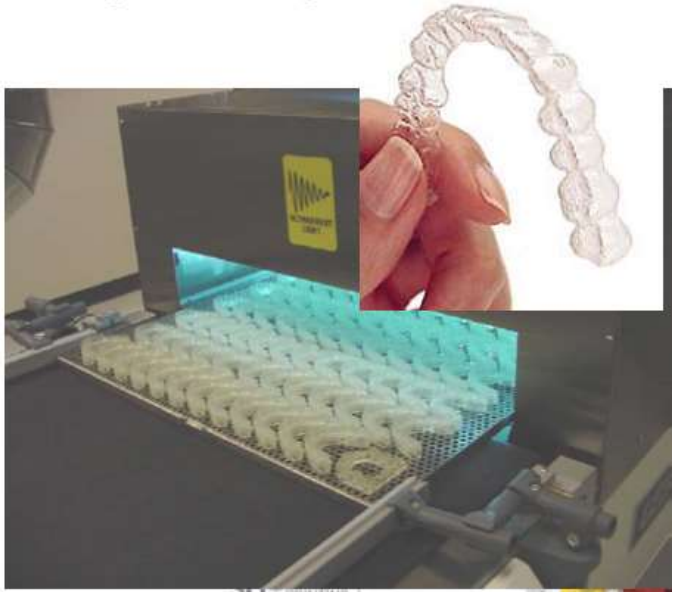
Custom Geometries

OsteoFab Patient Specific Cranial Device fabricated in polyetherketoneketone (PEKK) on EOS P800

Siemens, Phonak, Widex, etc.

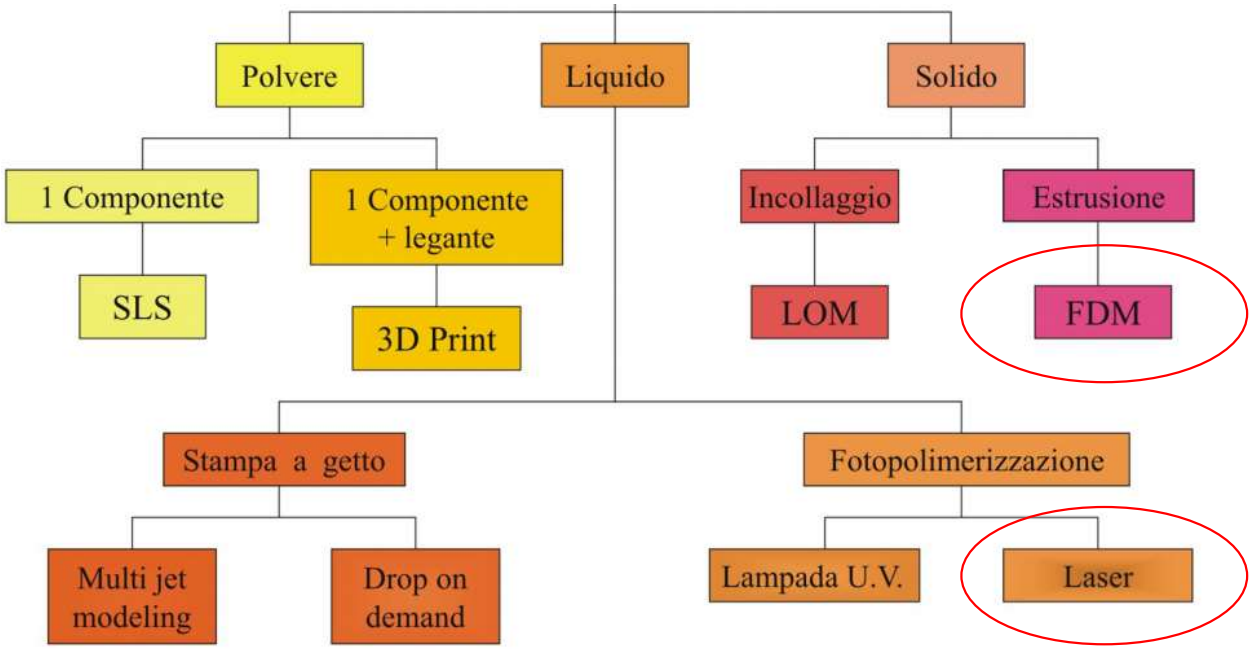


Align Technologies



AM: Additive Manufacturing

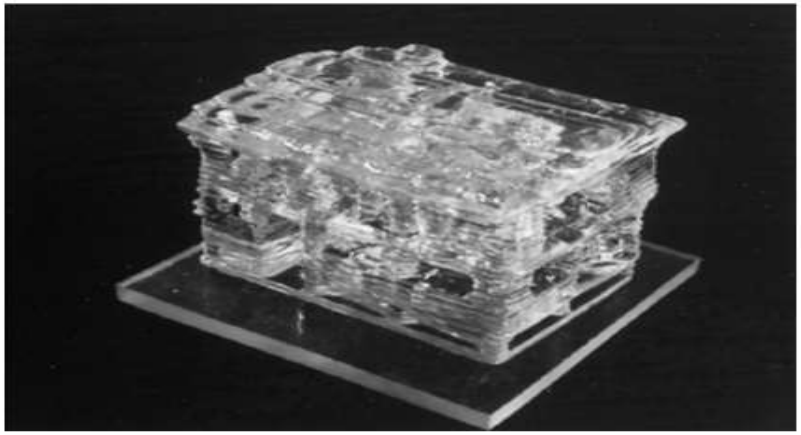
Materie plastiche

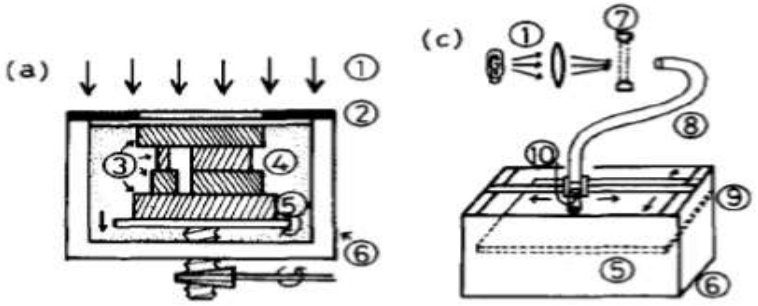


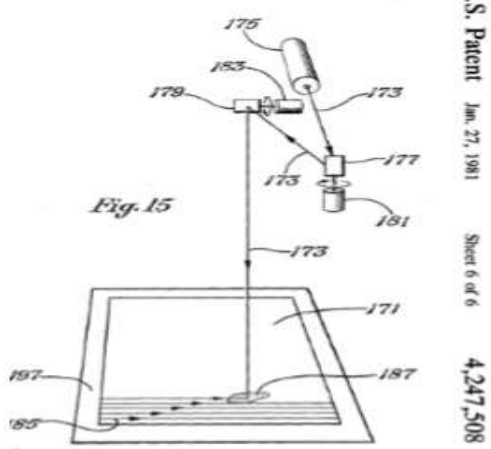
THE FIRST IDEA ->

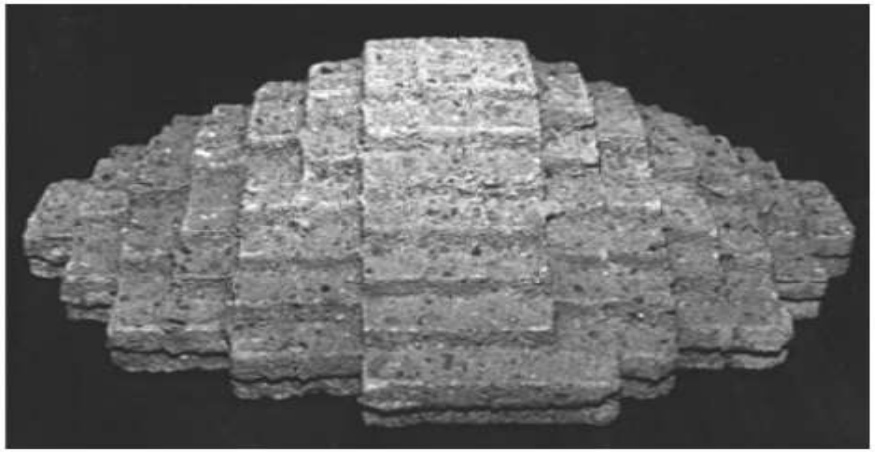
Earlier AM parts (arguably not the earliest)

Photopolymerization
Kodama, 1981 (Rev Sci Instr)









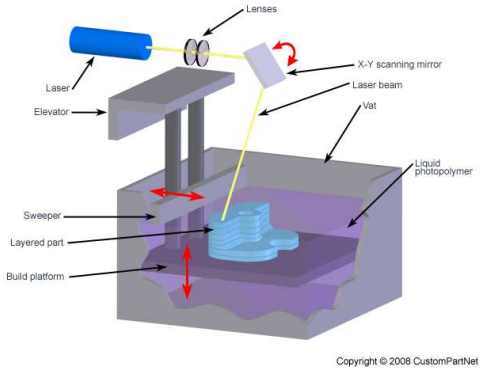
Sintering of metal/ceramic powder
Householder, 1979 (Patent)

Gli albori della tecnologia, la prototipazione rapida

Stereo **L**ithography (STL) – nasce negli anni 80 e si sviluppa negli anni ‘90

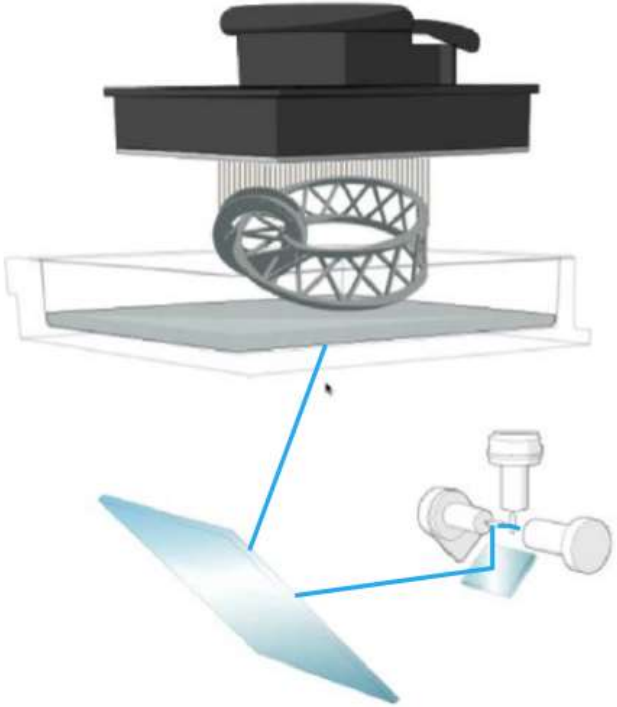
Attraverso l’impiego di un laser viene tracciata la sezione di un pezzo. Il laser cede energia, la resina fotosensibile polimerizza e si ottiene uno strato solido.

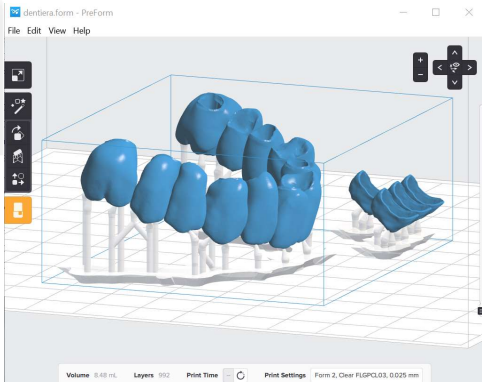
Successivamente viene aggiunto un altro strato di materiale liquido ed il procedimento si ripete fino a che da strati successivi si ottiene il prototipo.

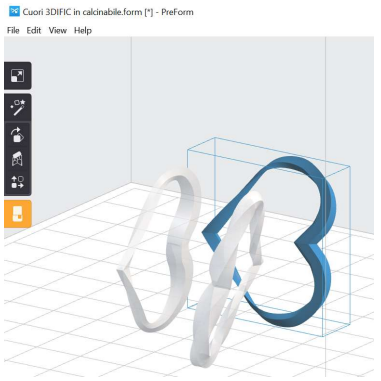


Form 2

The most advanced desktop 3D printer ever created.







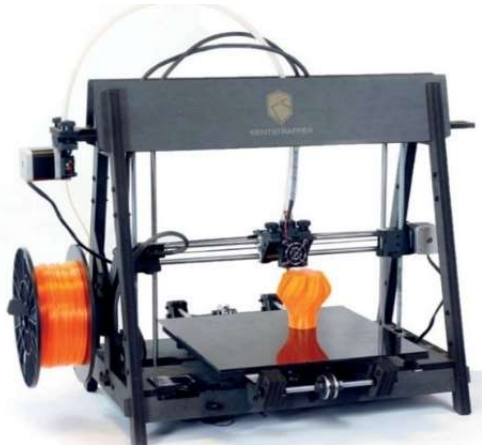
HOBBYIST FDM
Part Cost: $0.41
Machine Cost: $2,500

DESKTOP SLA (FORM 1+)
Part Cost: $1.67
Machine Cost: $3,299

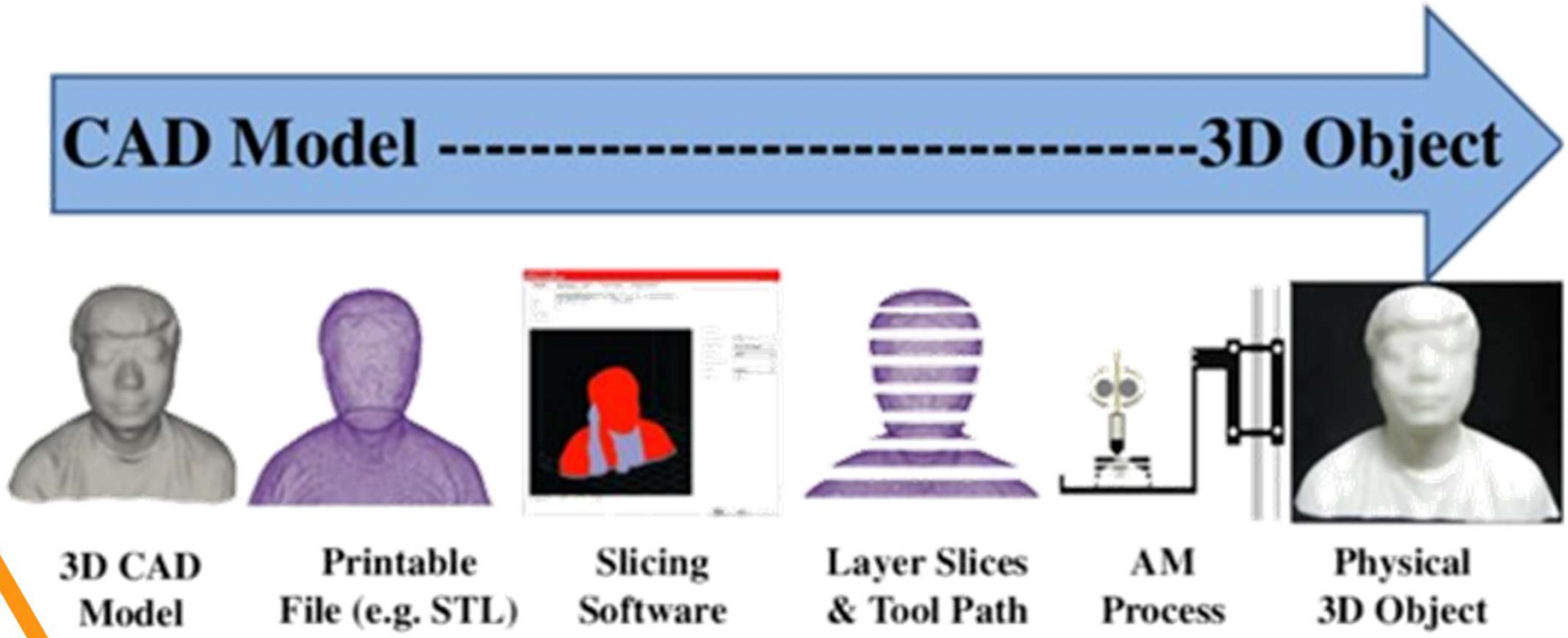
INDUSTRIAL SLA
Part Cost: $6.00
Machine Cost: $300,000

Fused **D**eposition **M**odeling
(FDM)

Scalable Technology



General 3D Printing Process

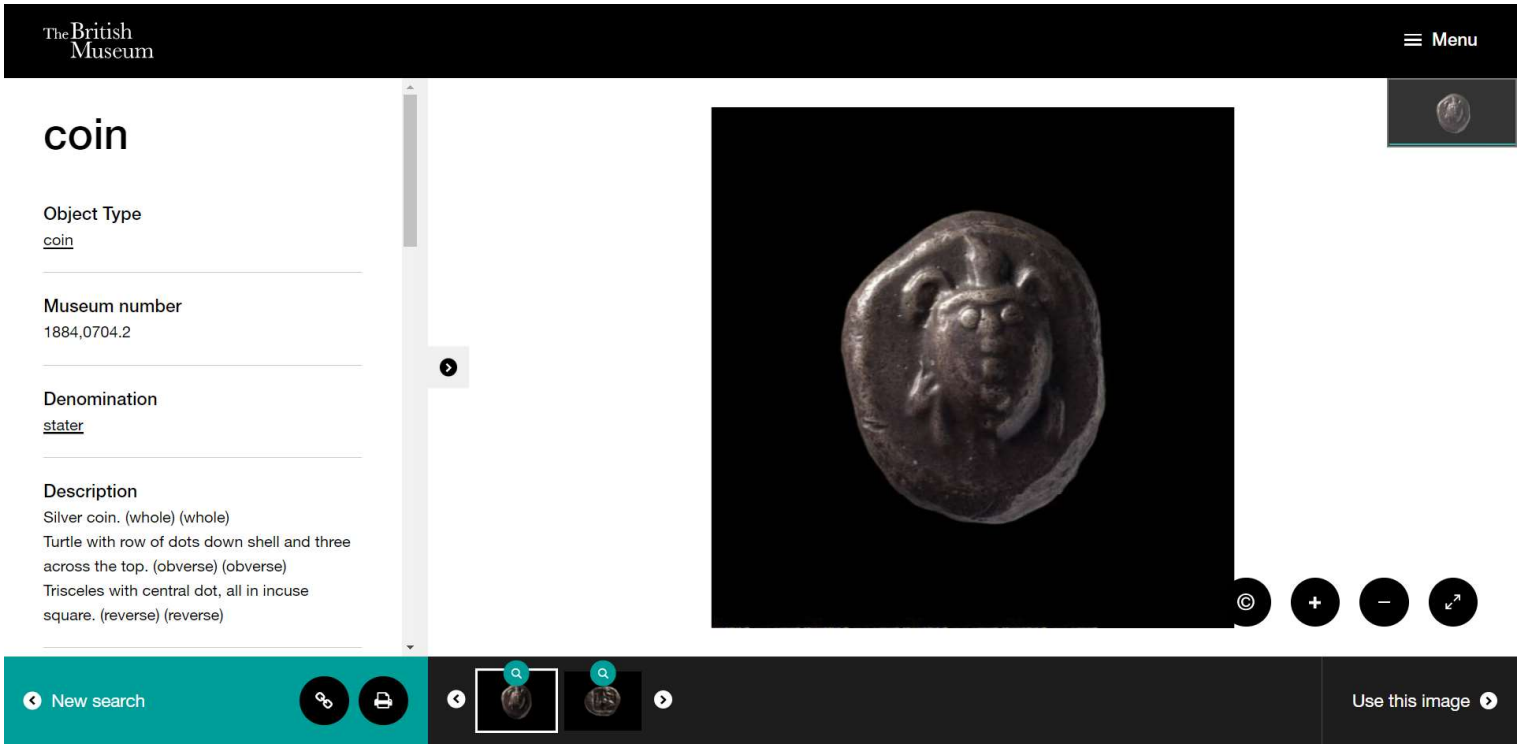


Hypothesis of process – step 1

- Going to find the resource you want to print

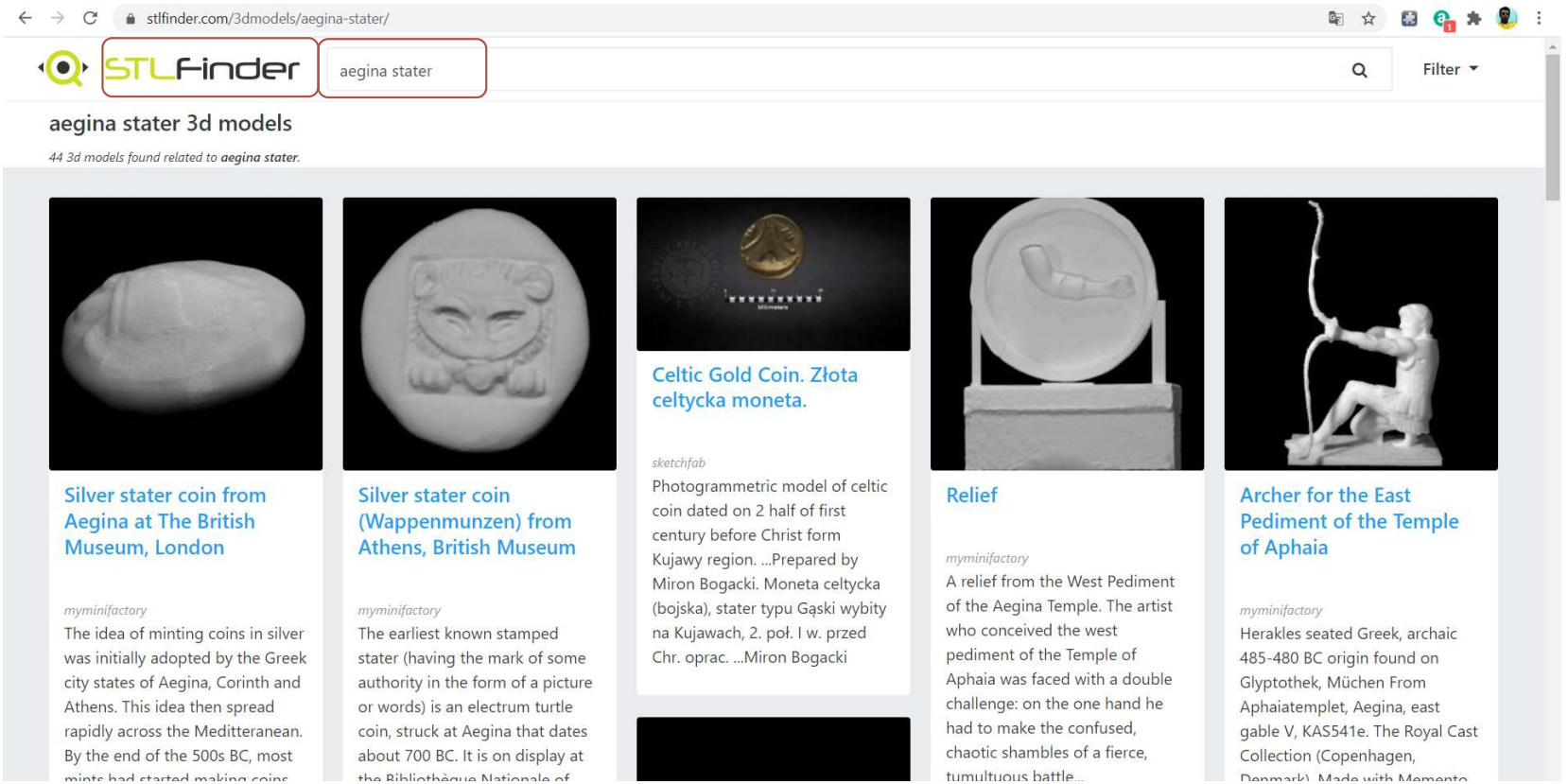
Hypothesis of process – step 2

- Choose the resource



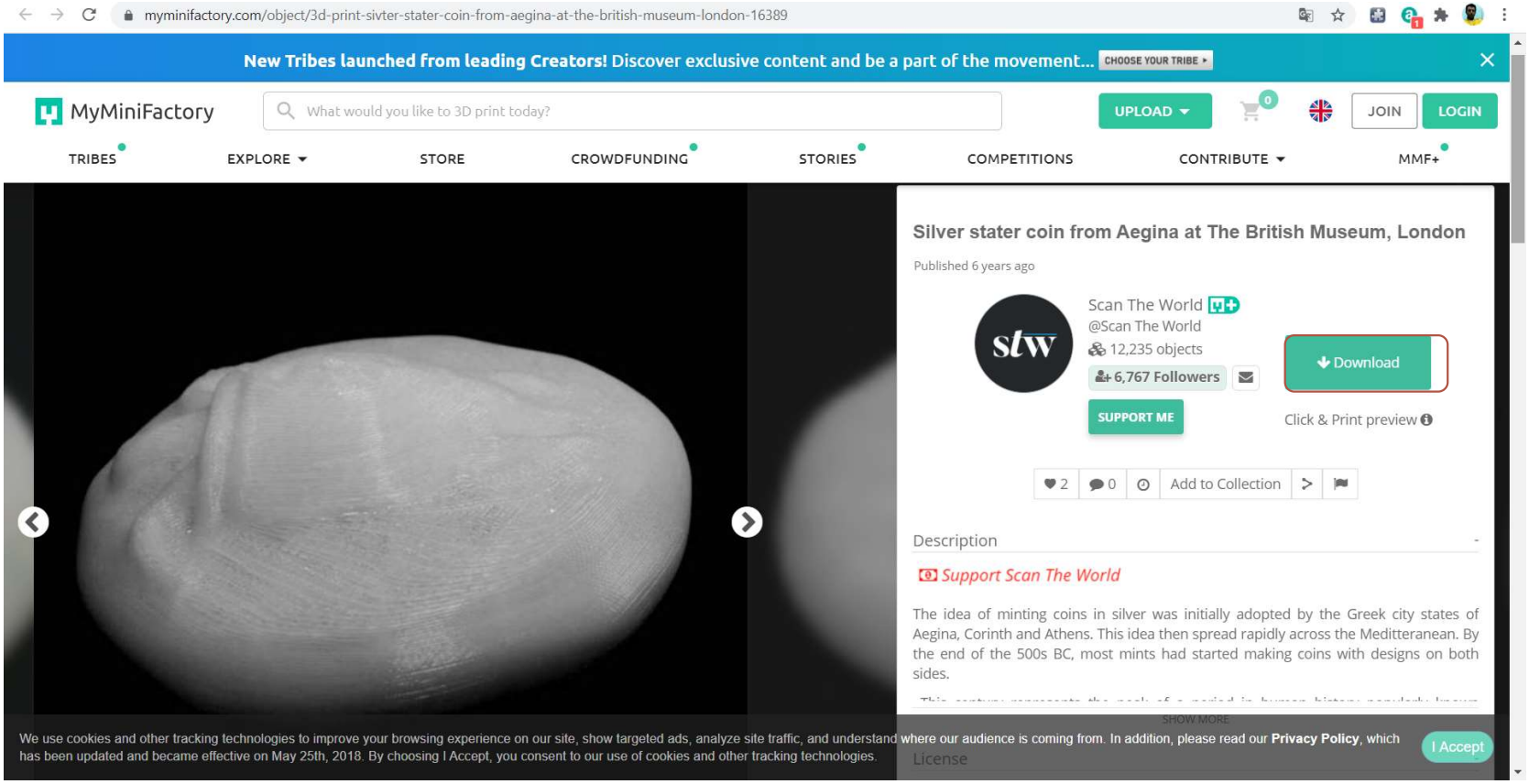
Hypothesis of process – step 3

- Downloading the STL file



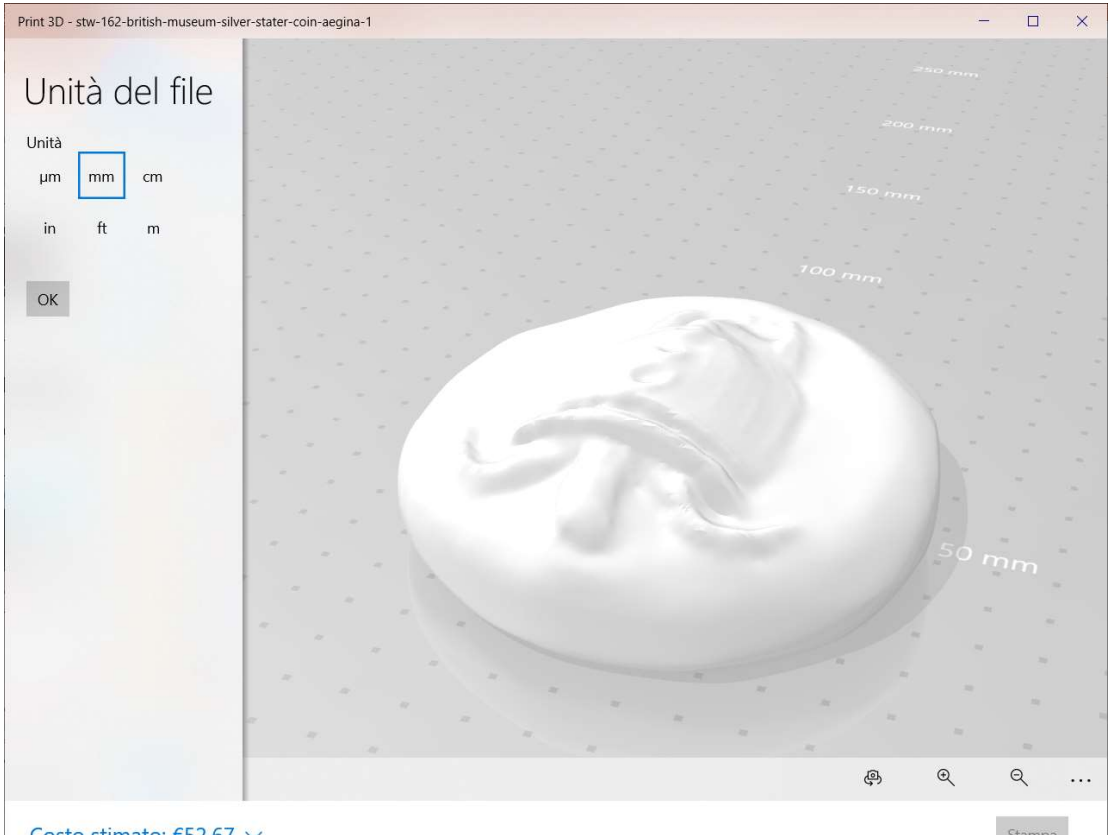
Hypothesis of process – step 3

- Downloading the STL file



Hypothesis of process – step 4

- Review of downloaded file (free *.stl viewer – viewstl.com)

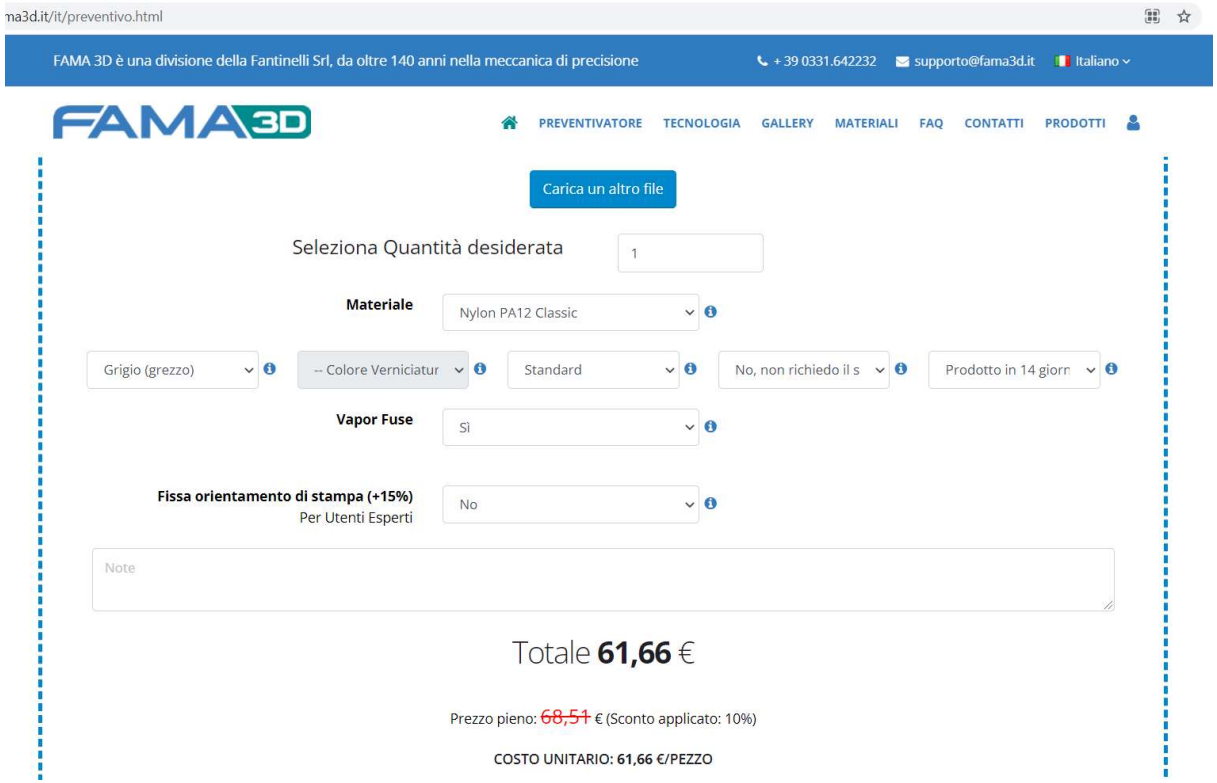


Hypothesis of process – step 5

- Remote 3D print cost estimation

Hypothesis of process – step 5

- Remote 3D print cost estimation



Riccardo Magni