de l'imprimante 3D à la fabrication additive

Conférence de la Performance Industrielle
Mardi 18 Mars 2014

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Introduction

- ***Additive manufacturing (AM) processes have been commonly used for rapid prototyping purposes during the last 30 years.***
- ***These technologies can now be used to manufacture metallic parts.***
- ***This breakthrough in manufacturing technology makes possible the fabrication of new shapes and geometrical features.***
- ***They allow net-shape manufacturing of complex parts.***
- ***They should provide improvements in terms of time-to-market, ecological impact and design compared to traditional industrial processes.***

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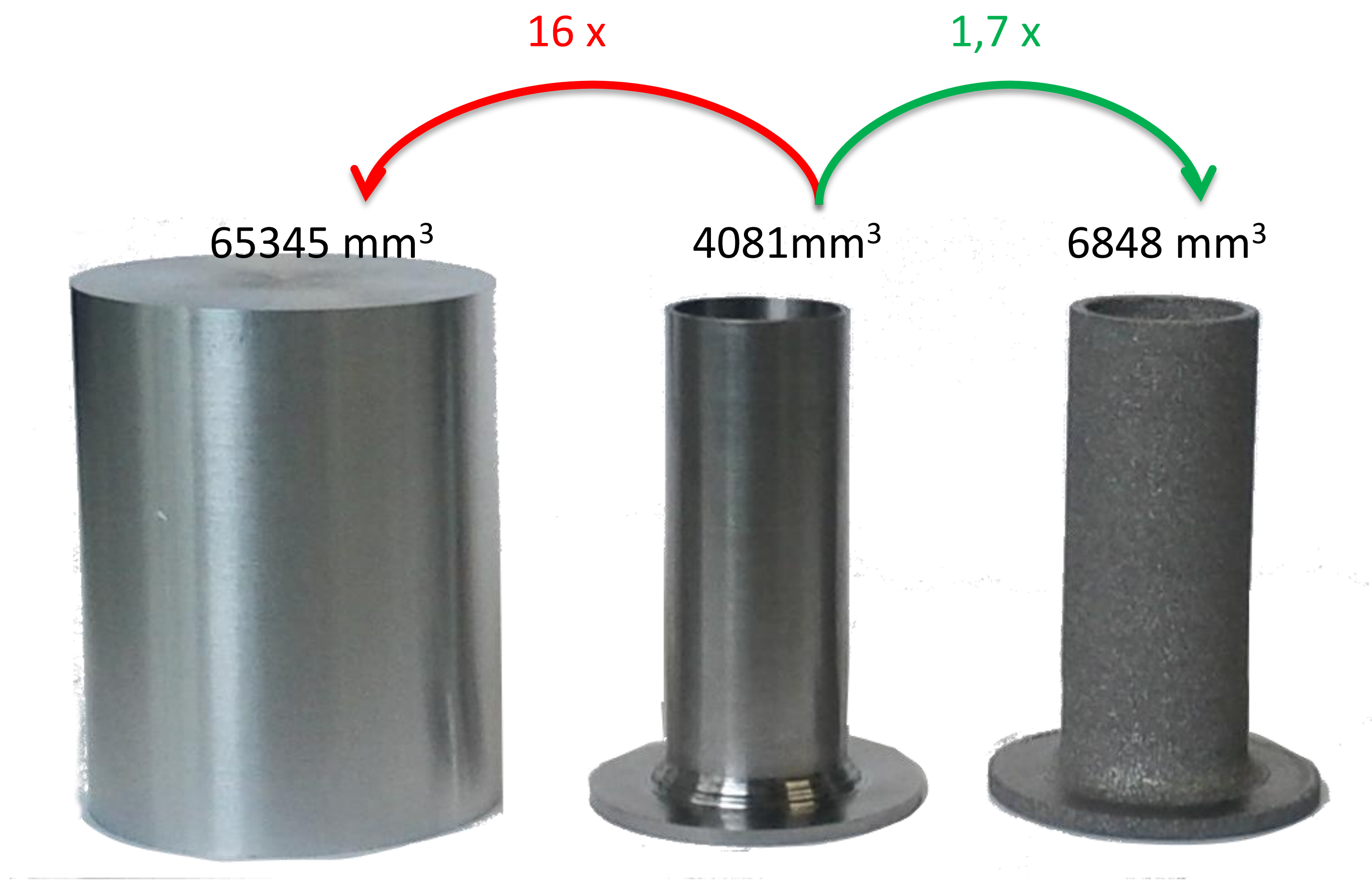
Introduction

- **From soustractive manufacturing**
  - Several manufacturing operations
  - Upto 95% of material removal
- **To additive manufacturing**
  - Reduced material removal rate
  - More freedom in parts shape design
  - Less tooling

New design paradigm

Reduced material removal rate



Extruded rough part

Part

EBM part

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Some Key date

- 1986 –3DSystem company
- 1988 First additive manufacturing technologie. Use a stereolithography process (60 patents)
- DTM corporation -> process SLS - Selective Laser Sintering
- STL format - 3D System company (Standard Tessellation Language) or (STereoLithography)
- 1988 : Stratasys -> process FDM - Fused Deposition Modeling
- 1993 : MIT-> process powder and inkjet printing.
- 1995 : Z corporation buy patents to process powder
- 1996 : use of the term : printer 3D
- 1999 : PolyJet by Objet Ltd.
- 2005 : beginning RepRap project (Adrian Bowyer)
- 2009 : MakerBot : Bre Pettis, Adam Mayer et Zachary Smith
- 2011 : 15000 marketed printer3D
- 2012: 38000 marketed new printer 3D
- 2013: 56000 printer3D
- 2014 : 98000 printer3D (estimate !)

- 1990 - Binded selective laser sintering (SLS)
  2000 - Direct Metal Lase sintering (DMLS)
- 2000 - Laser selective melting (SLM)
- 2006 - Electron beam melting (EBM)
- Direct metallic deposition (DMD/CLAD)
- 2014 DMG Mory Seiki…

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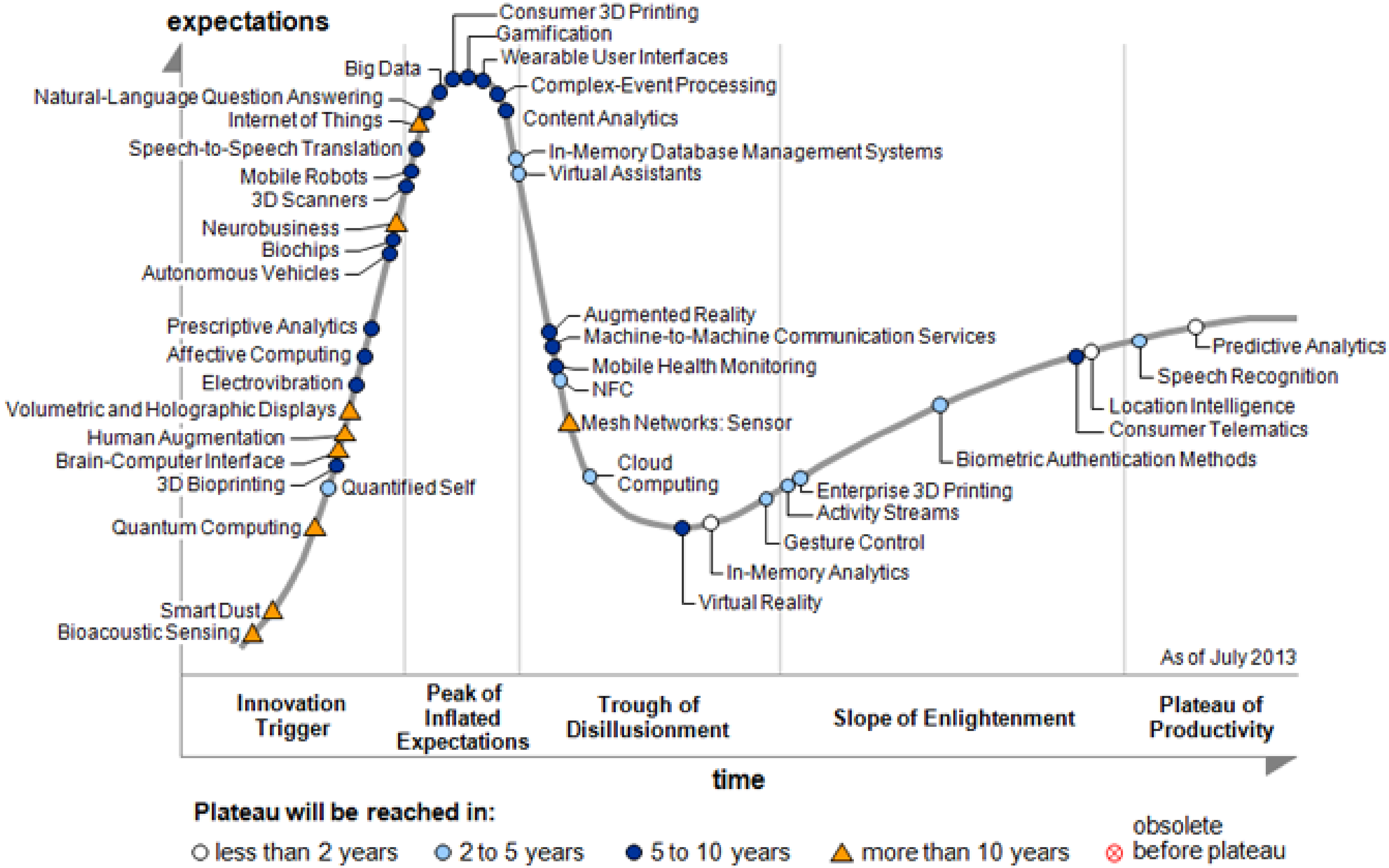
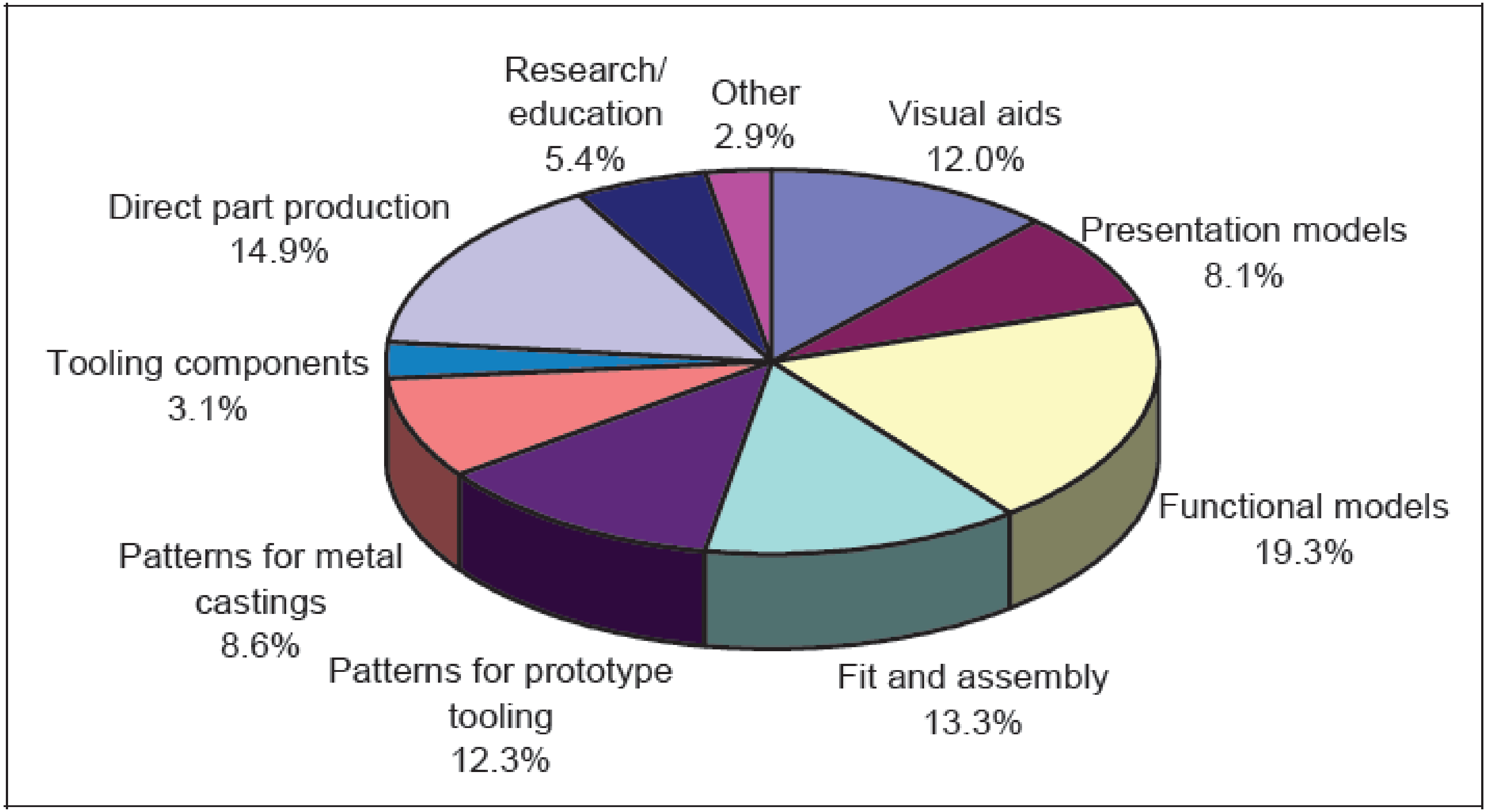


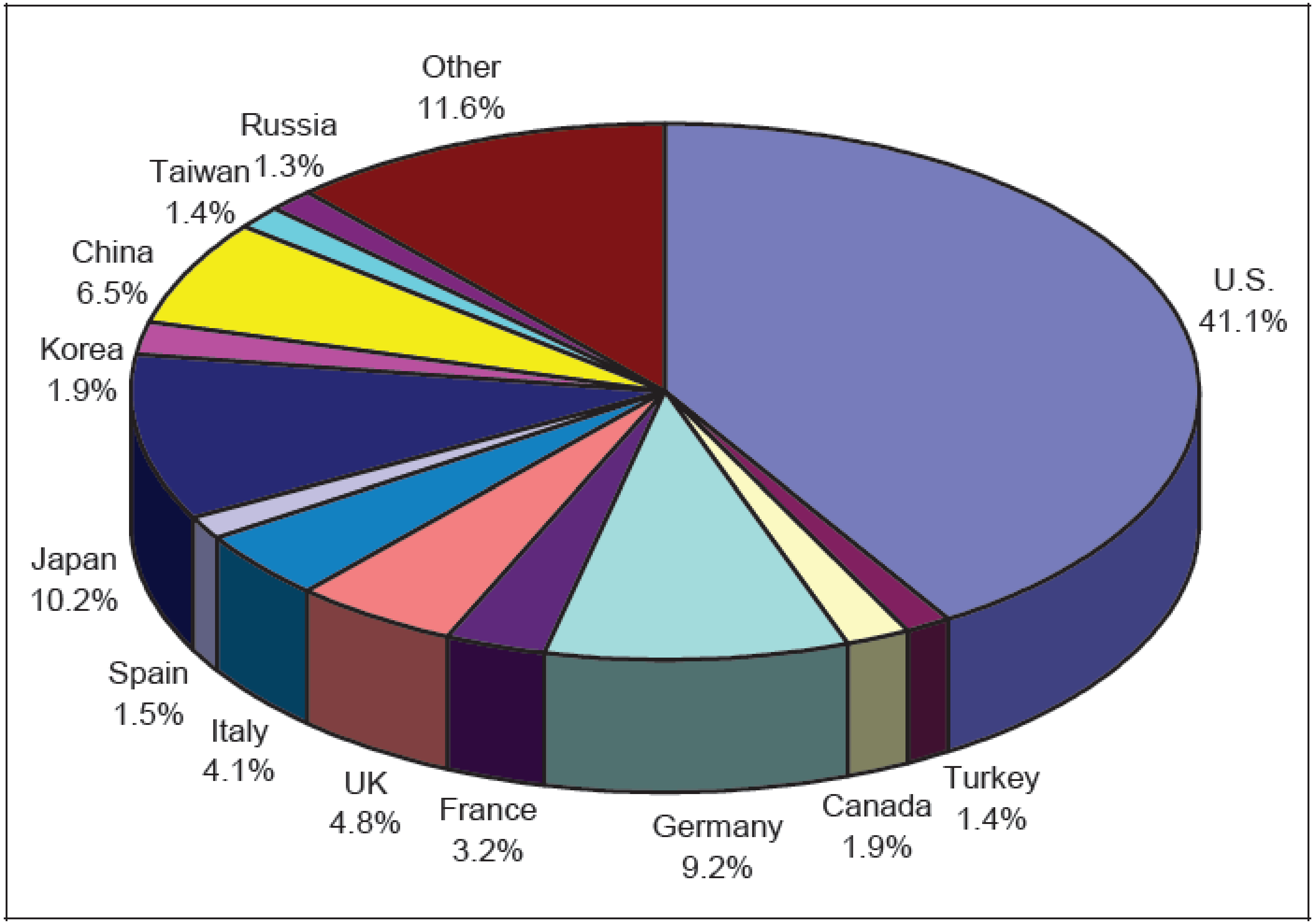
L'impression 3D est tout en haut de la courbe des attentes/espérances , selon le cabinet d'études Gartner. (Source : Gartner)

Additive manufacturing figures



Source: Wohlers Associates, Inc.

Additive manufacturing figures



Source: Wohlers Associates, Inc.

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Main machine manufacturer (metallic)

Technology	Manufacturer	Country
Selective **L**aser **S**intering	3D Systems EOS Trump	USA Germany China
Direct **M**etal **L**aser **S**intering	EOS	Germany
Selective **L**aser **M**elting	MTT (now 3D systems) Phenix System Concept Laser Realizer SLM Solutions Wuhan Binhu	UK France Germany Germany Germany China
Electron **B**eam **M**elting	Arcam	Sweden
Direct **M**etal **D**eposition	Optomec POM IREPA Laser Accufusion	USA USA France Canada

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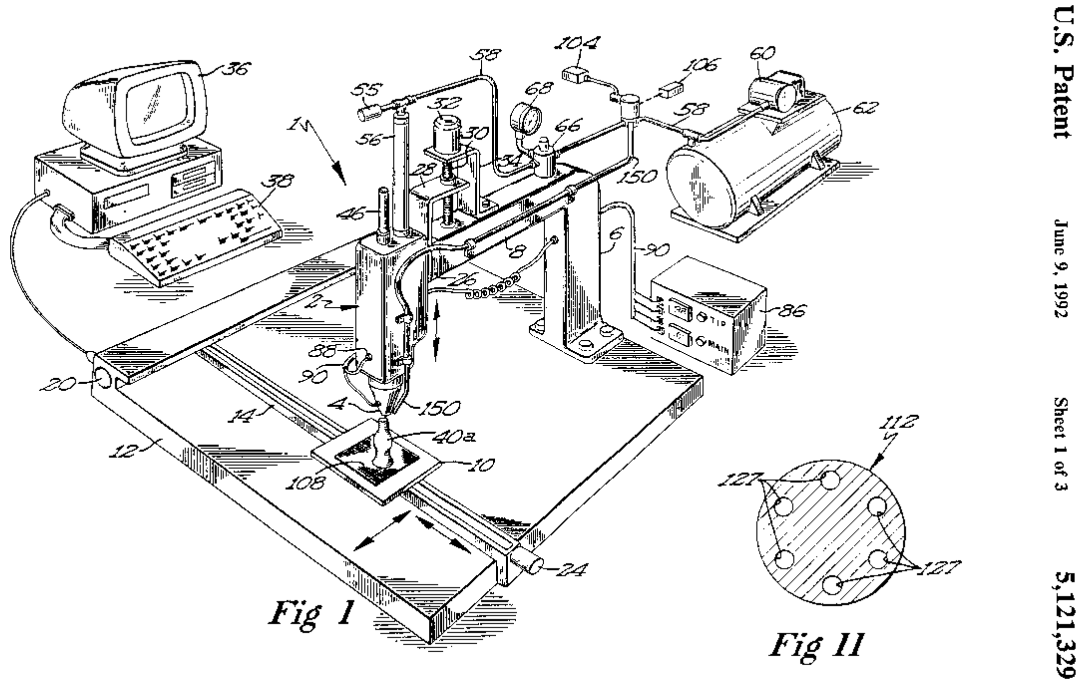
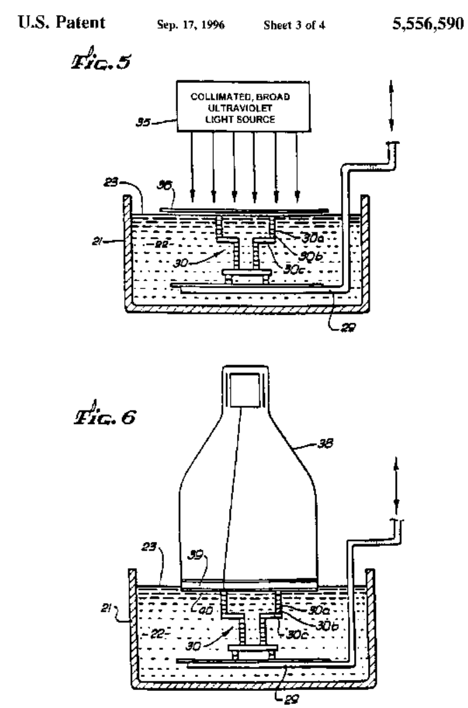
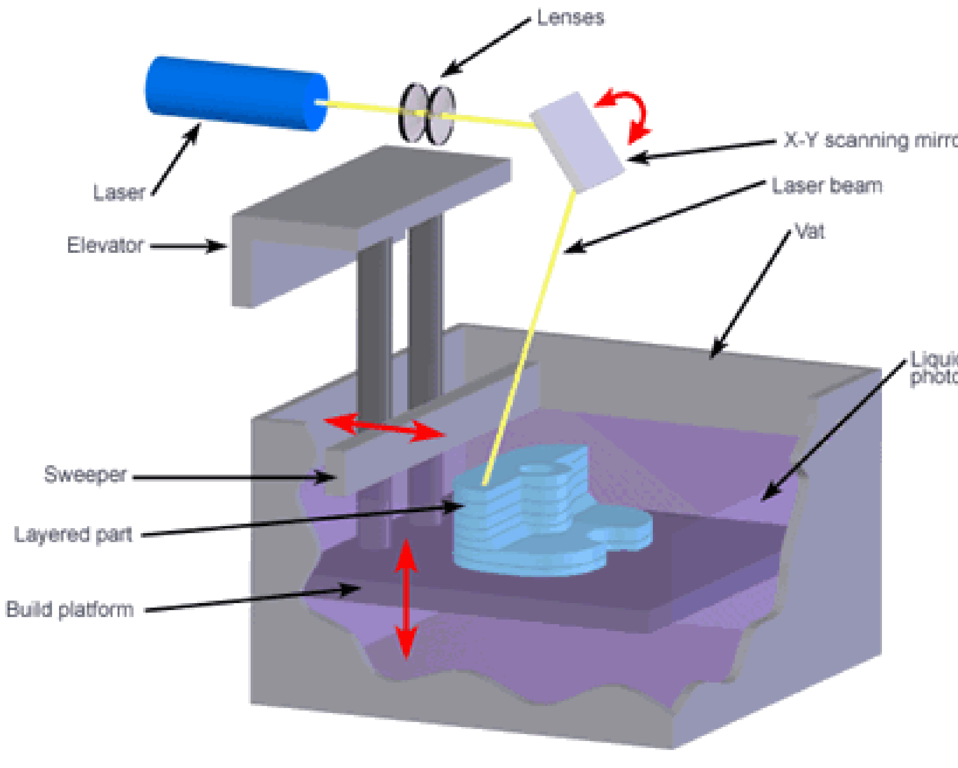
SLA

- Stereolithography (SLA) is the most widely used rapid prototyping technology. It can produce highly accurate and detailed polymer parts. It was the first rapid prototyping process, introduced in 1988 by 3D Systems, Inc., based on work by inventor Charles Hull.





SLA



Copyright © 2008 CustomPartNet

Material type:	Liquid (Photopolymer)
Materials:	Thermoplastics (Elastomers)
Max part size:	59.00 x 29.50 x 19.70 in.
Min feature size:	0.004 in.
Min layer thickness:	0.0010 in.
Tolerance:	0.0050 in.
Surface finish:	Smooth
Build speed:	Average
Applications:	Form/fit testing, Functional testing, Rapid tooling patterns, Snap fits, Very detailed parts, Presentation models, High heat applications

SLA

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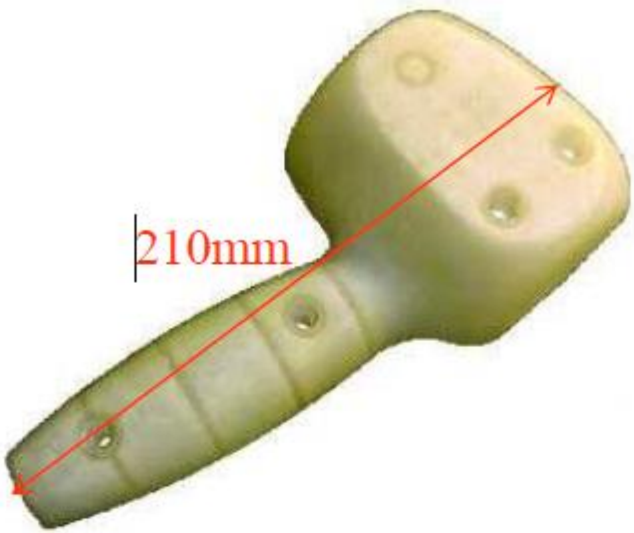
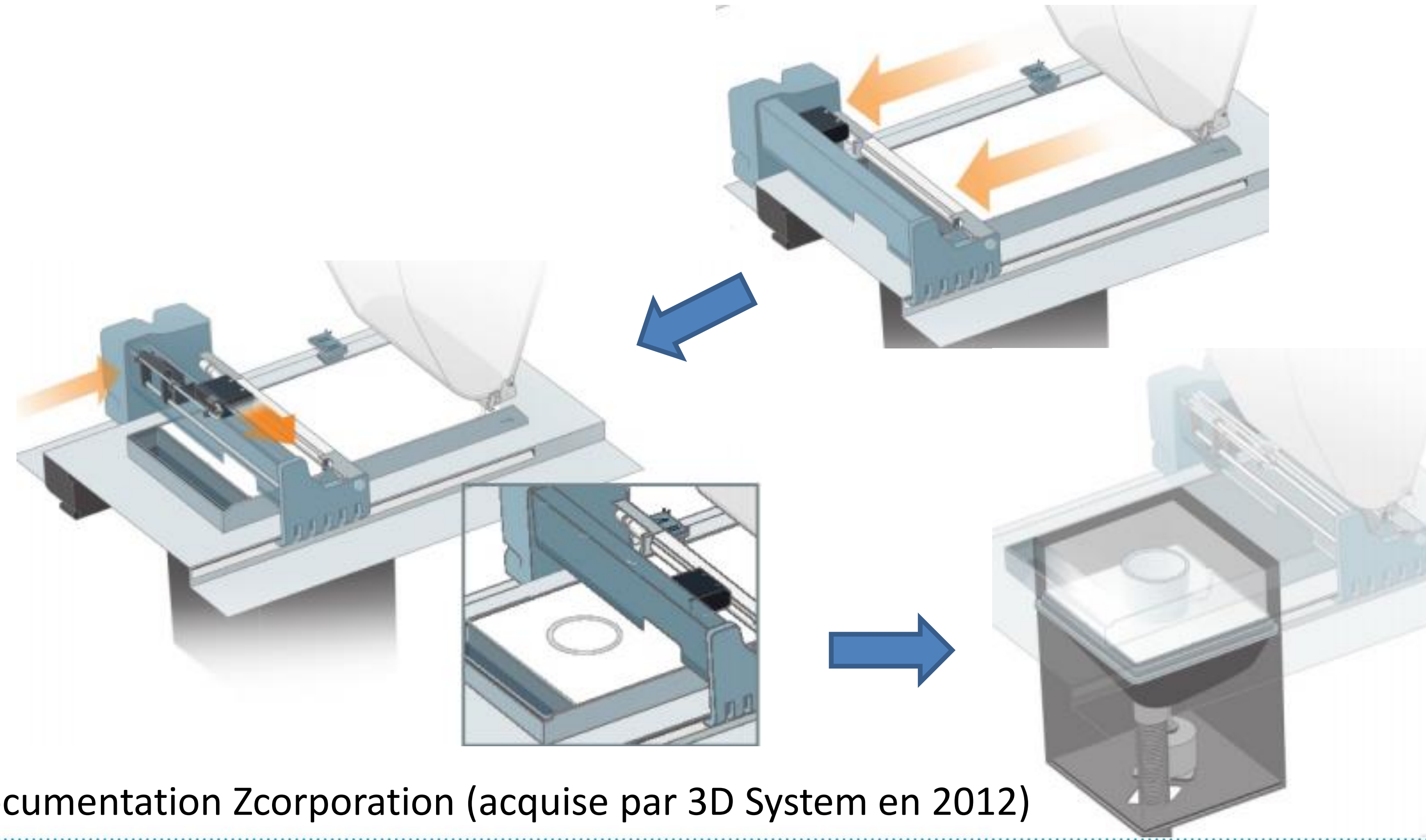


Inkjet Powder



Documentation Zcorporation (acquise par 3D System en 2012)

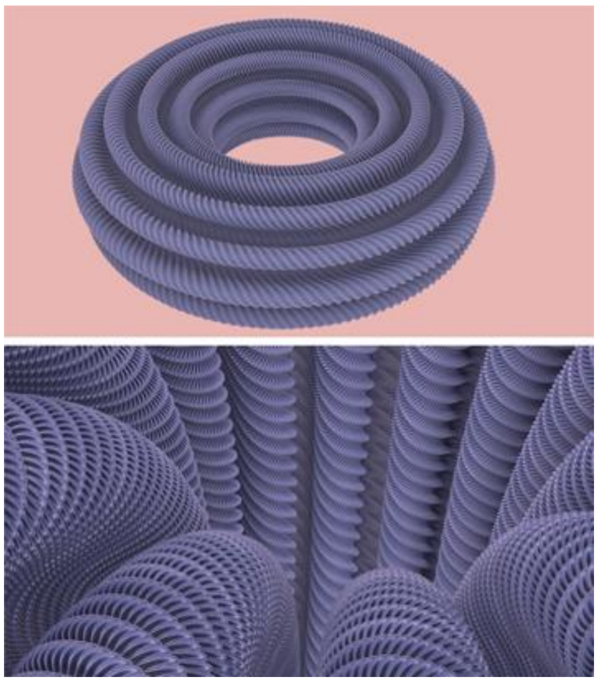
Inkjet Powder

• Tore plat

[lazarus –thibert]

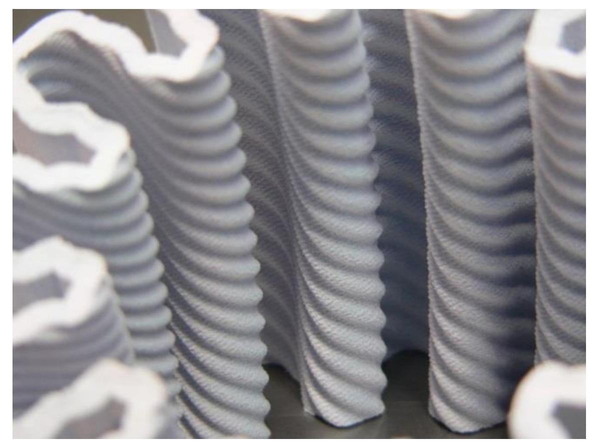
3 niveaux de corrugations:

VRML 32M de triangles, 16M de points, 0.6GBytes



Images de synthèse
5 niveaux de corrugation

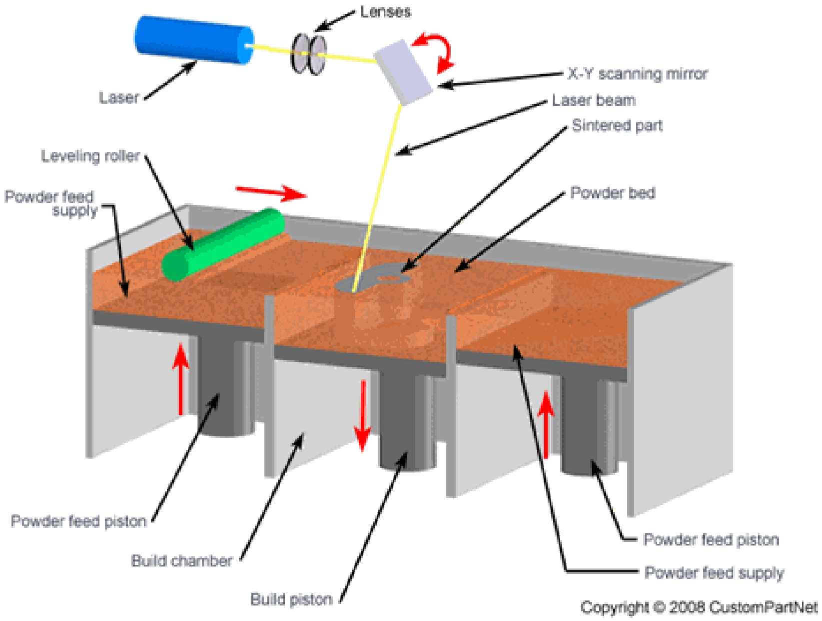
Zprinter Powder inkjet
Task : hollow part, fix model, adapt model precision



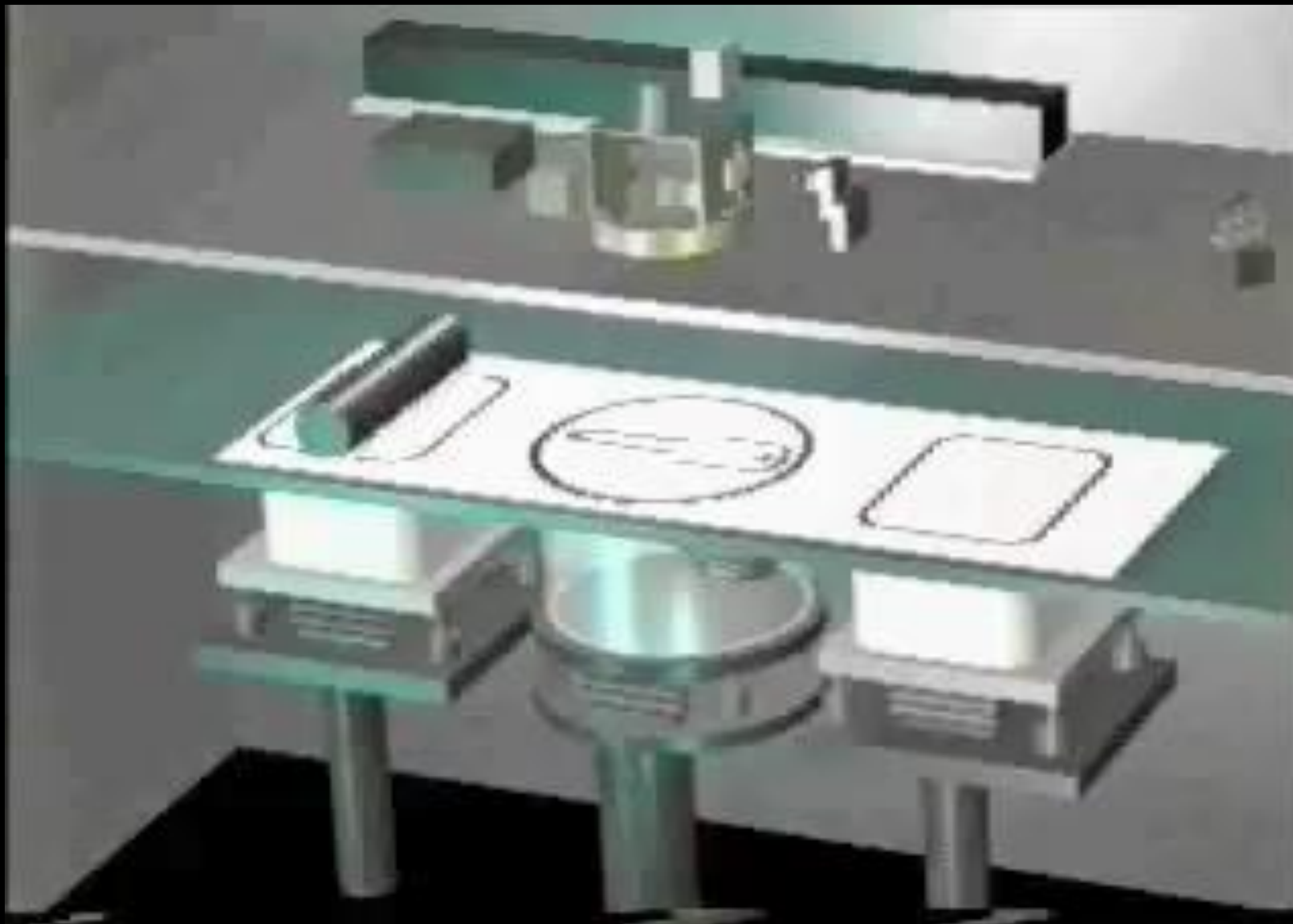
Method for 3D printing of highly complex geometries
The first “flat torus” printed in 3D – Henocque Ingegraph2013

SLS

- **Selective Laser Sintering (SLS) was developed at the University of Texas in Austin, by Carl Deckard and colleagues. The technology was patented in 1989 and was originally sold by DTM Corporation. DTM was acquired by 3D Systems in 2001.**

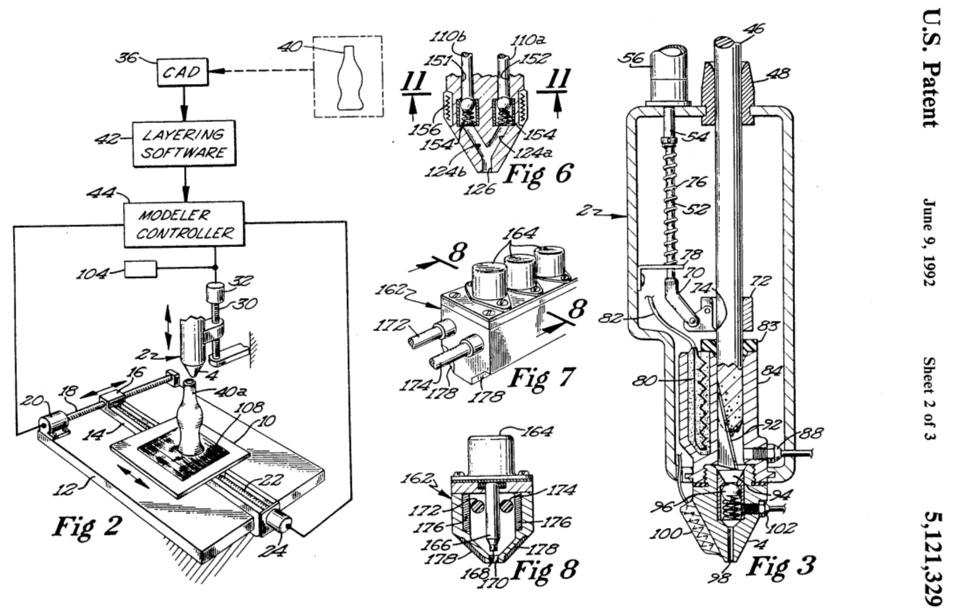


Material type:	Powder (Polymer)
Materials:	Thermoplastics such as Nylon, Polyamide, and Polystyrene; Elastomers; Composites
Max part size:	22.00 x 22.00 x 30.00 in.
Min feature size:	0.005 in.
Min layer thickness:	0.0040 in.
Tolerance:	0.0100 in.
Surface finish:	Average
Build speed:	Fast
Applications:	Form/fit testing, Functional testing, Rapid tooling patterns, Less detailed parts, Parts with snap-fits & living hinges, High heat applications

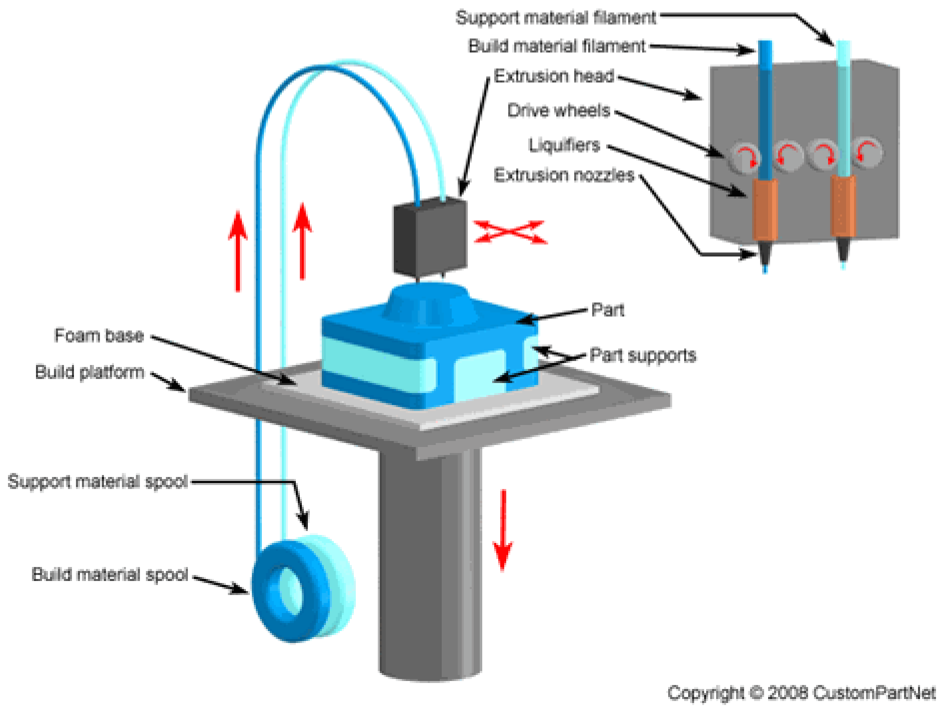


FDM

- Fused Deposition Modeling (FDM) was developed by Stratasys in Eden Prairie, Minnesota. In this process, a plastic or wax material is extruded through a nozzle that traces the part's cross sectional geometry layer by layer.



FDM

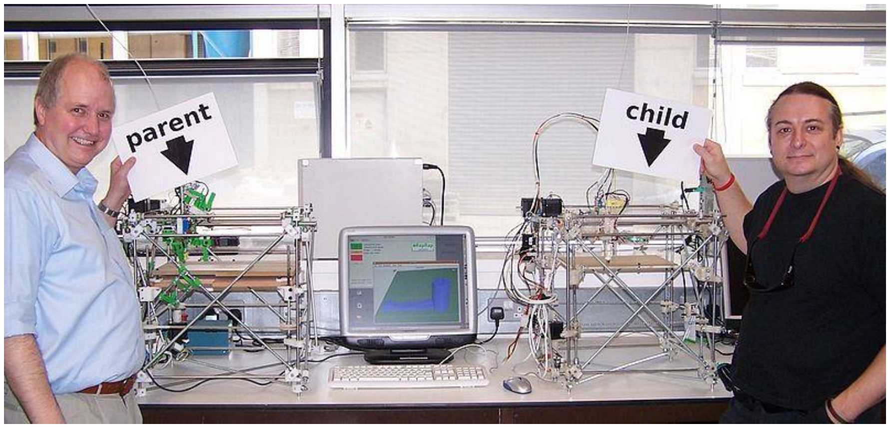


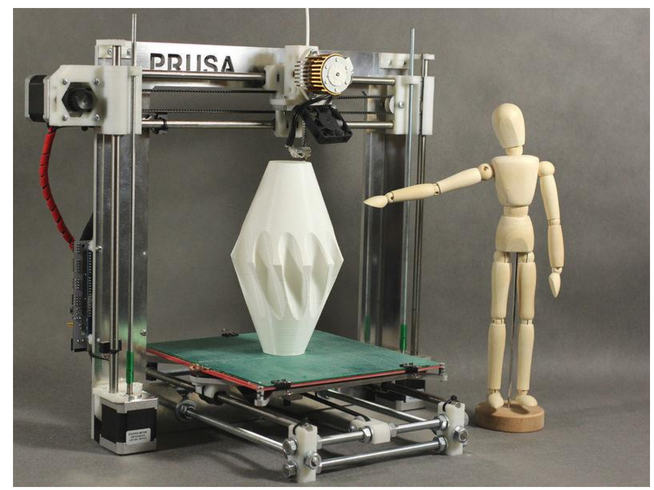
Material type:	Solid (Filaments)
Materials:	Thermoplastics such as ABS, Polycarbonate, and Polyphenylsulfone; Elastomers
Max part size:	36.00 x 24.00 x 36.00 in.
Min feature size:	0.005 in.
Min layer thickness:	0.0050 in.
Tolerance:	0.0050 in.
Surface finish:	Rough
Build speed:	Slow
Applications:	Form/fit testing, Functional testing, Rapid tooling patterns, Small detailed parts, Presentation models, Patient and food applications, High heat applications

3D Printing Stratasys

Les technologies OpenSources réplicantes

- **RepRap**





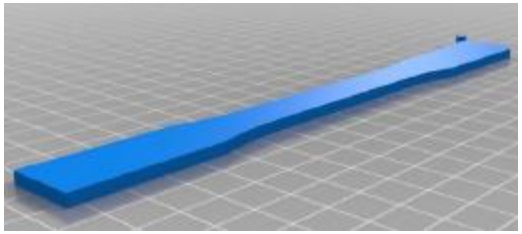
- Début du projet RepRap en 2005 à l’université de Bath: Adrian Bowyer
- Travaux sur l’openSource des Produits
- Notion de Réplication
- Projet Communautaire -> reprap.org

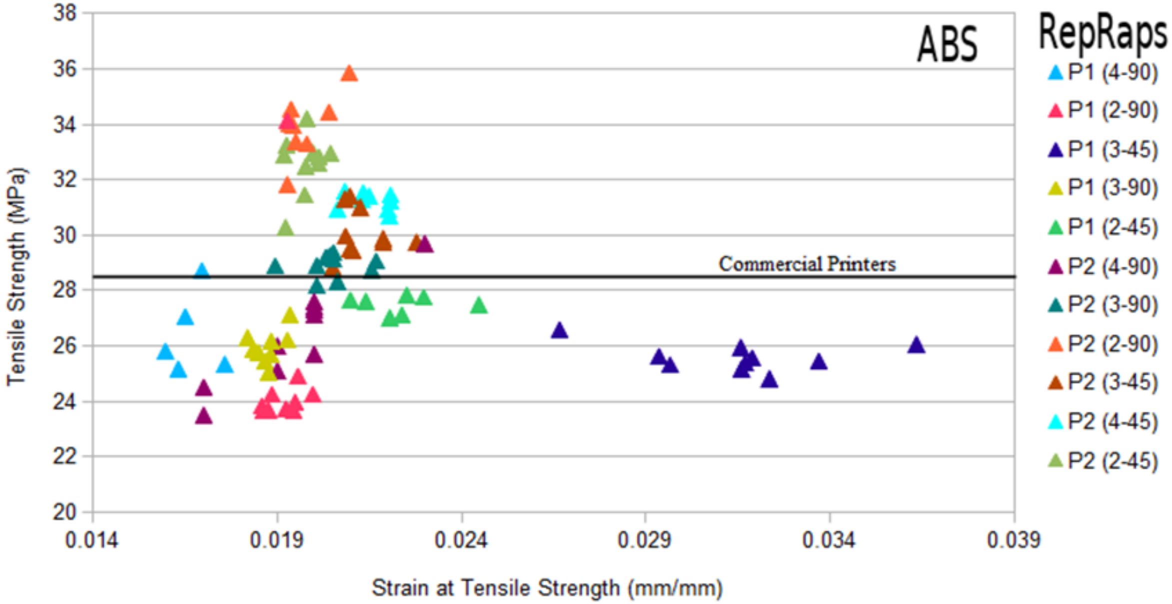
Les imprimantes 3D

Low Cost, High Quality

Table 2
Printers used for specimen printing.

Number	Type	Filament
Printer 1	MOST RepRap	Natural ABS, Clear PLA
Printer 2	Lulzbot Prusa Mendel RepRap	Natural ABS, Purple PLA, White PLA
Printer 3	Prusa Mendel RepRap	Black PLA
Printer 4	Original Mendel RepRap	Natural PLA

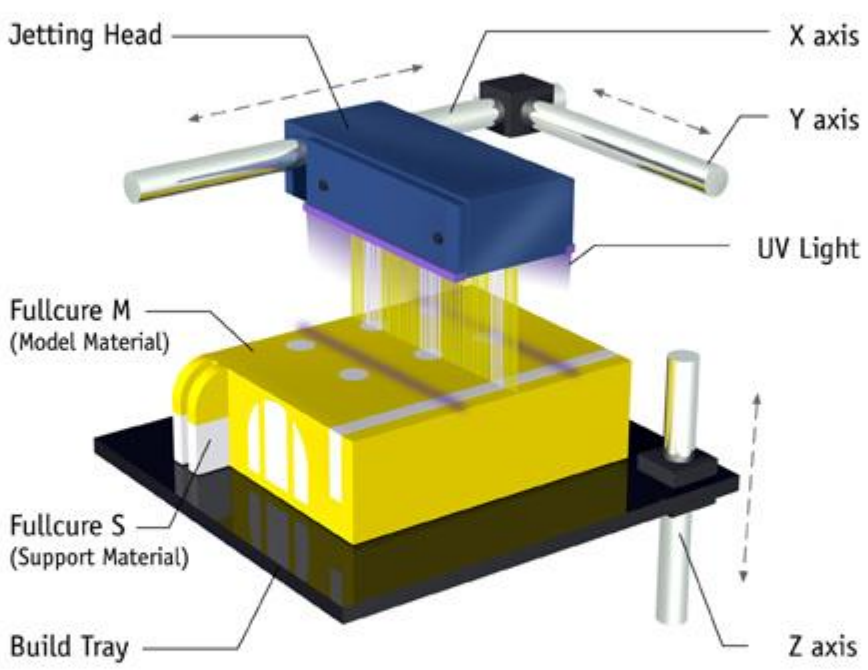




Mechanical Properties of components Fabricated with Open-Source 3-D Printers
Under Realistic Environnement Conditions : B.M. Tymrak, M. Kreiger and J.M. Pearce

PolyJet

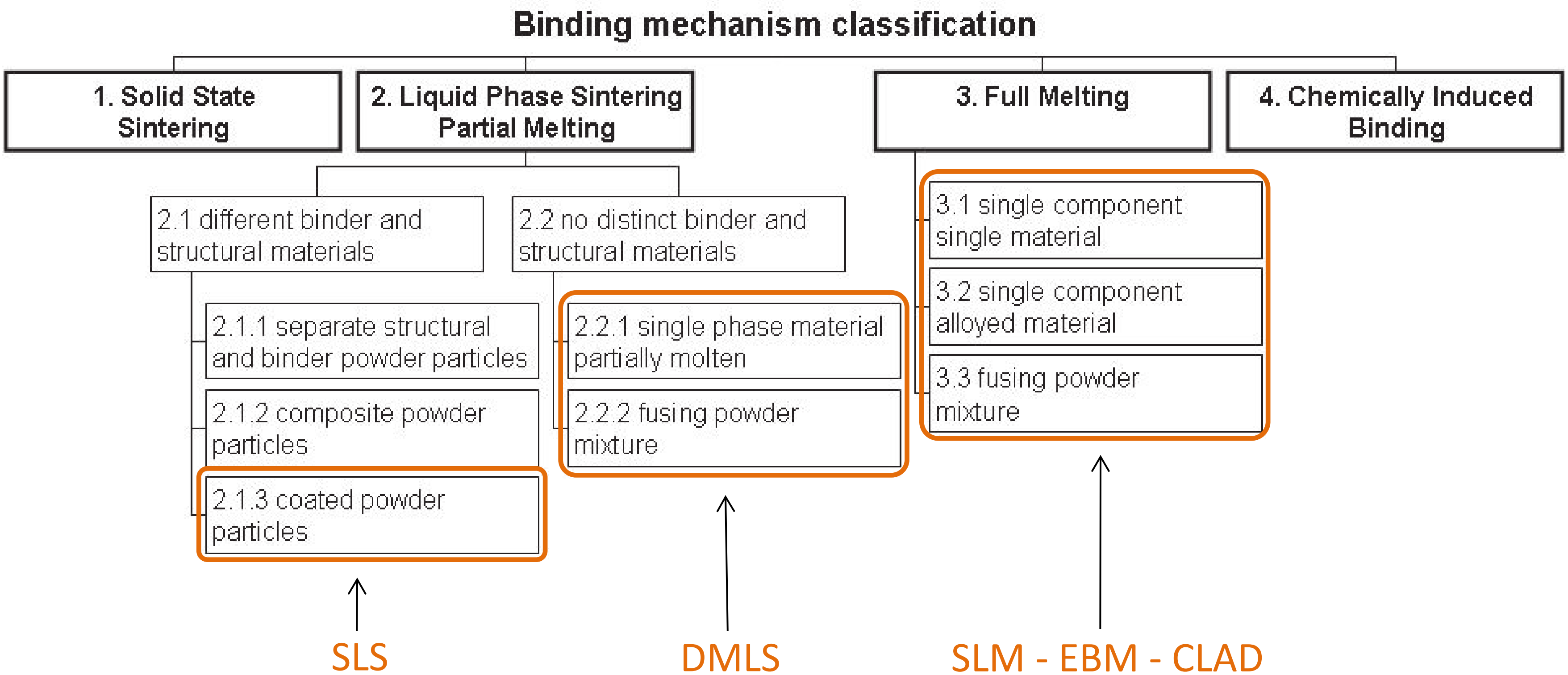
- **Polyjet was developed by Objet Ltd in 1999 (fusion stratasys 2012)**



The Objet PolyJet Process

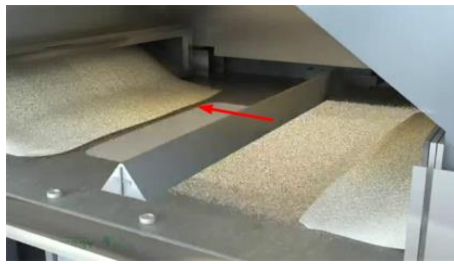
Is an additive fabrication process that produces models using photopolymer jetting

Metallic particles biding mechanism

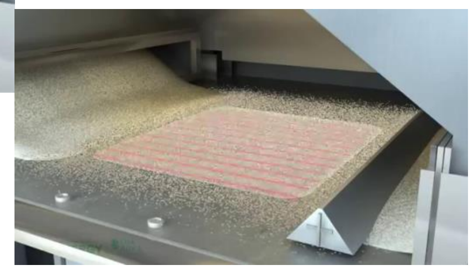


Layer based additive manufacturing

The building tray is moved down



Deposition of a layer of powder

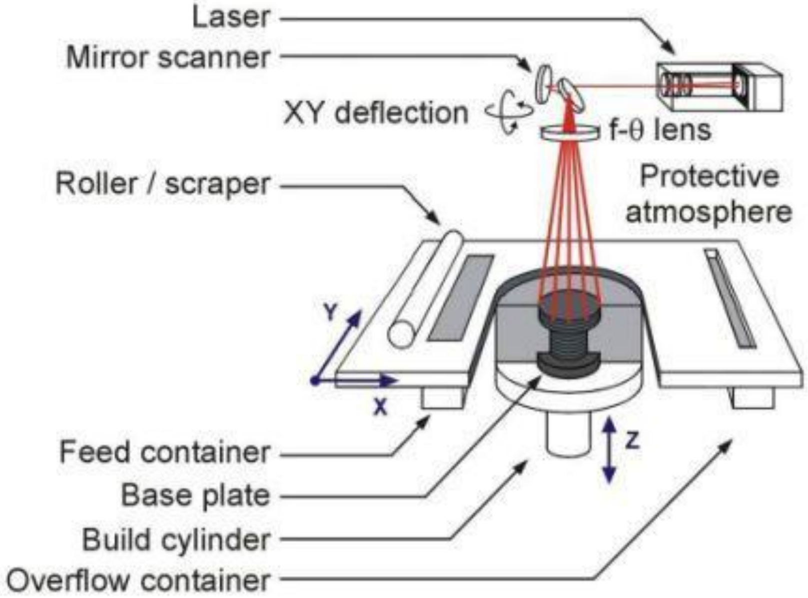


Consolidation of the powder

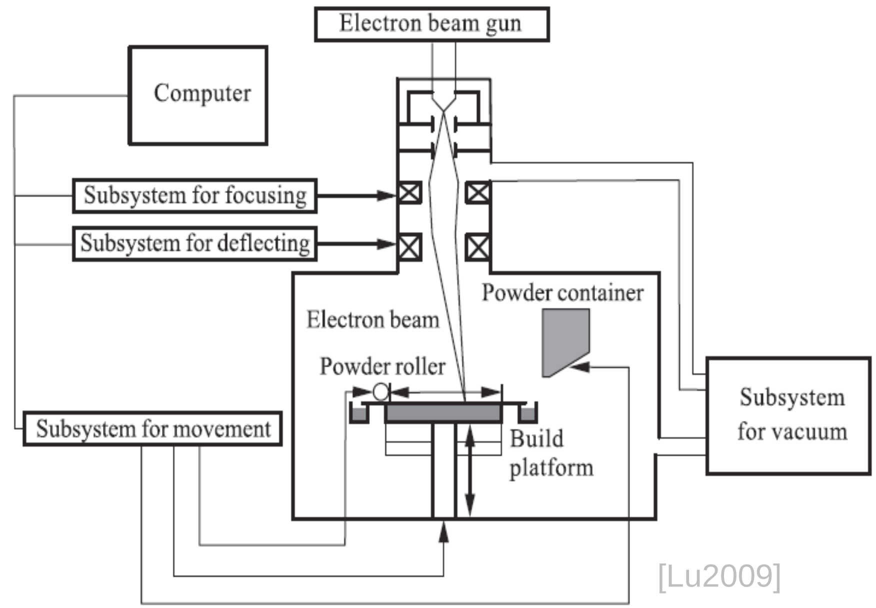
Energy is brought by the Electron beam to melt the particles

Laser vs electron beam

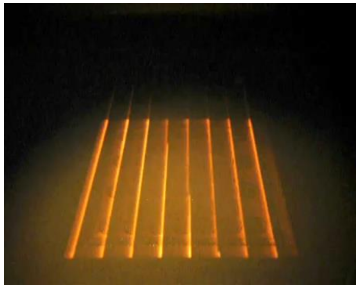
- **Laser beam**
  - Selective Laser Sintering (SLS)
  - Direct Metal Laser Sintering (DMLS)
  - Selective Laser Melting (SLM)



- **Electron beam**
  - Electron Beam Melting (EBM)



[Lu2009]



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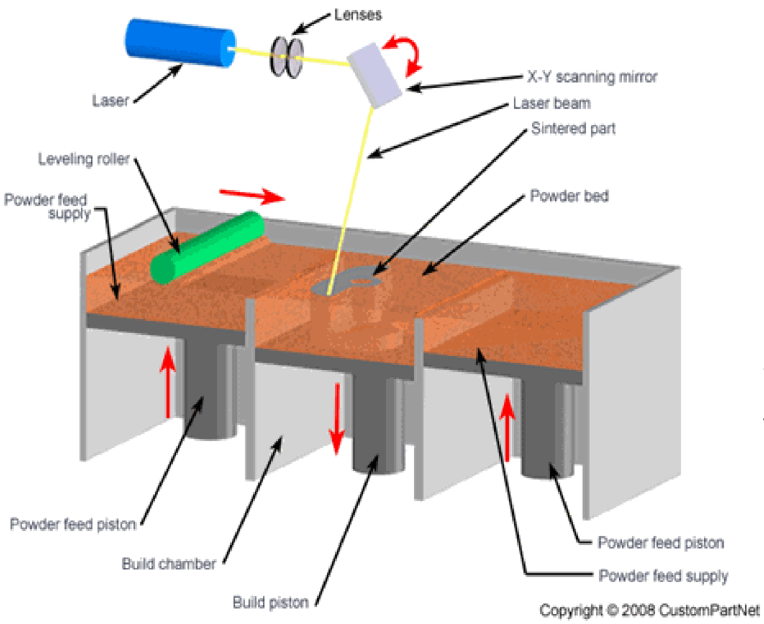
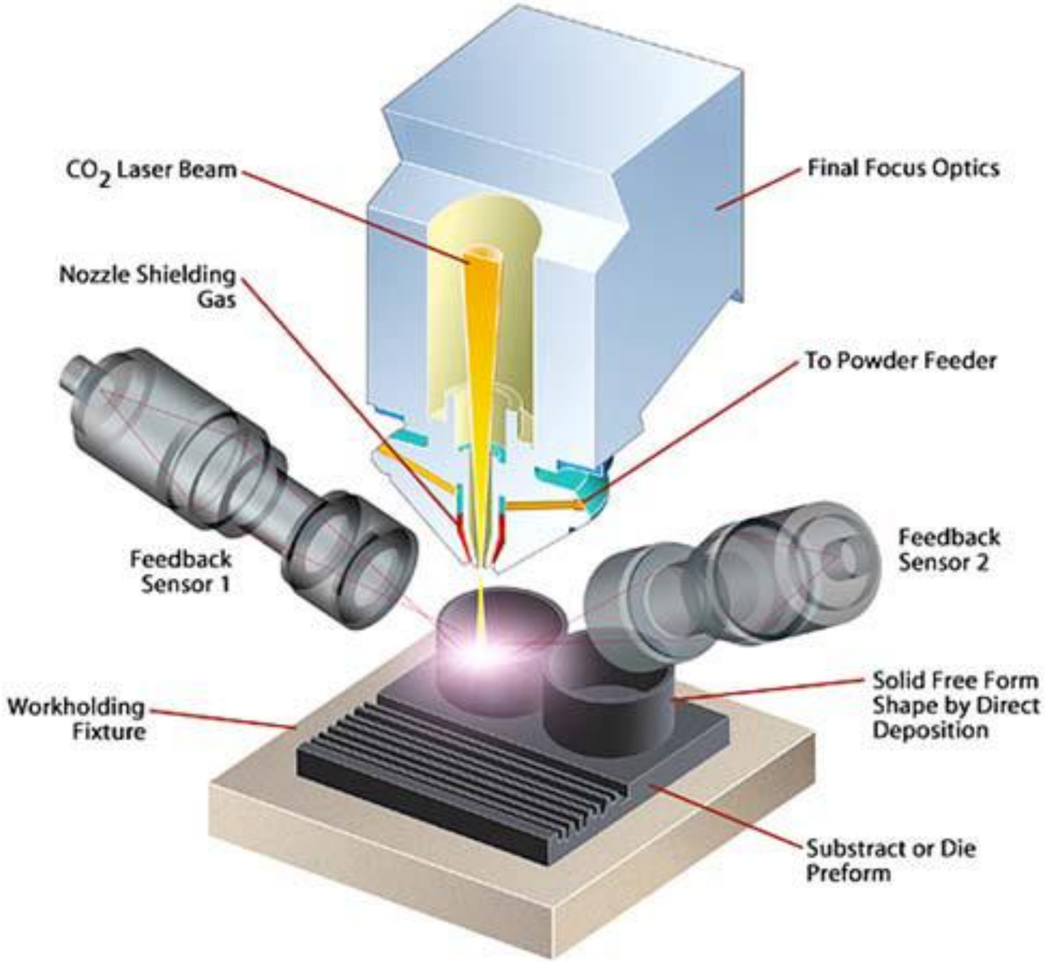
DMLS

- Direct Metal Laser Sintering (DMLS) was developed jointly by Rapid Product Innovations (RPI) and EOS GmbH, starting in 1994, as the first commercial rapid prototyping method to produce metal parts in a single process.
- With DMLS, metal powder (20 micron diameter), free of binder or fluxing agent, is completely melted by the scanning of a high power laser beam to build the part with properties of the original material.



Material type:	Powder (Metal)
Materials:	Ferrous metals such as Steel alloys, Stainless steel, Tool steel; Non-ferrous metals such as Aluminum, Bronze, Cobalt-chrome, Titanium; Ceramics
Max part size:	10.00 x 10.00 x 8.70 in.
Min feature size:	0.005 in.
Min layer thickness:	0.0010 in.
Tolerance:	0.0100 in.
Surface finish:	Average
Build speed:	Fast
Applications:	Form/fit testing, Functional testing, Rapid tooling, High heat applications, Medical implants, Aerospace parts

Direct metal deposition



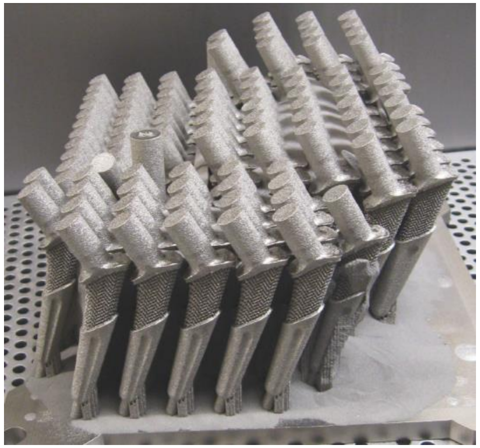
Hybride – DMG MORI-SEIKI

Industrial application

- **Medical industry**

hip endoprosthesis made of TA6V on EBM machine
[Enztec]

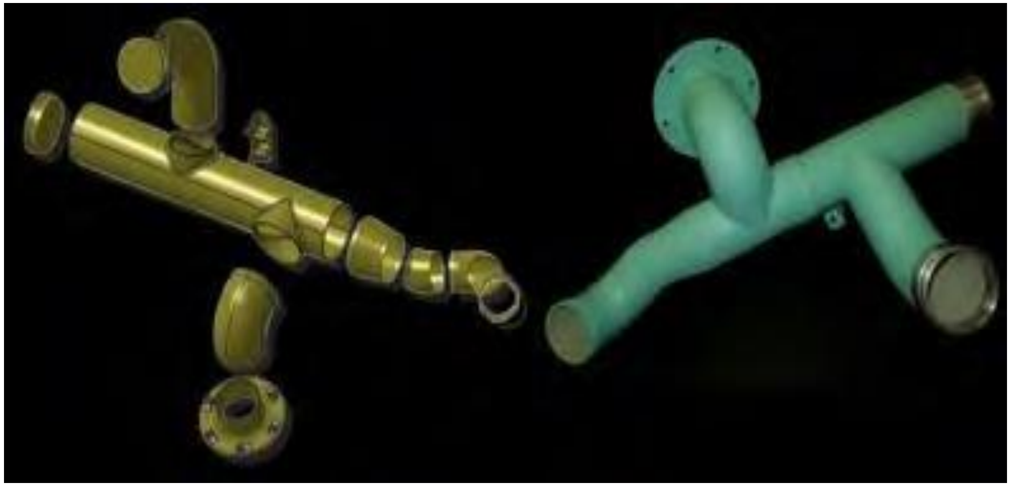
dental prostheses
SLM
[Concept Laser]



Additive manufacturing- the futur of production – AMT association manufactring technology

Industrial Application

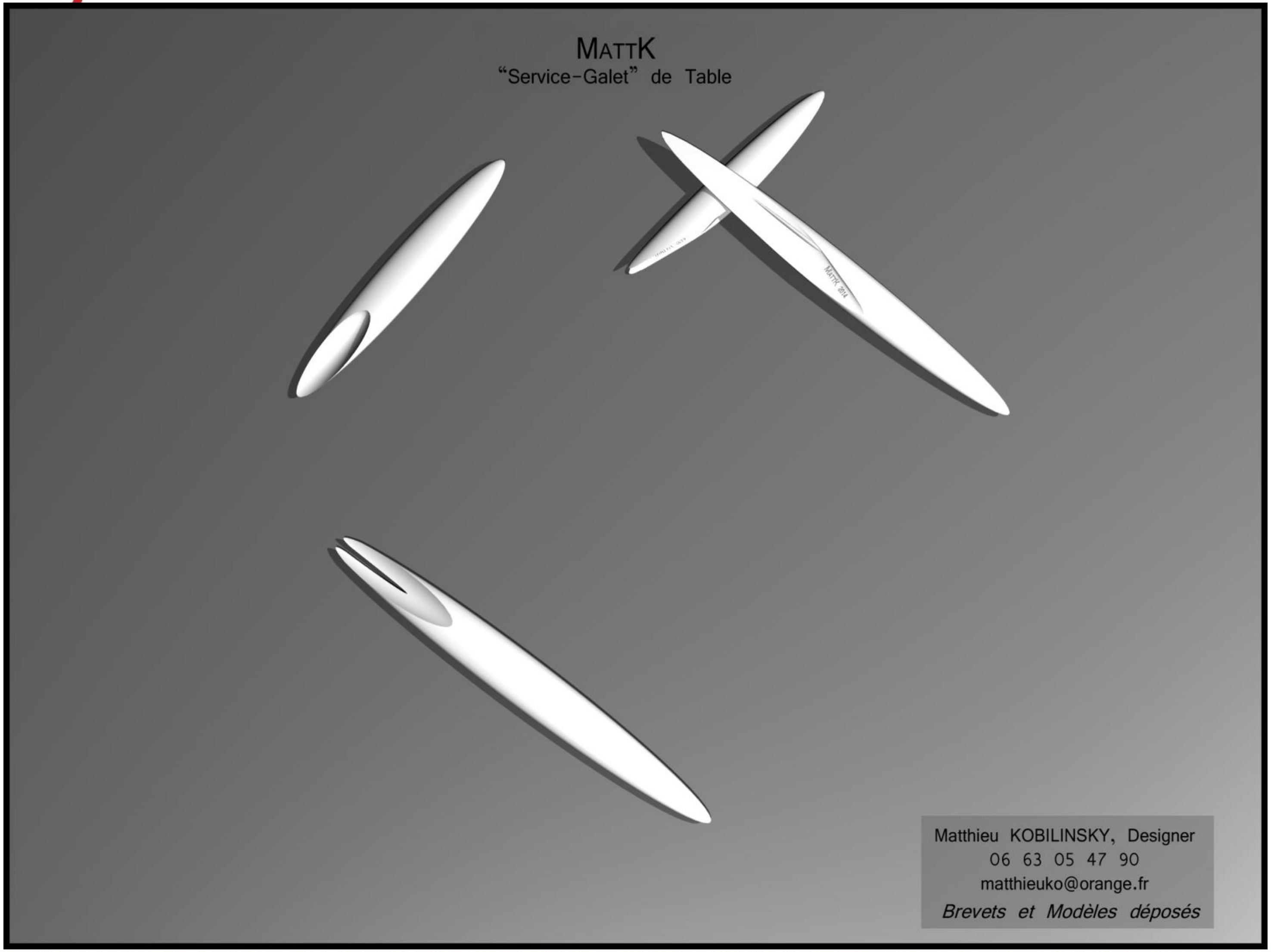
- **Airplane Industry**



Pipe
[Northrop Grumman]

air duct
[IRRCyN – IREPA Laser]

Designer


MATTK
"Service-Galet" de Table
Matthieu KOBILINSKY, Designer
06 63 05 47 90
matthieuko@orange.fr
Brevets et Modèles déposés

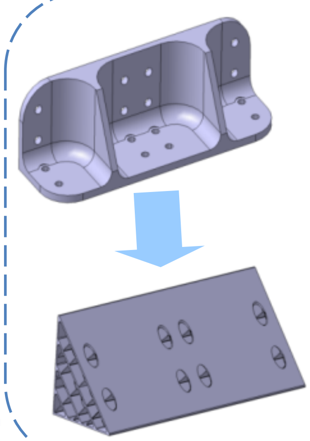
Who is working

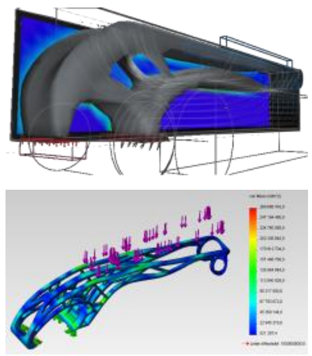
Financed by

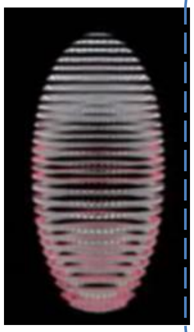
Research by

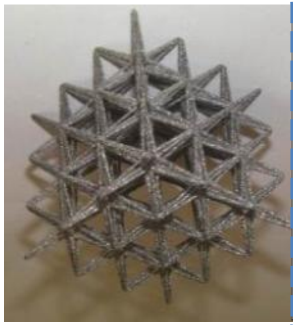
Laboratories of

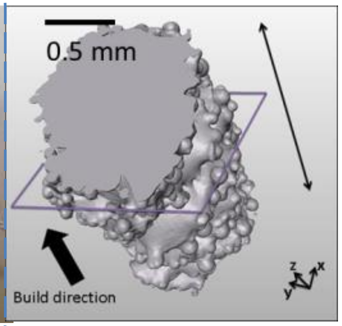
An integrated platform: from design to properties

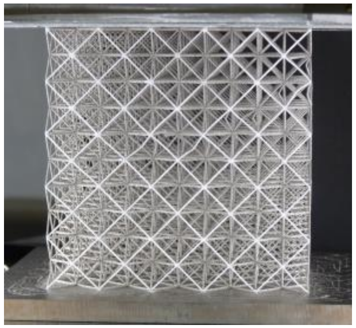




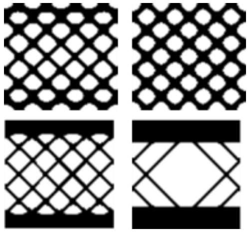








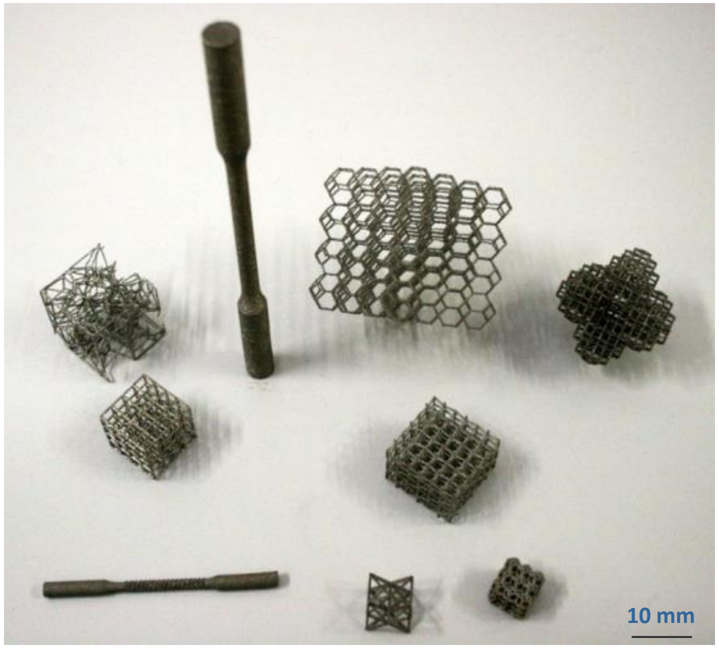
1. Design and shape optimisation (including topological optimisation)
2. CAD/CAM for additive manufacturing
3. EBM process simulation and optimisation
4. 3D characterisation
5. Mechanical testing



Materials issues

- **Micro (or meso) structure**
  - Architectured materials
  - “True” materials by design

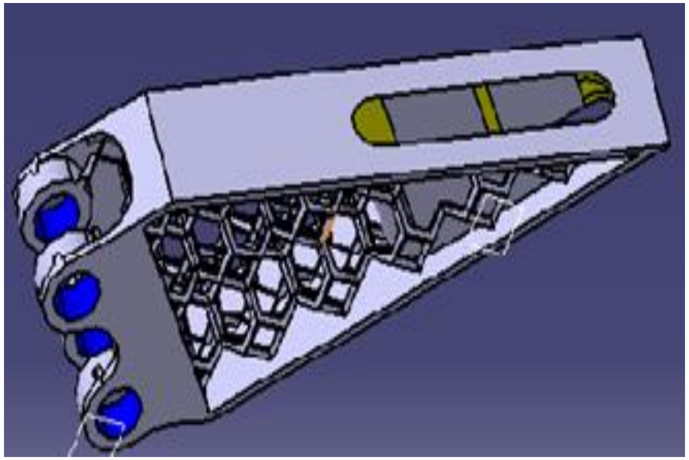
- **Properties**
  - Structural weight saving
  - Thermal properties
  - Multi functionality
  - New properties
  - Local properties



Contacts: remy.dendievel@simap.grenoble-inp.fr
guilhem.martin@simap.grenoble-inp.fr

Design issues

- **Design process**
  - Design requirements
  - Design rules
  - Shape optimisation
  - CAD for additive manufaturing

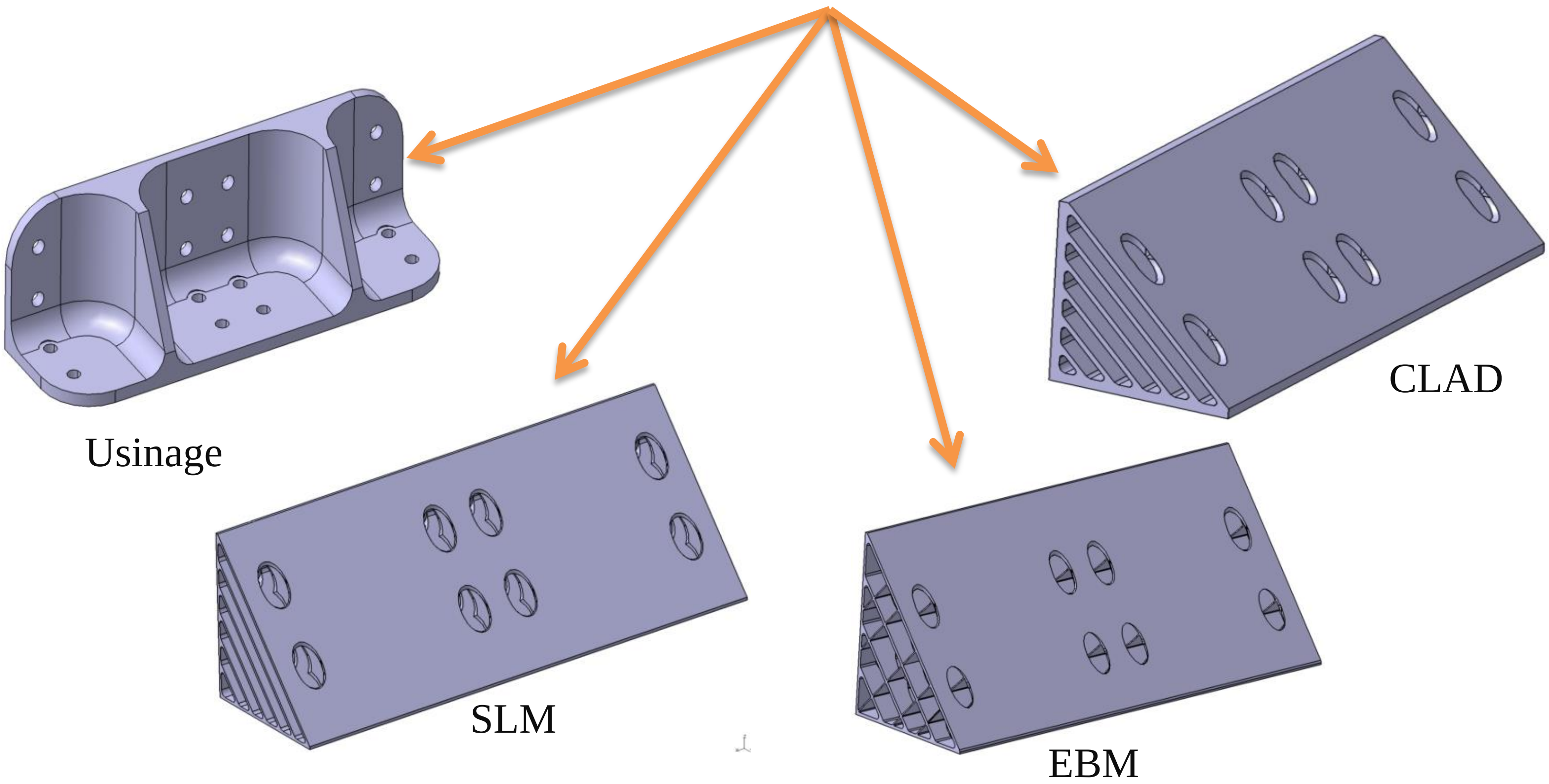


- **Manufacturing preparation**
  - Process simulation and optimisation
  - CAM for additive manufacturing

Contacts: frederic.vignat@grenoble-inp.fr
francois.villeneuve@grenoble-inp.fr

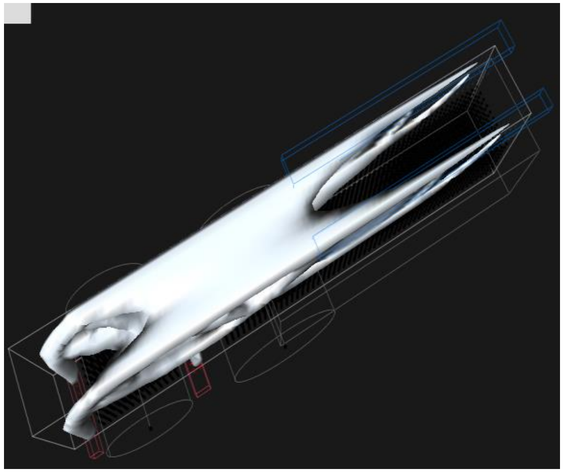
Design for additive manufacturing

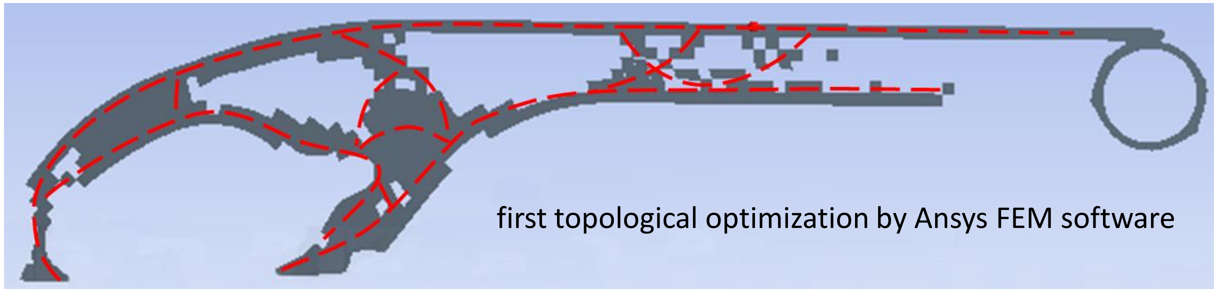
- **Design process for additive manufacturing**



Topological Optimization

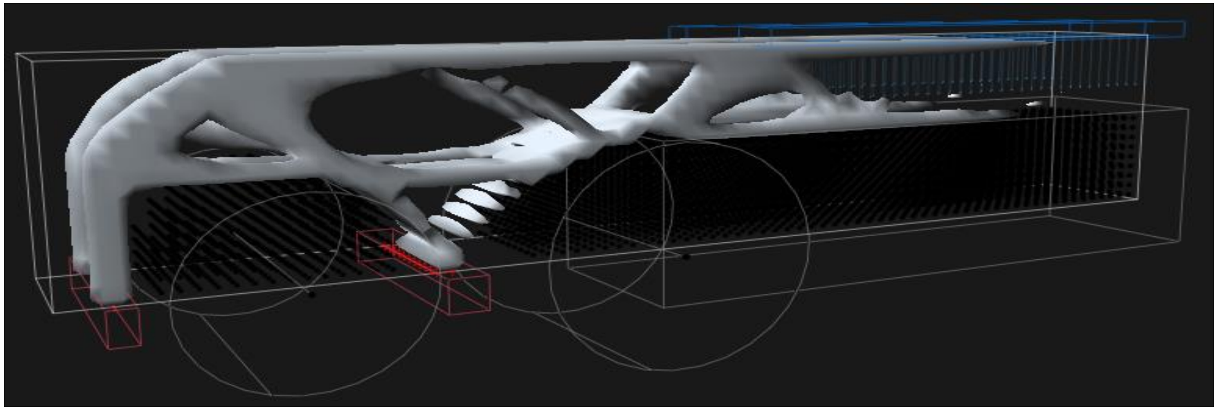
3.46 grams of Titanium alloy (density 4.2) with the logo – 420MPa





first topological optimization by Ansys FEM software

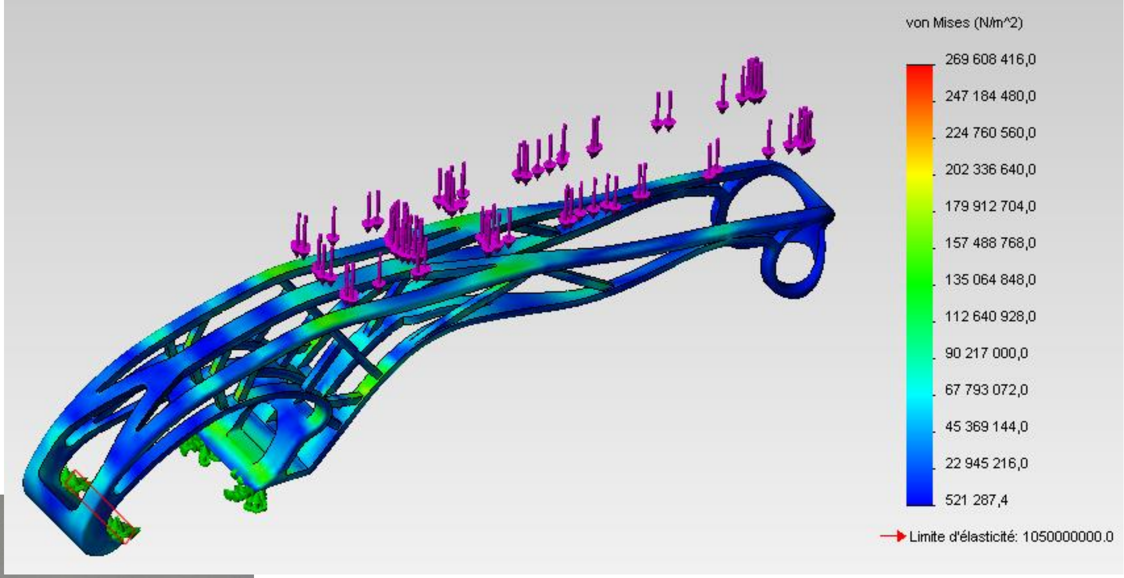
model inspired from Ansys 2D topological optimization results

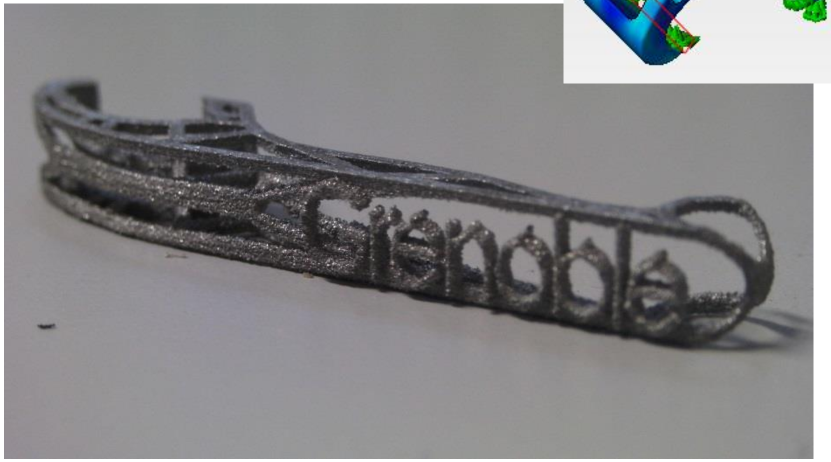


Material distribution in the width of the part - TopoStruc

Topological optimization: Ph Marin – G-Scop

Finite element Calculation

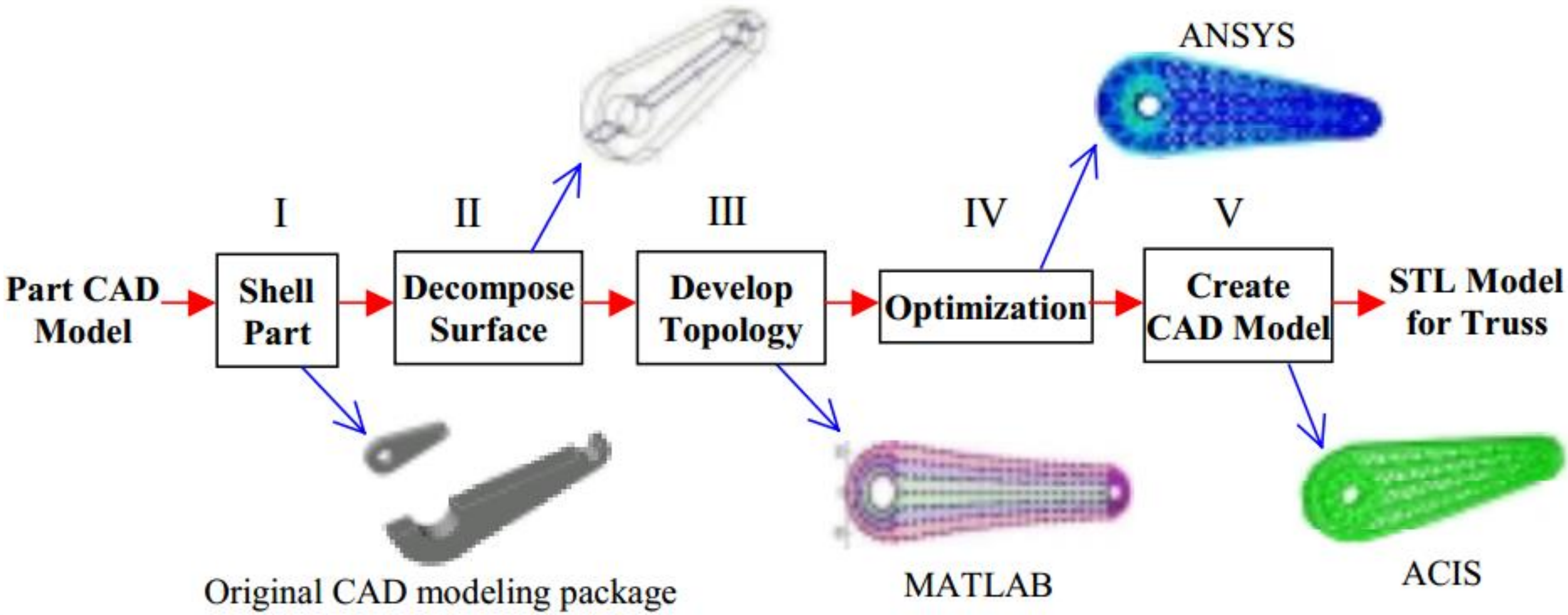




Titanium 2.1g, 270MPa

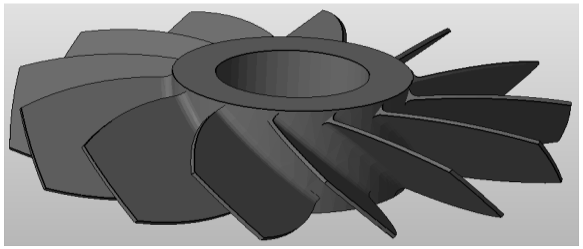
digital chain

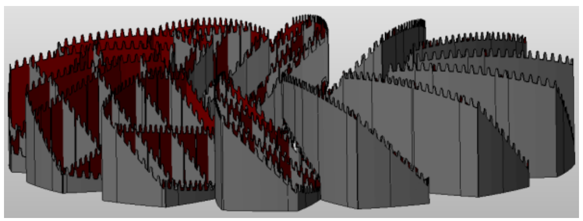
- New digital from CAD to additive manufacturing machine
- Latice structure model in CAD environment
- Simulation of additive manufacturing process

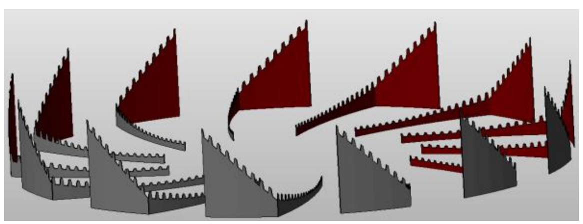


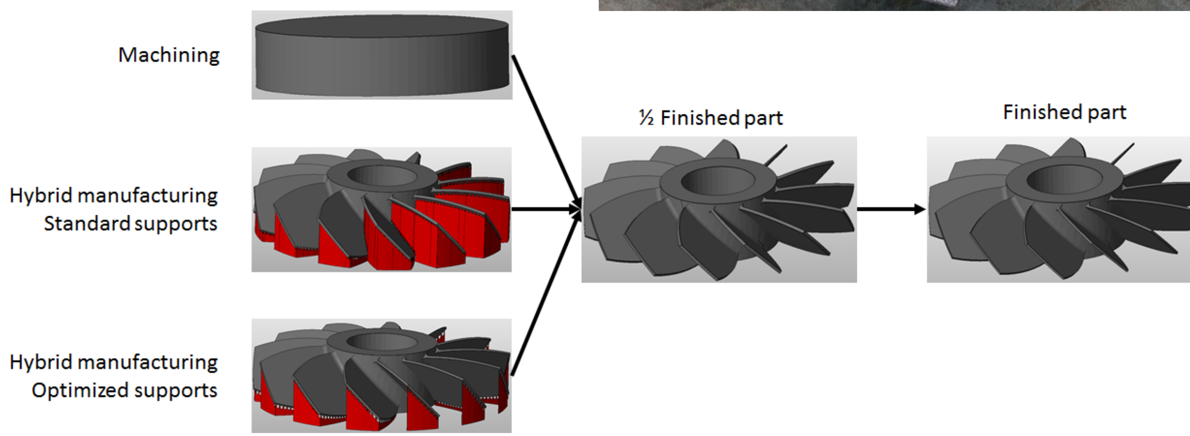
Conclusion

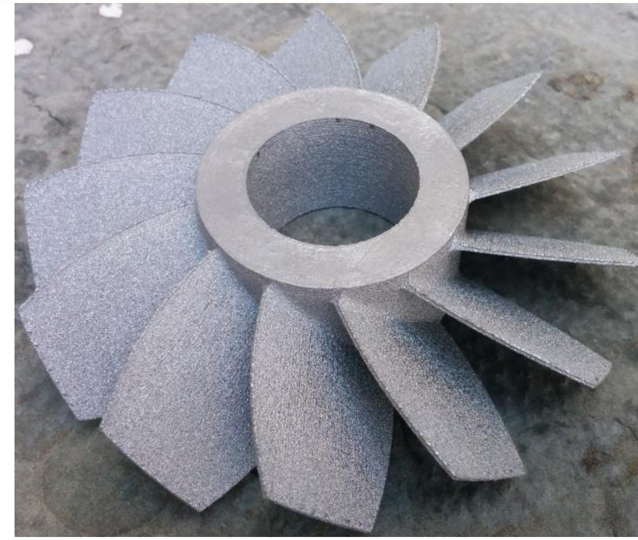
- Additive manufacturing will obviously take a large share of manufacturing processes
- It is a breakthrough in manufacturing technology
- Still a lot of research and development to be conducted to improve:
  - Speed
  - Quality
  - Cost
  - Size of parts
- Obviously an interesting technology from an environment point of view
- Need to be taken into account at design stage for optimal results











Scenario	Energy consumption	Duration	Material consumption
Machining	27 kWh	6h53	352.44 cm^3
Hybrid manufacturing with standard supports	14.55 kWh	4h47	98.95 cm^3
Hybrid manufacturing with optimized supports	14.55 kWh	4h47	81.98 cm^3