ESIPAP European School of Instrumentation in Particle and Astroparticle Physics

Addiditve Manufacturing

Thinking about innovation

Feedback on implementation on Additive Manufacturing Technics
For designing and manufacturing of definitive mechanical parts, since 1995
When could I use additive manufacturing ? Where could we find some informations ? Who could help ?

Enigmass

IPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG
http://www.iphc.cnrs.fr/

CNRS IN2P3 Les deux infinis

www.cnrs.fr
IN2P3
http://institut.in2p3.fr/

Addiditve Manufacturing

Thinking about innovation

http://www.iphc.cnrs.fr/

Summary

1- two complementary approaches
specific contexts

2- main additive manufacturing technics in use
processes, machine manufacturers, partners, …

3- achievement example
geometrical optimization in an IPHC project,
some research and development examples in several domains

4- some 3D printers

5- Outlook

6- workshop - CAD presentation
workshop - topological optimisation / slicing

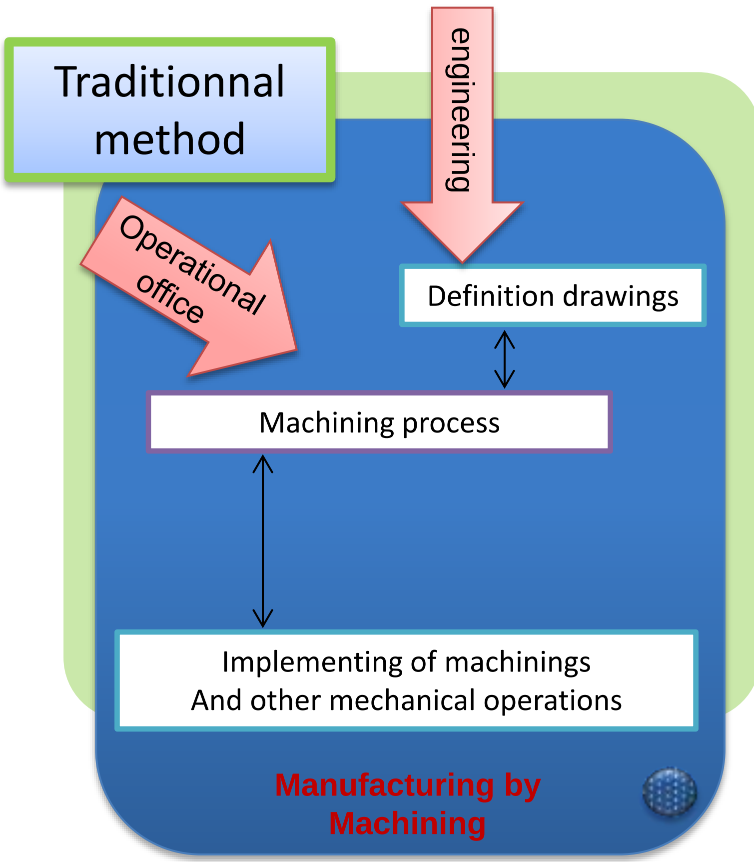
7- Conclusion

Annex : complementary informations

1- two complementary aproaches

specific contexts

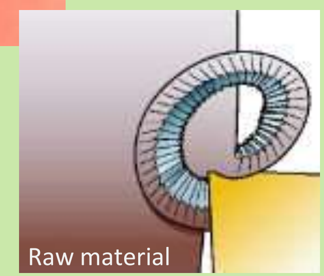
1- two complementary approaches



Machining
Metal cutting

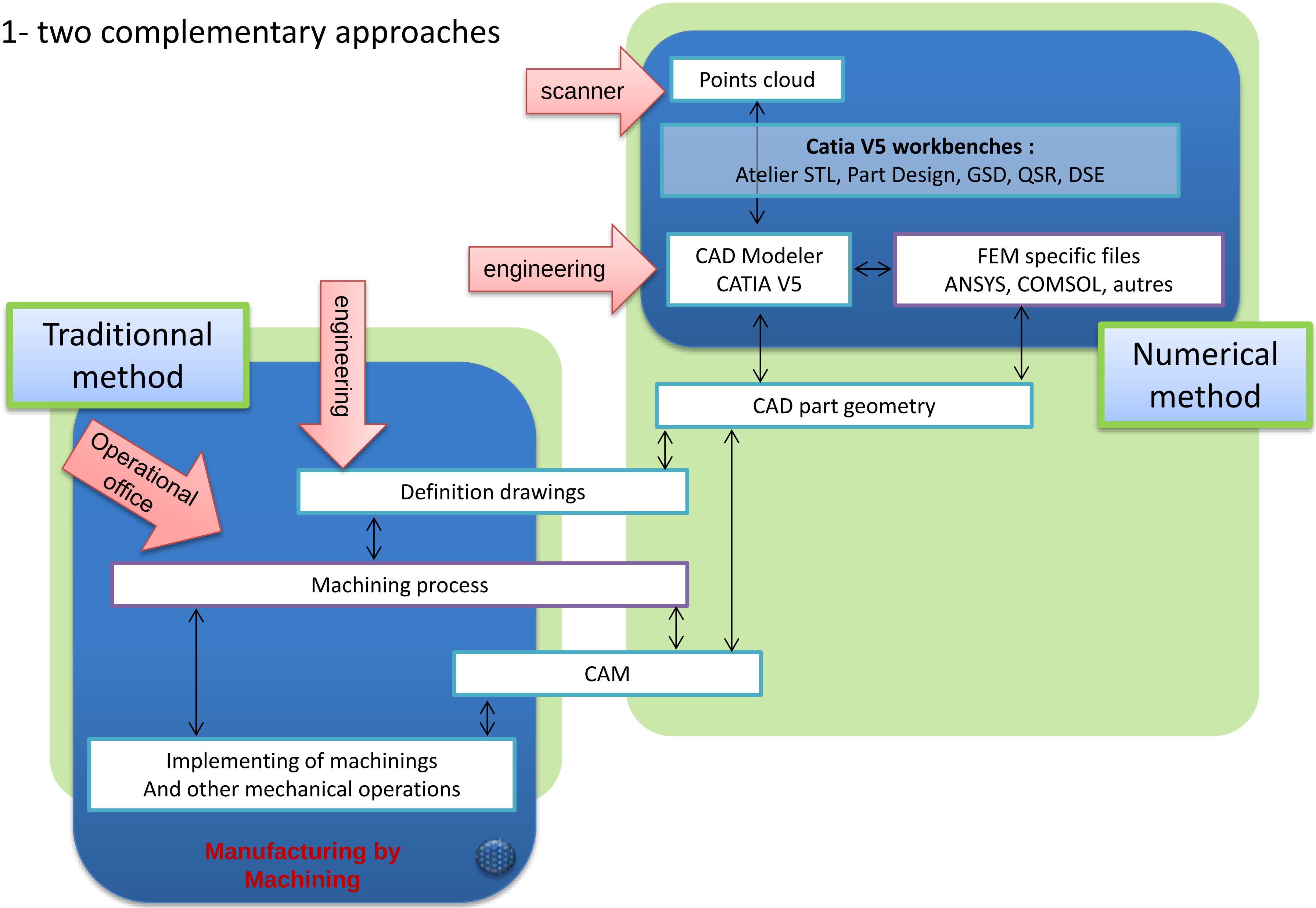
Metal chip

elasticity,
plasticity
rupture,
Strain,
stress



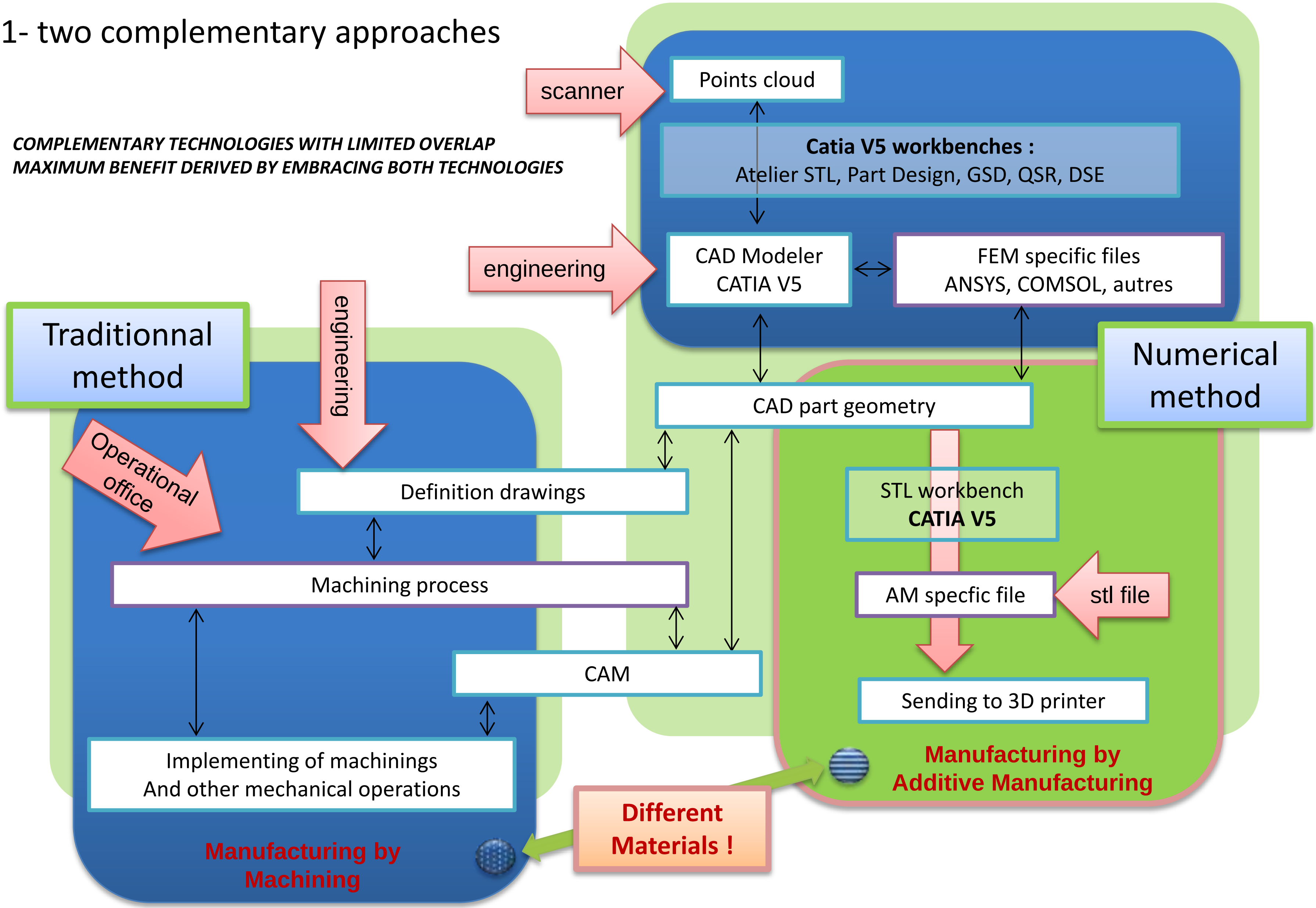
Source : http://www.sandvik.coromant.com/

1- two complementary approaches

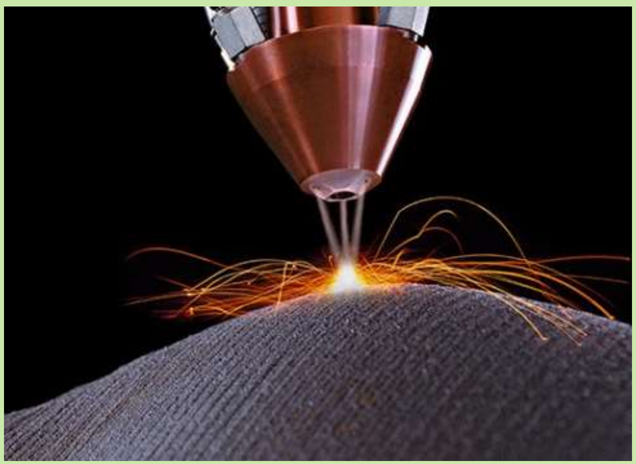


1- two complementary approaches

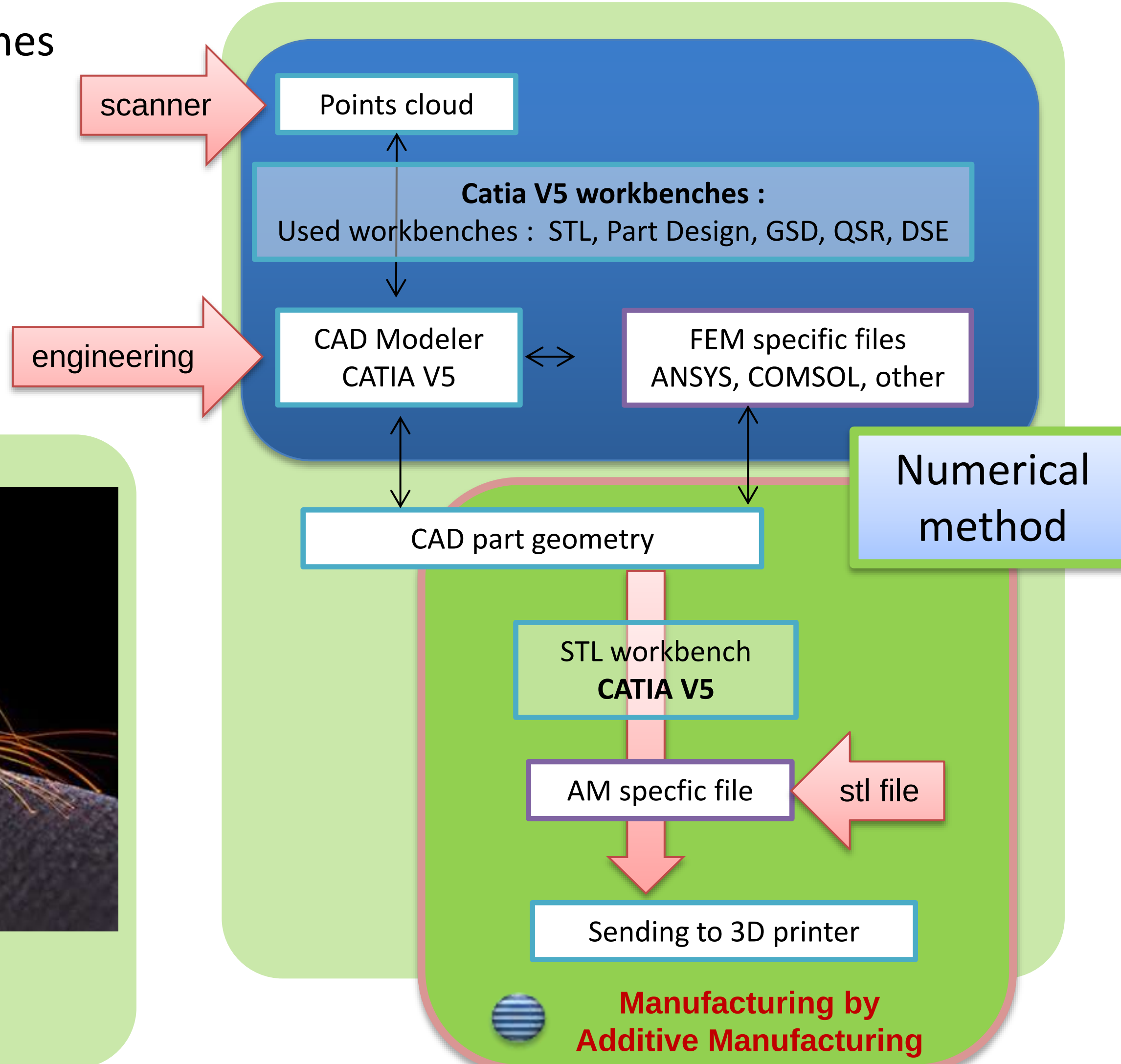
COMPLEMENTARY TECHNOLOGIES WITH LIMITED OVERLAP
MAXIMUM BENEFIT DERIVED BY EMBRACING BOTH TECHNOLOGIES



1- two complementary approaches



Metal powder and laser…
Direct manufacturing



less material waste
create products that is impossible to make with existing machining techniques.

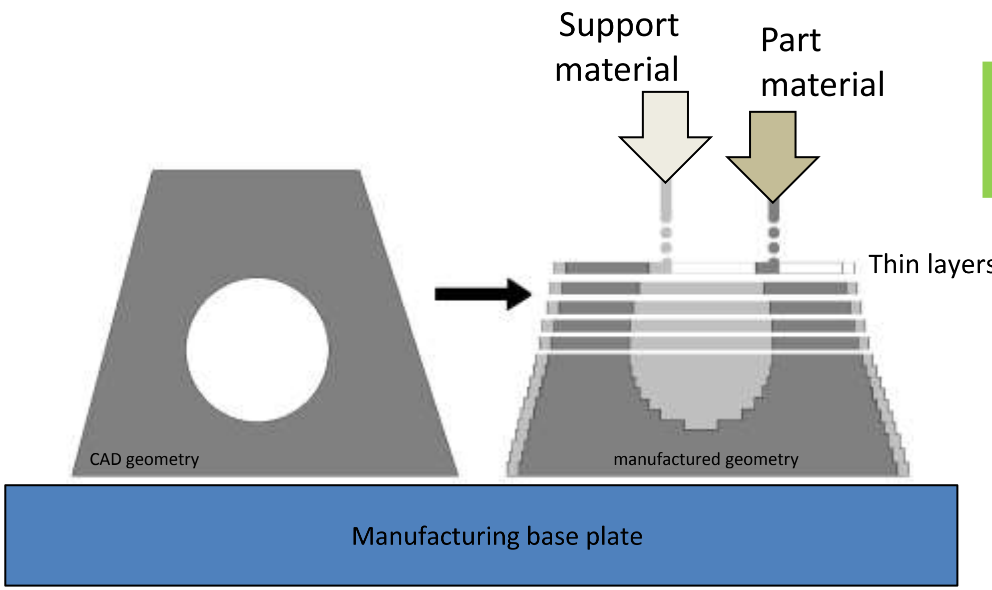
1- two complementary approaches : numerical method

Base principle

Additive Manufacturing (AM) is defined by ASTM norm under the name ‘Fast Manufacturing’

‘3D printing’ is the common name to describe all the process which use AM.

Invention of stereolithography begins in 1980’s, in a chemical school in Nancy (France).
Industrialisation begins in 1986 in USA by 3D Systems society.

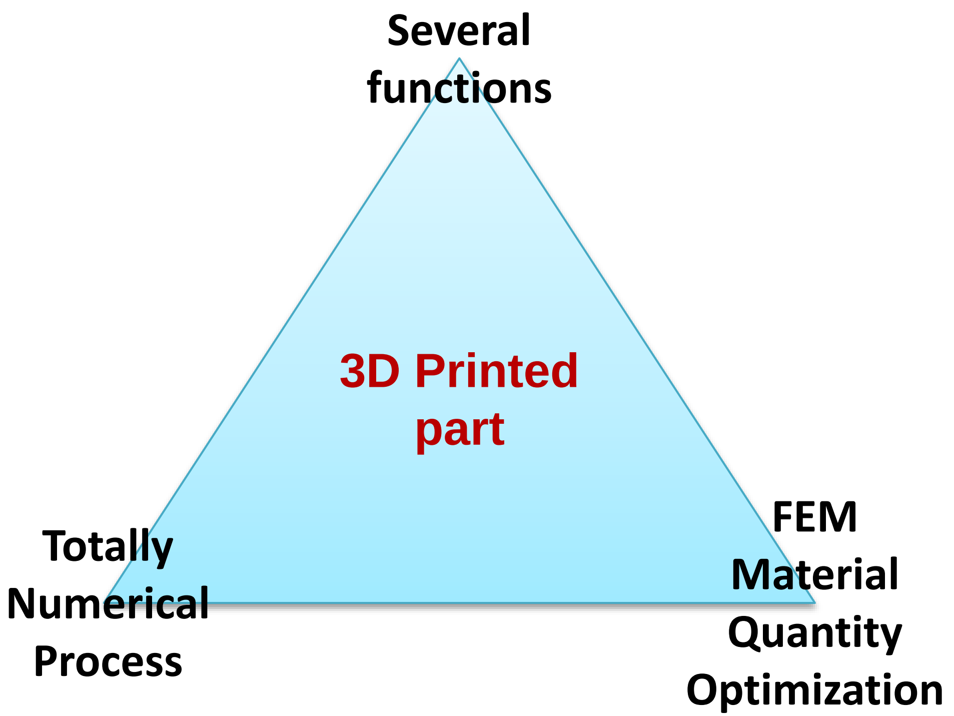


Aim : to stack layer upon layer

Material of support : specific resin or fine mechanical structure
needed by supporting part during manufacturing process
Material of part (anisotropical material) : plastic, metallic ou composite

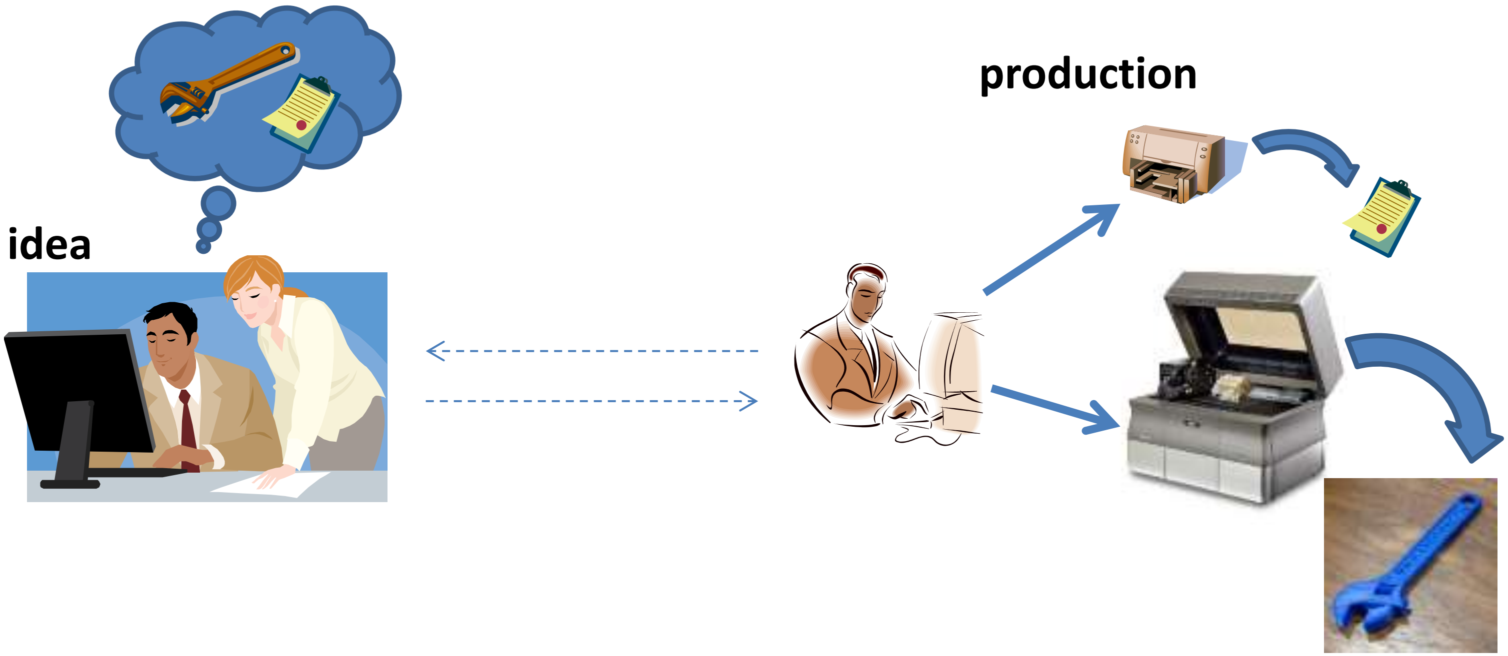
1- two complementary approaches : numerical method

the revolution …



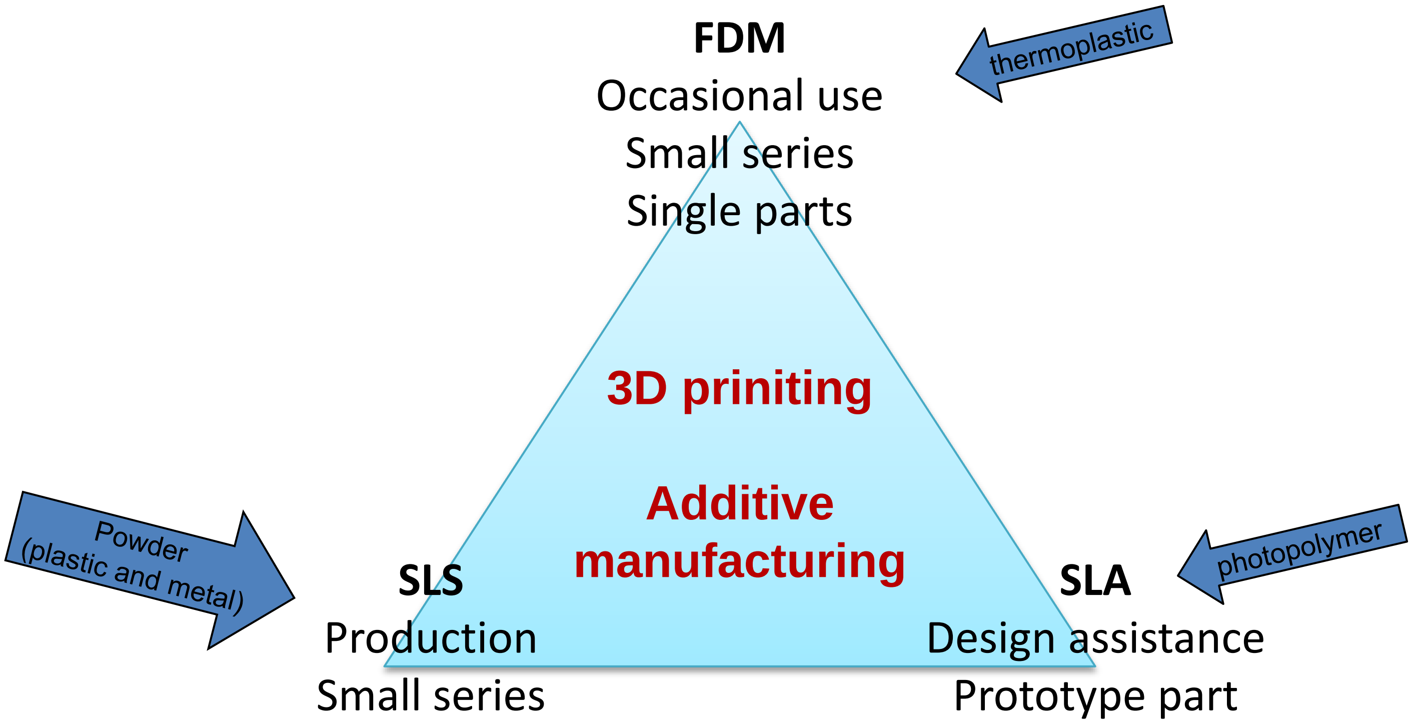
1- two complementary approaches : numerical method

the revolution …



1- two complementary approaches : numerical method

Main existing printing processes …

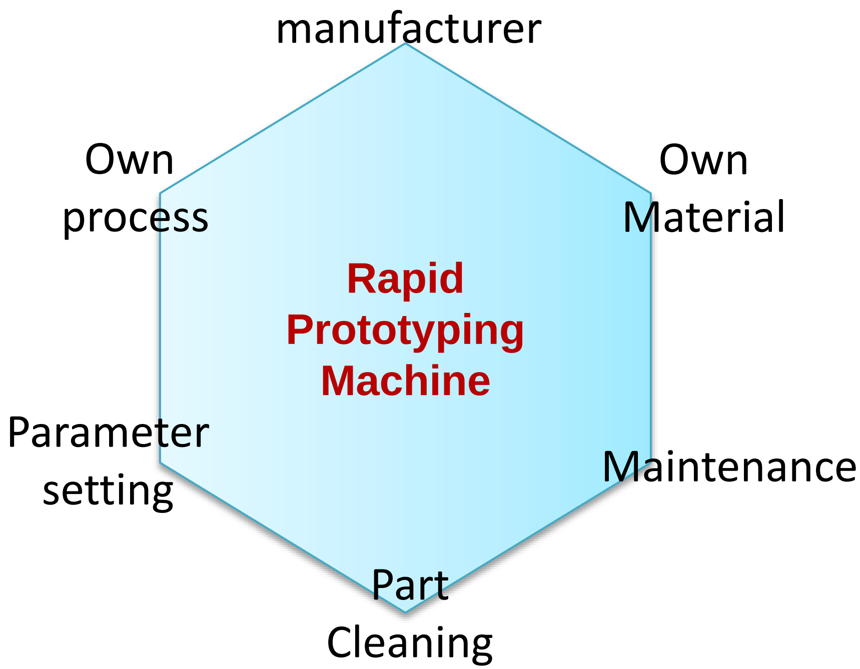


FDM = Fused Deposition Modeling
SLS = Selective Laser Sintering / DMLS = Direct Metal Laser Sintering
SLA = stereolithography

-> http://fr.wikipedia.org/wiki/Impression_tridimensionnelle
http://en.wikipedia.org/wiki/3d_printing

1- two complementary approaches : numerical method

Inseparable items…



2- main additive manufacturing technics in use

processes, machine manufacturers, partners, …

Main : industrial use, make durable and accurate parts, with well known material

2- Main direct fabrication technics in use

Stratoconception (hybrid principle : stack of machined plates or cutted sheets : glued, welded or screwed together)

Using of traditionnal machining technics
Halfway between machining and AM

packaging

mold

Stratoconception original patent

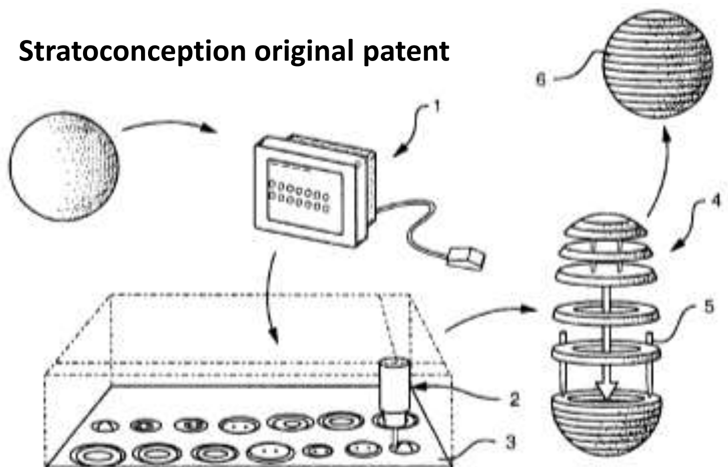
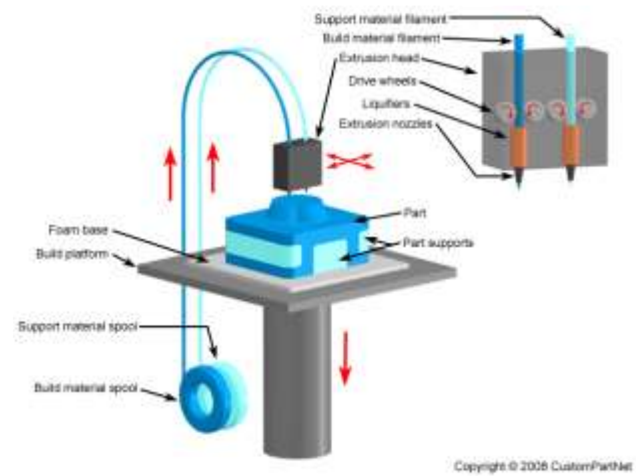


Image Source : http://www.freepatentsonline.com/6745446.html

➲ Fused Deposition Modeling at CEMES laboratory (CNRS, Toulouse)

machines DIMENSION and Stratoconcept (manufacturer : STRATASYS)

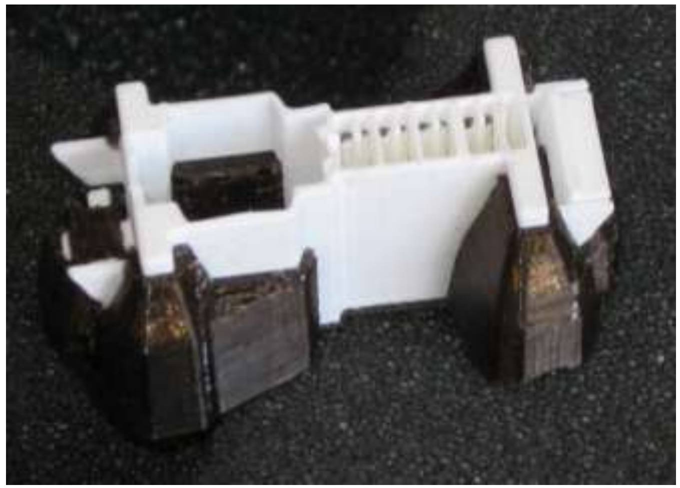


Soluble resin and part material (ABS) are deposed together .

L'I3D du CEMES propose un parc de machines mutualisées… http://www.i3d.cemes.fr/

Fused Deposition Modeling

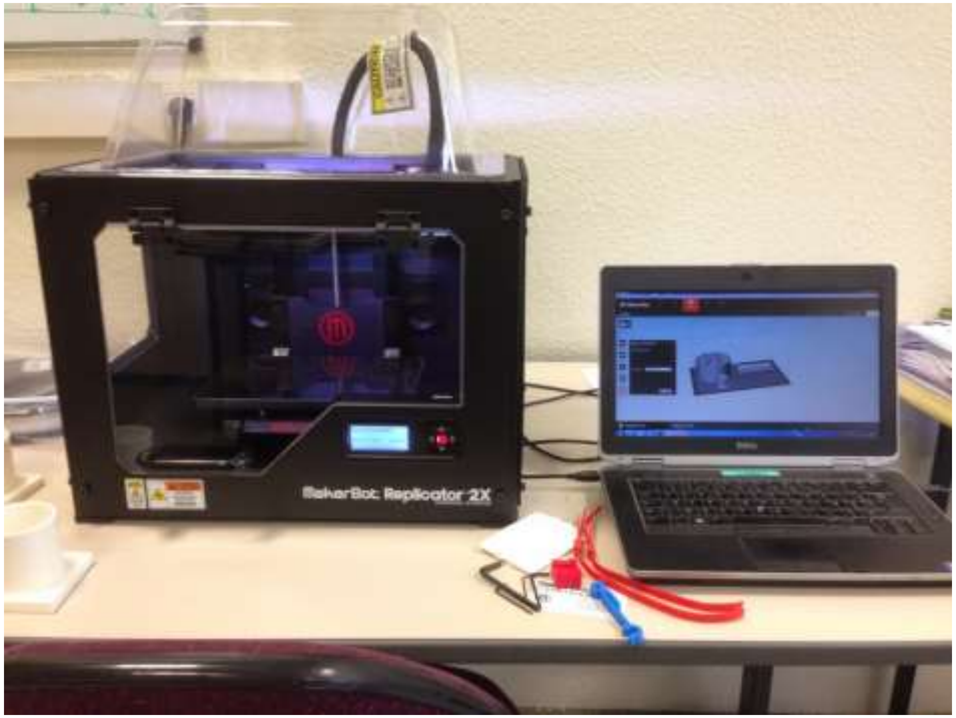
What’s coming out of the printer ?



Cleaning by immersion : support material is soluble
! two different materials

IPHC 3D fdm printer
'Makerbot Replicator 2X'

Direct 3D printing or through SD card storage



goal :
good Design and final parts

Maximum printing size :
150x250x150 mm

Layer thickness : 0.1, 0.2 or 0.3 mm

Printing time :
0.5 – 25 hours / peace

Used material : ABS (several colors)

Used with raft and support : ABS

Price : ~3000 € HT
Test review : https://www.3dhubs.com/3d-printers/replicator-2x
Seller : http://www.machines-3d.com/

IPHC 3D fdm printer
'ZORTRAX M200'

Direct 3D printing or through SD card storage

goal :
good Design and final parts

Maximum printing size :
200x200x180 mm

Layer thickness : 0.09, 0.14 or 0.19 mm

Printing time :
0.5 – 72 hours / peace

Used material : ABS (several colors)

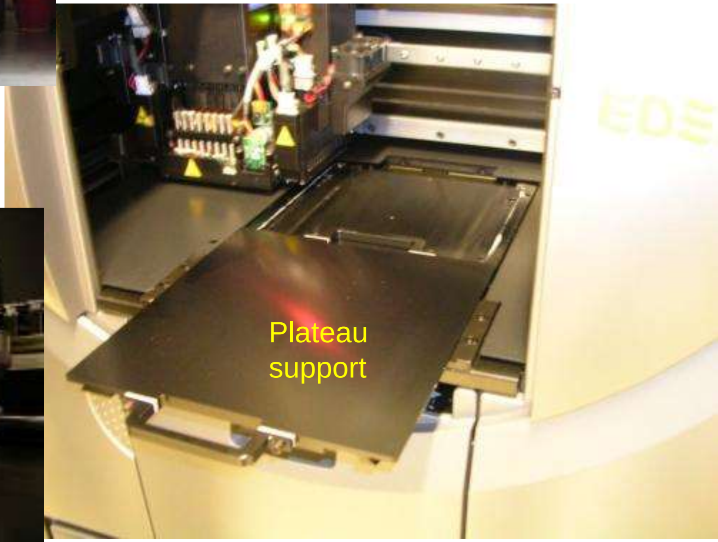
Used with raft and support : ABS

Price : ~2000 € HT
Test review : http://www.lesnumeriques.com/imprimante-3d/zortrax-m200-p22789/test.html
Seller : http://www.machines-3d.com/

- **Photopolymer with UV curing with CADINDUS Society (Mulhouse, F) and pôle ORTECH from LpoDeck (Guebwiller, F)**

Photos INTERNET (Société OBJET)

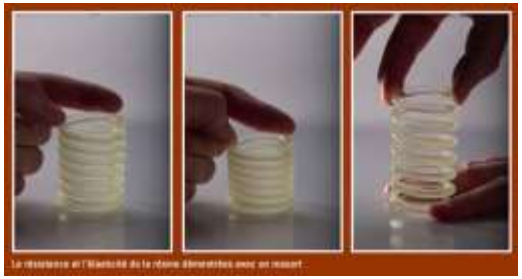
Bimaterial production
(with CONNEX 500)



EDEN machine
by OBJET Society

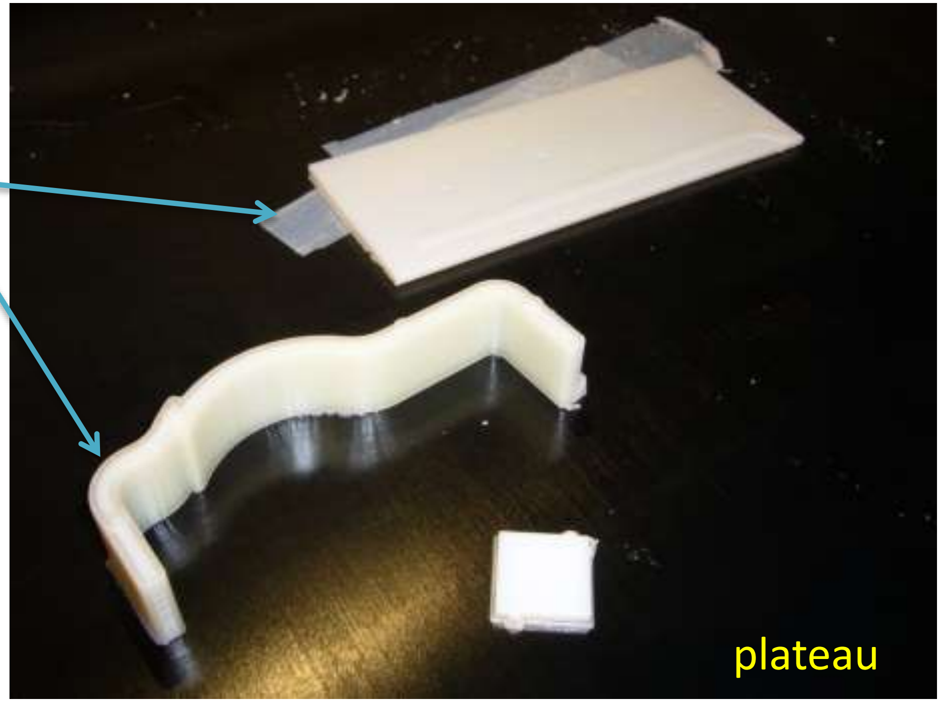
Unremovable parts : bearing

spring



Photopolymer UV curing

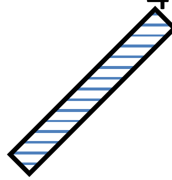
resin
support

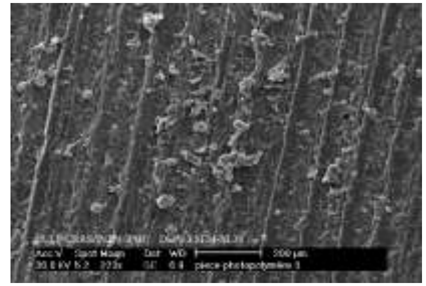


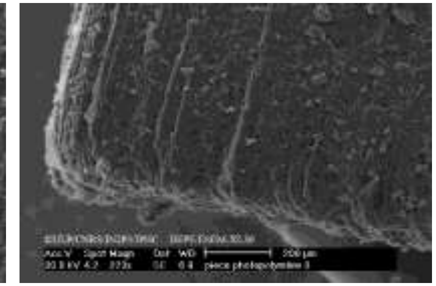
Cleaning : water jet and scraper
! resin support and part : same chemical base

3D printing with EDEN 330, viewed by electron microscope ESEM (IPHC)

45°



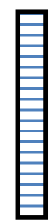


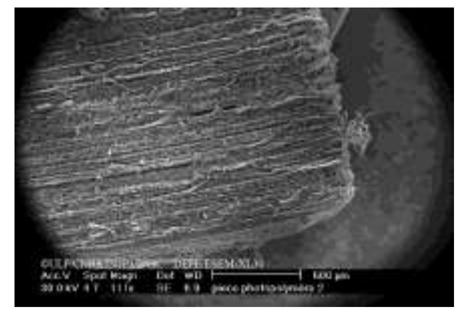


Sample fabrication
10mm x 10mm x 1mm

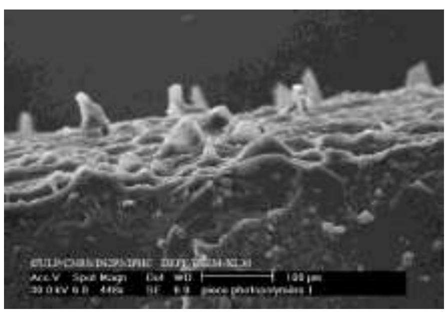
Layers thickness : 16µm

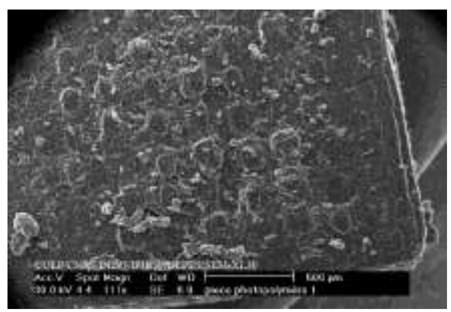
90°





0°





©IPHC / DEPE / ESEM : Environnemental Scanning Electron Microscope

Source : http://en.wikipedia.org/wiki/Environmental_scanning_electron_microscope

Selective laser sintering (sls)

PA parts production at LpoDECK and 3DPROD (France)

Ofen temperature : 170°C + laser

Layer thicknesss : ~100 µm

EOS sample

Ensemble indémontable
Couches d'épaisseur 0.1mm

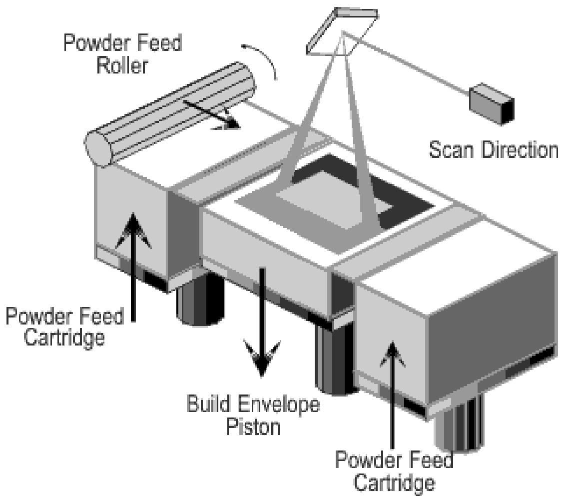


Image source : http://3dprinting.com/

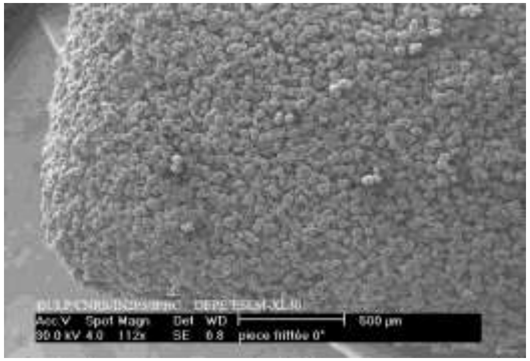
EOS Formiga P100 : Polyamid (PA) printing

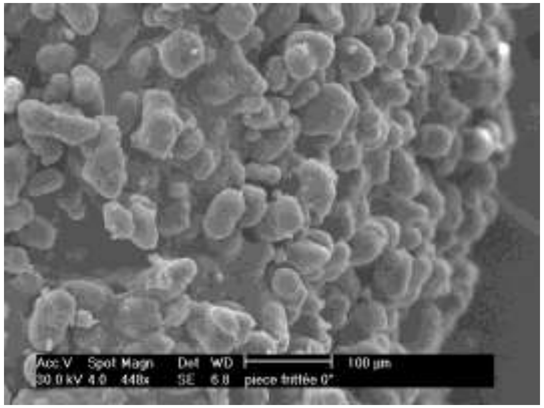
metal or ceramic possible on other machine

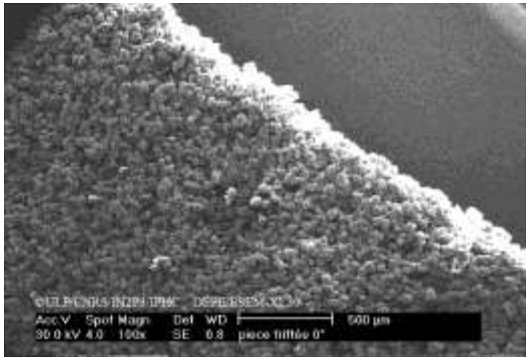
➲ 3D printing with EOS FORMIGA 100, viewed under ESEM (IPHC)

Powder grain size less than 100 µm

Partially melted on surface

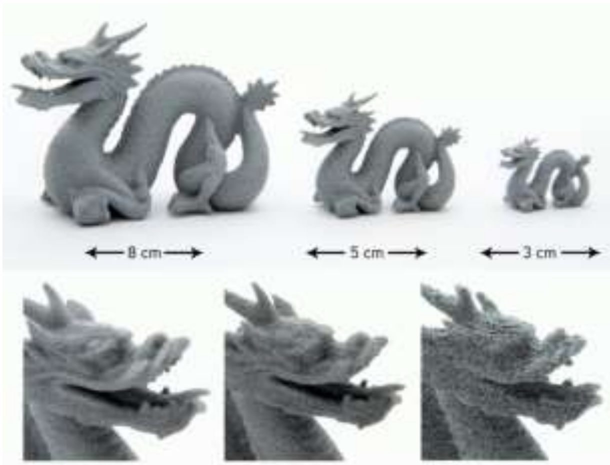




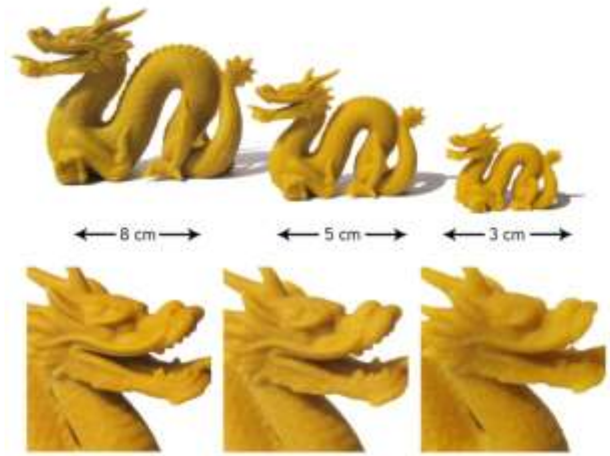


©IPHC / DEPE / ESEM : Environnemental Scanning Electron Microscope

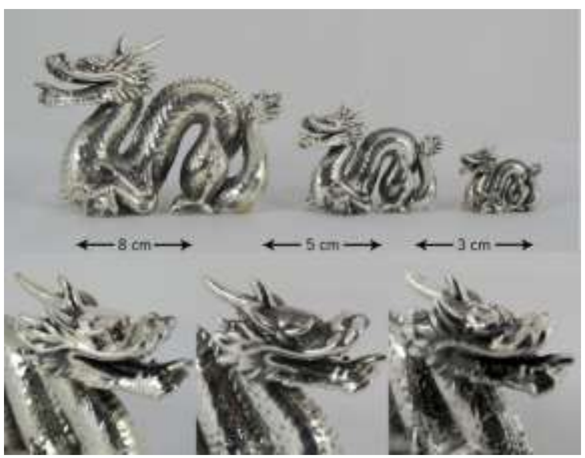
Scale effects



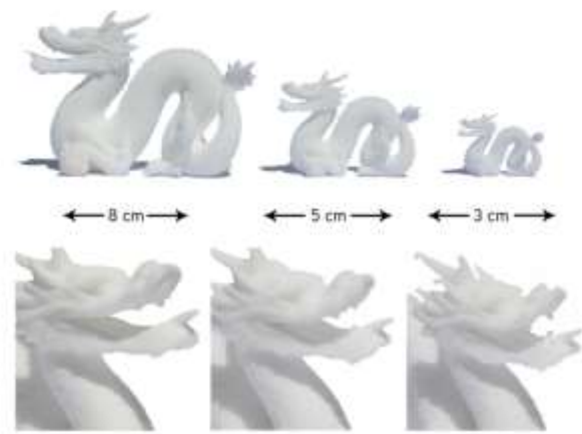
alumide



zcorp



argent

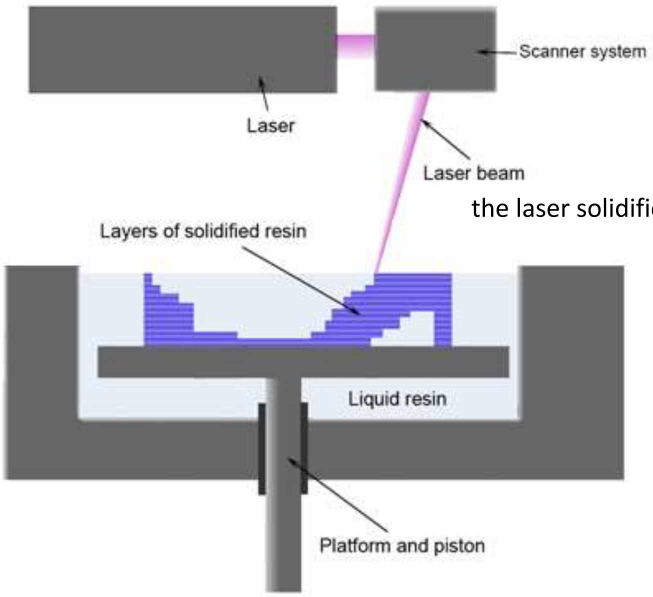


eos

sculpteo Source : http://www.sculpteo.com/fr/help/

Stereolithography (SLA)

Photo-solidification : 3D printing patent (1986)
Using of a vat of liquid ultraviolet curable photopolymer and ultraviolet laser

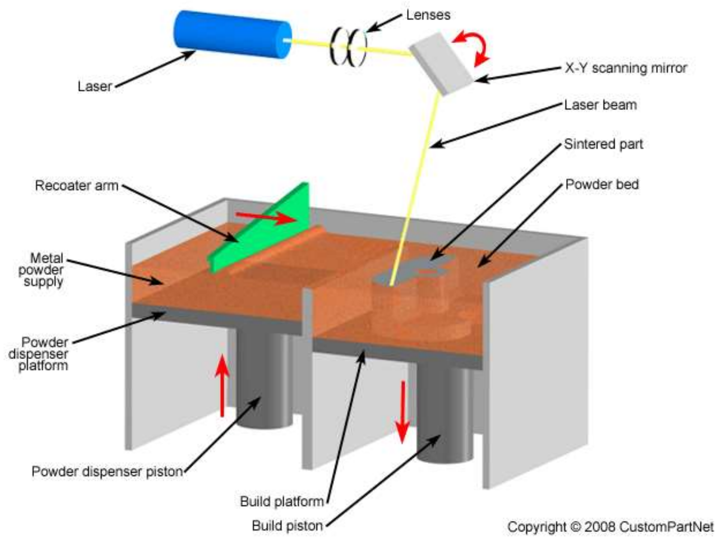


the laser solidifies the liquid surface

Source : http://en.wikipedia.org/wiki/Stereolithography

Direct Metal Laser Sintering (DMLS)

Today, the way to produce metal parts…

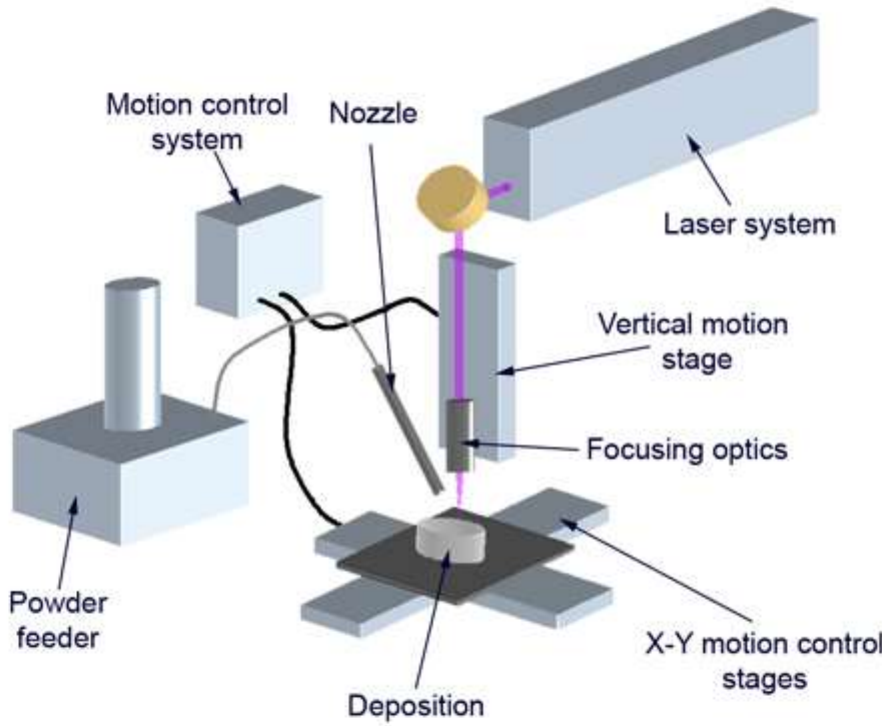


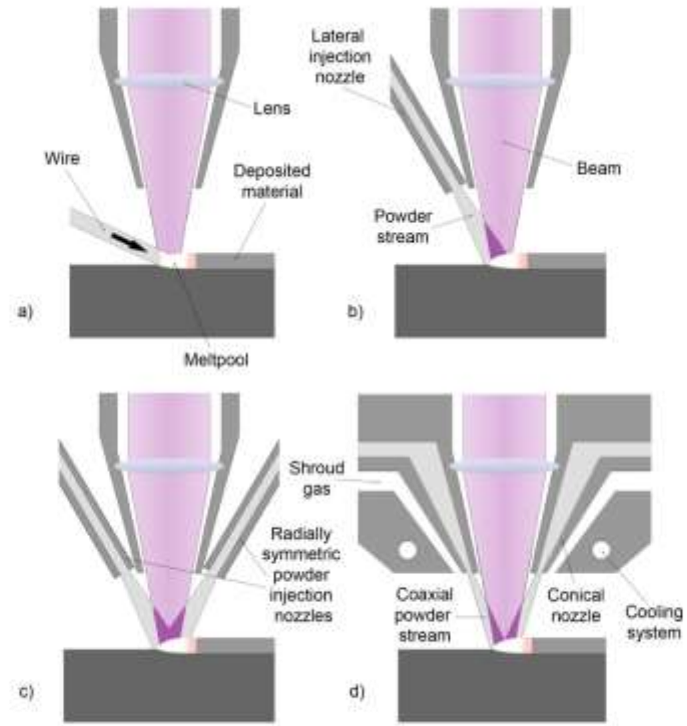
Laser : ~200 W

Layer thicknesss : ~20 µm

Image source : http://www.custompartnet.com/wu/direct-metal-laser-sintering/

➲ Laser cladding (CLAD)

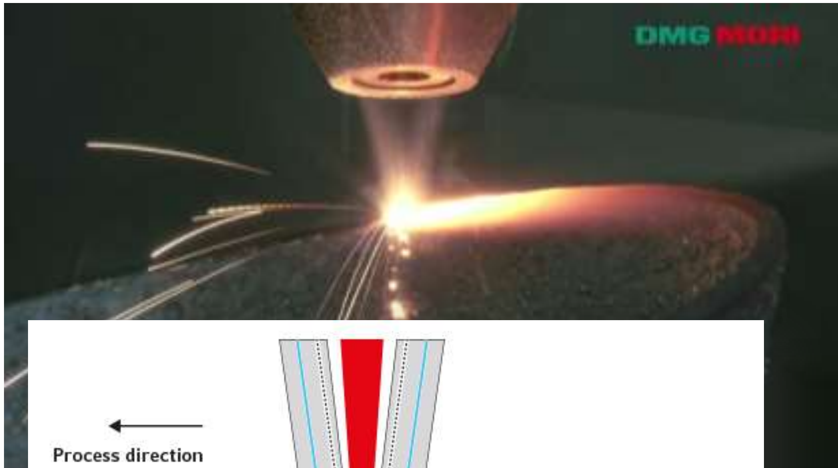


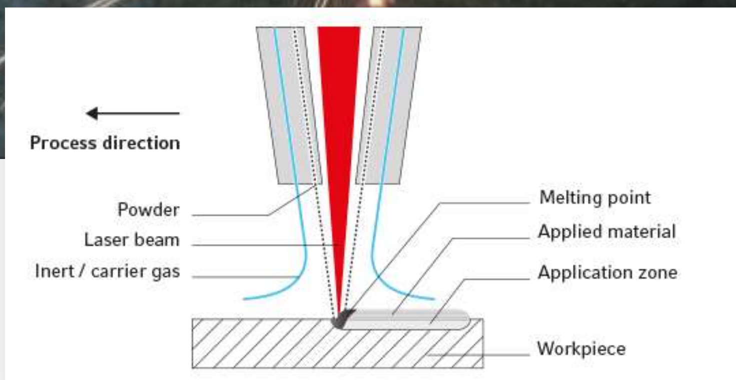


Laser and powder stream are coaxial

Source : http://en.wikipedia.org/wiki/Cladding_(metalworking)

DMG MORI
LASERTEC 65 AM
special manufacturing machine





- **Laser CLADDING**
- **Machining**
- **Repairing**
- **Coating**

Source : http://www.dmgmori.com/webspecial/journal_2014_1/en/lasertec-65.htm

2- Main 3D additive manufacturing technics in use

1- **fdm process** (fused deposition molding) : thermoplastic fused deposition / extruder hole diameter ~ 0,4 mm

2- **Objets 3D printers** (Objet.com ; polyjet printing) : thin layers (less than 30 µm)
Remove with spatule, remove support material with water jet
Clear the tray with spray / Build tray is ready for the next model

3- **voxeljet** (voxeljet.com)
Pouder and binder jet
Parts complete curing after 24 h standing
Make vax parts for lost wax casting
Layer thickness 0,006 inch
Depoudering station to remove the pouder by hand to prevent damage
Final curing process : low temperature for 5 h
When curing is complete, remaining excess pouder is removed with low pressure air jet
Final step : quick dip in vax to seal the part
A heater can as used to remove the excess vax from the surface

4- **stratoconception**
Cutting parts in thin hard or soft plates (foam, wood, plastic, metal, …)
Stack the pieces to construct the whole geometry

5- **stereolithography** (materialise.com ; SLA = StereoLytography Apparatus)
Pieces are produced in liquid polymer, with a same material builded supporting structure.
The polymer is solidified layer by layer : during the process, the pieces supporting tray go down in the polymer.

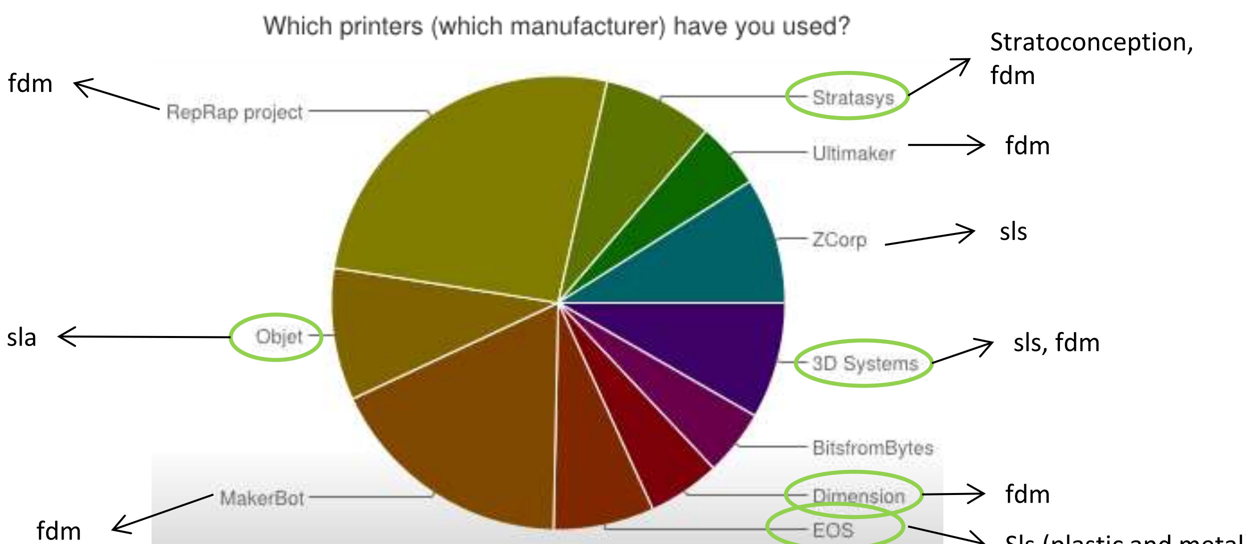
6- **polyshape process** (SLS = Selective Laser Sintering ; DMLS = Direct Metal Laser Sintering, SLM = selective laser melting)
Pouder layers with selective laser melting or sintering, layer by layer (plastic or metal)
The support, the pouder and the pieces are cooled before cleaning

7- **CLADDING :**
Simultaneous metal powder projection and melting by laser : the melted powder solidifies and forms the part layer by layer. The support can be curved.

Sources : http://www.industrie-techno.com/sept-facons-de-fabriquer-en-3d.23174
http://en.wikipedia.org/wiki/Cladding_(metalworking)

2- Main direct fabrication technics in use

Several machine manufacturers …



source : http://reprap.org/

2- Main direct fabrication technics in use – Who could make the part ?

3d prod prototypage rapide
SLS polymer and metal, finishing

CADindus Ingénierie et services CAO DAO
SLA (simple ou bimatière), finitions

I3D Model Your Concept
FDM

SLA, SLS
Pôle ORTECH
Frittage PA et photopolymère
UGV, Electroérosion, MMT, scanner 3D

IPHC Institut Pluridisciplinaire Hubert Curien Strasbourg

collaboration LpoDECK UdS CNRS IPHC
IPHC-ORTECH collaboration

SLA, SLS, …
3D HUBS
sculpteo
POLY-SHAPE additive manufacturing
3Dsolution.fr
CLAD
IRÉPALASER CONCEPTEUR DE SOLUTIONS LASER
BV PROTO
protomold

Subcontractors and partners

3DSYSTEMS
Polymer et metal

Stratasys FOR A 3D WORLD
STRATASYS + OBJET = Stratasys

eos e-Manufacturing Solutions
Polymer and metal

Additive manufacturing machine manufacturers

www.cnrs.fr
IN2P3
http://institut.in2p3.fr/

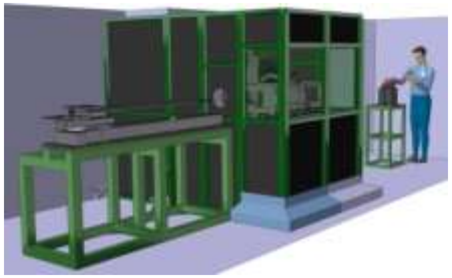
http://www.iphc.cnrs.fr/

3- achievement examples

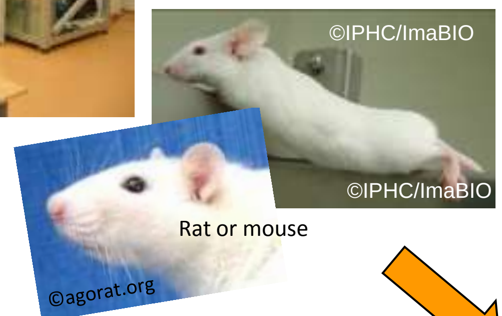
geometrical optimization in an IPHC project,
Quick overview of
some research and development examples in several domains

ESIPAP European School of Instrumentation in Particle and Astroparticle Physics

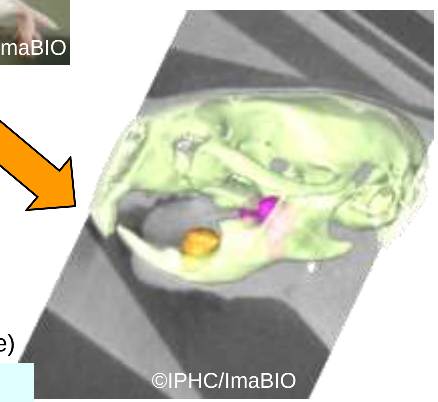
Numerical method at IPHC



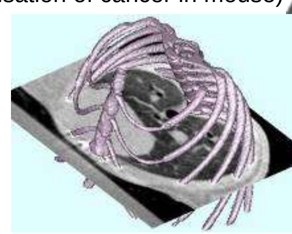
Imaging System
AMISSA
developped and used at IPHC



Rat or mouse



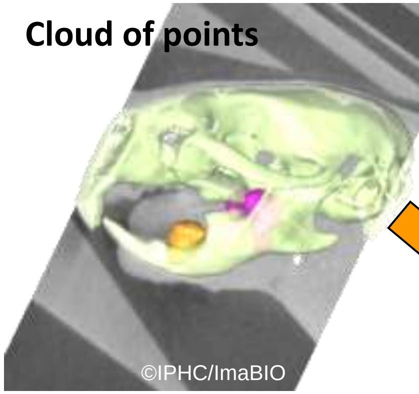
3D images superposition
Acquisition by µTEMP and µCT
(skeleton, flesh
and localisation of cancer in mouse)



Cloud of points

Numerical method at IPHC

Cloud of points



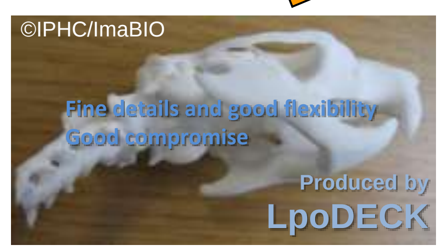
3D CAD volume
After treatment with CATIA V5
(skull and head of a rat)

.stl printing file

Not well cleaned part

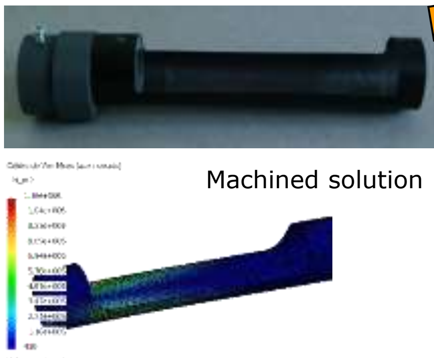
Impression 3D

collaboration LpoDECK UdS CNRS IPHC
CADindus
Ingénierie et services CAO DAO

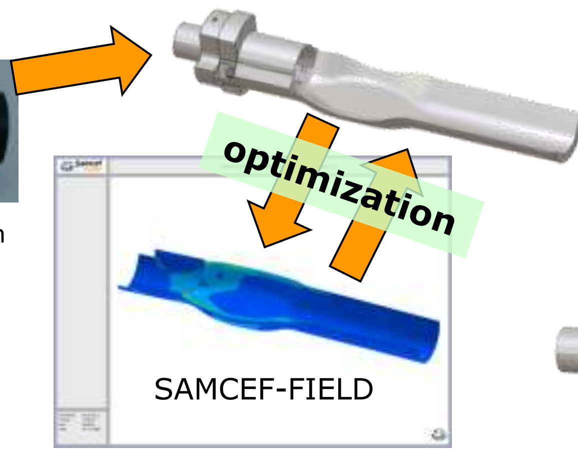


Rat skull printing

➲ Mouse supporting during scanning time



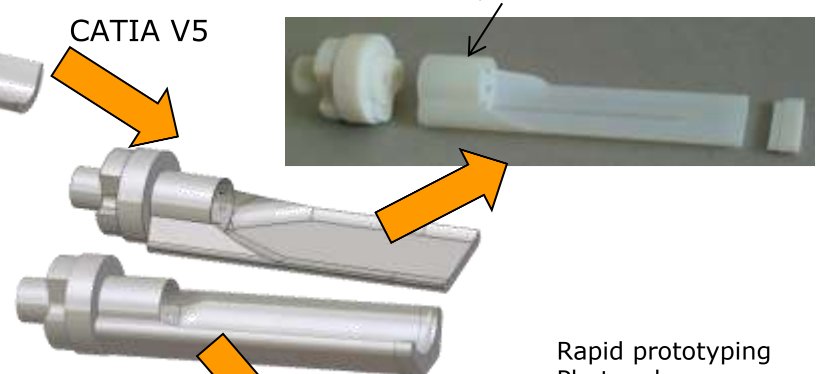
Machined solution



Shell FEM Model

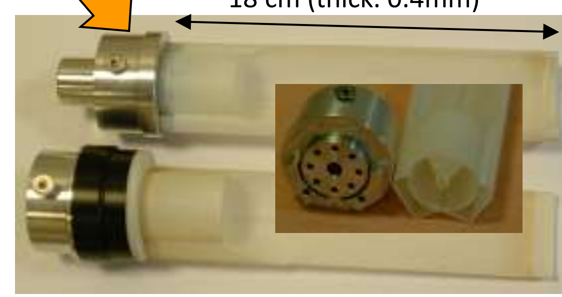
CATIA V5

Bed first generation
End-peace ϕ 30 mm



Rapid prototyping
Photopolymer

18 cm (thick. 0.4mm)

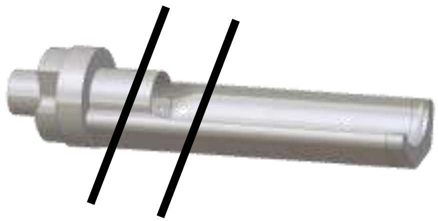


Technics Association

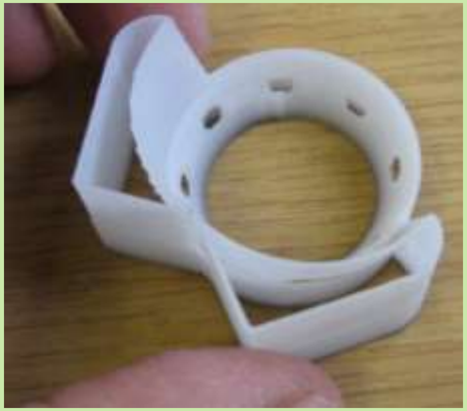
Requests :
- General Anesthesia
- Mechanical supporting of mouse (40 gr)
- Material optimization around the mouse
- Possibility of hot air circulation

Produced by CADindus

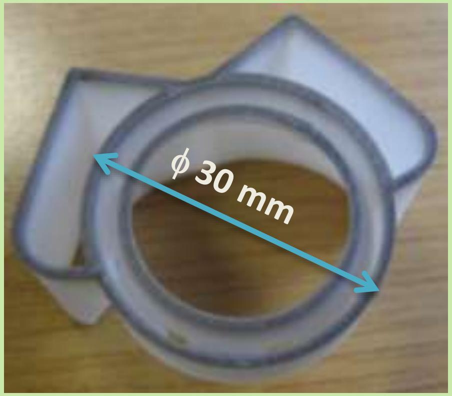
FDM on STRATASYS/DIMENSION (at CEMES Toulouse) :
ABS thread / layer thickness = 0,254 mm



Paroi ép. 1 fil

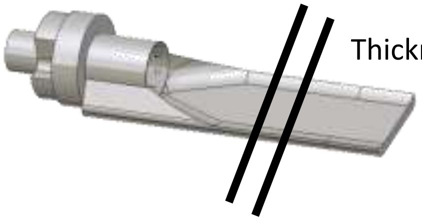


Paroi ép. 2 fil



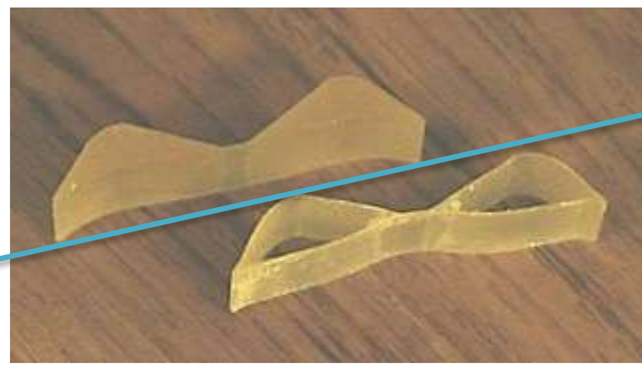
Photopolymer support by OBJET 250

Material evolution, in water immersed part and leave in sun shine



Thickness wall = 0,4 mm

Unused part



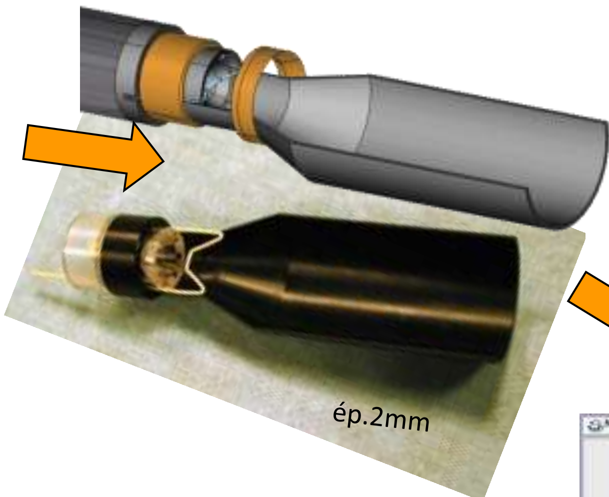
Totally removed supporting resin
Total in water immersion
Solar UV ray exposition

After 3 days :
- Deformation
- hardening

Produced by CADindus

Ingénierie et services CAO DAO

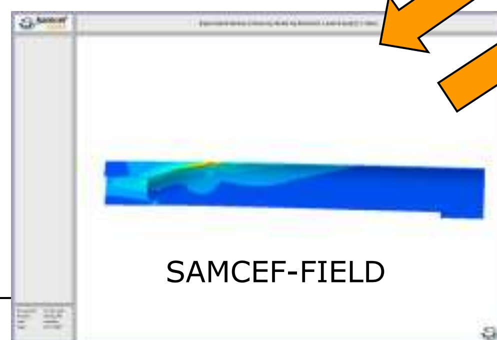
➲ Rat supporting during scanning time



optimization

End-peace ϕ 40 mm

CATIA V5



SAMCEF-FIELD

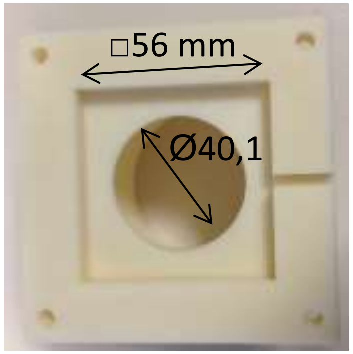
PA SLS

27 cm (thick. 1mm)

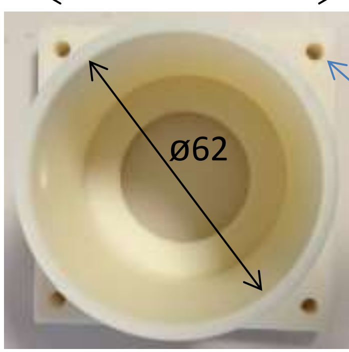
Produced by
3DProd
Du Concept à la Réalité

Requests :
- General Anesthesia
- Mechanical supporting of rat (800 gr)
- Material optimization around the mouse
- Possibility of hot air circulation

IPHC contact IPHC : Christophe Ruescas, christophe.ruescas@iphc.cnrs.fr / Marc Krauth, marc.krauth@iphc.cnrs.fr



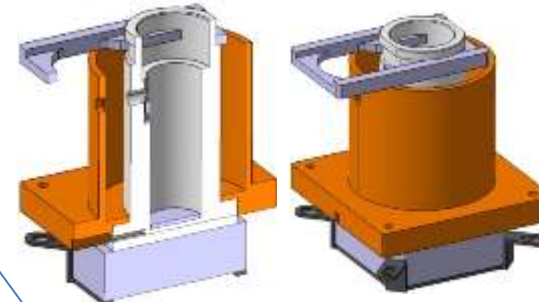
□90 mm



Some theoretical values

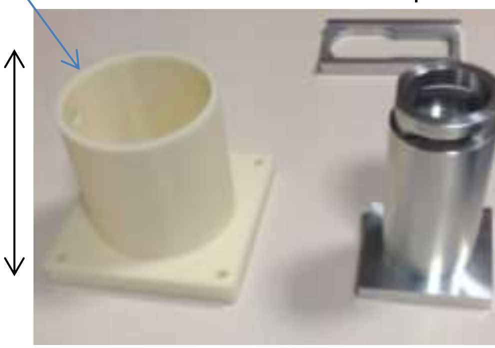
Hole ø 5 mm

ABS fdm part



Assembled parts

Height 73 mm
Thickness plate 12 mm
Cylindrical part thickness 4 mm



Differencies between several numerical dimensions and real produced dimensions are between 0,04 and 0,2 mm .

Part produced by Cadvision
Contact : Stefka BARZAKOVA / stefka@cadvision.fr

Photos : ©IPHC.cnrs.fr

Décembre 2013

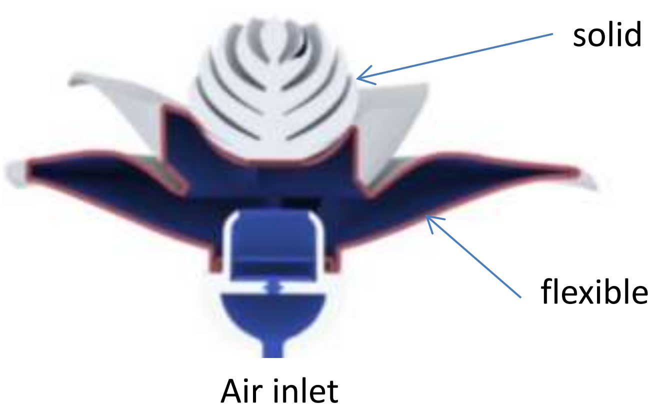
Source : http://www.industrie-techno.com/fleurs-de-techno.27541

Techno flower

Printed by OBJET connex

multimaterial 3D printing

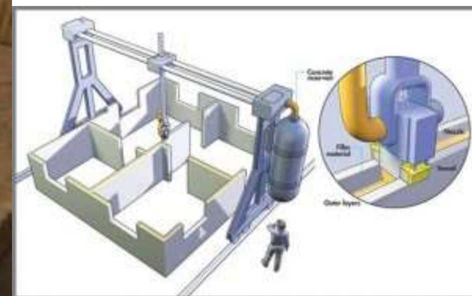
Inflatable structure

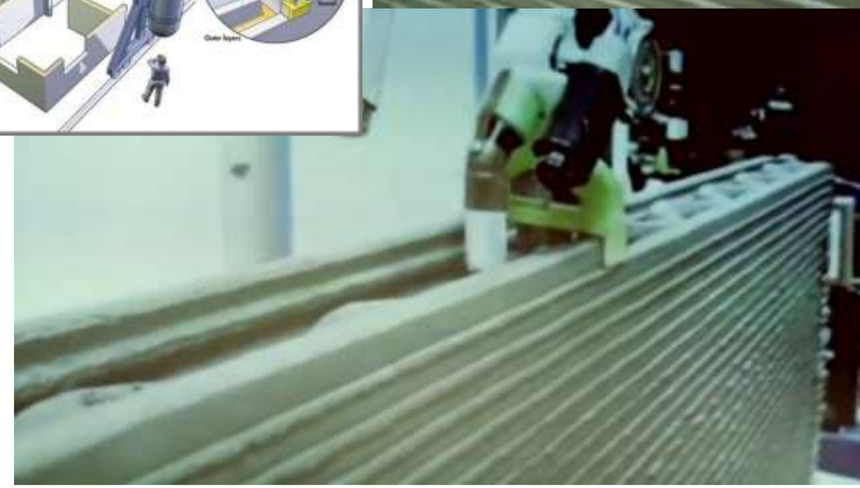


Source : http://www.contourcrafting.org/

Building 3D printing – concrete masonry unit -1-

Contourcrafting.org





Extrusion of
high performance concrete
Strength : 3 000 to 10 000 psi

NASA developpement

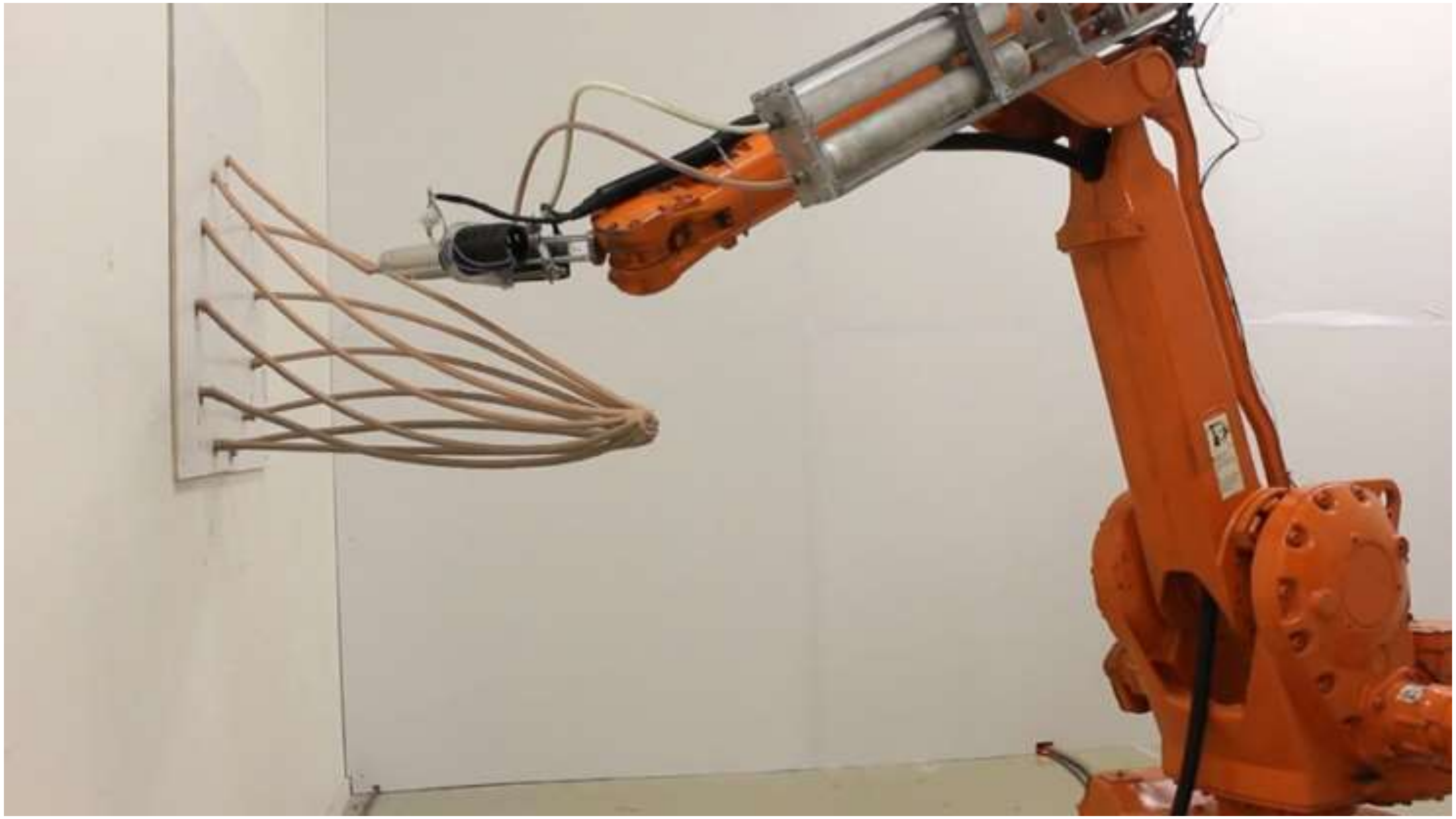
Source : https://www.youtube.com/watch?v=ehnzfGP6sq4&list=PLwZuNacIKo6a3C1tavZ5hnS2WABYSGbJv
http://www.contourcrafting.org/

Building 3D printing – concrete masonry unit -2-

Source : https://www.youtube.com/watch?v=EfbhdZKPHro&list=PLwZuNacIKo6a3C1tavZ5hnS2WABYSGbJv

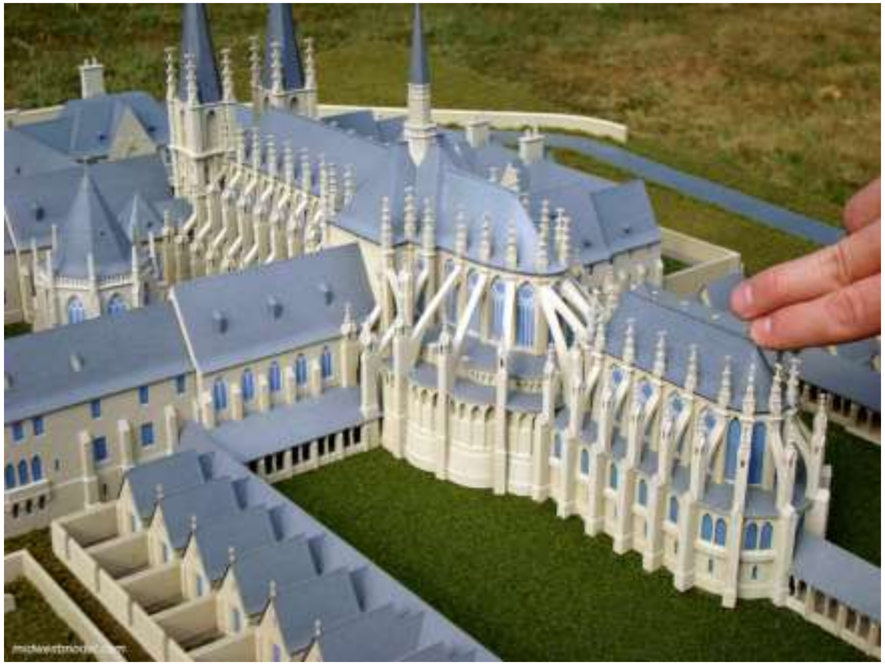
Source : http://www.dvice.com/2013-5-22/mataerial-anti-gravity-3d-printer

Robot 3D printing

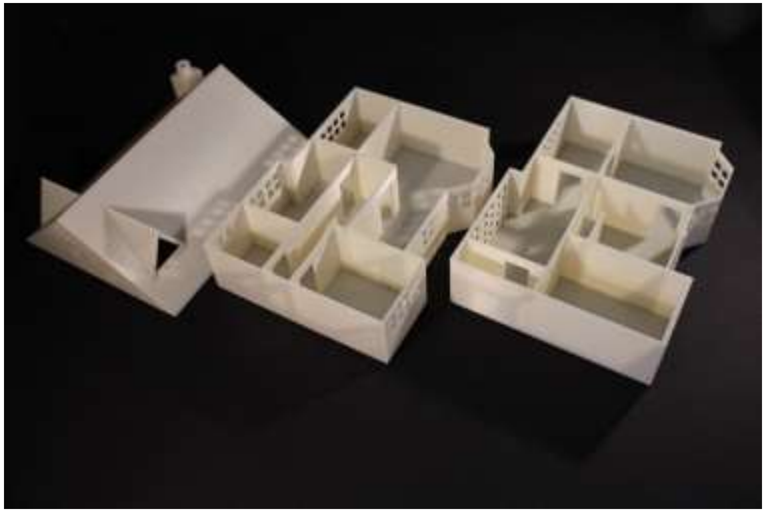


Architecture models

How it was…
How it could be…



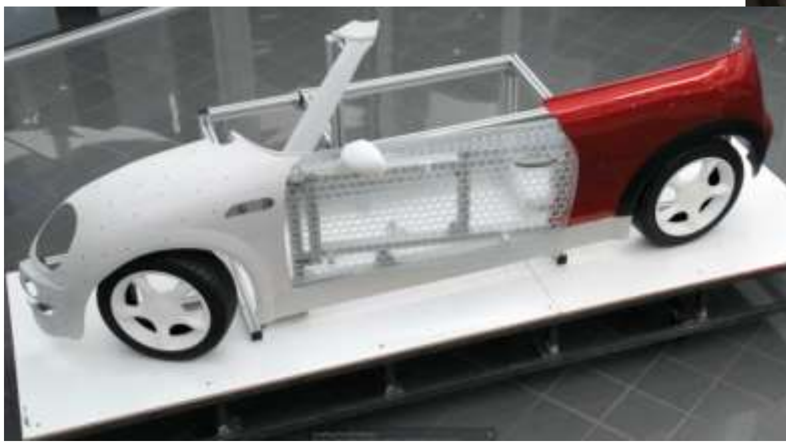
Source : http://www.midwestmodel.com/pagesroot/pages/ProjectDetails.aspx?ProjectId=339&DetailsType=ATOZ



Source : http://www.hp3dprinting.co.uk/applications.htm

Automobile Design

research and development department
Combination of manufacturing technics

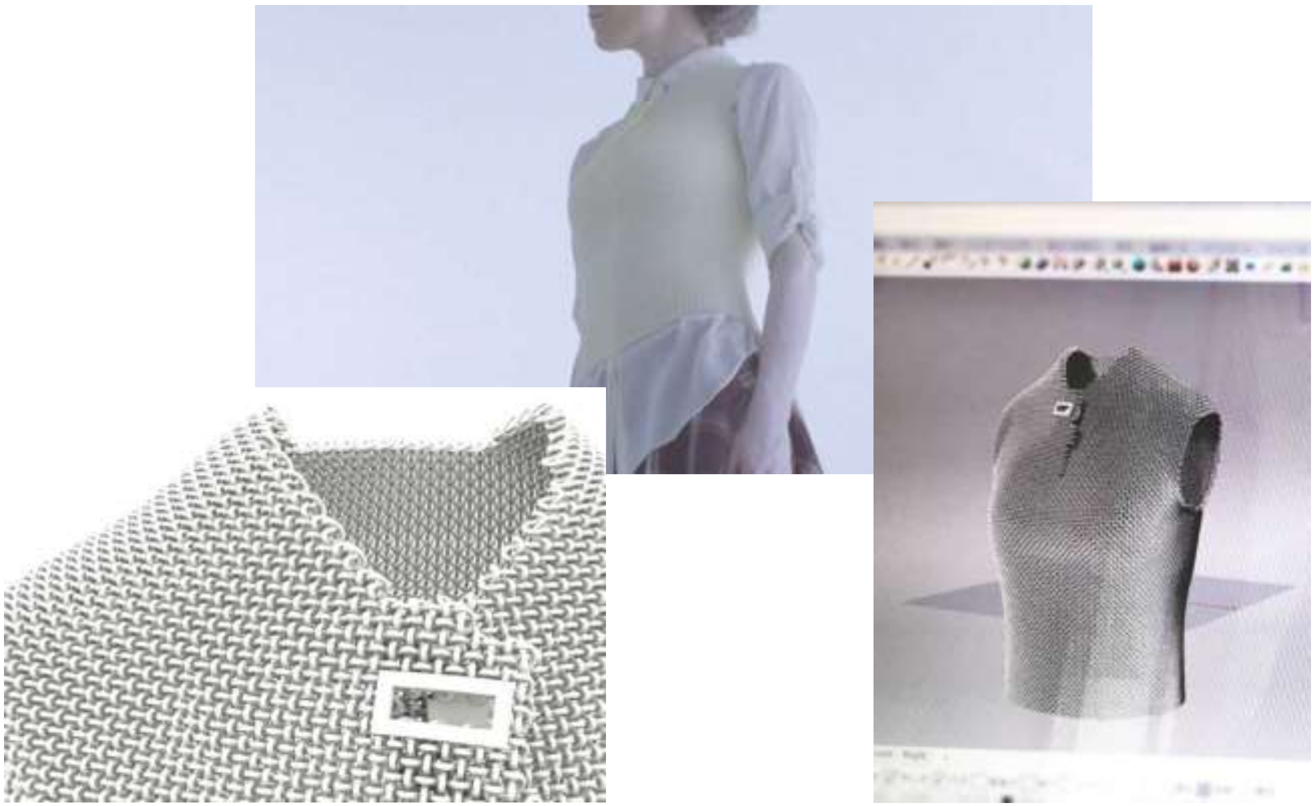


First Asian 3D Print Fashion Show

2013
First fashion meeting with 3D printed wears, organized by Materialise, belgian company.

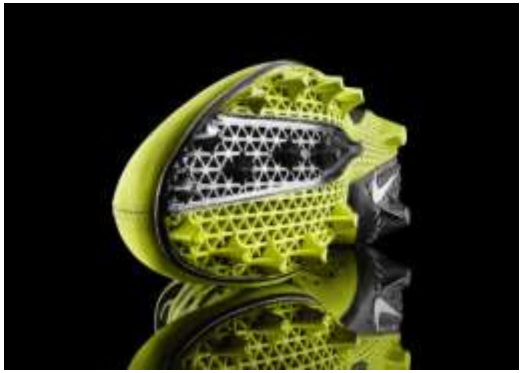
Source : http://www.numerama.com/magazine/26298-un-defile-de-mode-pour-l-impression-3d.html

“The clothing was modeled as it would be if it were knitted with thread inside the 3D software,” Ono told 3DPrint.com.



Source : https://3dprint.com/149870/3d-printed-amimono-woven-fashion/

Nike Debuts First 3D-Printed Football Cleat



Source : http://mashable.com/2013/02/27/nike-3d-printed-cleat/

MADE IN 3D challenge - 2011

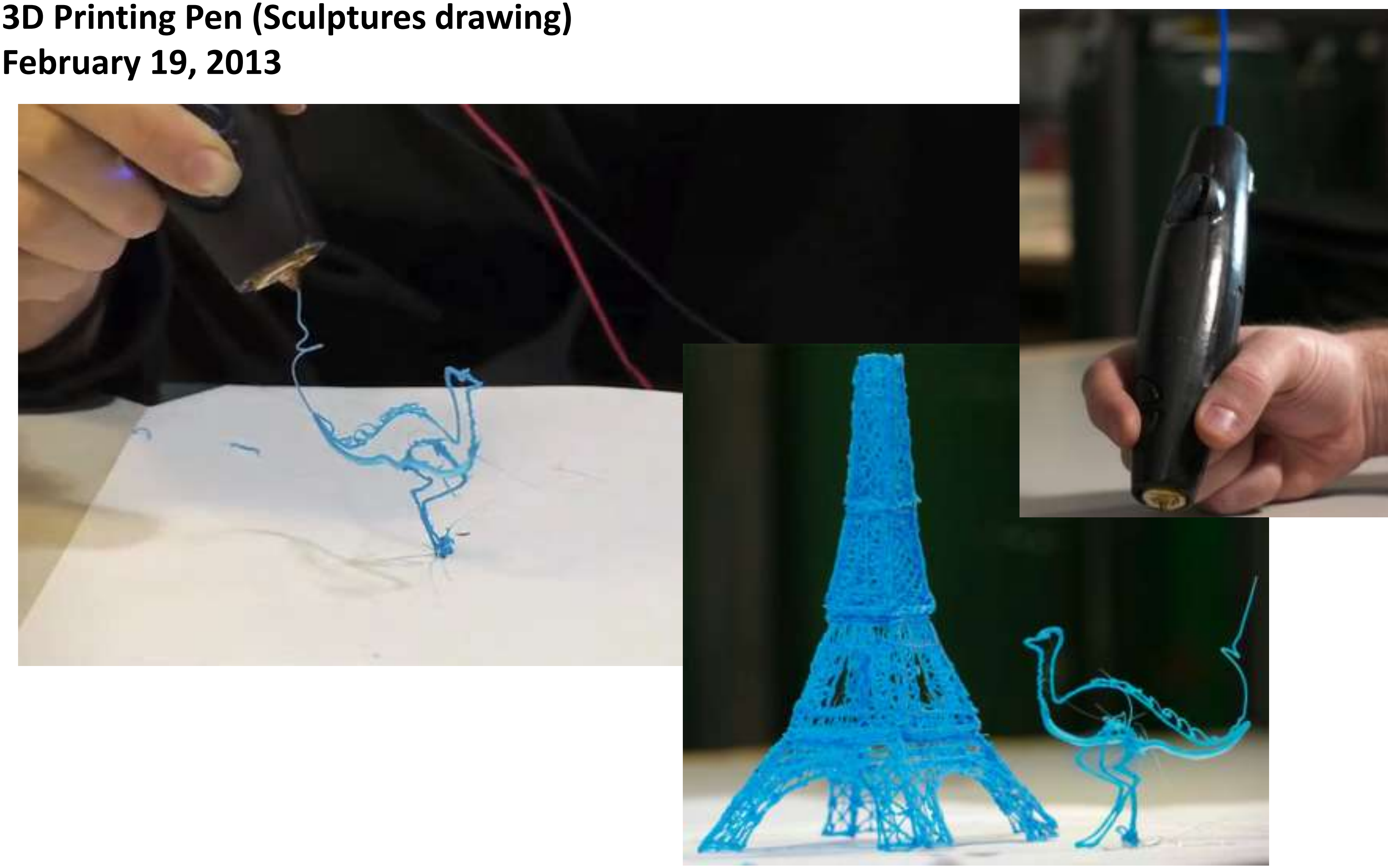
This strange parts supports an Iphone and emplifys sound coming out the phone.

To make a 3D ready printing design is the main goal.

This part is called the 'Mush' and was designed with CATIA V5 by a young designer .

Source : http://blogs.cotemaison.fr/archiboom/2011/06/26/made-in-3d-%E2%80%93-design-et-impression-3d/
http://www.3dvia.com/blog/made-in-3d-challenge/

3D Printing Pen (Sculptures drawing)
February 19, 2013



Source : http://www.thisiscolossal.com/2013/02/the-worlds-first-3d-printing-pen-that-lets-you-draw-sculptures-in-real-time/

A kid drawing converted into 3D part

a sheet of paper becomes a 3D object

Source : http://journalmetro.com/dossiers/la-liste-du-lundi/338524/objets-3d/

Edible prints

Although these ideas are only being experimented in labs for now, it's thrilling to know that these innovations might be very soon a part of our daily consumption.

Source : http://blsciblogs.baruch.cuny.edu/yomara89/?p=7

Food

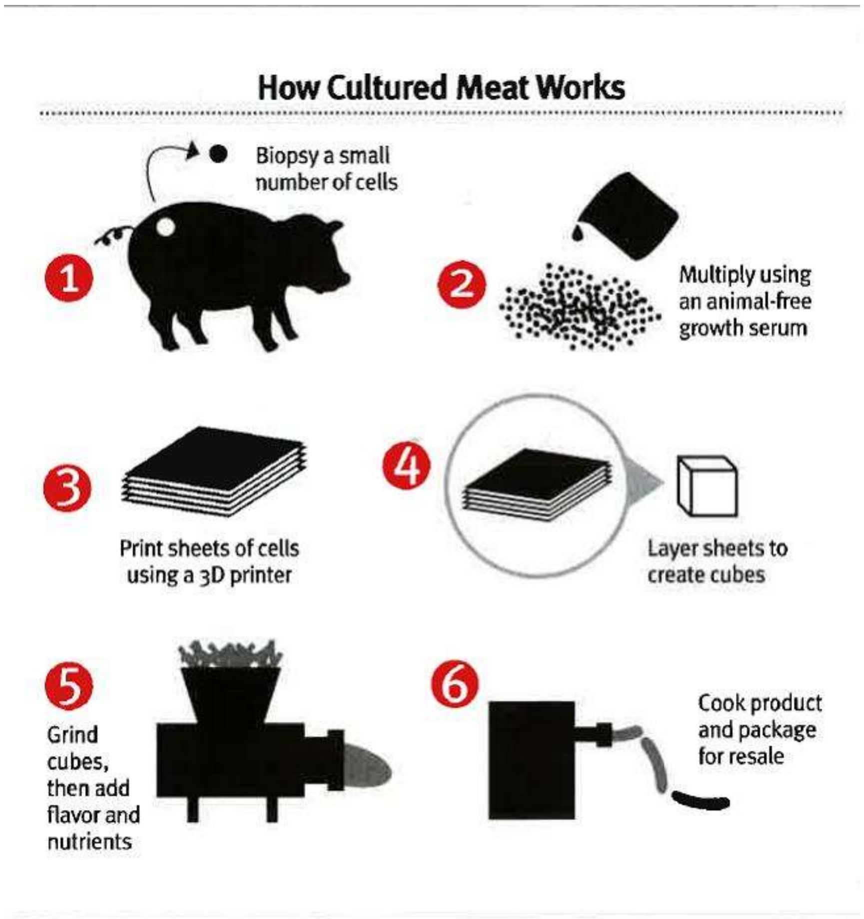
Food Ink enterprise

Chocolate 3D printing

Source : http://www.lesimprimantes3d.fr/limprimante-3d-fabrique-chocolat/

http://www.materiel.net/minisites/guide-achat-imprimante-3d/les-applications-3d-futures.php

Meat 3D printing



Source : http://veganvine.blogspot.fr/2013/08/you-can-take-meat-out-of-animal-but-you.html

Source : http://veganvine.blogspot.fr/

Source : http://www.peta.org/issues/animals-used-for-food/meat-wastes-natural-resources/

Industry news

Renault Trucks enterprise prints their motors

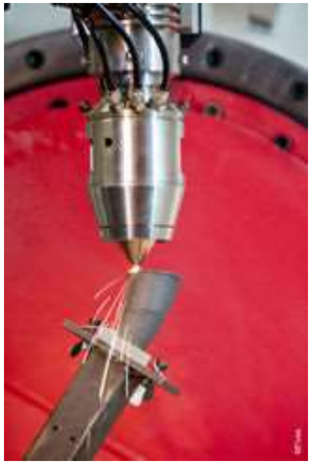
1/2017

Source : https://www.industrie-techno.com/renault-trucks-imprime-ses-moteurs-en-3d-metal.47535

Michelin and Fives enterprises wants to be leaders in metal additive manufacturing

9/2015

Source : https://www.industrie-techno.com/impression-3d-metal-michelin-et-fives-se-positionnent-sur-le-marche.39690



1/2015

BeAM entrerprise adds its technology in Fives 5 axis production machines

Source : https://www.industrie-techno.com/fabrication-additive-beam-integre-sa-technologie-aux-batis-5-axes-de-fives.38970

-> CLAD printing process (IREPA Laser)
See machines by DMG MORI

-> http://www.beam-machines.fr/

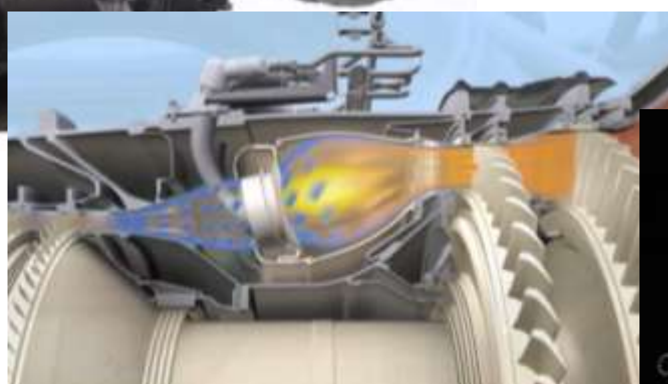
Source : http://www.youtube.com/watch?v=l0SXlkrmzyw

Leap Fuel Nozzle

Aviation développement :
Problem of nozzle : cooking with carbon deposition
Function : Spray fuel into combuster

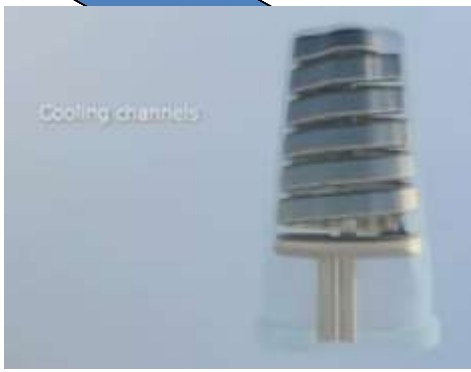
- The temperature increases up to 3000°C -

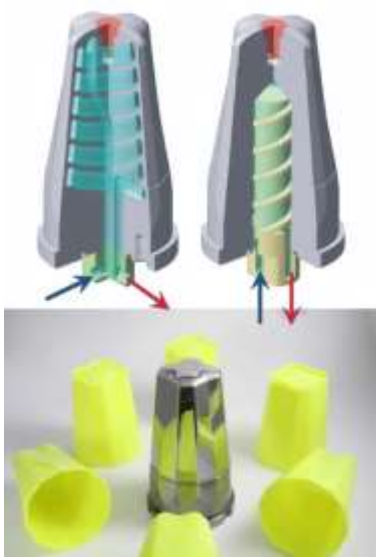
Solution with DMLS :
Efficiency
engine durability (X5)
18 parts in one single piece
Weight -25%
Better than casting, machining, welding,…
Production speed x20



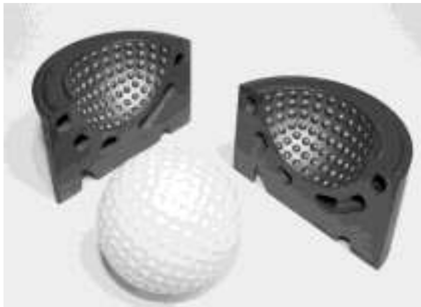
Numerical method
CAD – DMLS – PLASTIC INJECTION

Source : http://machinedesign.com/3d-printing/difference-between-machined-and-3d-printed-metal-injection-molds





Industry news



Printing maraging steel parts
Source : http://www.incept3d.com/metal--dmls.html

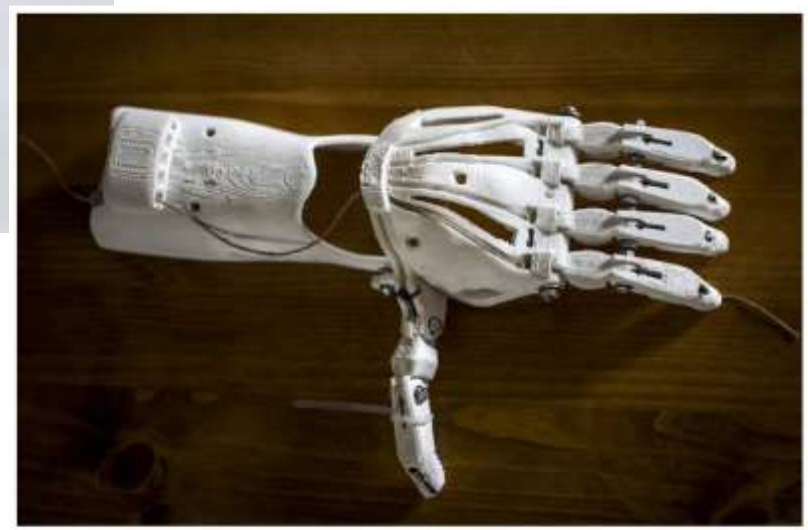
Printing Titanium bike frame
Source : http://inhabitat.com/empire-cycles-unveils-the-worlds-first-ultralight-3d-printed-titanium-bike/

Printing completed wirh machining
Source : http://www.3ders.org/articles/20120918-shell-makes-complex-structures-with-3d-printing.html

Printing Nylon bike
Source : http://inhabitat.com/3d-printed-air-bike-is-as-strong-as-steel-but-13rd-the-weight-of-aluminium/

Implants

Custom Prosthetics

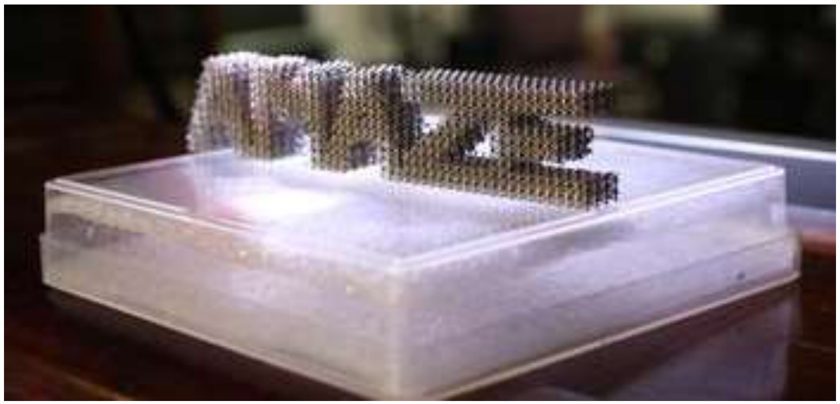


Source : http://www.treehugger.com/green-architecture/heavy-metal-meets-downloadable-designs-3d-printing-from-cad-to-metal.html

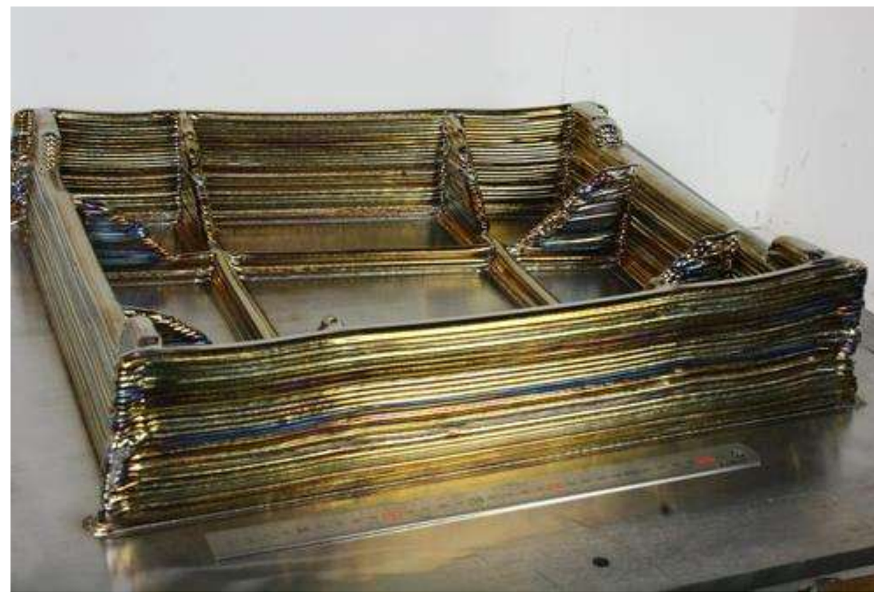
http://www.materiel.net/minisites/guide-achat-imprimante-3d/les-applications-3d-futures.php

ESA : 3D Printing Metals on earth and in Space

The AMAZE project team printed its logo in titanium as an intricate net shaped to millimeter-level precision to demonstrate what metal 3D printing can do. The project is working with materials that can withstand temperatures up to 3500 °C and involves 28 industrial and educational partners across Europe.
(Source: ESA-N. Vicente)

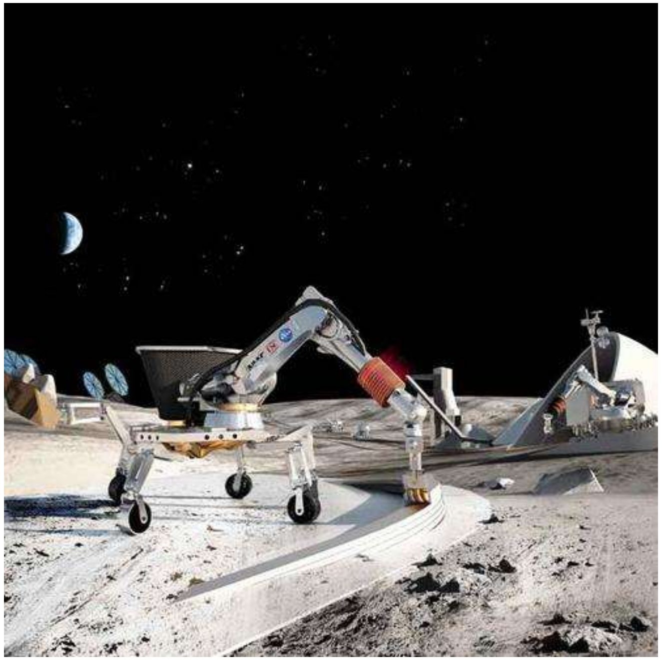


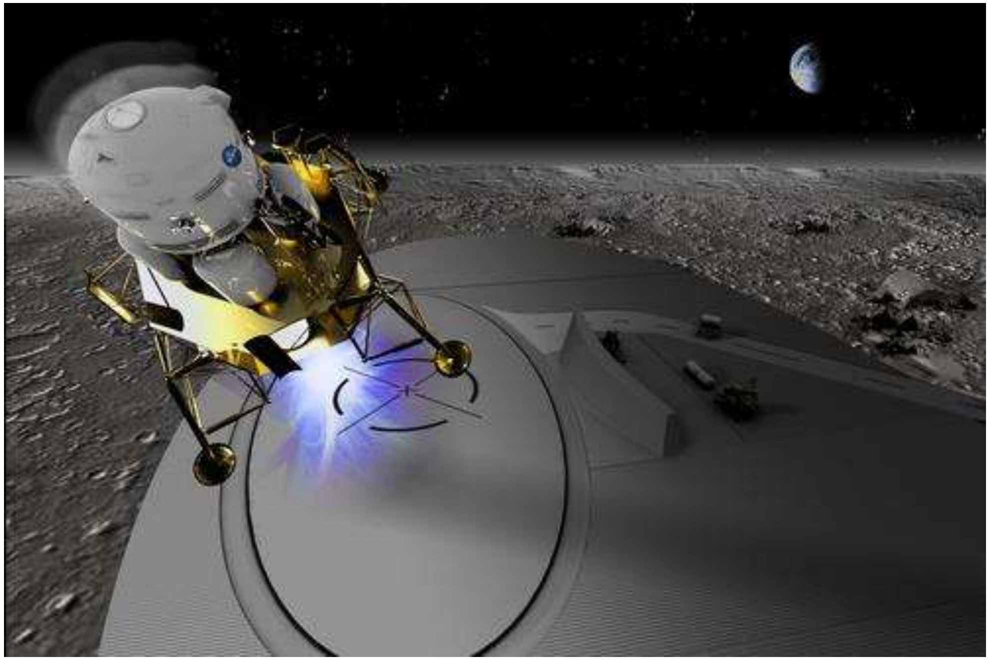
Titanium 3D printing



Source 2013 : http://www.esa.int/Our_Activities/Human_Spaceflight/Research/3D_printing_for_space_the_additive_revolution

NASA : 3D Printing Metals on earth and in Space





NASA-funded research by University of Southern California professors Behrokh Khoshnevis, Madhu Thangavelu, Neil Leach, and Anders Carlson is exploring how structures on the moon can made using the Contour Crafting robot. Under NASA's Innovative Advanced Concepts program, the researchers aim to develop methods for creating infrastructure, such as roads and landing pads, to support human settlement on the moon. The technology can create structures *in situ* from local materials, which is especially important for long-term, continuously expanding operations on the moon. For example, the team is exploring a nozzle system that heats lunar soil into a cement-like paste. In this visualization by Behnaz Farahi and Connor Wingfield, a lander descends on a pad fabricated by the Contour Crafting robot.
(Source: University of Southern California/Contour Crafting)

www.cnrs.fr
IN2P3
http://institut.in2p3.fr/

http://www.iphc.cnrs.fr/

4- some 3D printers

ESIPAP European School of Instrumentation in Particle and Astroparticle Physics

4- some 3D printers

Stratasys uPrint SE

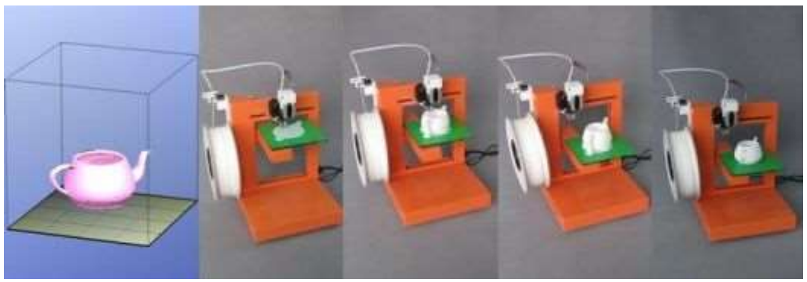
ABSPlus thermoplastic thread
With soluble resin support
Oven temperature : 260°C
Layers thickness between 0,12 and 0,25 mm
Geometrical precision ~0,2 mm
Production 3D array 152 x 203 x 152 mm
~20 k€

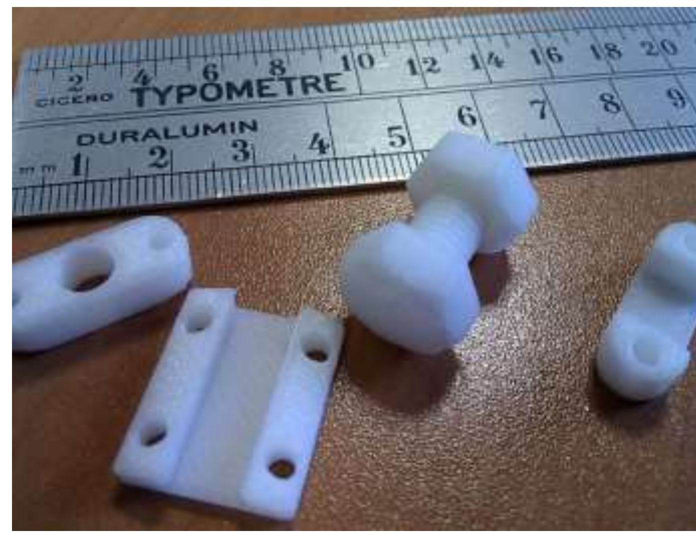
Source : http://www.u-print.fr/

63

4- some 3D printers

UP MINI 3D PRINTER
ABS withe thread
layers 0,15 to 0,40 mm
3D array : 140 x 140 x 135 mm
~3k€





Source : http://modeler3d.fr/

A2 V2

3 nozzles
ABS, PLA, NylonCarbon, PC, PC-ABS, PETG, …
thermoplastic thread
With soluble resin support (SSU01)
Regulated oven temperature : 80 °C
Max nozzle temperature : 410 °C
Max plate temperature : 135 °C
Minimum layer thickness : 0,05 mm
Resolution : 0,015 mm
Geometrical precision ~0,2 mm
Production 3D array 620 x 350 x 490 mm
~25 k€

Source : http://www.3ntr.eu/a2/

Apium
Additive Technologies GmbH

Apium P 155

High performance polymers
PEEK, POM-C, PVDF, PEI Ultem 1000 …
thermoplastic thread
Specific regulated oven temperature
Max nozzle temperature : 520 °C
Plate temperature : up to 120 °C
Minimum layer thickness : 0,1 mm
Machine resolution : X Y 0,0125 mm / Z 0,05 mm
Product resolution : X Y 0,5 mm / Z 0,1 mm
Production 3D array 145 x 135 x 148 mm
~35 k€


PEEK

Source : http://apiumtec.com/

KREOS

3D Roboze One+400

High performance polymers
PEEK, Carbon Pa, PC, PMMA, …
thermoplastic thread
Specific regulated oven temperature
Max nozzle temperature : 520 °C
Plate temperature : up to 150 °C
Minimum layer thickness : 0,1 mm
Machine resolution : 0,05 mm
Production 3D array 200 x 200 x 200 mm
~40 k€

Source : http://www.primante3d.com/kreos-roboze-20160520/

4- some 3D printers

Objet30 Pro

Polyjet printer
3D array : 294 x 192 x 148.6 mm
Layers thickness 28 microns
Layers thickness 16 microns with VeroClear material
Resolution: 600 x 600 x 900 dpi
Precision about 0.1 mm
7 different photopolymers (indépendant prinitings)
With resin support material
~20k€

Source : http://fr.objet.com/

EDEN 260 at Pôle ORTECH (Lycée Théodore Deck, in Guebwiller, France)

http://www.lyceedeck.fr/poleortech/equip_eden.html

4- some 3D printers

FORMIGA P100
sls PA 100µm
~200 k€
Maintenance ~2-4k€/an

FORMIGA P100 at Pôle ORTECH (Lycée Théodore Deck, in Guebwiller, France)

http://www.lyceedeck.fr/poleortech/equip_eos.html

Source : http://www.eos.info/en

Powder and binder jet
By Zcorp (3D System since 2012)

ZPRINTER 150 by ZCORP
monochrom (white)
Resolution : 300 x 450 dpi
minimal size : 0,4 mm
vertcal creation speed : 20 mm/heure
fabrication maximal size : 236 x 185 x 127 mm
layer thickness 0,1 mm

Zprinter 150
Monochrom voxeljet ~15k€

Zprinter 250
Polychrom voxeljet ~25k€

Source : http://www.zcorp.com/
(this adress doesn't work anymore)

Powder and binder jet
By VOXELJET

Powder = PMMA or SAND
Print resolution x, y 600 dpi
Layer thickness 120/300 µm
Build speed 15,4 mm/h (=123 l/h)

build space : **4000 x 2000 x 1000 millimetres**

voxeljet

Source : http://www.voxeljet.de/en/systems/vx4000/

3Z MAX printer by SolidScape

Precision and High quality wax printing

For lost wax casting

Source : http://www.multistation.com/3Z-MAX

5- Materials

Several possible materials used in 3D printing industry

Several plastic materials by STRATASYS

Stratasys fdm production possibilities :

ABSplus-P430, ABSi, ABS-E SD7, ABS-M30, ABS-M30i, PC-ABS, PC-ISO, PC, Nylon 12, ULTEM-9085, PPSF PPSU

Source : http://www.stratasys.com/materials/fdm/compare-fdm-materials

Stratasys Polyjet plastic production possibilities :

Vero, Translucent Rigid, High Temp, Durus, Digital ABS, Digital ABS2, Tango (Rubber-Like / Flexible), Performance Digital, Rubber-Like Digital, Biocompatible

Material Mimic : Polypropylene – PP, High-Density Polypropylene – HDPE (PEHD), Polystyren – PS, Poly Methyl Methacrylate – PMMA (plexiglas), Polycarbonates – PC, Acrylonitrile Butadiene Styrene – ABS, High-Impact Polystyrene – HIPS, Styrene-Based Thermoplastic Elastomers, Ethylene Propylene Diene Monomer M-class – EPDM Rubber,

Source : http://www.stratasys.com/materials/polyjet/compare-polyjet-materials

http://www.stratasys.com/

Several plastic and metal materials by EOS

EOS SLS plastic production possibilities :

Alumide (polyamide alumium filled), CarbonMide (polyamide carbon fiber-reinforced), PEEK HP3 (PEEK, polyaryletherketone), PA 1101 (PA11), PA 2015 (PA12), PA 2200, PA 3200, PrimeCAST 101 (PS, polystyrene),

Source : data sheet on http://eos.materialdatacenter.com/eo/standard/main/ds

EOS DMLS metal production possibilities :

Aluminium AlSi10Mg, CobaltChrome MP1, CobaltChrome SP2, MaragingSteel MS1, NickelAlloy IN625, NickelAlloy IN718, StainlessSteel GP1, StainlessSteel PH1, Titanium Ti64

Source : http://www.moulds.asia/whats-new/dmls-direct-metal-laser-sintering/

Source : http://www.eos.info/

Several materials by 3D SYTEMS

3D Systems SLA plastic production possibilities : Accura series

Accura 25, 55, 60, 48HTR, ABS Black (SL 7820), ABS white (SL 7810), Amethyst, Bluestone, Casto, Casto Free (SL 7800), CeraMAX Composite, ClearVue, ClearVue Free, e-Stone, Peak, Sapphire, SL 7840, Xtreme, Xtreme White 200

3D Systems SLS plastic production possibilities : CastForm PS and Duraform series
Duraform EX Black, EX Natural, Flex, FR100, GF, HST Composite, PA, ProX

Source : data sheet on
http://www.3dsystems.com/materials/production

3D Printer plastic production possibilities : VisiJet series (27 different materials)

Source :
http://www.3dsystems.com/materials/professional

DMS metal production possibilities :

17-7 PH, Aluminium, Berylium Copper, Brass, Carbon Steel, Copper, Nickel Alloys, Phosphor Bronze, Spring Steel, Stainless Steel, Titanium
Also some finishes : anodized, Heat Treated, Laser Welded, Painted, Powder Coated, …

Source : http://www.3dsystems.com/quickparts/production/quick-sheet-metal

Source : http://www.3dsystems.com/

Material today in use or development in progress

Plastics or ‘plastic like’

ABS Acrylonitrile Butadiene Styrene
Nylon
PEHD
Polycarbonate
ULTEM (Stratasys)
PLA
Polyjet Resin
PMMA
PA
PEEK
PSU
Multicolor or not
…

Soluble

PVA
HIPS

Other

Ceramic (ZrO_2, TiO_2, SiC)
Sand
Wax
Alumid

Metals

Aluminium
Nickel
Tantale
Tungsten
Titanium (Ti-6A-4V)
Maraging steel
Stainless steel 316L
Inconel
Cr-Co alloy
Aluminium alloy
Gold, silver

Alternative :

Biological material : bone, lever, skin, …
Meat,
Pizza,
Chocolate, sugar

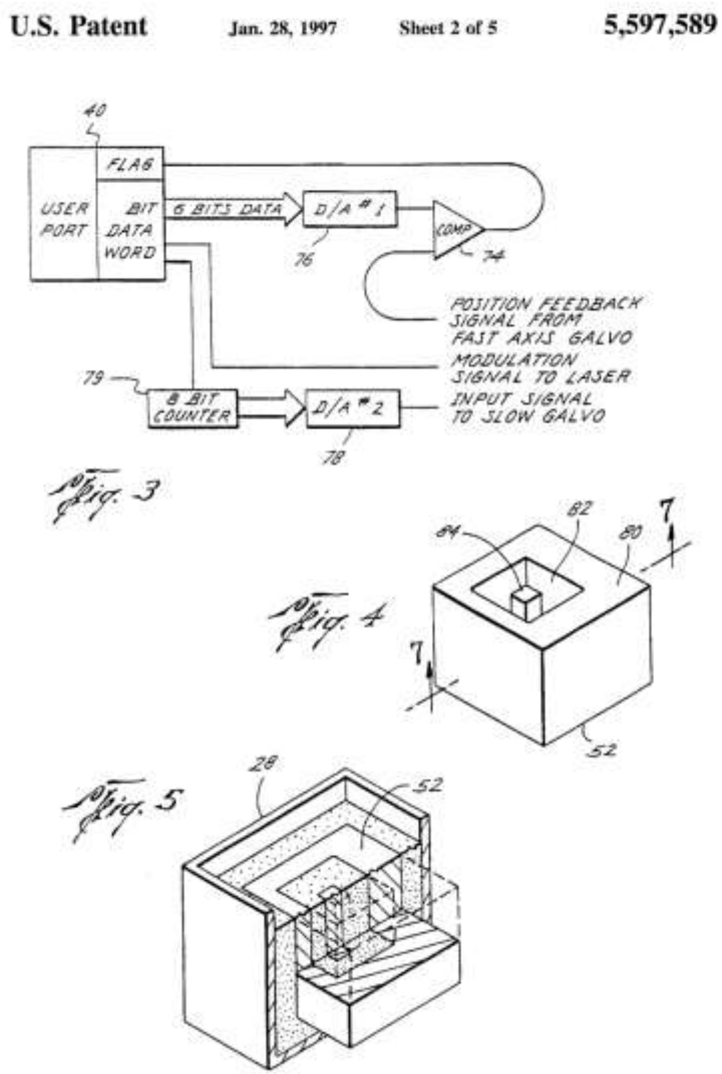
www.cnrs.fr
IN2P3
http://institut.in2p3.fr/

http://www.iphc.cnrs.fr/

6- Outlook

ESIPAP European School of Instrumentation in Particle and Astroparticle Physics

5- Outlook



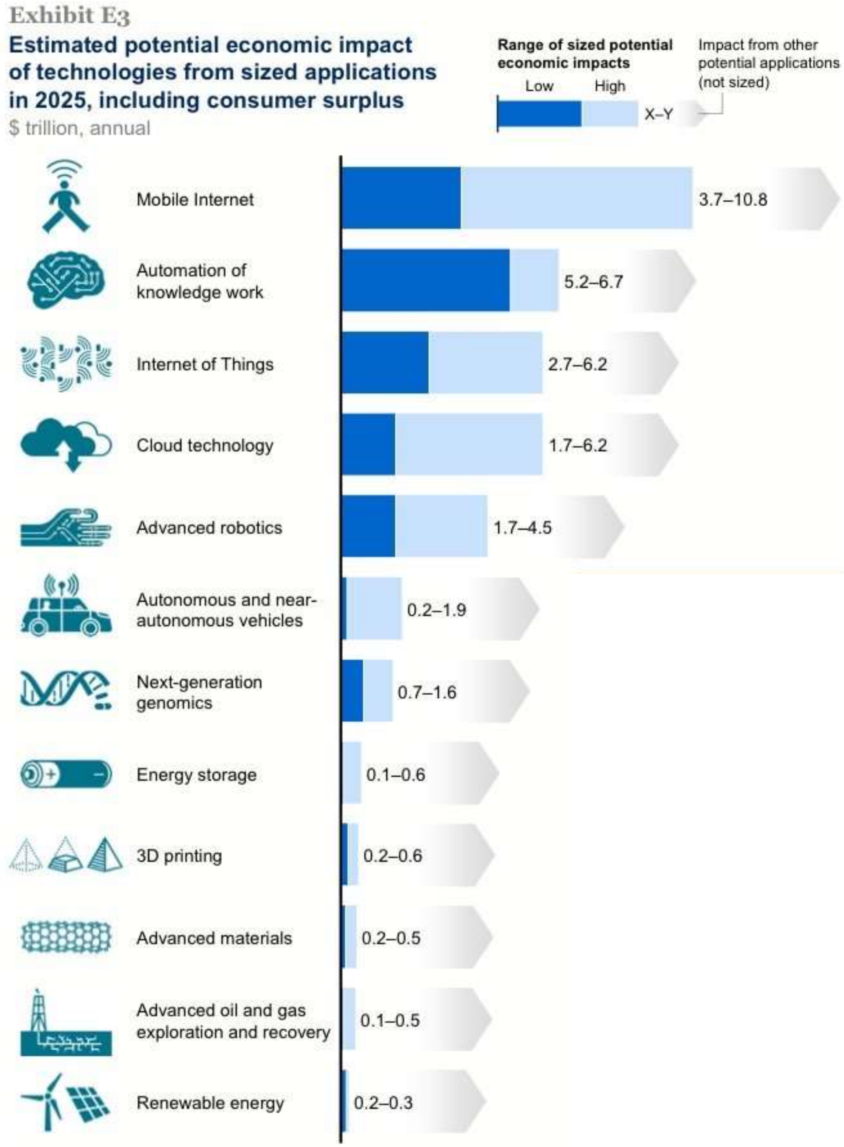
Fdm patent is already expired (in 2009)

Key 3D printing patent expired 28th of January 2014

Apparatus for producing parts by selective sintering
US 5597589 A
Abstract :
An apparatus for selectively sintering a layer of powder to produce a part made from a plurality of sintered layers. The apparatus includes a computer controlling a laser to direct the laser energy onto the powder to produce a sintered mass. The computer either determines or is programmed with the boundaries of the desired cross-sectional regions of the part. For each cross-section, the aim of the laser beam is scanned over a layer of powder and the beam is switched on to sinter only the powder within the boundaries of the cross-section. Powder is applied and successive layers sintered until a completed part is formed. Preferably, the powder dispensing mechanism includes a drum which is moved horizontally across the target area and counter-rotated to smooth and distribute the powder in an even layer across the target area. A downdraft system provides controlled temperature air flow through the target area to moderate powder temperature during sintering.

Even it's a little different, but
3D printing using pouder will explode in 2014
More possible materials !

5- Outlook



Source : http://www.3ders.org/articles/20130529-mckinsey-report-12-disruptive-technologies-by-2025-3d-printing-included.html

Possibilities for innovation in physics developpements

Including 3D wire screen (filter),
Cooling channels,
Volume optimisation

Without assembling
or
Assembling by glueing, bolting, screwing, …

Multifunctionnal parts

Where are the limits ?

Geometries

Additive Manufacturing Machine

New materials

Plastics,
Metals,
Composites

integration
In existing manufacturing process

EBM
Electron
Beam
Melting

DMLS
Direct
Metal
Laser
Sintering

Some benchmarks :
- Service society : Specialized in additive manufacturing
- Possible plastics : ABS, PLA, PC, PA, Plastique ceramic charged, fibres or aluminium alloy charged,…
- Possible metals : 316L, Ti64, TA6V, maraging steel, CR-CO, Bronze, Inconel, Nickel alloy, aluminium alloy, ceramics, …

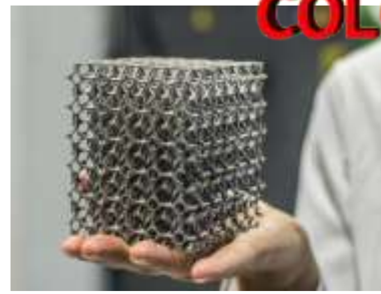
Metal 3D Printing Services

I3DFG enterprise

Aluminium, titatium, stainless steel,
maraging steel, inconel (IN718) or customer powder

Source : http://www.i3dmfg.com/industries/tooling/

3DPRINTING COLORADO



Aluminum, Stainless Steal, and Titanium DMLS printing possibilities
Source : http://3dprintingcolorado.com/3d-metal-printing/

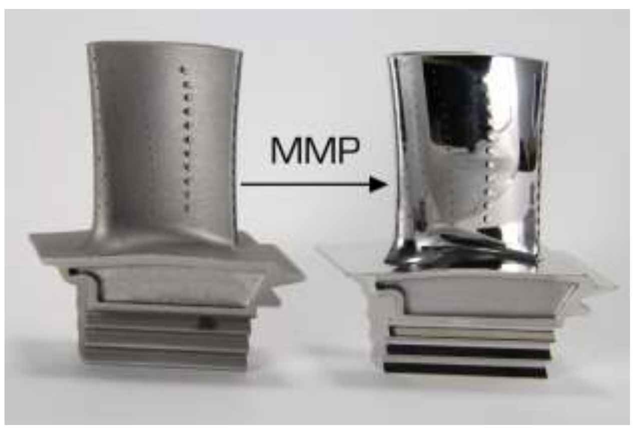
Smit Röntgen enterprise

smit RÖNTGEN

Tungsten alloy parts

Source : http://www.smitroentgen.com/

Post treatment processes



Source : http://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/4042/First-Surface-Oberflachentechnik-GmbH-EOS-and-BESTinCLASS-Found-Joint-Venture-for-the-German-speaking-Market.aspx

5- Outlook

Be carefull about copyright !

Where is the limit of 3D printing ?

A lot of leaders : each in his domain …

5- Outlook : questions…

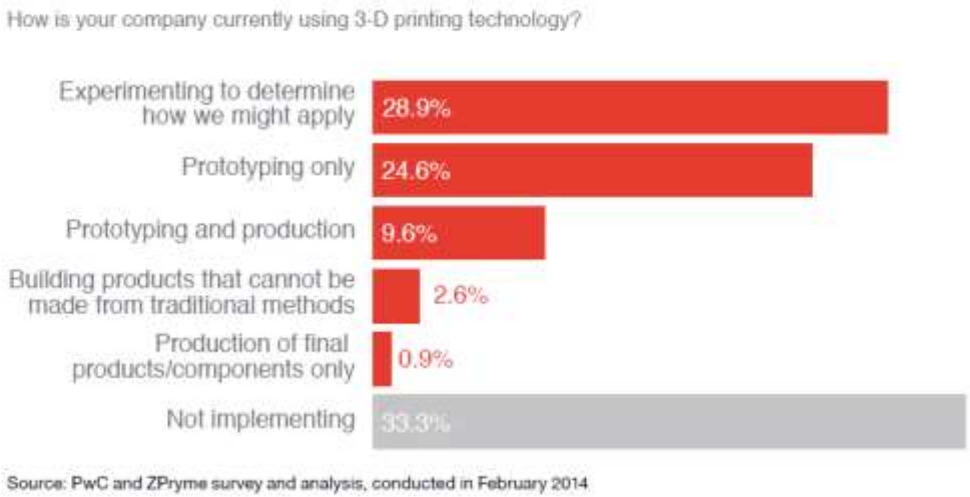
When will I use 3D printing technology ?

What have I to do with it ? What can I do with it ?

Just think, simulate and print …

Source : http://www.dezeen.com/2013/02/13/protohouse-2-3d-printed-house-by-softkill-design/

How will you use 3D printing ?



Source : http://www.pwc.com/us/en/technology-forecast/2014/3d-printing/features/future-3d-printing.html

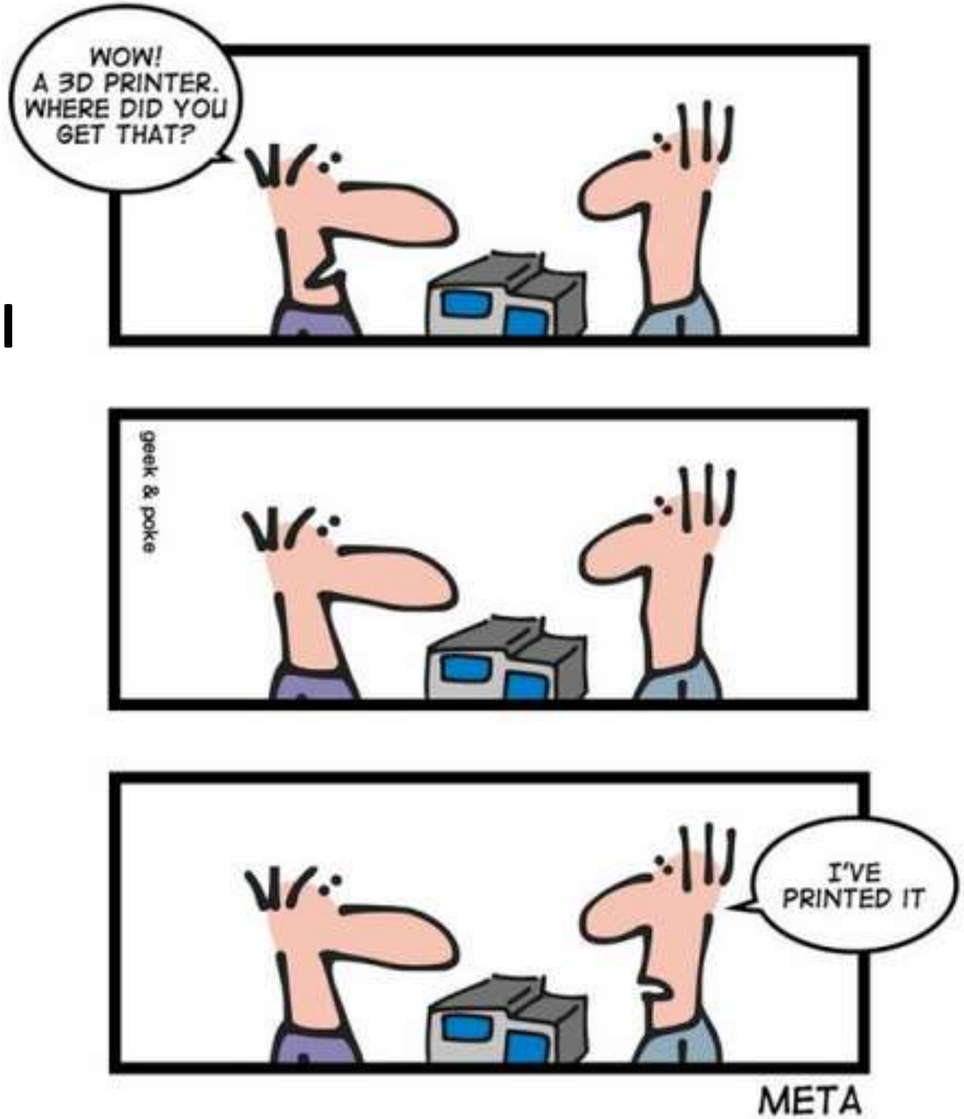
Innovation : ears and guns produced by 3D printing
Some steps were forgotten …

And printing something between ears ?

Source : http://www.clubic.com/diaporama/photo-la-semaine-de-flock-enleve-les-bigoudis-de-l-actu-61890/

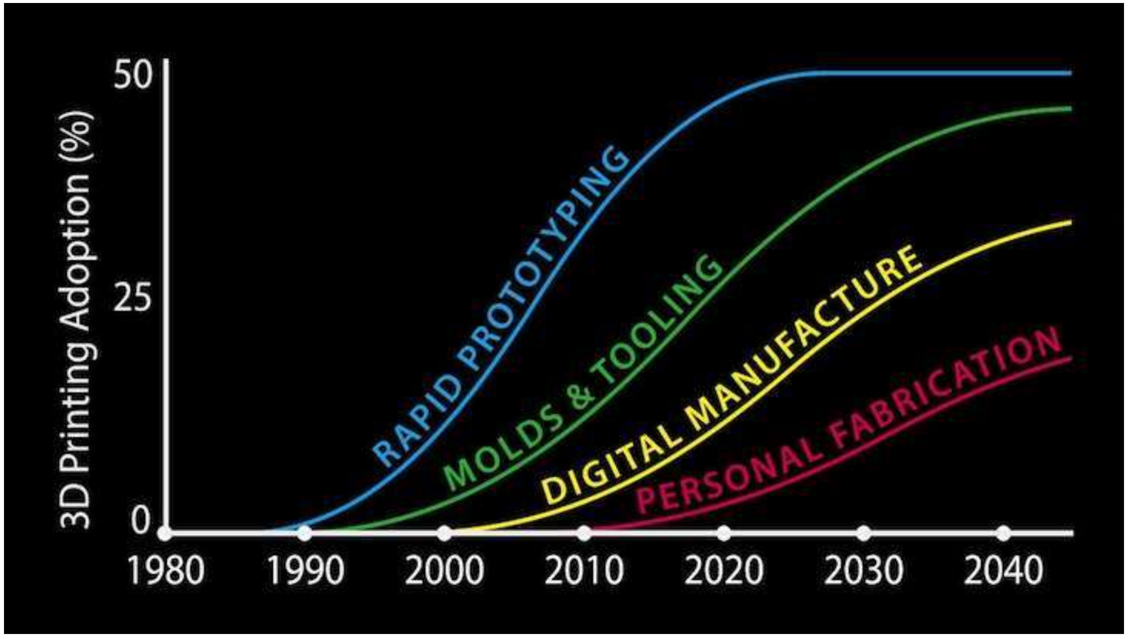
Easy copy

We should be carefull
About file protection



Source : http://textually.org/3DPrinting/2012/12/031489.htm

Futur is 3D printing



Source : http://www.3dprinter.net/3d-printing-the-business-opportunities

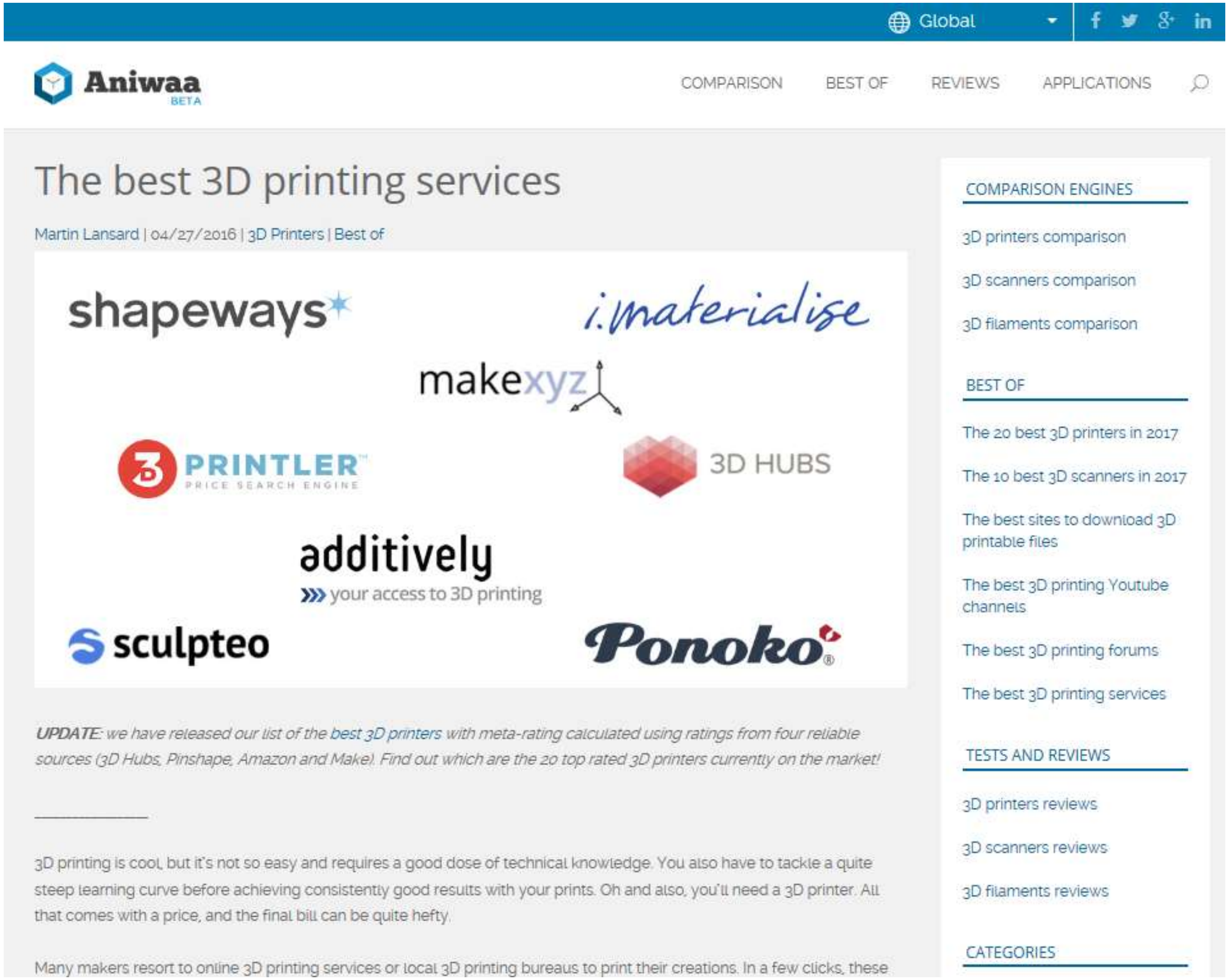
www.cnrs.fr
IN2P3
http://institut.in2p3.fr/

http://www.iphc.cnrs.fr/

Annex

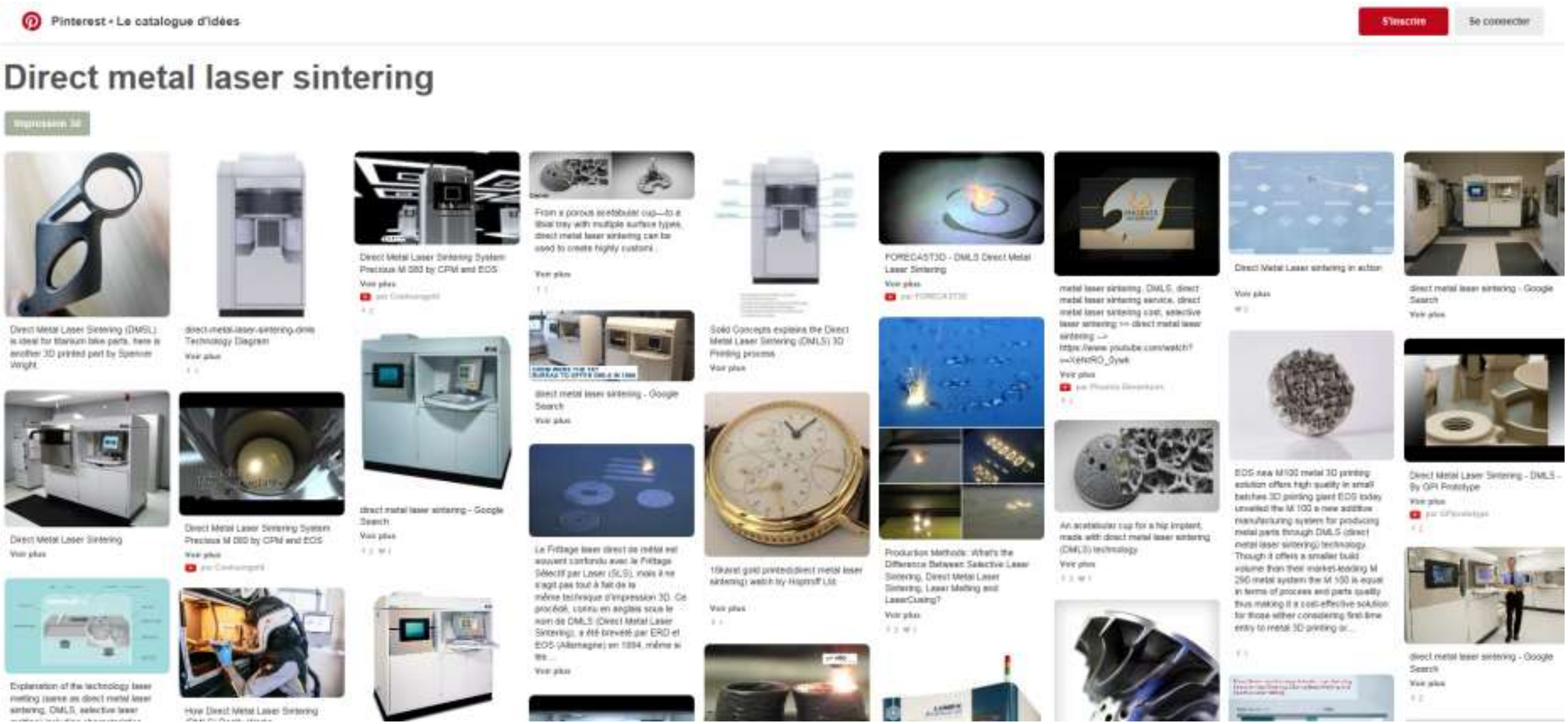
ESIPAP European School of Instrumentation in Particle and Astroparticle Physics

Plastic printing services



Source : http://www.aniwaa.com/blog/the-best-3d-printing-services/

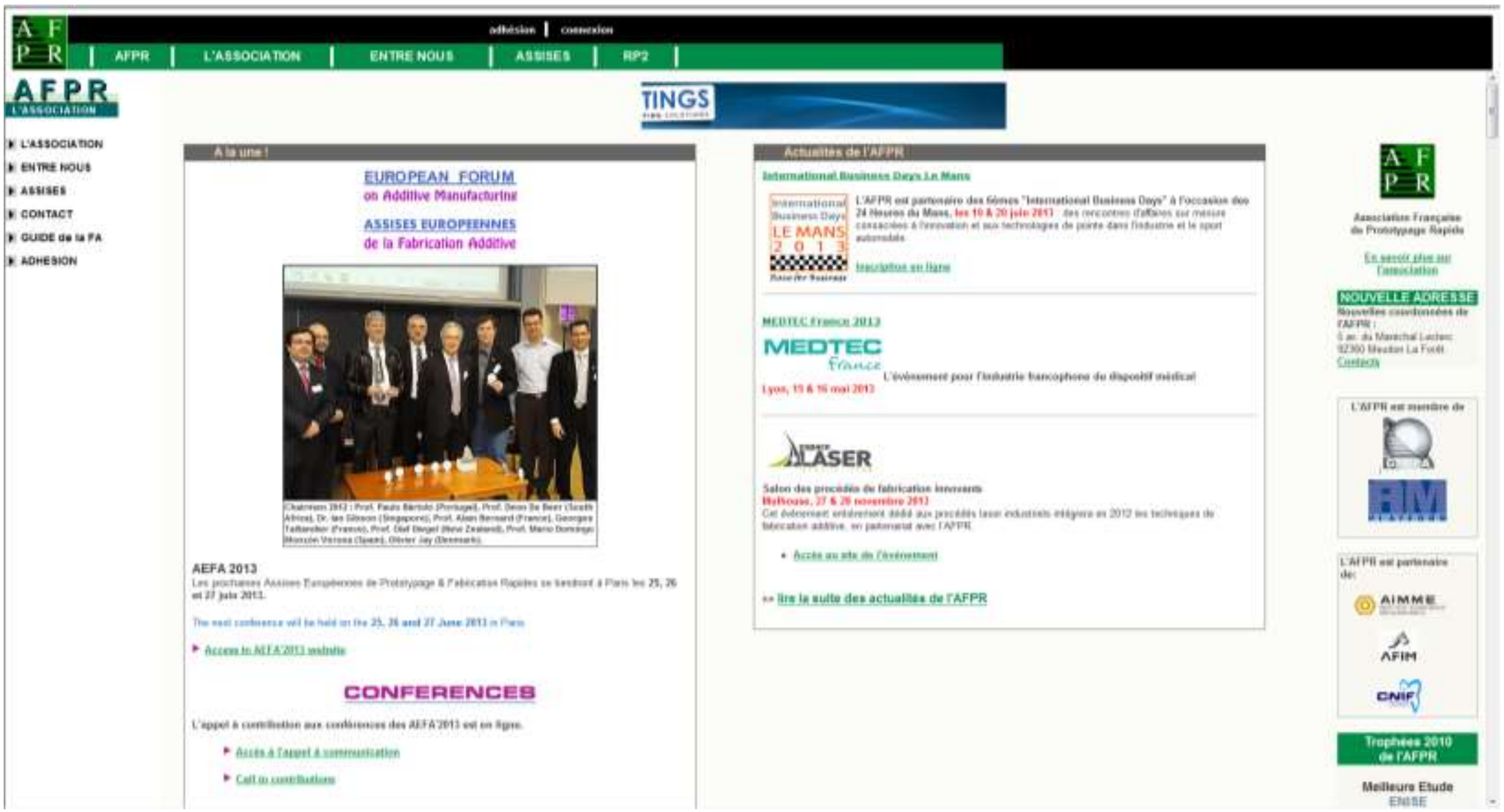
News on Internet



Source : https://fr.pinterest.com/explore/direct-metal-laser-sintering/

Association Française de Prototypage Rapide :
http://www.afpr.asso.fr/

Assises Européennes de Prototypage Rapide :
http://code80.net/afpr/aepr/



National Additive Manufacturing Innovation Institute :

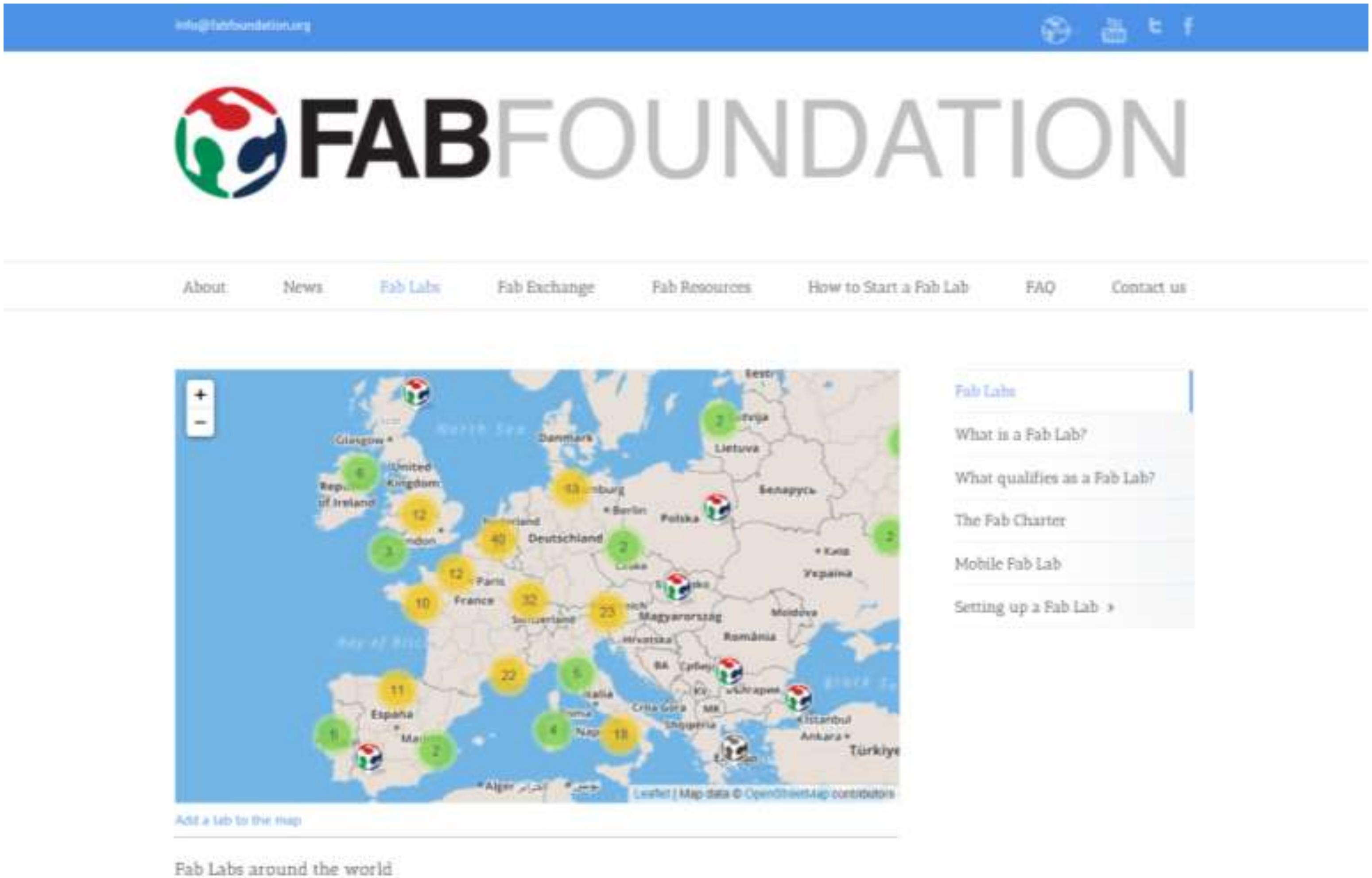
SOURCE : http:/namii.org/resources/presentations/

77 members from 15 countries

Direct Metal Laser Sintering
About powder production…

Source : http://www.epma.com/

Some Fab Labs in Europe



Source : http://www.fabfoundation.org/

The Fab Charter

What is a fab lab?

Fab labs are a global network of local labs, enabling invention by providing access to tools for digital fabrication

What's in a fab lab?

Fab labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared

What does the fab lab network provide?

Operational, educational, technical, financial, and logistical assistance beyond what's available within one lab

Who can use a fab lab?

Fab labs are available as a community resource, offering open access for individuals as well as scheduled access for programs

What are your responsibilities?

safety: not hurting people or machines
operations: assisting with cleaning, maintaining, and improving the lab
knowledge: contributing to documentation and instruction

Who owns fab lab inventions?

Designs and processes developed in fab labs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from

How can businesses use a fab lab?

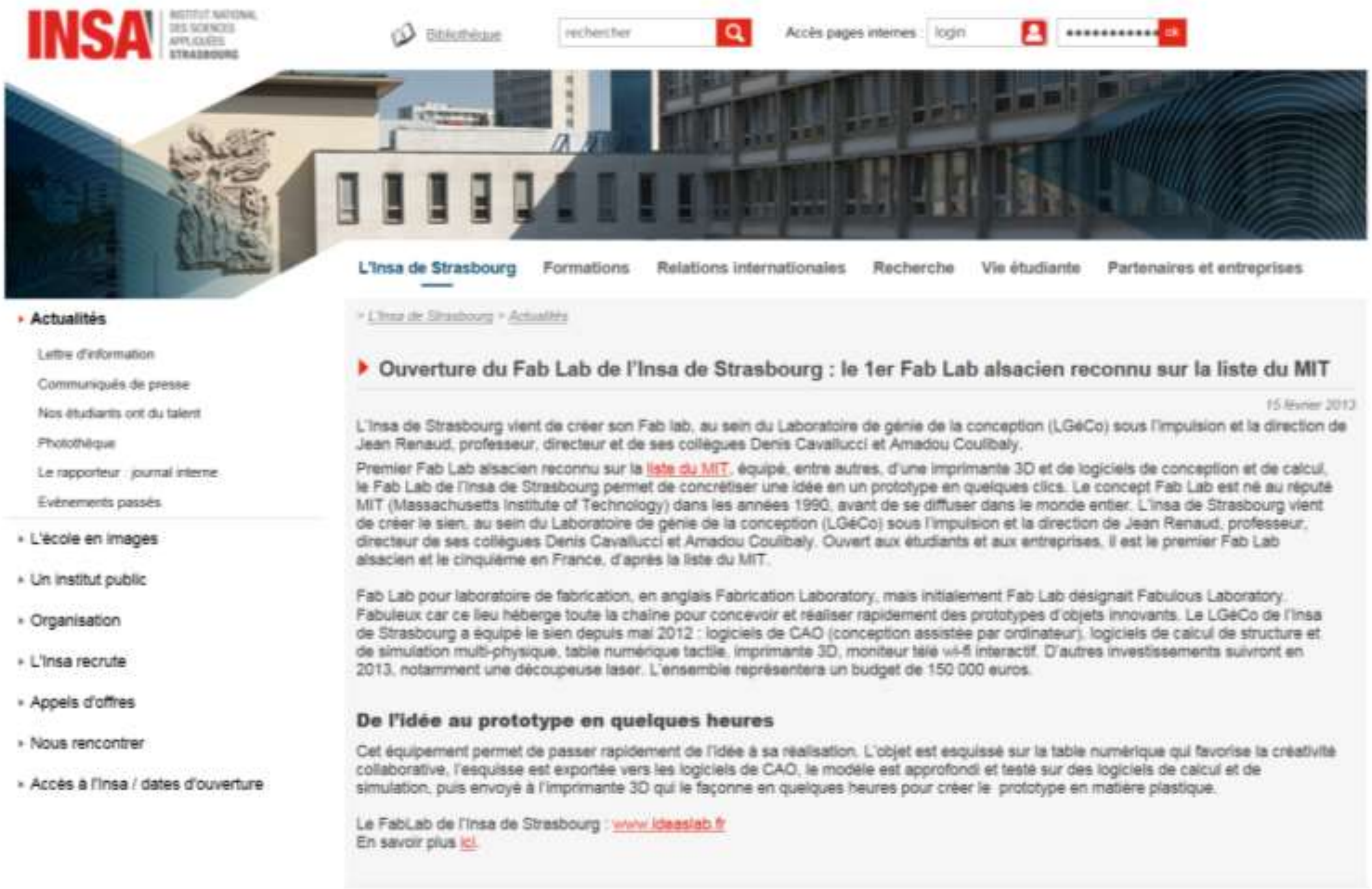
Commercial activities can be prototyped and incubated in a fab lab, but they must not conflict with other uses, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success

draft: October 20, 2012

Source : http://www.fabfoundation.org/fab-labs/the-fab-charter/

FABLABs around the world

A Fab Lab in Strasbourg…

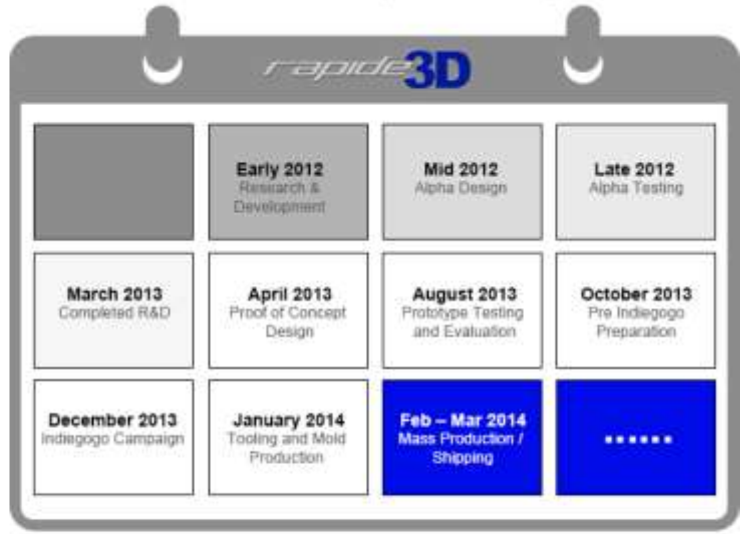


3D printer prices



	Rapide One	Replicator 2	Cube X
Price	$2499	$2799	$2799
Build Volume	170x170x170mm	250x160x150mm	275x265x240mm
Layer Resolution	100um	100um	100um
Material	PLA/ABS/PVA/Nylon	1.75mm PLA	PLA/ABS
Nozzle Diameter	0.4mm	0.4mm	0.4mm
Maximum Print Temp	350C	230C	280C
Dimensions	532x449x345mm	490x420x531mm	515x515x598mm
Chassis	Aircraft Grade Aluminum (CNC)	Powder Coated Steel	Steel
Body	Aluminum & Plexiglas	PVC Panels	Acrylic
Body Type	Fully Enclosed	Open	Open
Body Style	Designer	Box	Box
Build Platform	Heated Aluminum	Heated Aluminum	Heated Aluminum
XYZ Actuation	Water Resistant Bronze	Water Resistant Bronze	Liniar Bearings
Connectivity	USB, SD Card	USB, SD Card	USB
Operating System	Windows (7+) Mac OS X (10.6+) Linux (Ubuntu 12.04+)	Windows (7+) Mac OS X (10.6+) Linux (Ubuntu 12.04+)	Windows (7+)

Timeline for the Rapide One Project



Source 2012 : http://www.indiegogo.com/projects/rapide-one-affordable-professional-desktop-3d-printer-by-rapide-3d

3D printer prices

Source : Industrie et Technologies – May 2010

Marque	Multi station	Solido	3D Systems		Zcorporation		Stratasys		Solid scape	Objet
Nom	Extru 3D plastique	SD3000 Pro	V-Flash	Projet 3000 Dentaire	Zprinter 350	Zprinter 650	uPrint	Dimensio n	3D cire	Alaris 30
Taille Objet	60 x 60 x 80 x cm	46 x 77 x 42 cm	66 x 69 x 79 cm	73 x 125 x 150 cm	20 x 25 x 20 cm	25 x 38 x 20 cm	63 x 66 x 78 cm	NC	55 x 49 x 40 cm	82 x 62 x 59 cm
Résolution	400 µm	100 µm	220 µm	328 x 606 dpi	450 x 300 dpi	600 x 540 dpi	200 µm	100 µm	76 µm	600 x 900 dpi
Consomm able	ABS	PVC	FTI230	Bimatériau Support/ré sine	Poudre + liant	Poudre + liant	Bobine ABS	Cartouche ABS	Cire spécifique	VeroWhite
Principe	Extrusion fil plastique	Plastic sheet lamination	Type stéréolitho graphie	Ajout de couches	Jet d'encre couleur sur poudre	Jet d'encre couleur sur poudre	Fused Deposition Modeling	Fused Deposition Modeling	Dépôt de couches cire	Dépôt résine photopoly mère
Prix	1 000 €	7 950 €	9 900 €	70 000 €	22 000 €	50 000 €	11 999 €	15 300 €	31 900 €	34 500 €
Les plus	La moins chère	Faible coût impressio n	Prix peu élevé et simplicité	Wax up dentaire en continue	Proto couleur, faible coût impression (0.1 €/cm^3)	Idem Z350 avec bac impressio n plus grand	Technolog ie nid d'abeille, moins de matériau	idem	Haute précision	Qualité impressio n 28 µm
Les moins		Pas de détails très fins			Opacité des pièces	Opacité des pièces	Plateau impressio n petit	Que de l'ABS		

Comparatif Imprimantes 3D du marché - Source : Industrie et Technologies - Mai 2010

SOURCE : http://p1.storage.canalblog.com/16/54/447324/54635666.png

http://souspression.canalblog.com/archives/2010/06/28/18432637.html

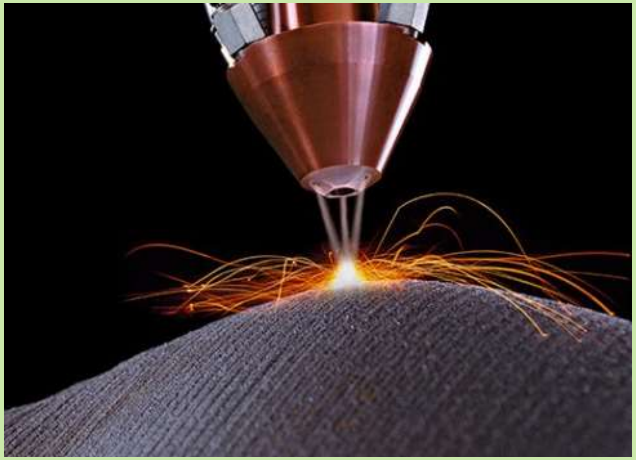
www.cnrs.fr
IN2P3
http://institut.in2p3.fr/

http://www.iphc.cnrs.fr/

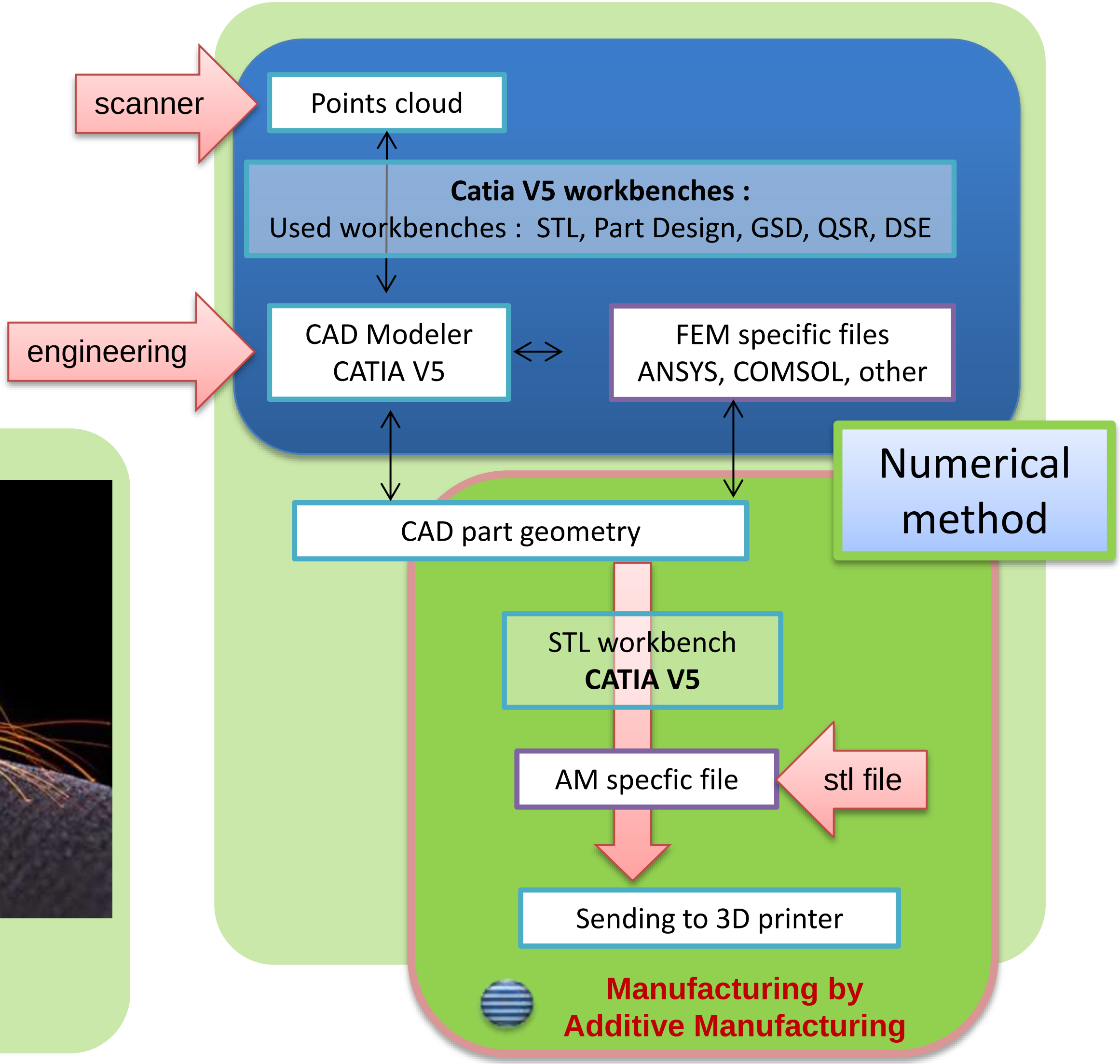
6- Workshop

ESIPAP European School of Instrumentation in Particle and Astroparticle Physics

Workshop



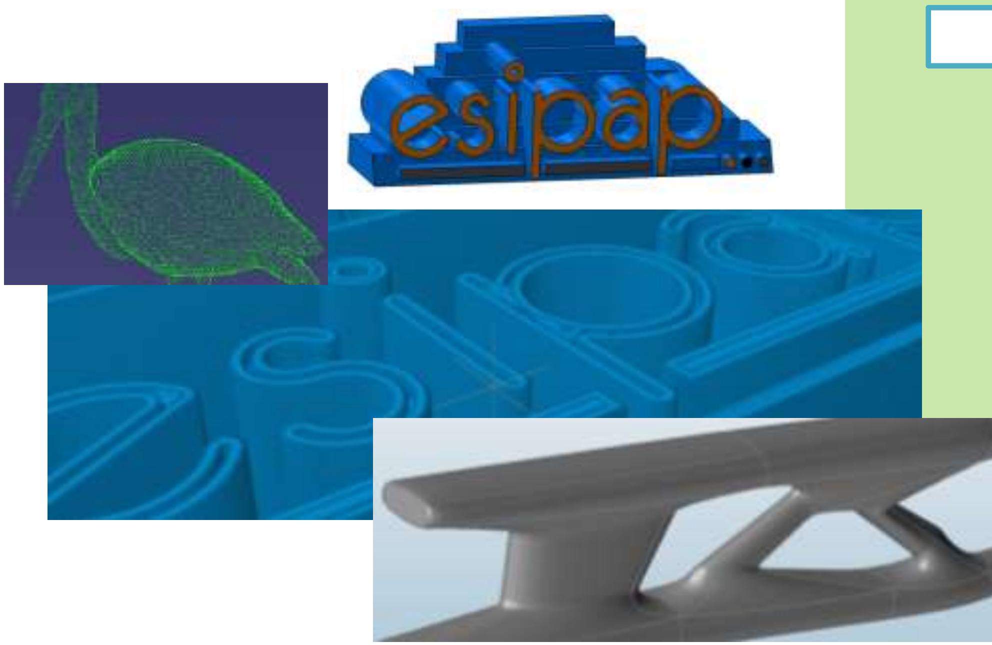
Metal powder and laser…
Direct manufacturing

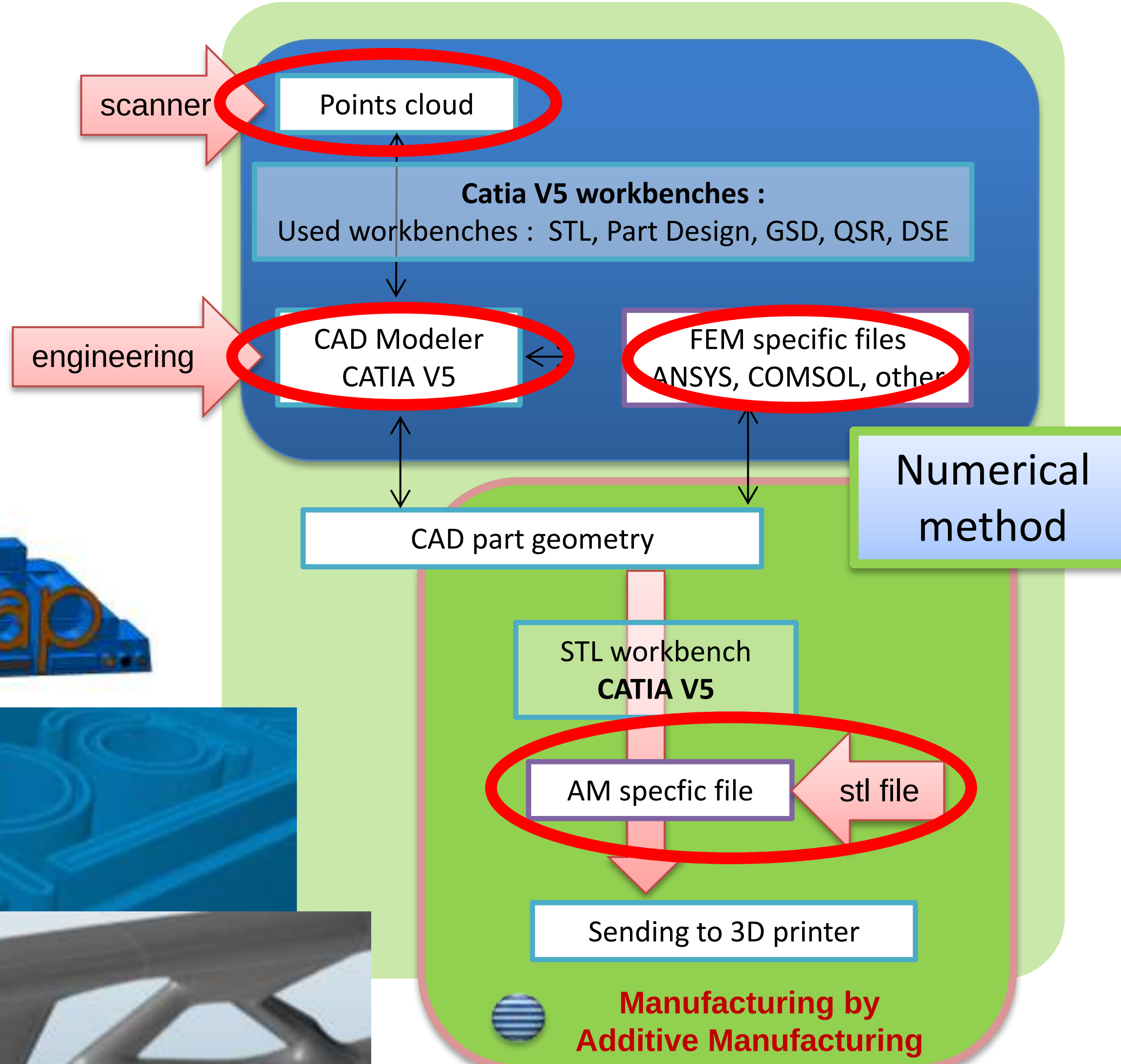


less material waste
create products that is impossible to make with existing machining techniques.

Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing





less material waste
create products that is impossible to make with existing machining techniques.

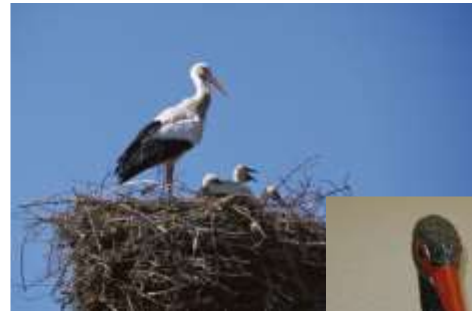
Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing

CATIA V5

Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing



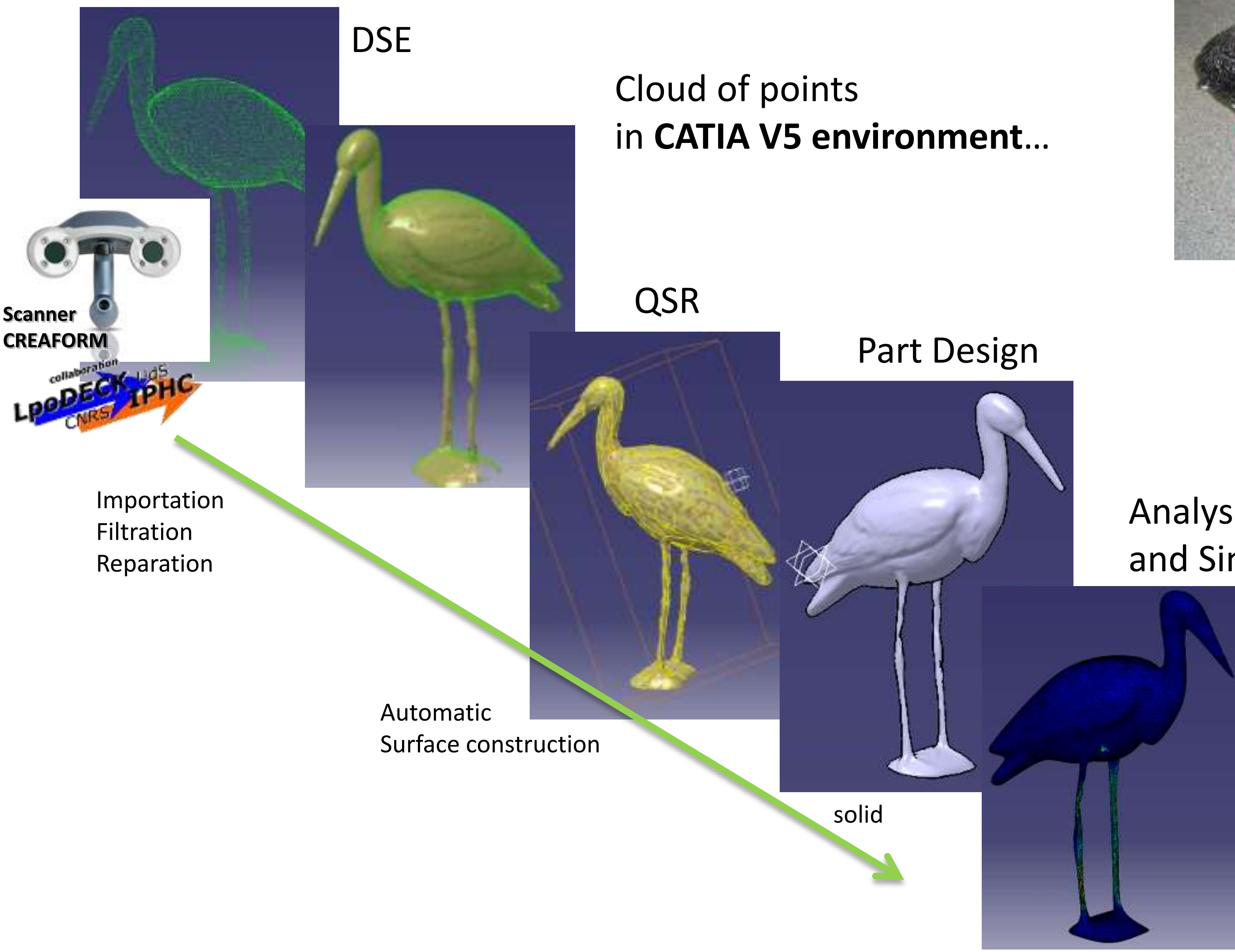
Plastic
Stork model

CAD logo

CATIA V5

scanned
Stork model
with logger

Numerical method from cloud to simulation



DSE

Cloud of points
in **CATIA V5 environment…**

QSR

Part Design

Analysis
and Simulation

Importation
Filtration
Reparation

Automatic
Surface construction

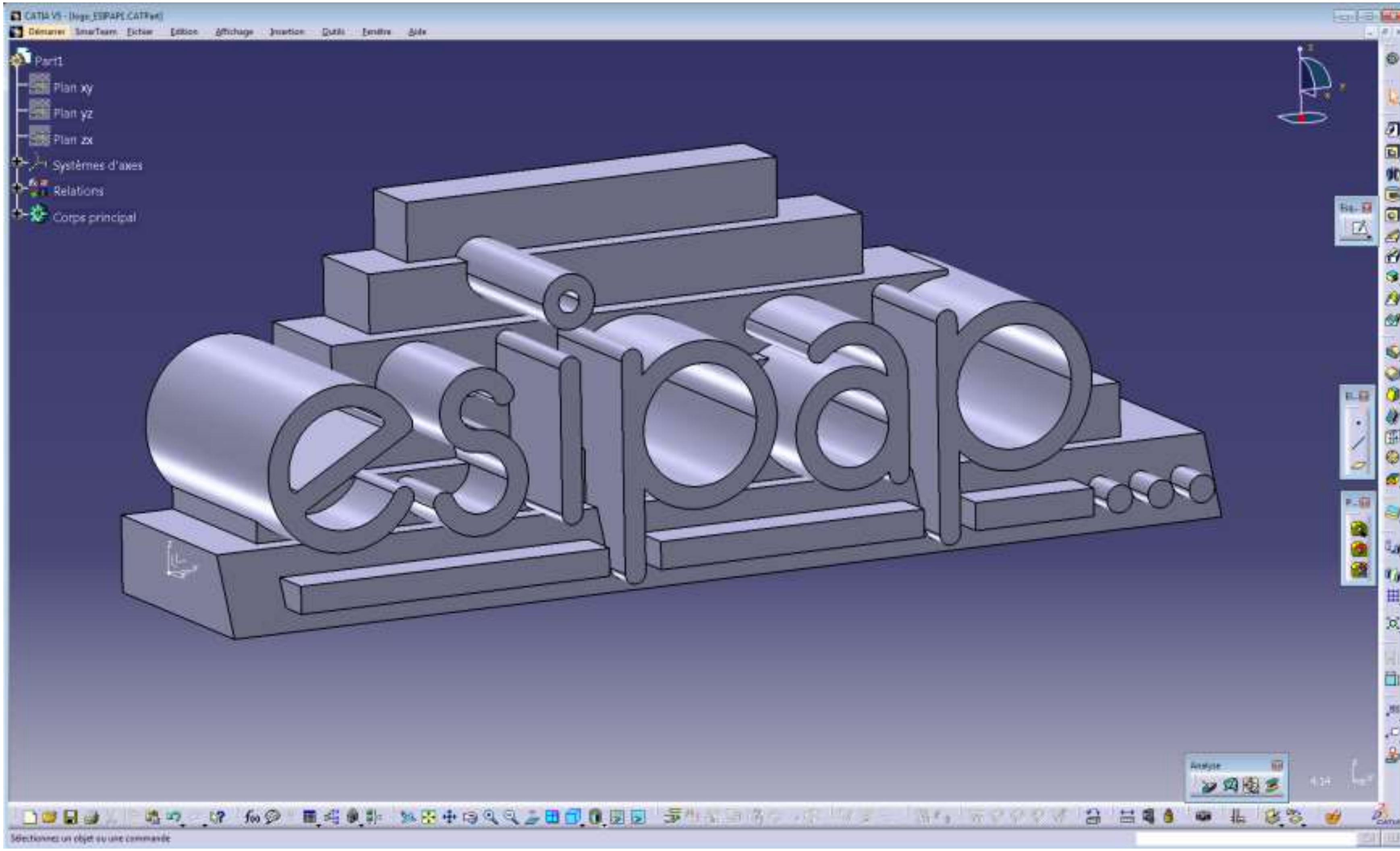
solid

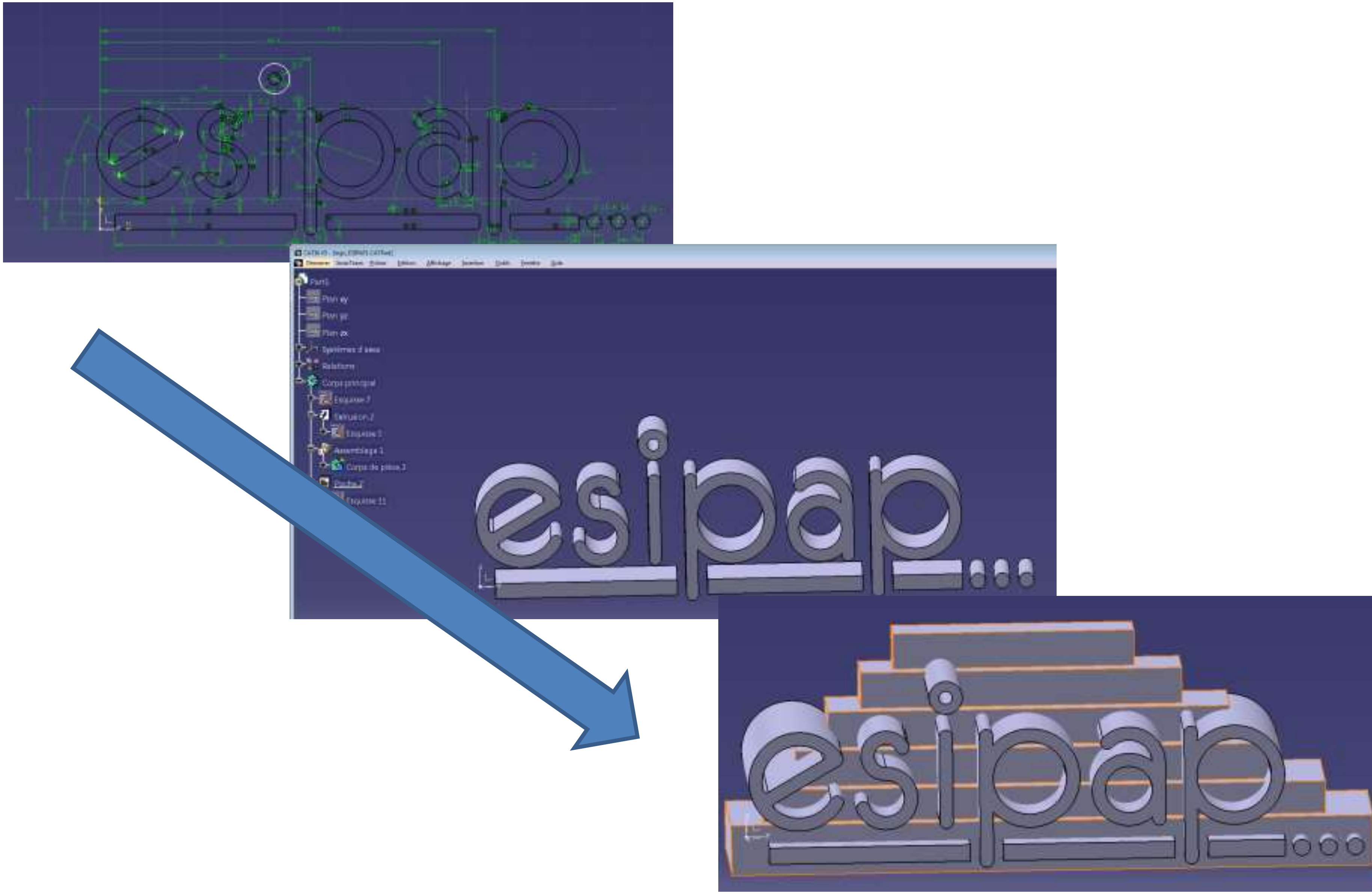
Exportation
Simulation


CATIA
© Dassault Systèmes
CATIA ® is a registered trademark of Dassault Systèmes

CATIA V5


esipap


Part1
Plan xy
Plan yz
Plan zx
Systèmes d'axes
Relations
Corps principal



Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing

ON YOUR DESKTOP

Where should be the marerial to optimise the piece response ?

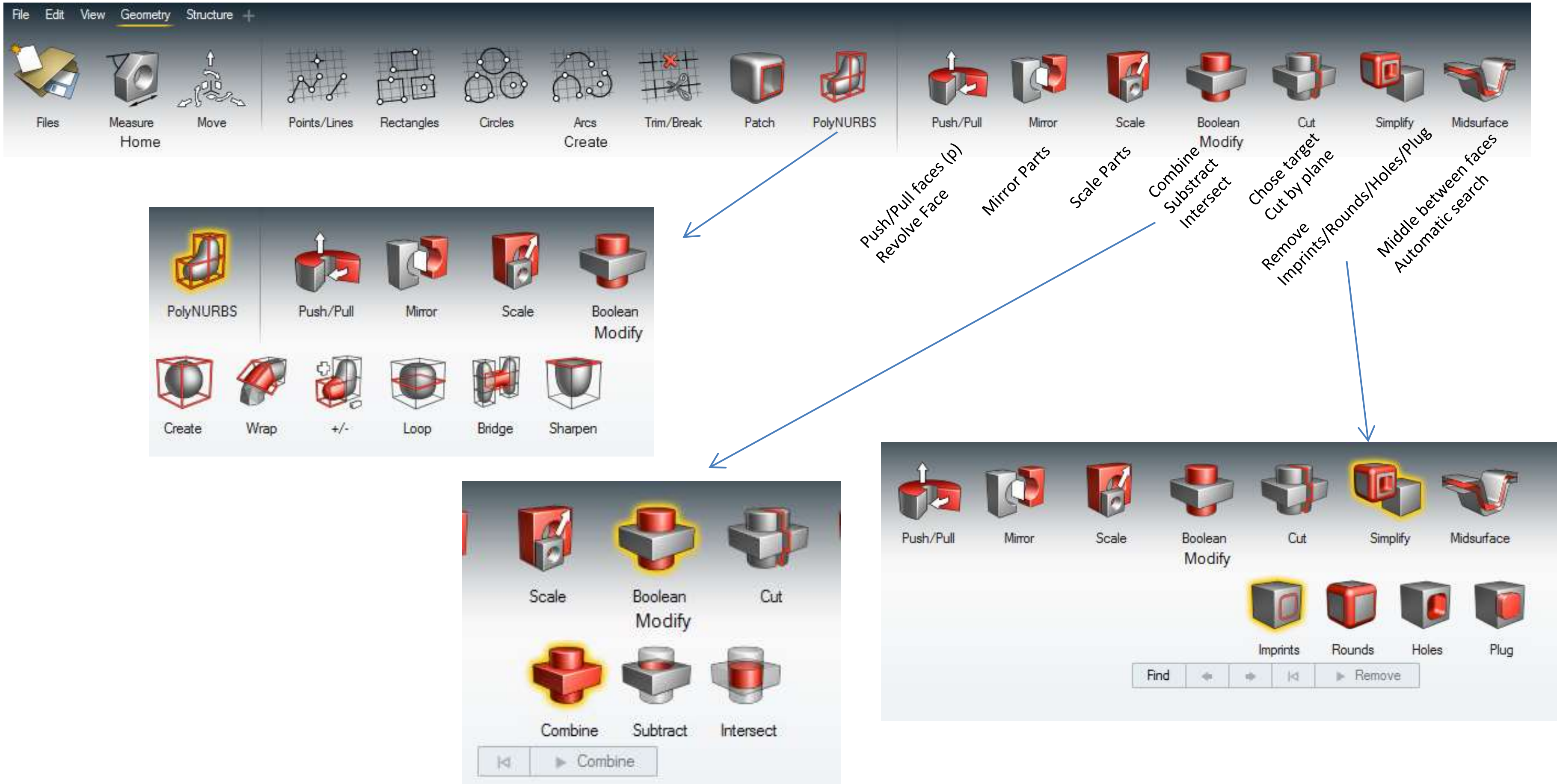
INSPIRE
solidThinking / WHERE IDEAS TAKE SHAPE

http://www.altairhyperworks.com/product/solidThinking-Inspire

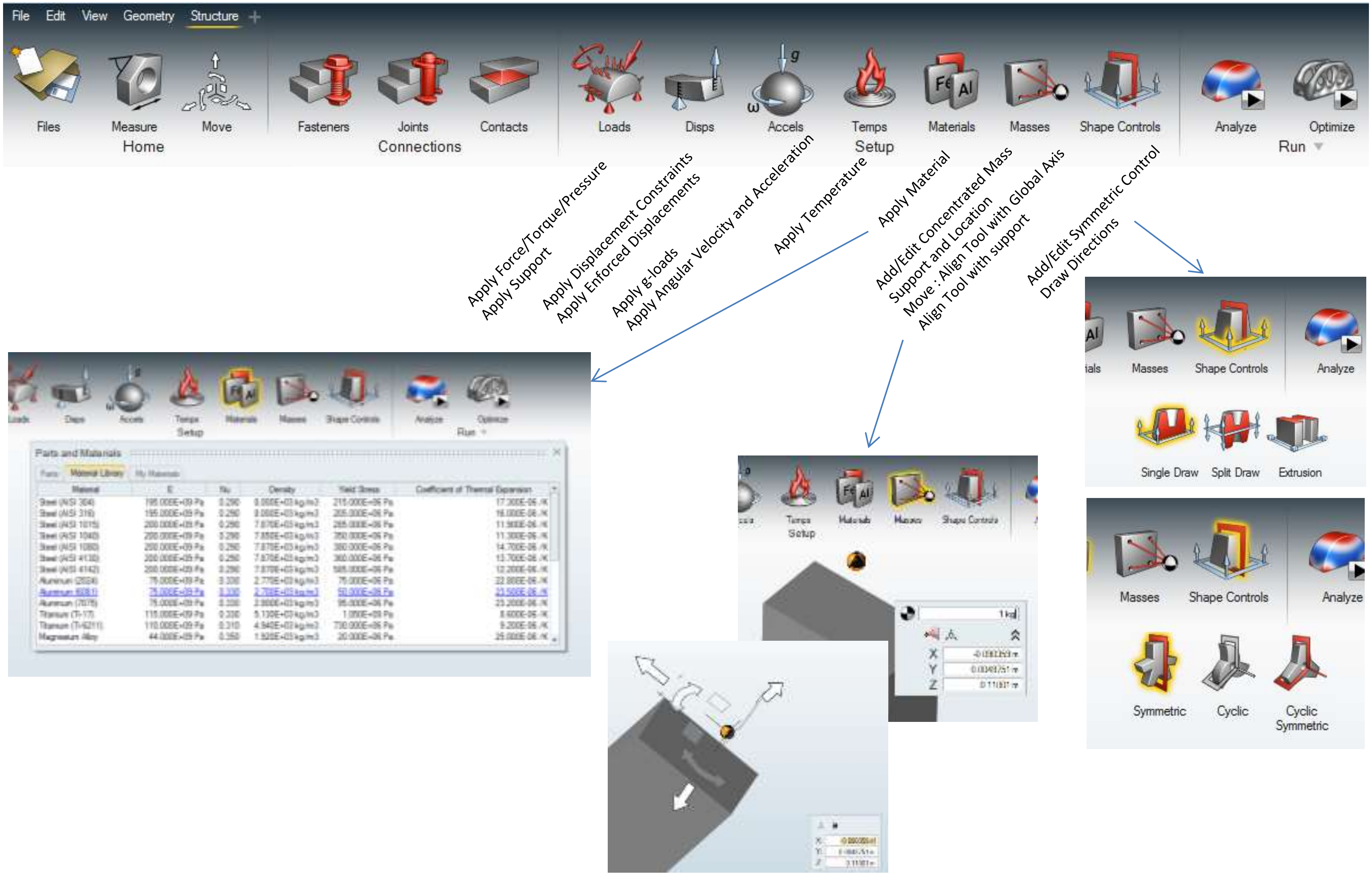
SolidThinking/University Products :
http://www.solidthinking.com/DownloadProducts.aspx?category=Download&item=Products

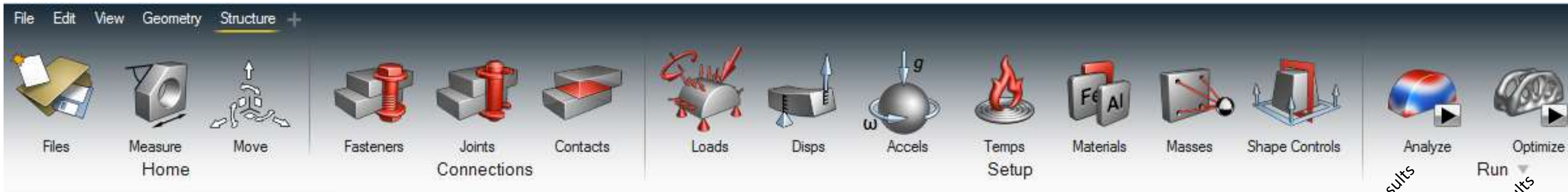
Altair contact :
Julien Grezolle, Application Engineer, jgrezolle@altair.com

Altair HyperWorks



File Edit View Geometry Structure
Files
Measure
Move
Home
Points/Lines
Rectangles
Circles
Arcs
Trim/Break
Patch
PolyNURBS
Create
Push/Pull
Mirror
Scale
Boolean
Cut
Simplify
Midsurface
Modify
Push/Pull faces (p)
Revolve Face
Mirror Parts
Scale Parts
Combine
Substract
Intersect
Chose target
Cut by plane
Remove
Imprints/Rounds/Holes/Plug
Middle between faces
Automatic search
PolyNURBS
Push/Pull
Mirror
Scale
Boolean
Modify
Create
Wrap
+/-
Loop
Bridge
Sharpen
Scale
Boolean
Cut
Modify
Combine
Subtract
Intersect
Combine
Push/Pull
Mirror
Scale
Boolean
Cut
Simplify
Midsurface
Modify
Imprints
Rounds
Holes
Plug
Find
Remove


File
Edit
View
Geometry
Structure
Files
Measure
Move
Home
Fasteners
Joints
Contacts
Connections
Loads
Disps
Accels
Temps
Materials
Masses
Shape Controls
Setup
Analyze
Optimize
Run
Apply Force/Torque/Pressure
Apply Support
Apply Displacement Constraints
Apply Enforced Displacements
Apply g-loads
Apply Angular Velocity and Acceleration
Apply Temperature
Apply Material
Add/Edit Concentrated Mass
Support and Location
Move : Align Tool with Global Axis
Align Tool with support
Add/Edit Symmetric Control
Draw Directions
Parts and Materials
Material Library
Single Draw
Split Draw
Extrusion
Symmetric
Cyclic
Cyclic Symmetric

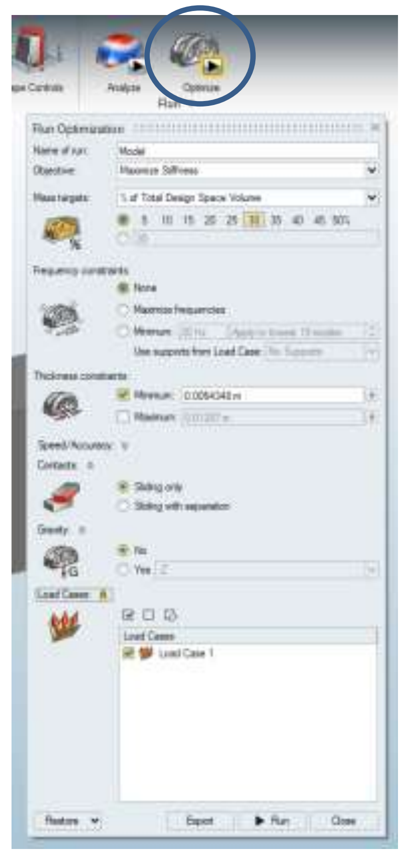


Run/Show Analysis Results

Run/Show Optimisation Results

Static analysis

Topological optimisation



 Show/Hide

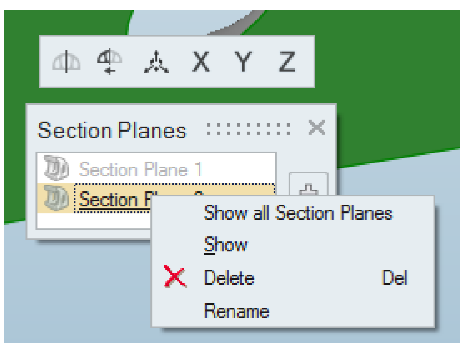
 Store/Recall Views

 Switch to Perspective Projection

 Rotate to closest principal axes

 Fit Selected (f)

 Add/Edit Section cuts

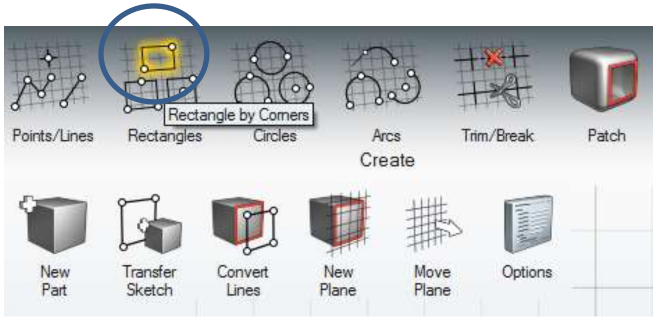
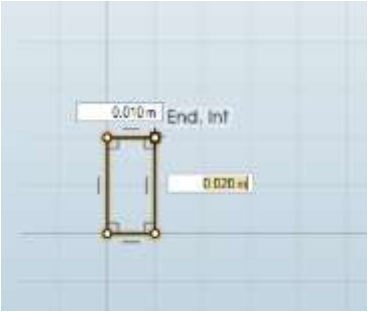


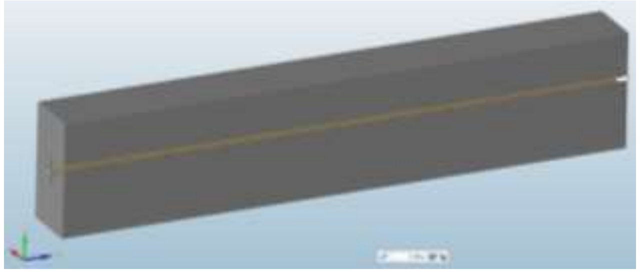
Workshop

Topolical optimisation
of a
Cantilever beam

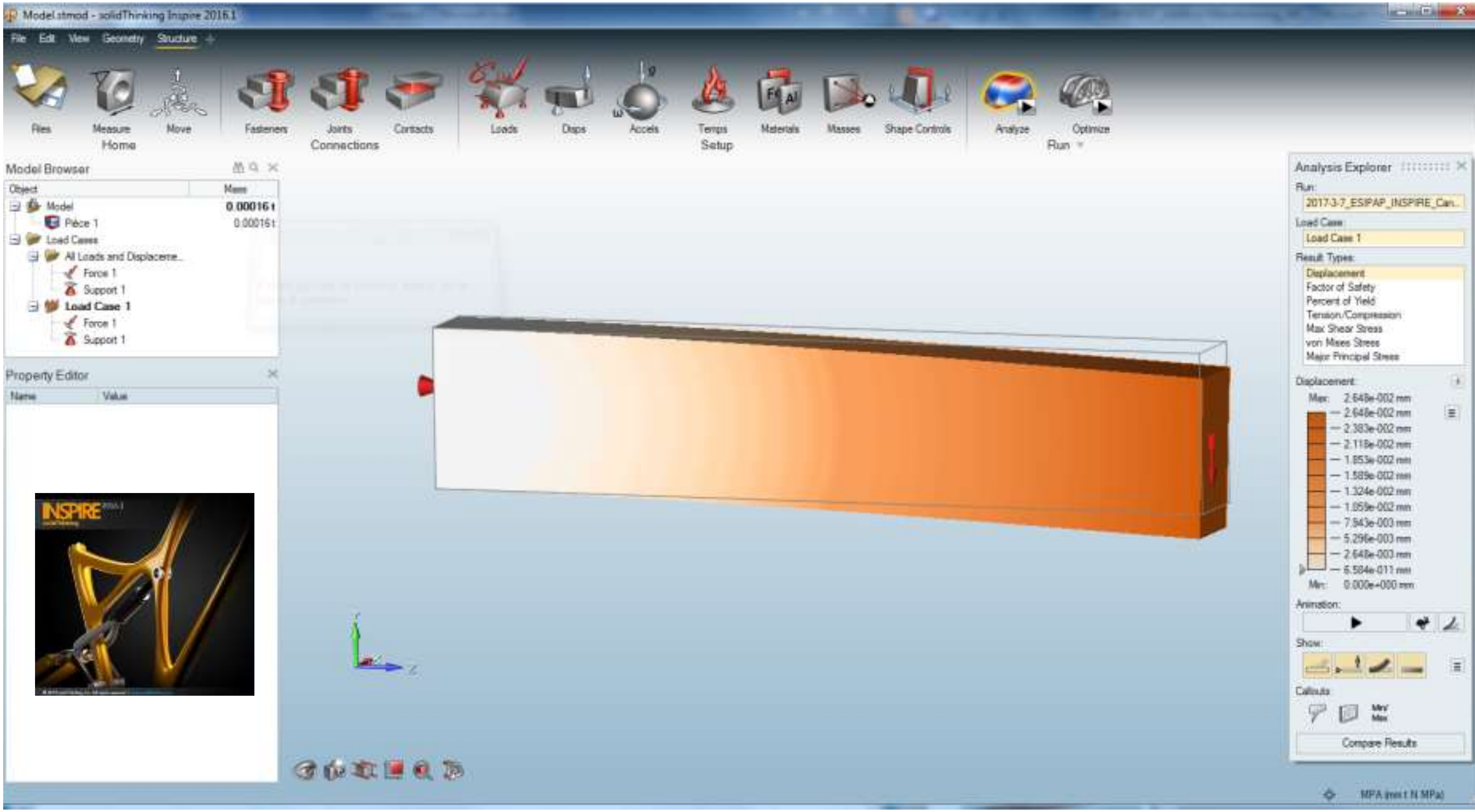
width 10 mm x height 20 mm x length 100 mm
Steel AISI 304 ($E = 195.10^9$ N/m^2)
Support fixed
Force = 100 N
Mesh size = default value

Theoretical Beam deflection : without shear effect
$d = F.l^3 / 3EI = 100.0{,}1^3 / (3.195.10^9.(10.20^3)/12) = 3{,}08.10^{-4}$ mm
Finite Element deflection : with shear effect, $d = 2{,}65.10^{-2}$ mm

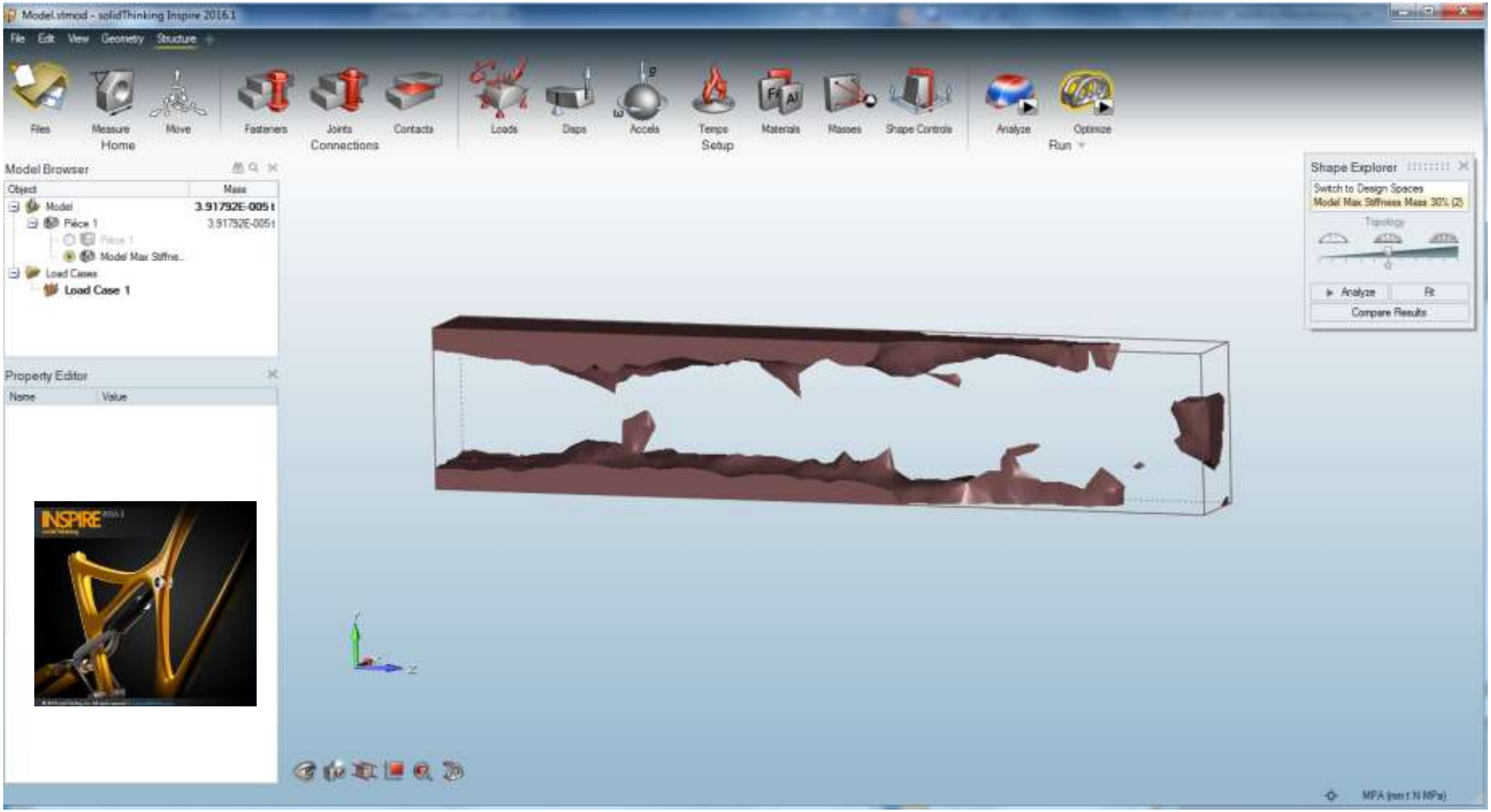

Rectangle by Corners
Points/Lines
Rectangles
Circles
Arcs
Trim/Break
Patch
Create
New Part
Transfer Sketch
Convert Lines
New Plane
Move Plane
Options

End, Int



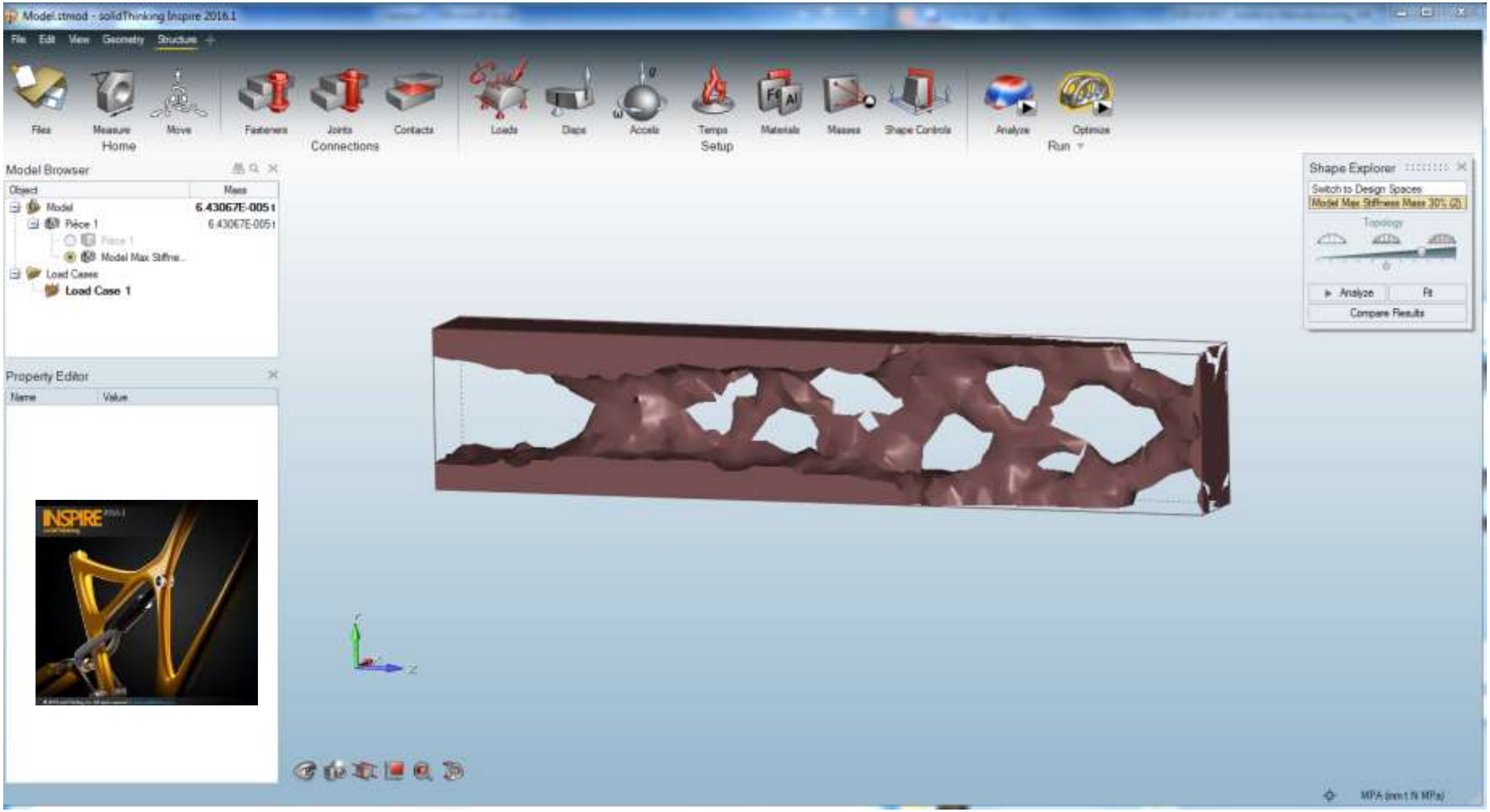
With default values **-> deflection = 2,65.10^{-2} mm**



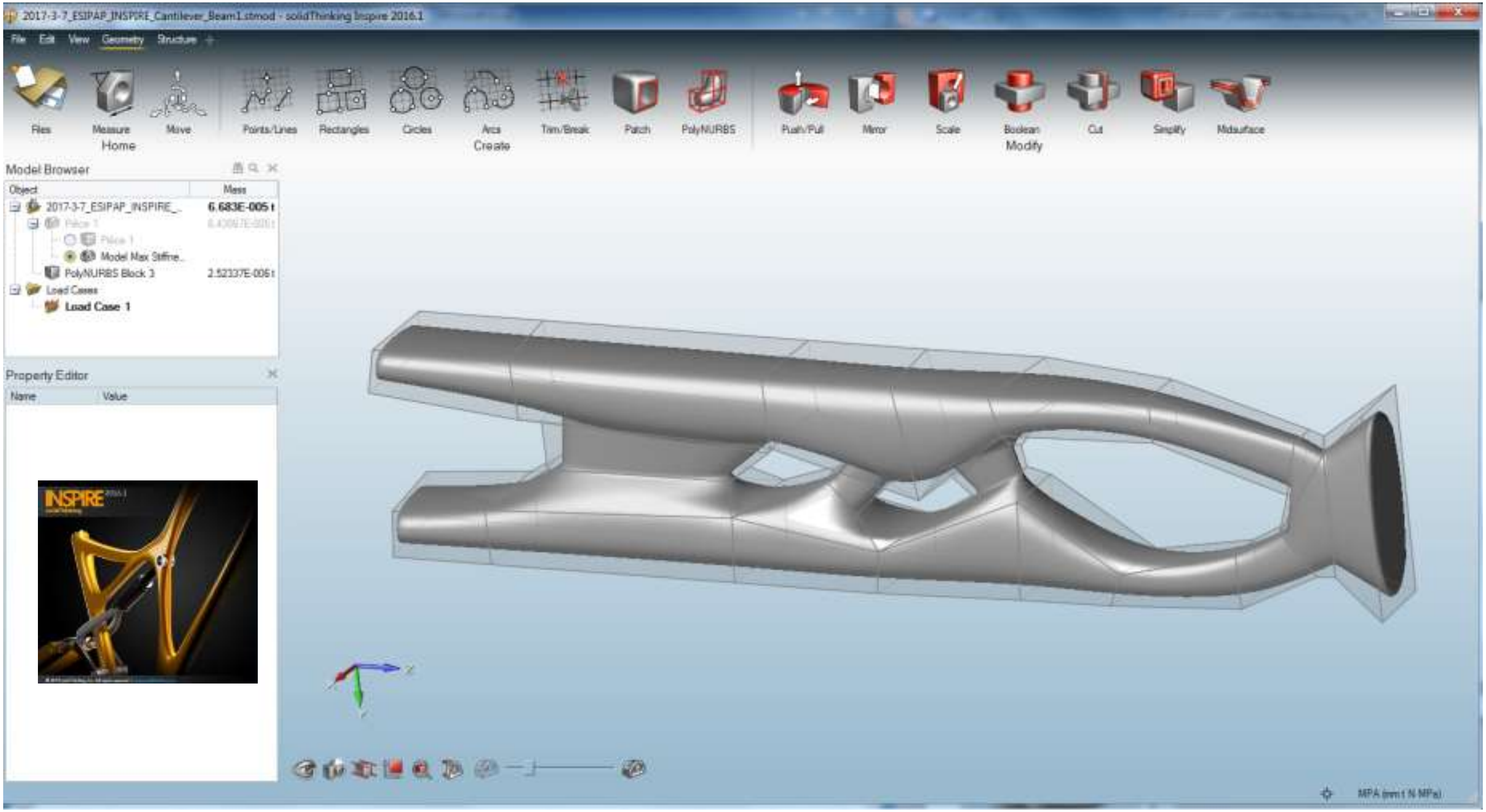
With default values



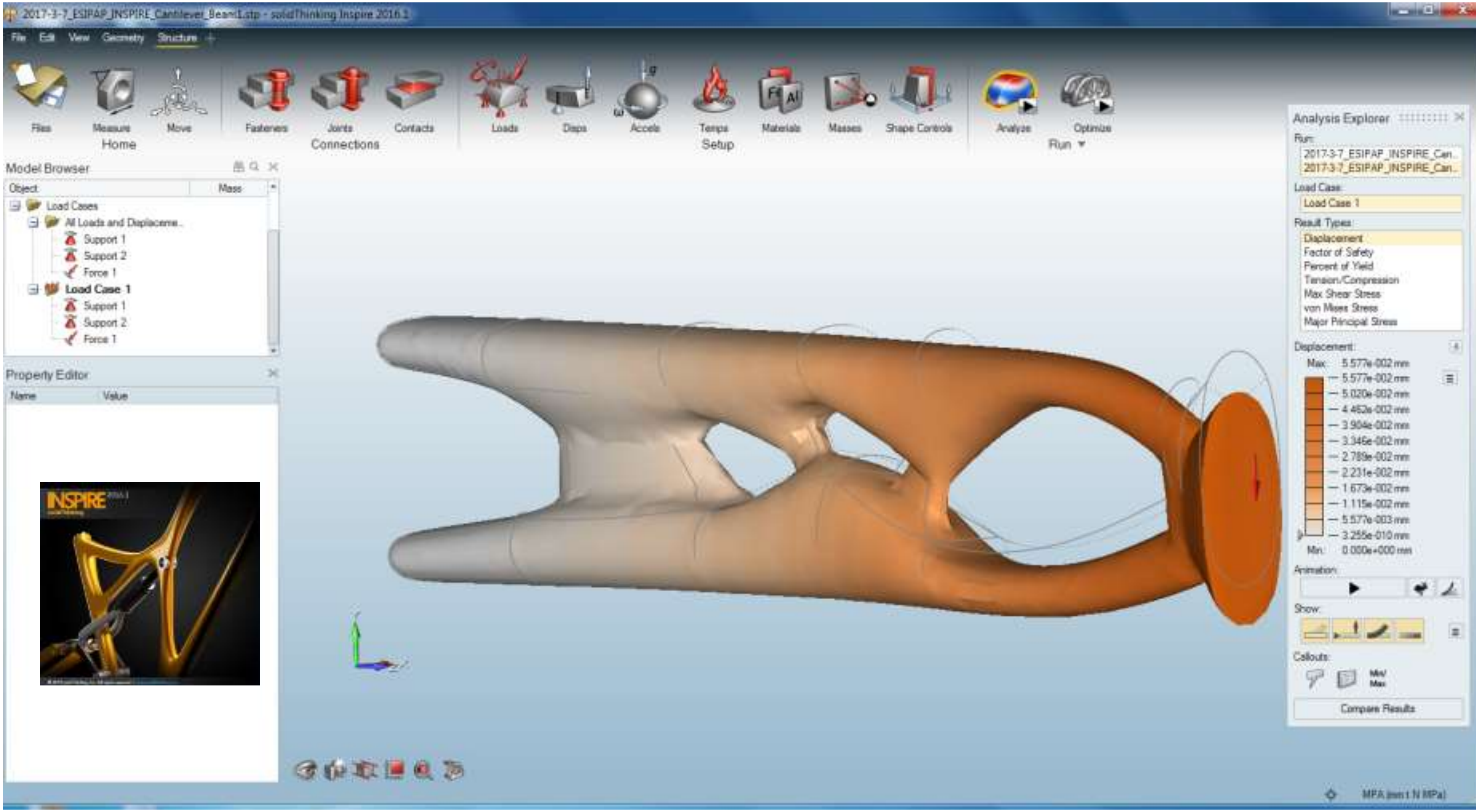
Évolution of topology



PolyNURBS solution **-> export to STEP file**



PolyNURBS solution **-> deflection = 5,58.10^{-2} mm**

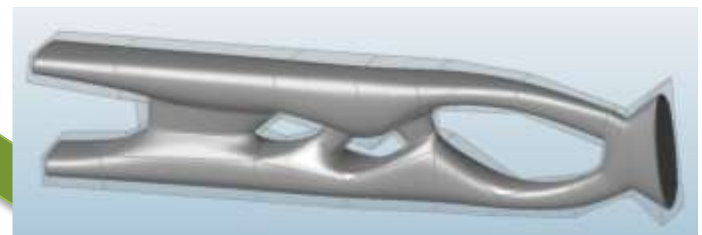


Main steps

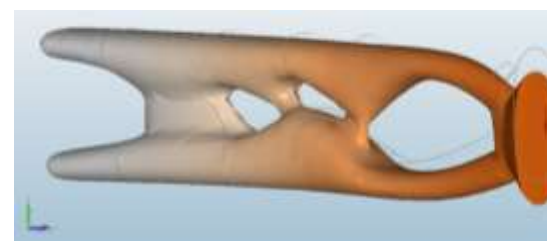
With default values

deflection = $2{,}65.10^{-2}$ mm

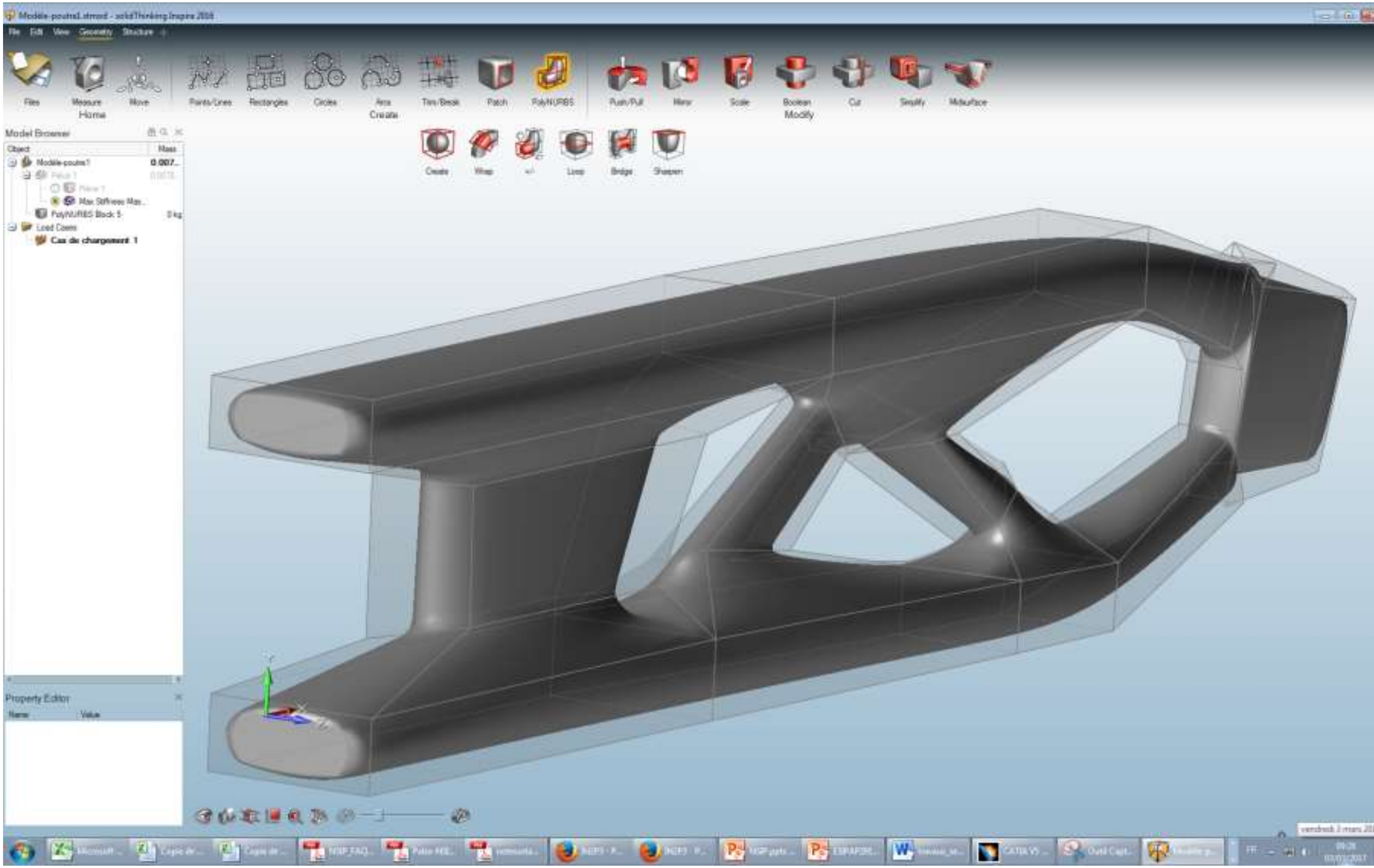
Topological optimisation



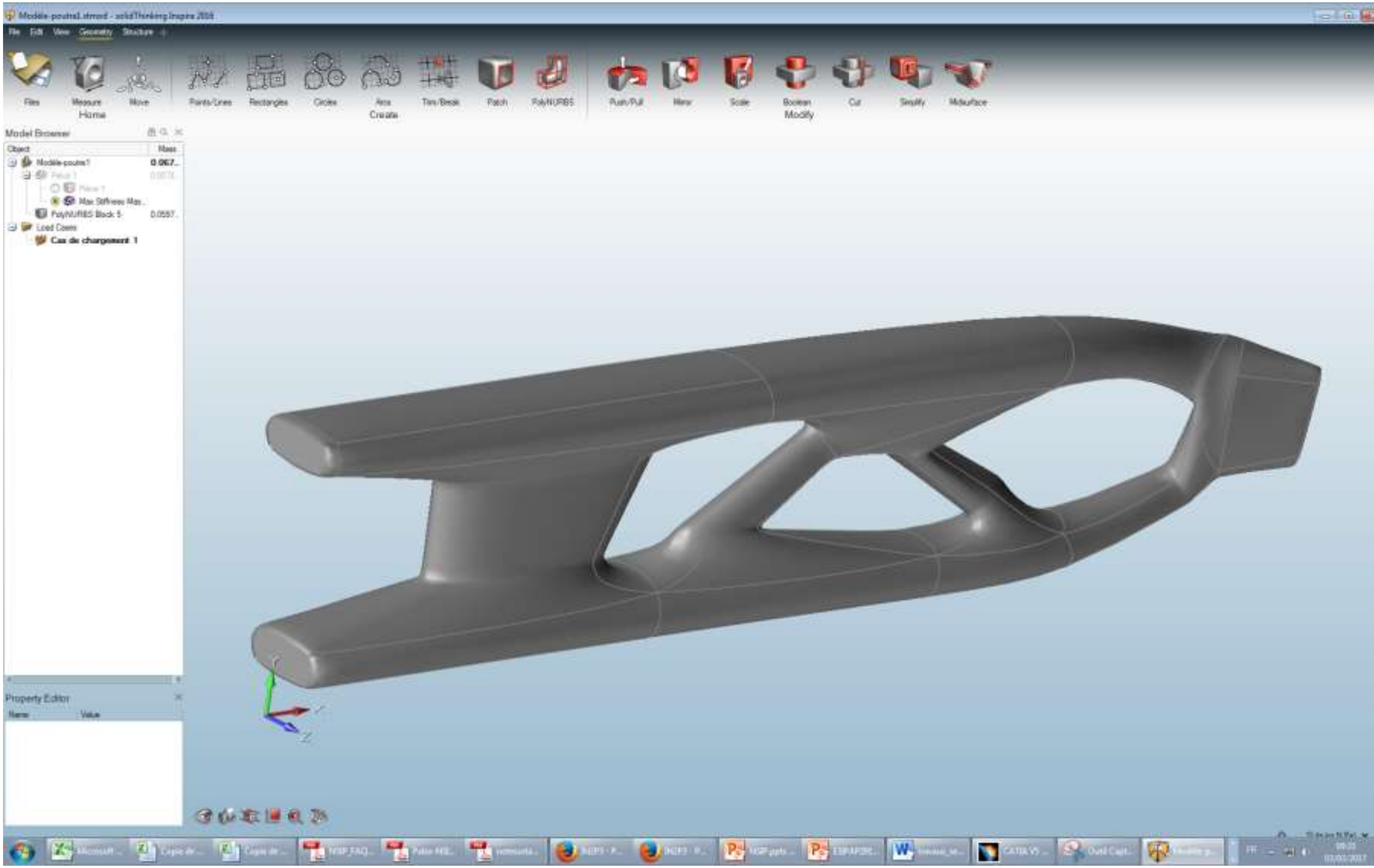
PolyNURBS
-> STP file

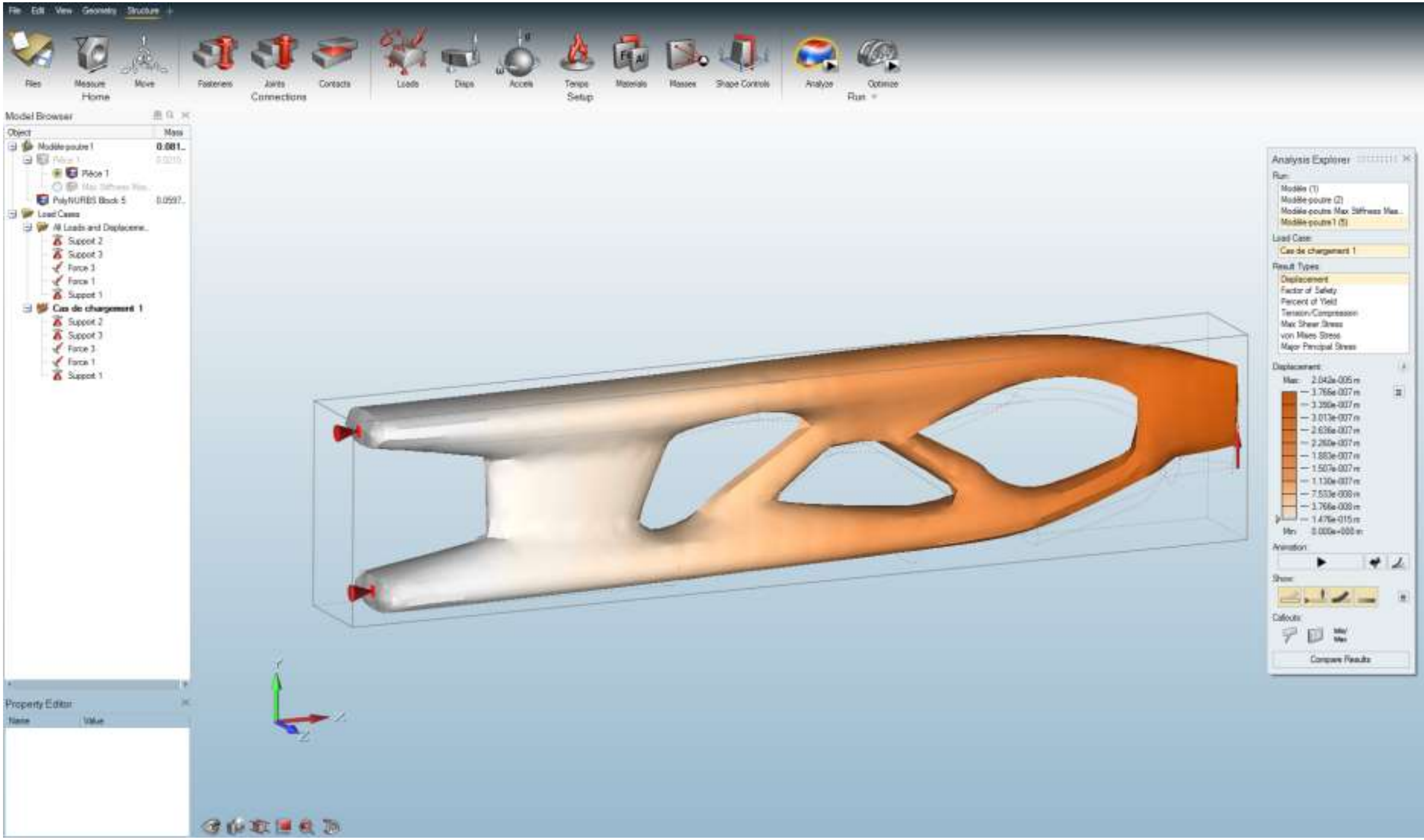


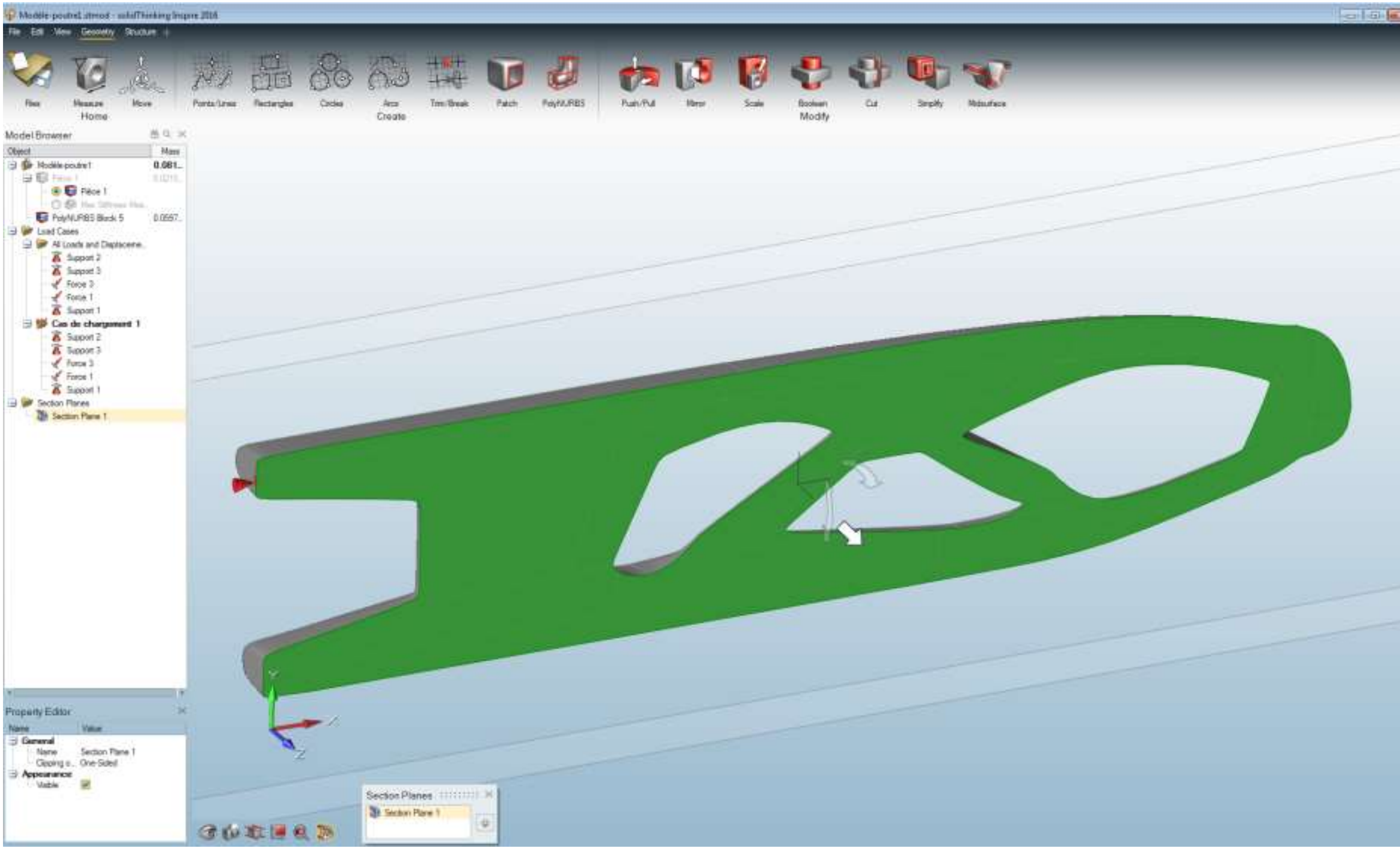
deflection = $5{,}58.10^{-2}$ mm

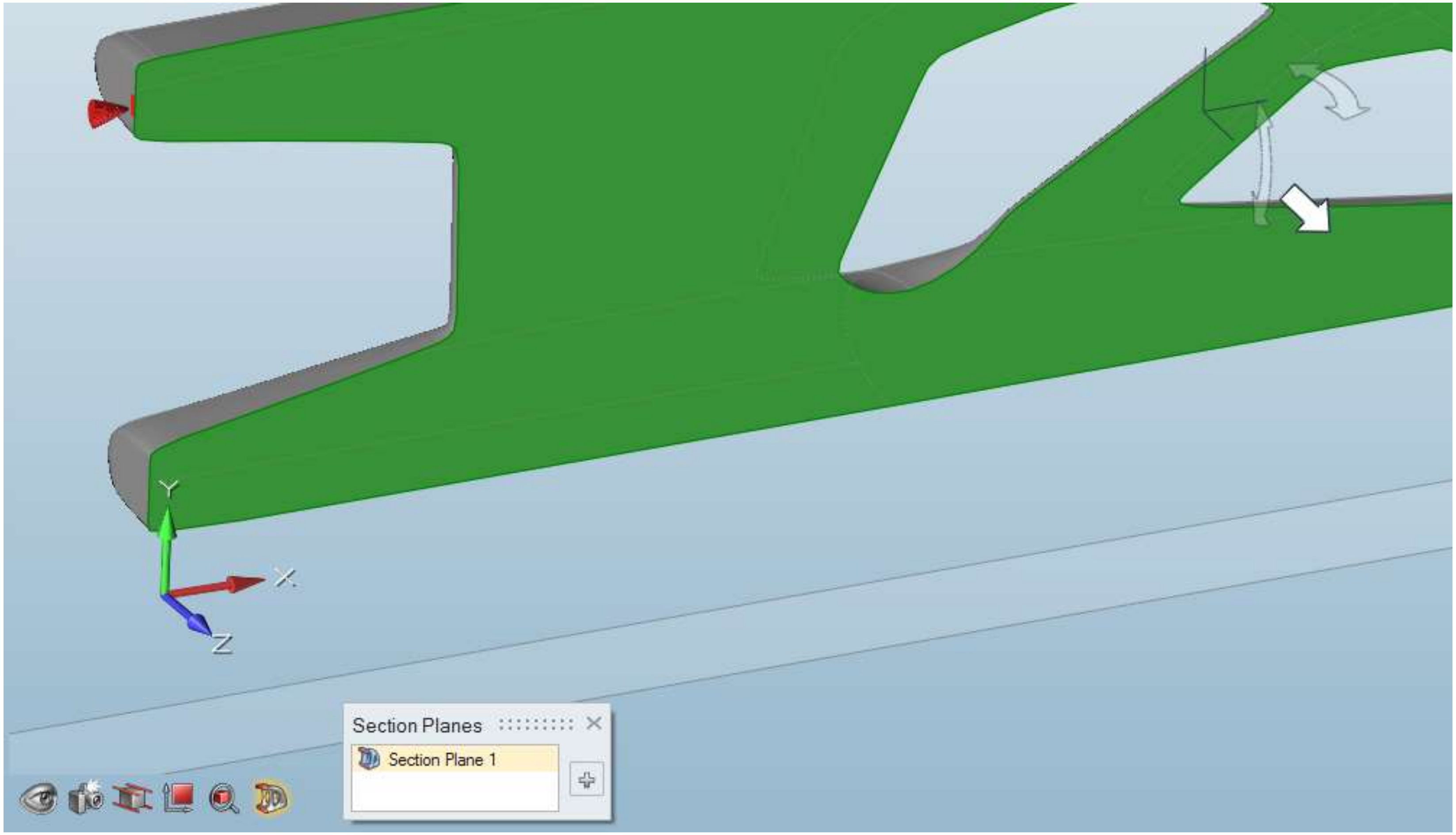


Files
Measure
Move
Home
Points/Lines
Rectangles
Circles
Arcs
Create
Trim/Break
Patch
PolyNURBS
Push/Pull
Mirror
Scale
Boolean
Modify
Cut
Simplify
Midsurface
Create
Wrap
Loop
Bridge
Sharpen
Model Browser
Object
Mass
PolyNURBS Block 5
Load Cases
Cas de chargement 1
Property Editor
Name
Value


Files
Measure
Move
Home
Points/Lines
Rectangles
Circles
Arcs
Create
Trim/Break
Patch
PolyNURBS
Push/Pull
Mirror
Scale
Boolean
Modify
Cut
Simplify
Midsurface
Model Browser
Object
Mass
Load Cases
Cas de chargement 1
Property Editor
Name
Value

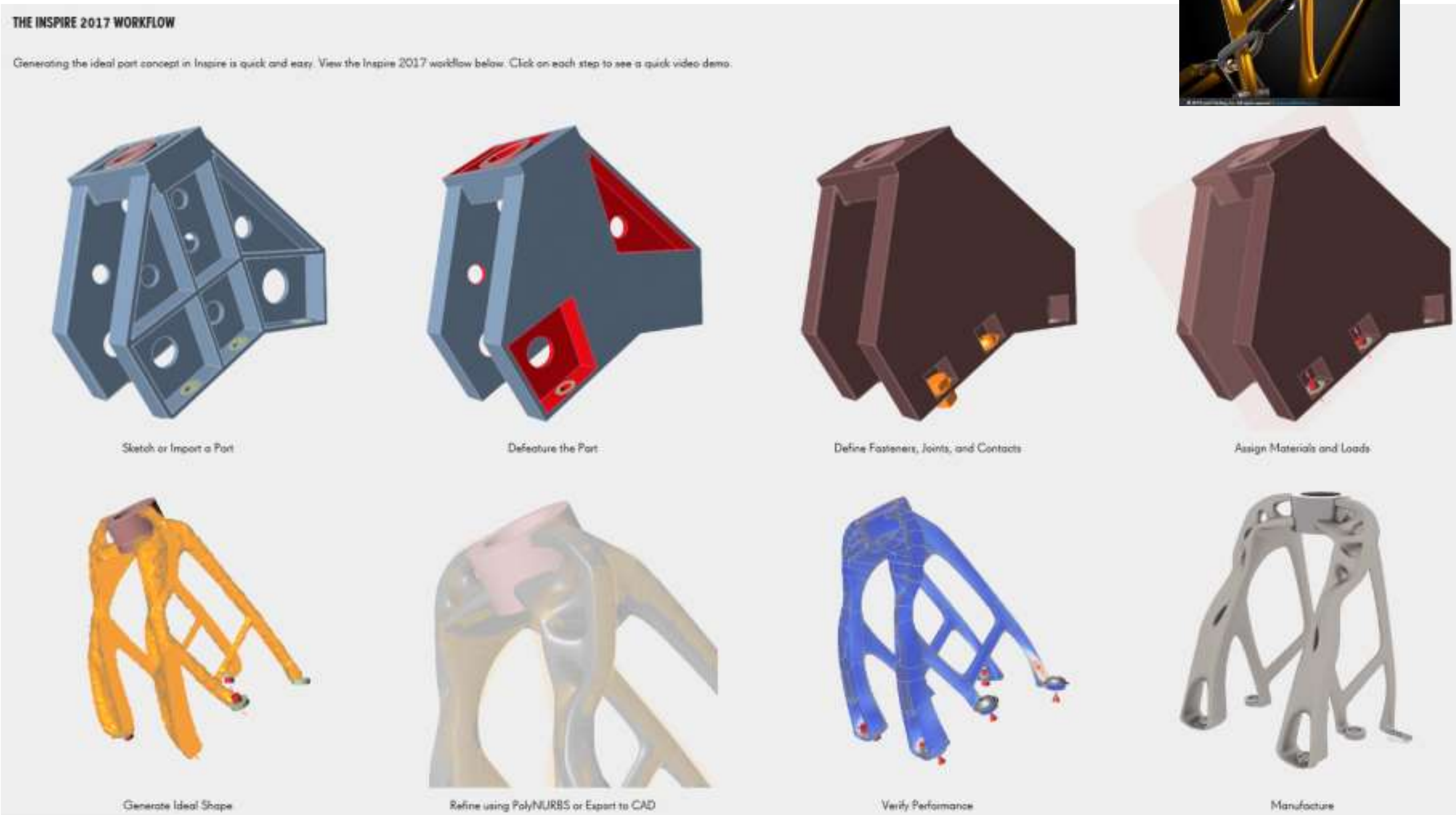

File Edit View Geometry Structure
Files
Measure
Move
Home
Fasteners
Joints
Contacts
Connections
Loads
Disps
Accels
Temps
Materials
Masses
Shape Controls
Setup
Analyze
Optimize
Run
Model Browser
Object
Mass
Load Cases
Cas de chargement 1
Support 2
Support 3
Force 3
Force 1
Support 1
Analysis Explorer
Load Case:
Result Types:
Displacement
Factor of Safety
Percent of Yield
Tension/Compression
Max Shear Stress
von Mises Stress
Major Principal Stress
Animation:
Show:
Callouts:
Compare Results
Property Editor
Name
Value


File
Edit
View
Geometry
Structure
Files
Measure
Move
Home
Points/Lines
Rectangles
Circles
Arcs
Create
Trim/Break
Patch
PolyNURBS
Push/Pull
Mirror
Scale
Boolean
Modify
Cut
Simplify
Midsurface
Model Browser
Object
Mass
Load Cases
Support 2
Support 3
Force 3
Force 1
Support 1
Cas de chargement 1
Section Planes
Section Plane 1
Property Editor
Name
Value
General
Appearance
Section Planes



Y
X
Z
Section Planes
Section Plane 1

SOLIDTHINKING INSPIRE 2017



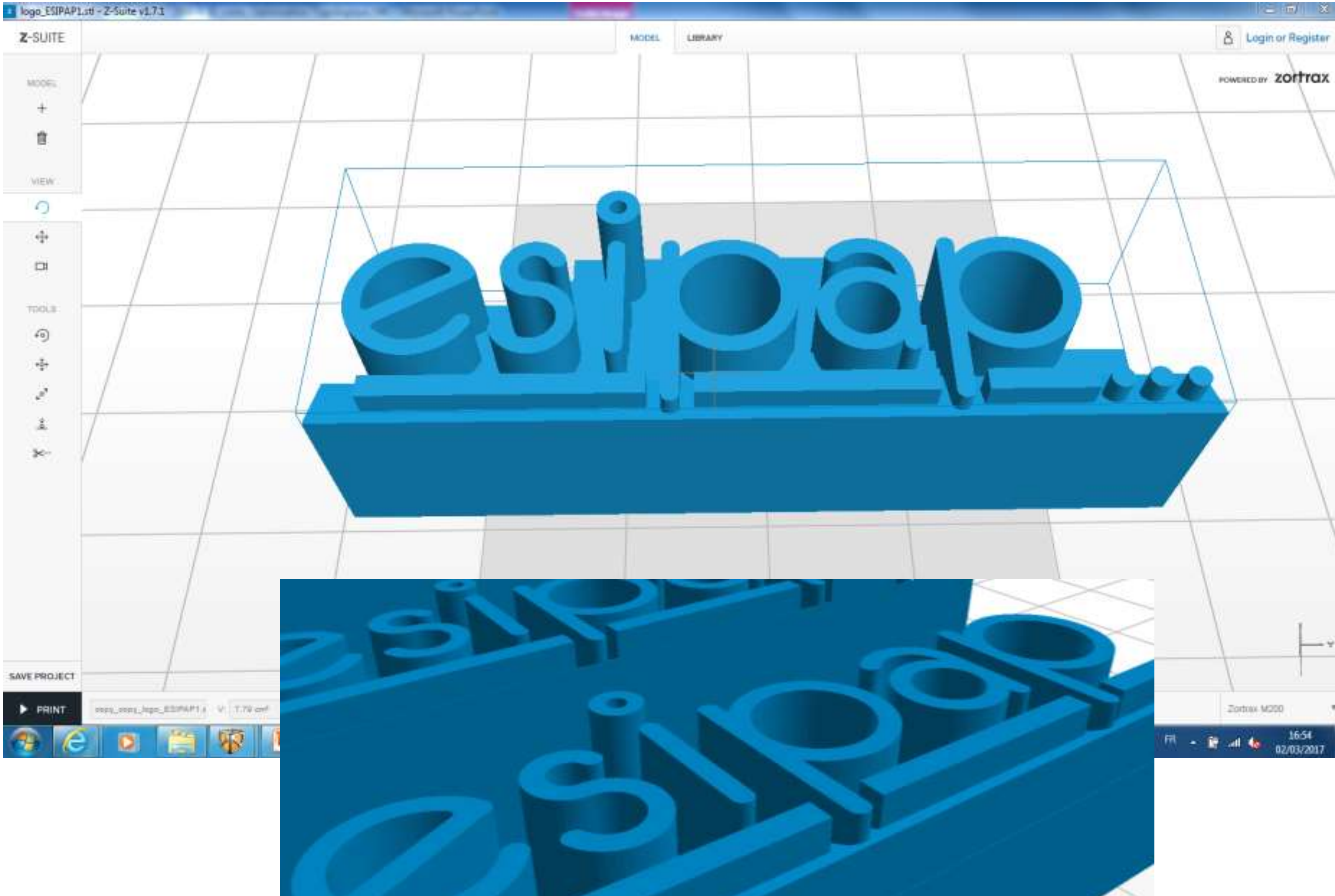
Source : http://www.solidthinking.com/inspire2017.html

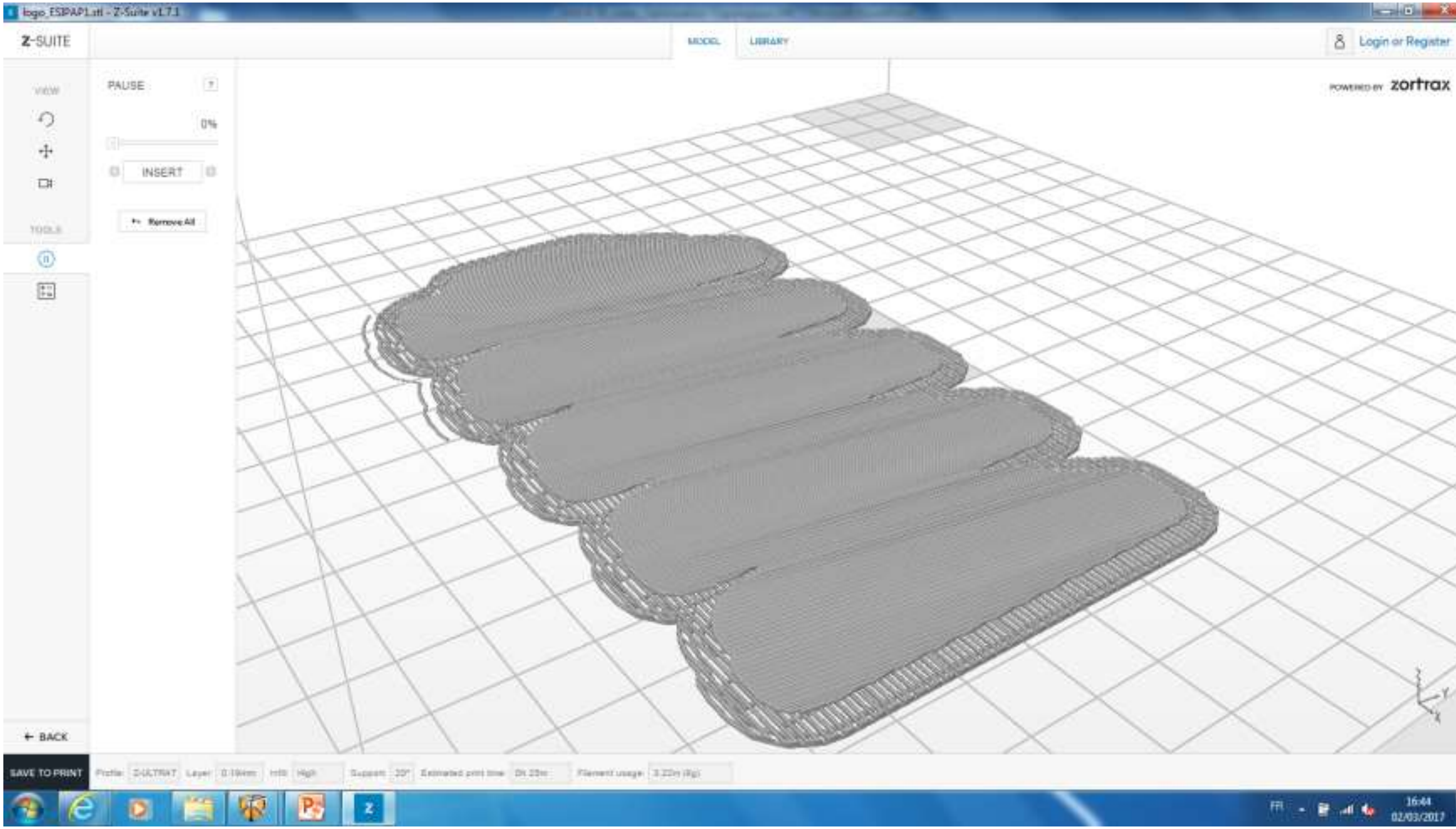
Workshop

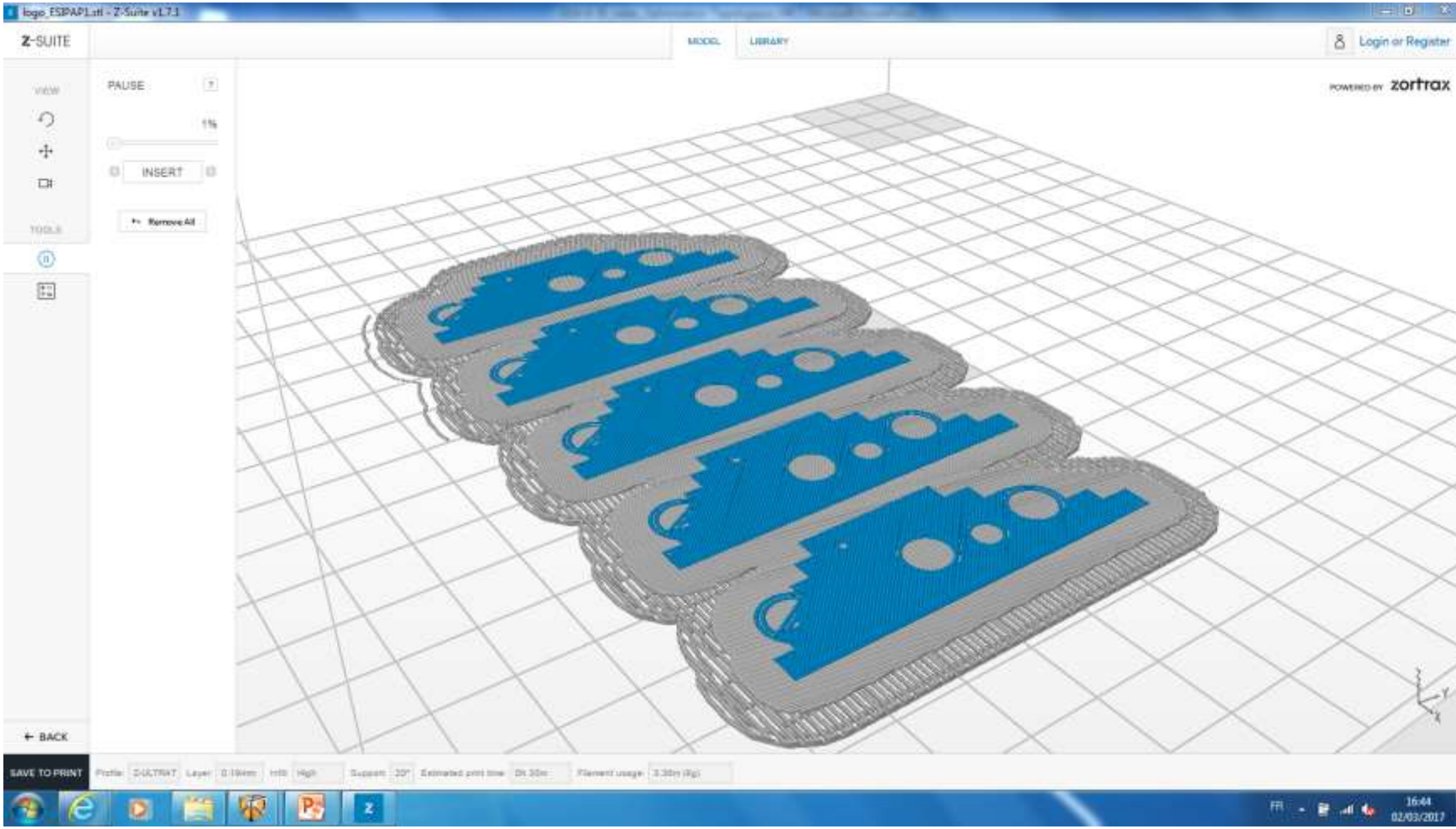
1- CAD (presentation)
2- Topological optimisation
3- stl file slicing

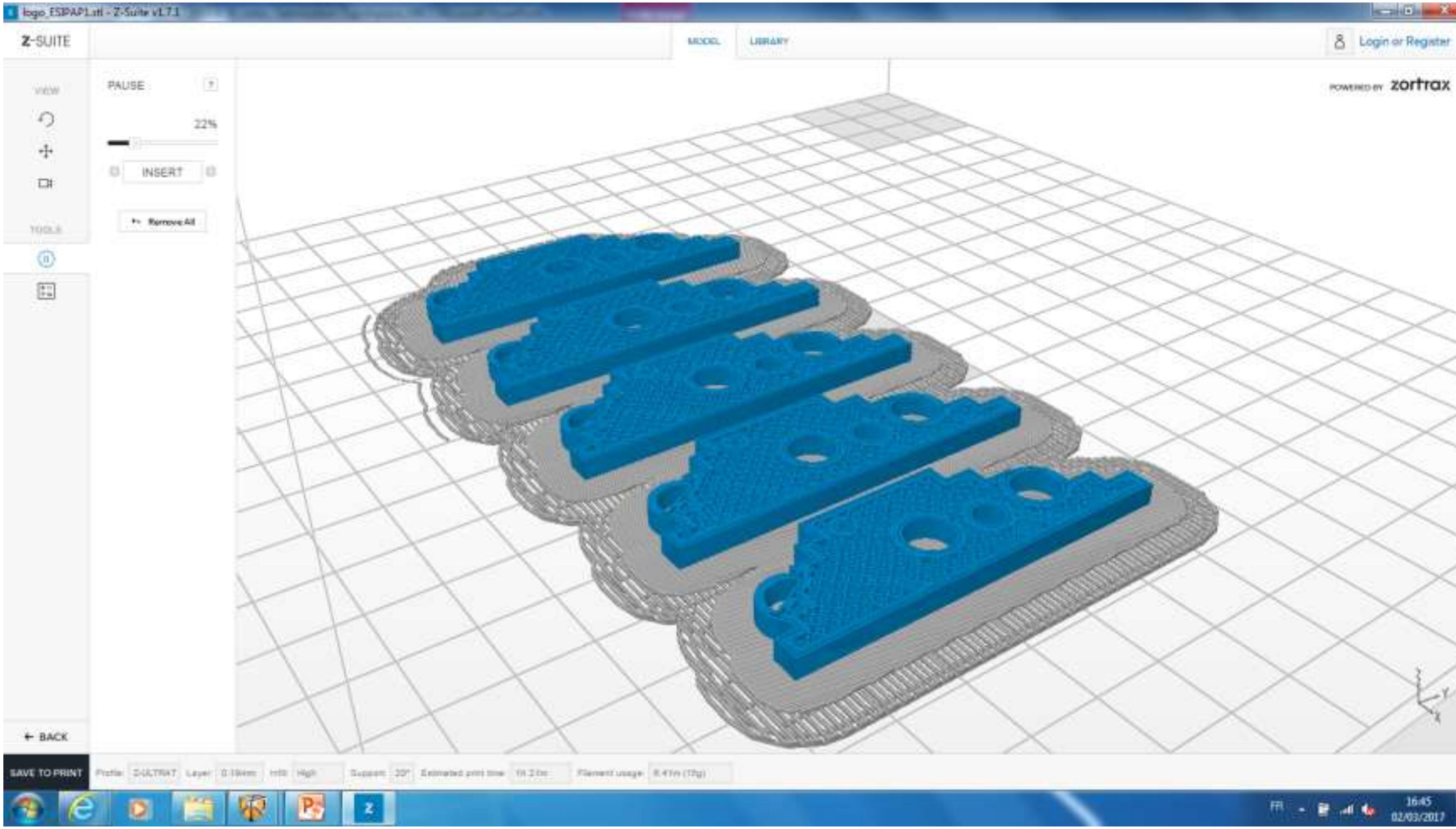
Seller :

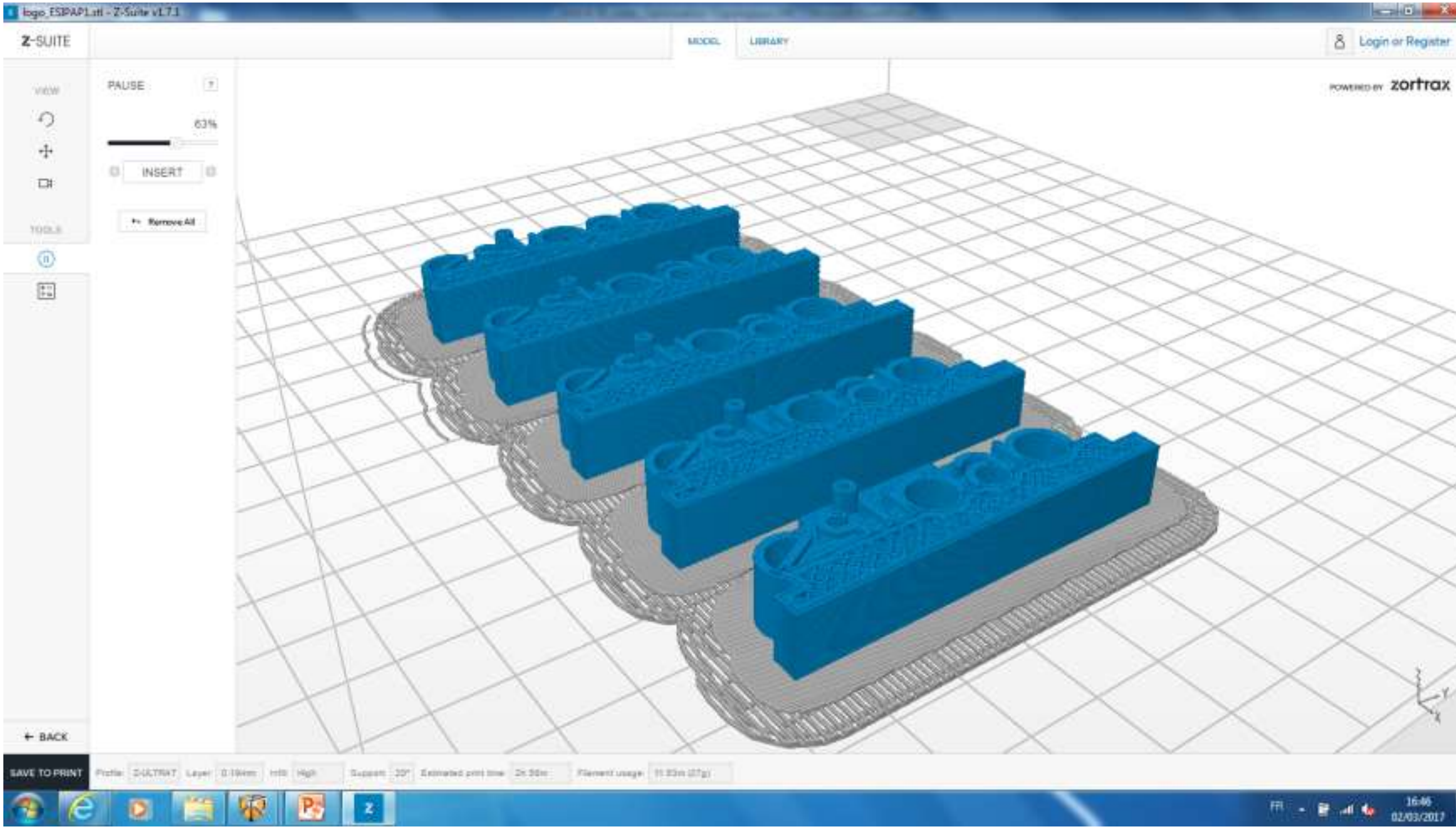
zortrax M200®

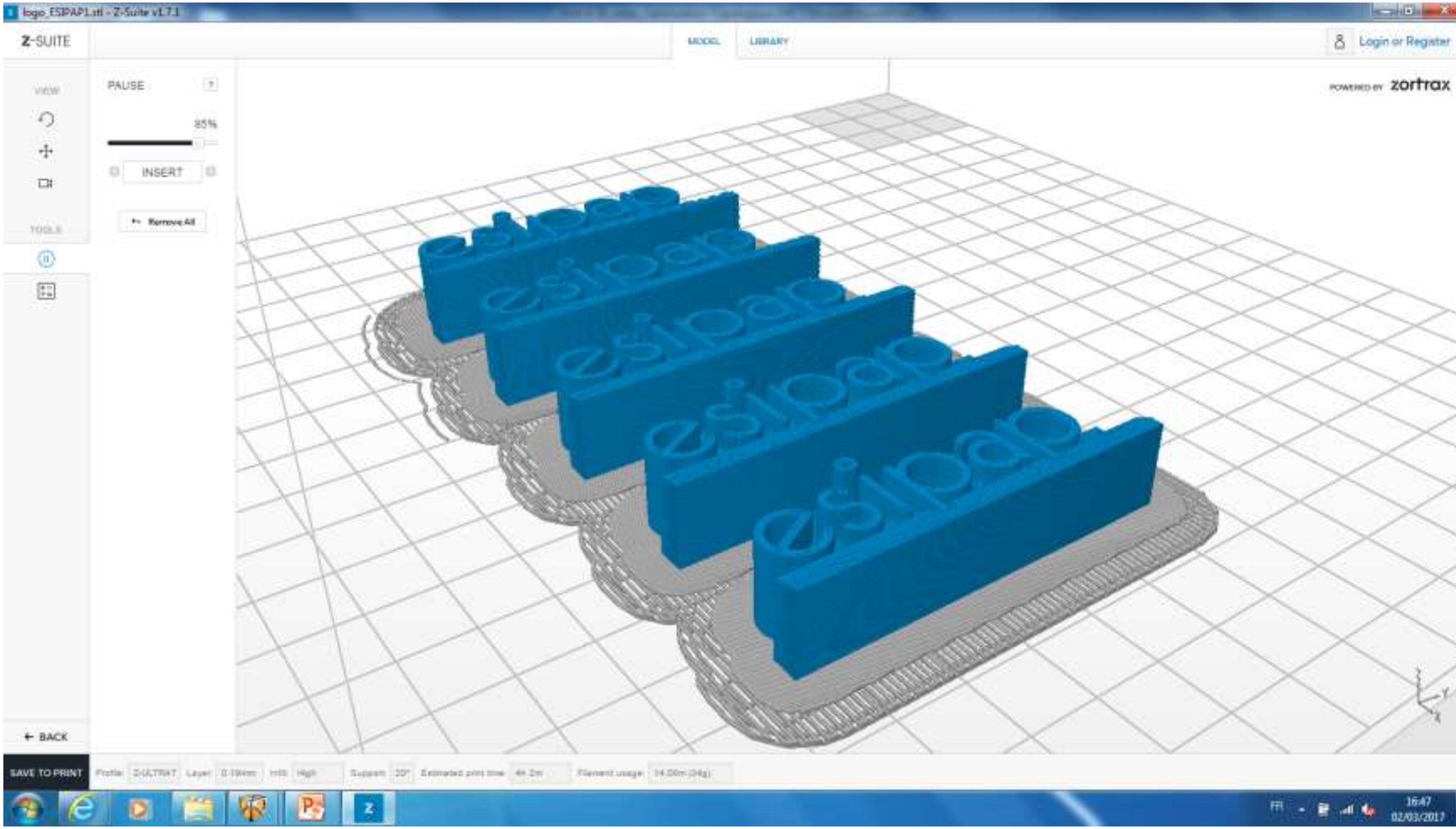

logo_ESIPAP1.stl - Z-Suite v1.7.1
Z-SUITE
MODEL
LIBRARY
Login or Register
POWERED BY zortrax
MODEL
VIEW
TOOLS
SAVE PROJECT
PRINT
Zortrax M200
FR
16:54
02/03/2017

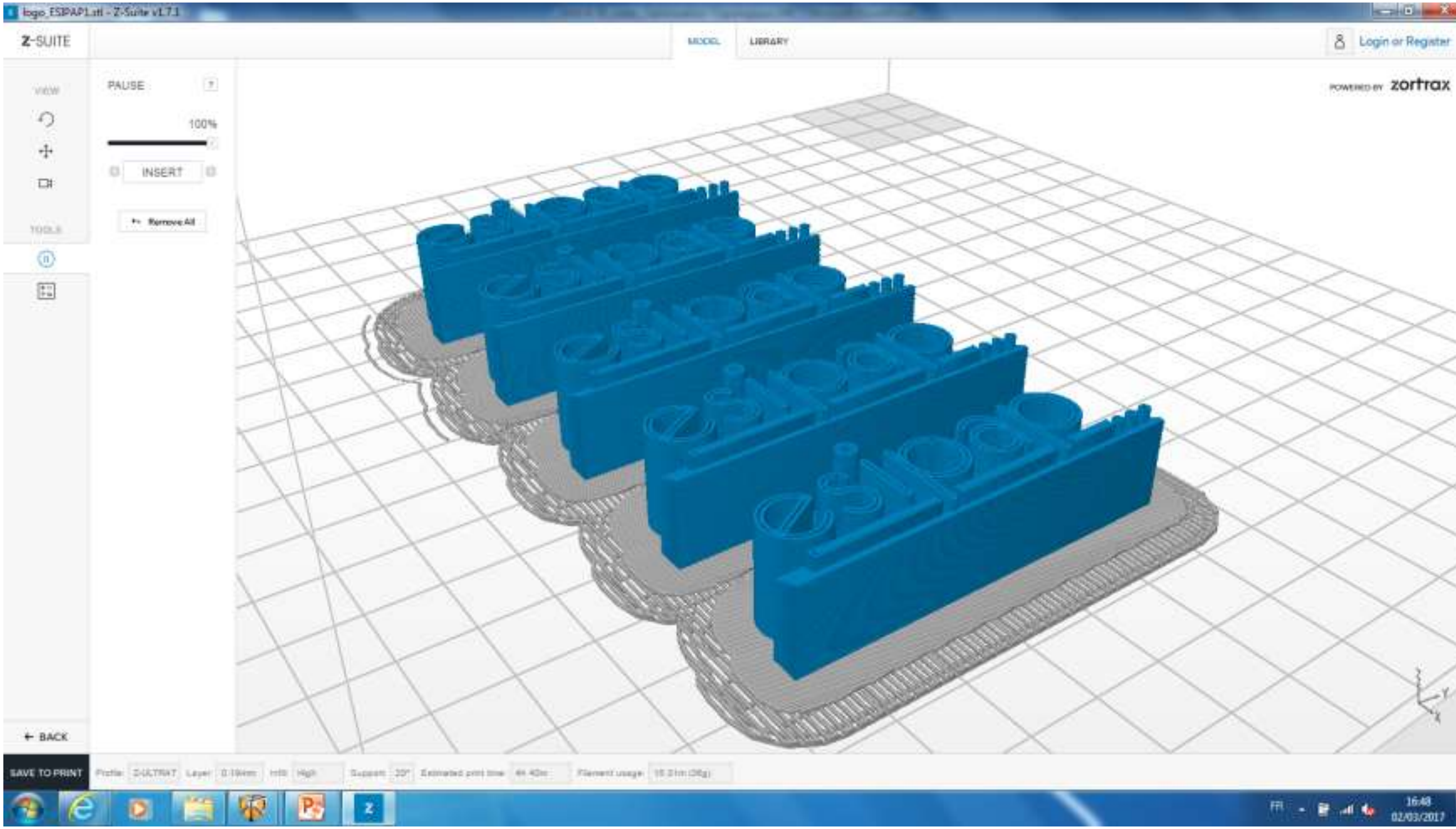

logo_ESIPAP1.stl - Z-Suite v1.7.1
Z-SUITE
MODEL
LIBRARY
Login or Register
POWERED BY zortrax
VIEW
PAUSE
0%
INSERT
Remove All
TOOLS
BACK
SAVE TO PRINT


logo_ESIPAP1.stl - Z-Suite v1.7.1
Z-SUITE
MODEL
LIBRARY
Login or Register
zortrax
PAUSE
1%
INSERT
Remove All
BACK
SAVE TO PRINT
16:44
02/03/2017

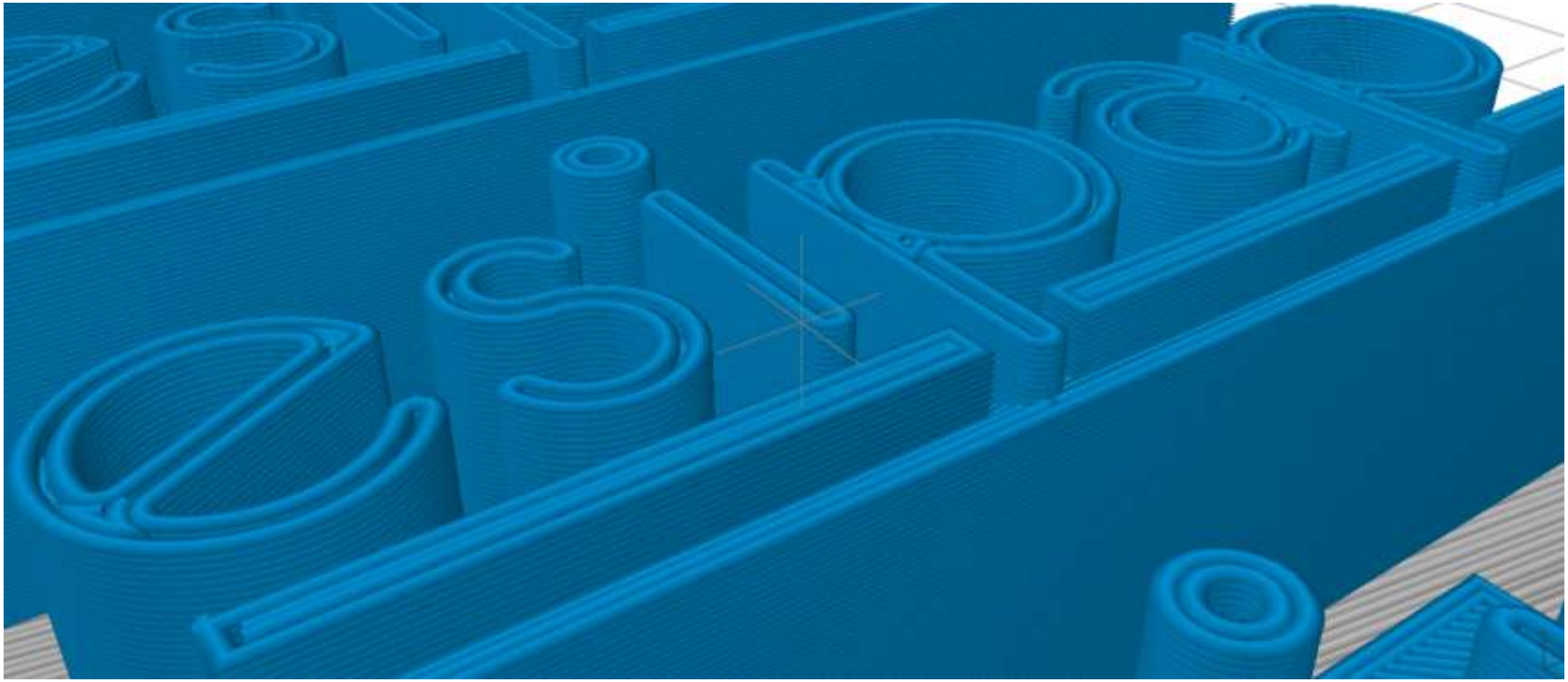

Z-SUITE
MODEL
LIBRARY
Login or Register
zortrax
PAUSE
22%
INSERT
Remove All
BACK
SAVE TO PRINT


logo_ESIPAP1.stl - Z-Suite v1.7.1
Z-SUITE
MODEL
LIBRARY
Login or Register
zortrax
PAUSE
63%
INSERT
Remove All
BACK
SAVE TO PRINT


logo_ESIPAP1.stl - Z-Suite v1.7.1
Z-SUITE
MODEL
LIBRARY
Login or Register
zortrax
VIEW
PAUSE
85%
INSERT
TOOLS
Remove All
esipap
esipap
esipap
esipap
esipap
BACK
SAVE TO PRINT
16:47
02/03/2017



Z-SUITE
MODEL
LIBRARY
Login or Register
POWERED BY zortrax
PAUSE
100%
INSERT
Remove All
BACK
SAVE TO PRINT

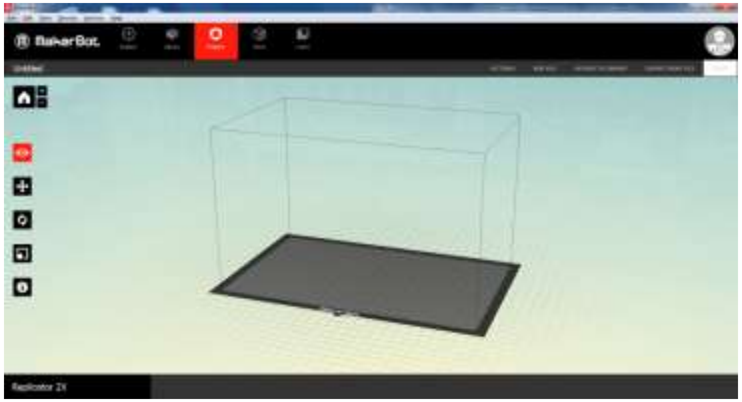


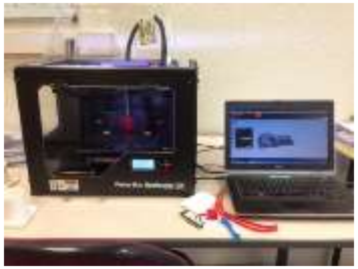
Workshop

1- CAD (presentation)
2- Topological optimisation
3- stl file slicing

ON YOUR DESKTOP

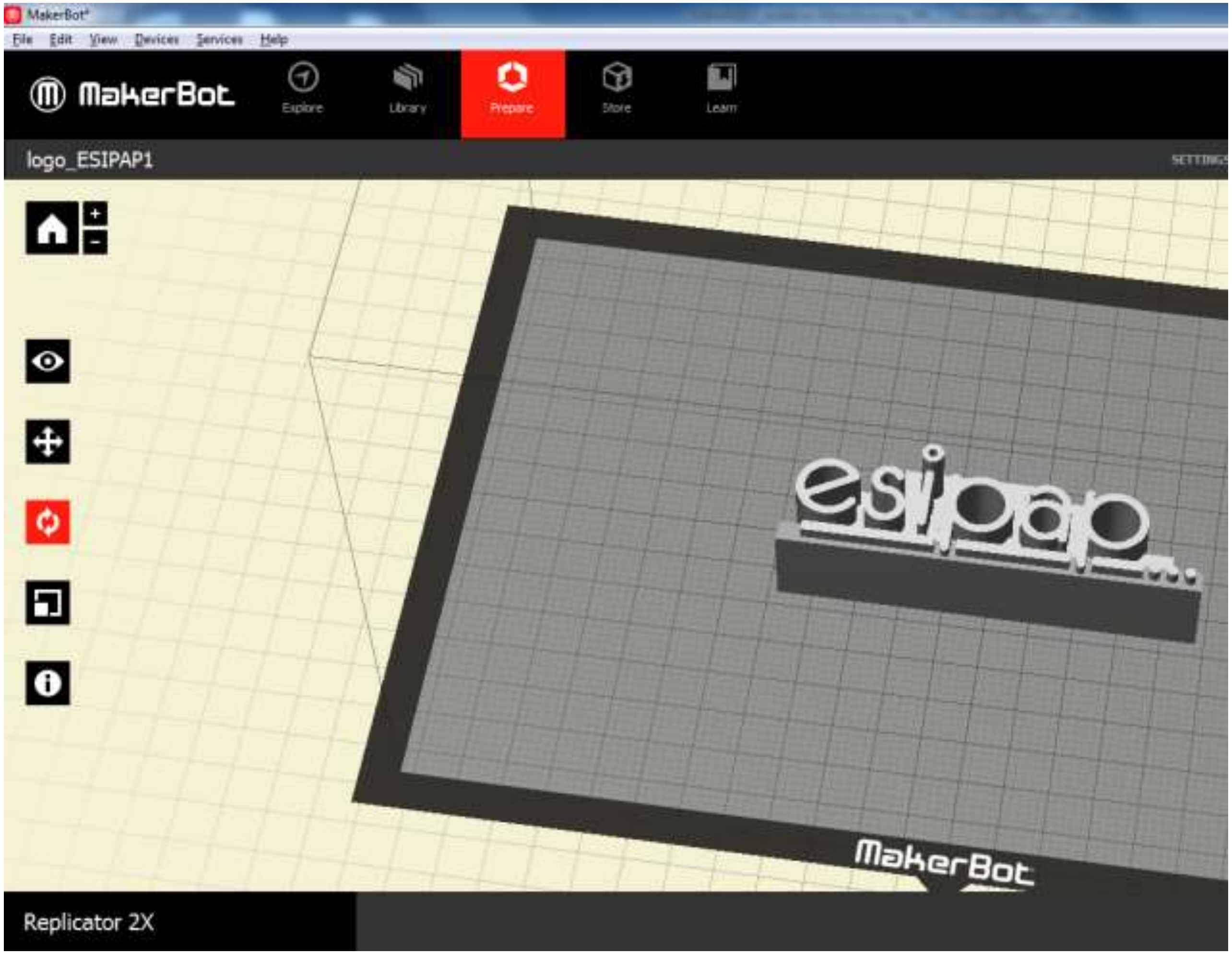
Makerbot Desktop 3.7

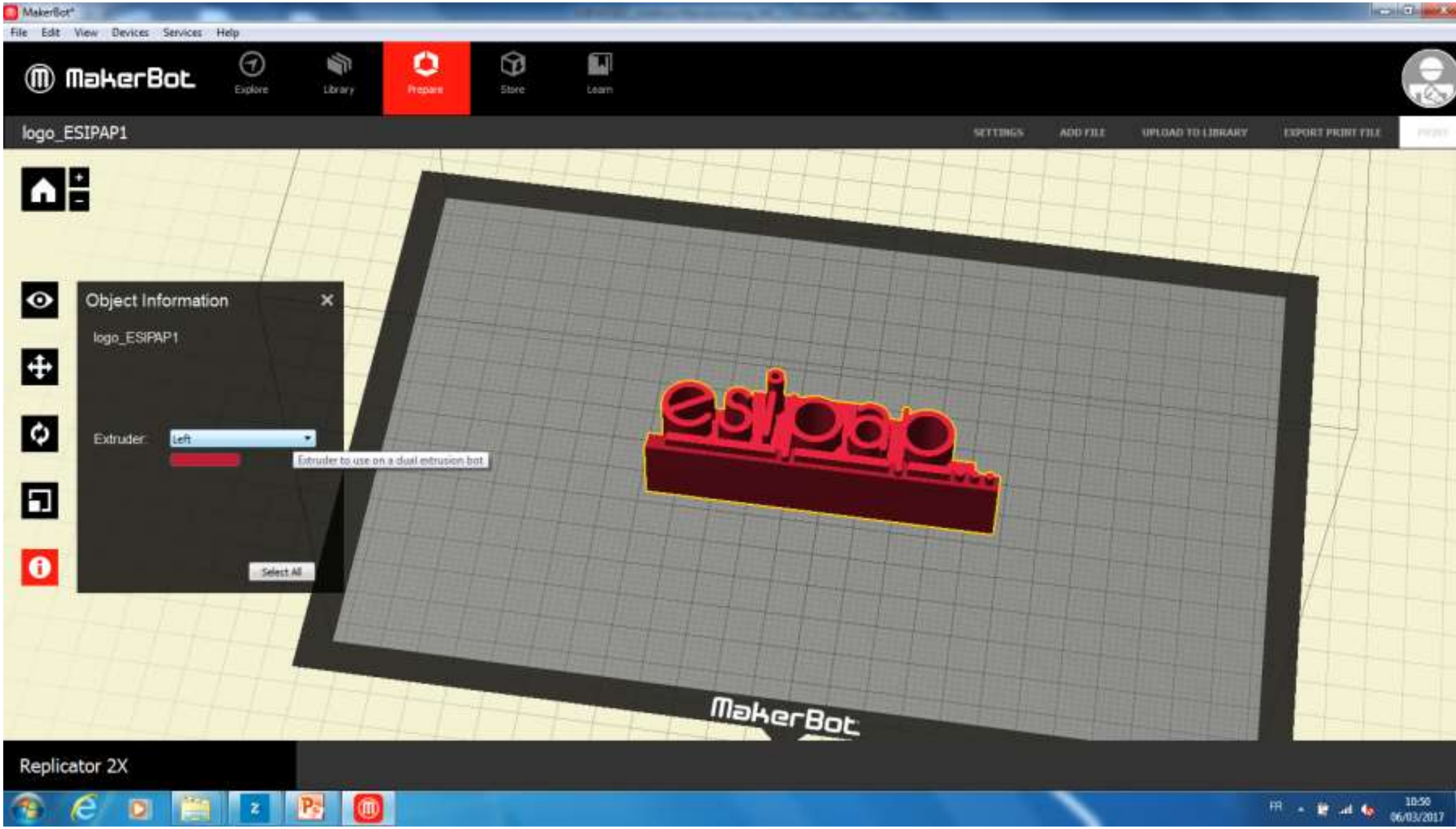




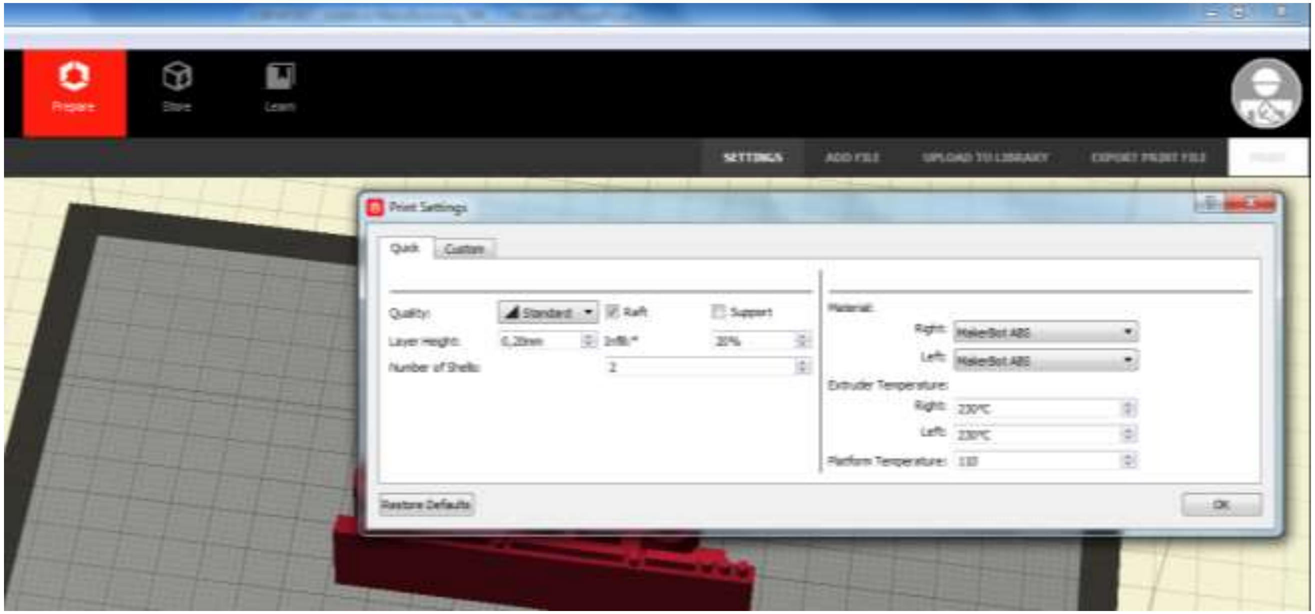
Makerbot Replicator 2X

Seller :

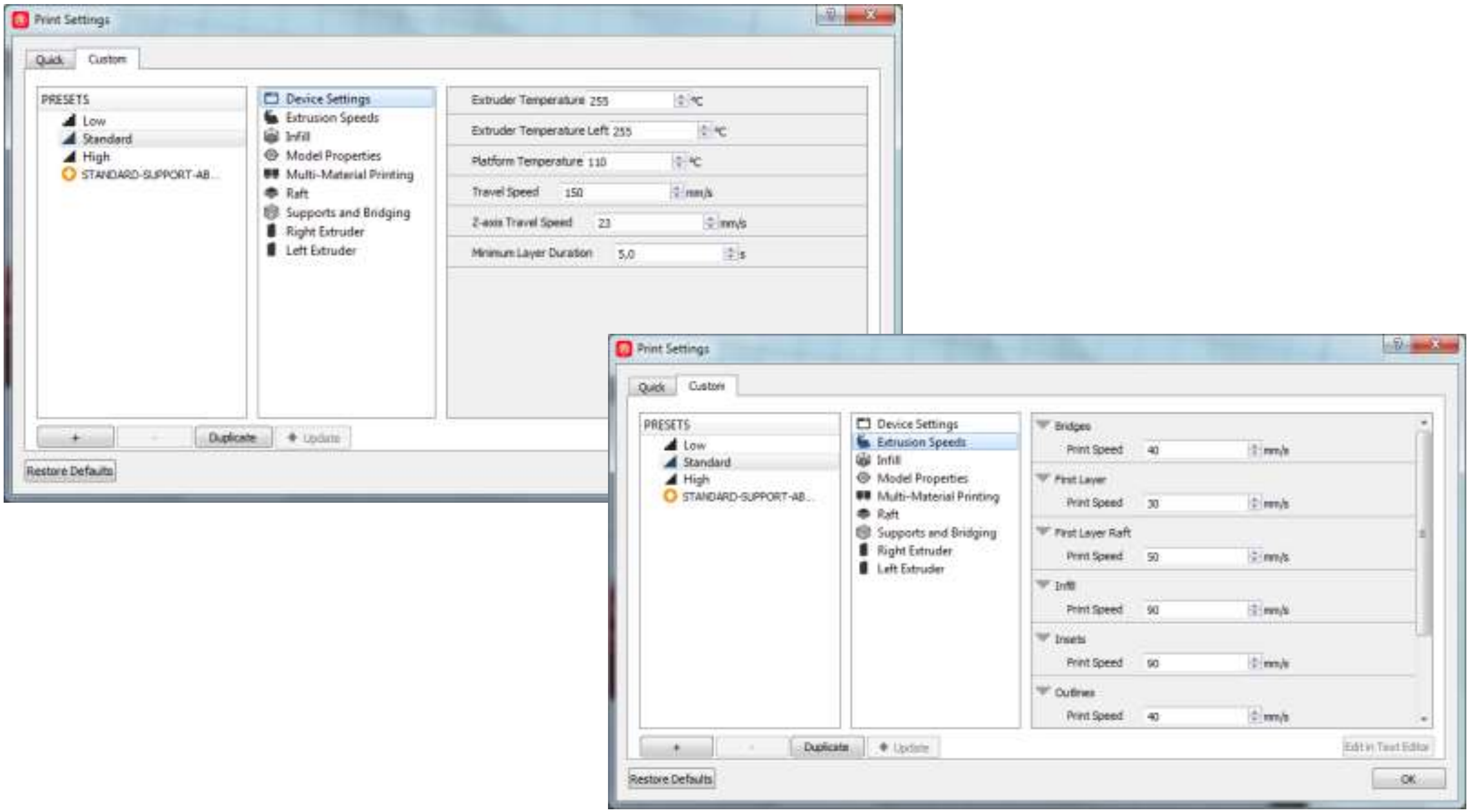

MakerBot
File Edit View Devices Services Help
MakerBot
Explore
Library
Prepare
Store
Learn
logo_ESIPAP1
esipap
MakerBot
Replicator 2X


MakerBot*
File Edit View Devices Services Help
MakerBot
Explore
Library
Prepare
Store
Learn
logo_ESIPAP1
SETTINGS
ADD FILE
UPLOAD TO LIBRARY
EXPORT PRINT FILE
Object Information
logo_ESIPAP1
Extruder:
Left
Extruder to use on a dual extrusion bot
Select All
esipap
MakerBot
Replicator 2X
FR
10:50
06/03/2017

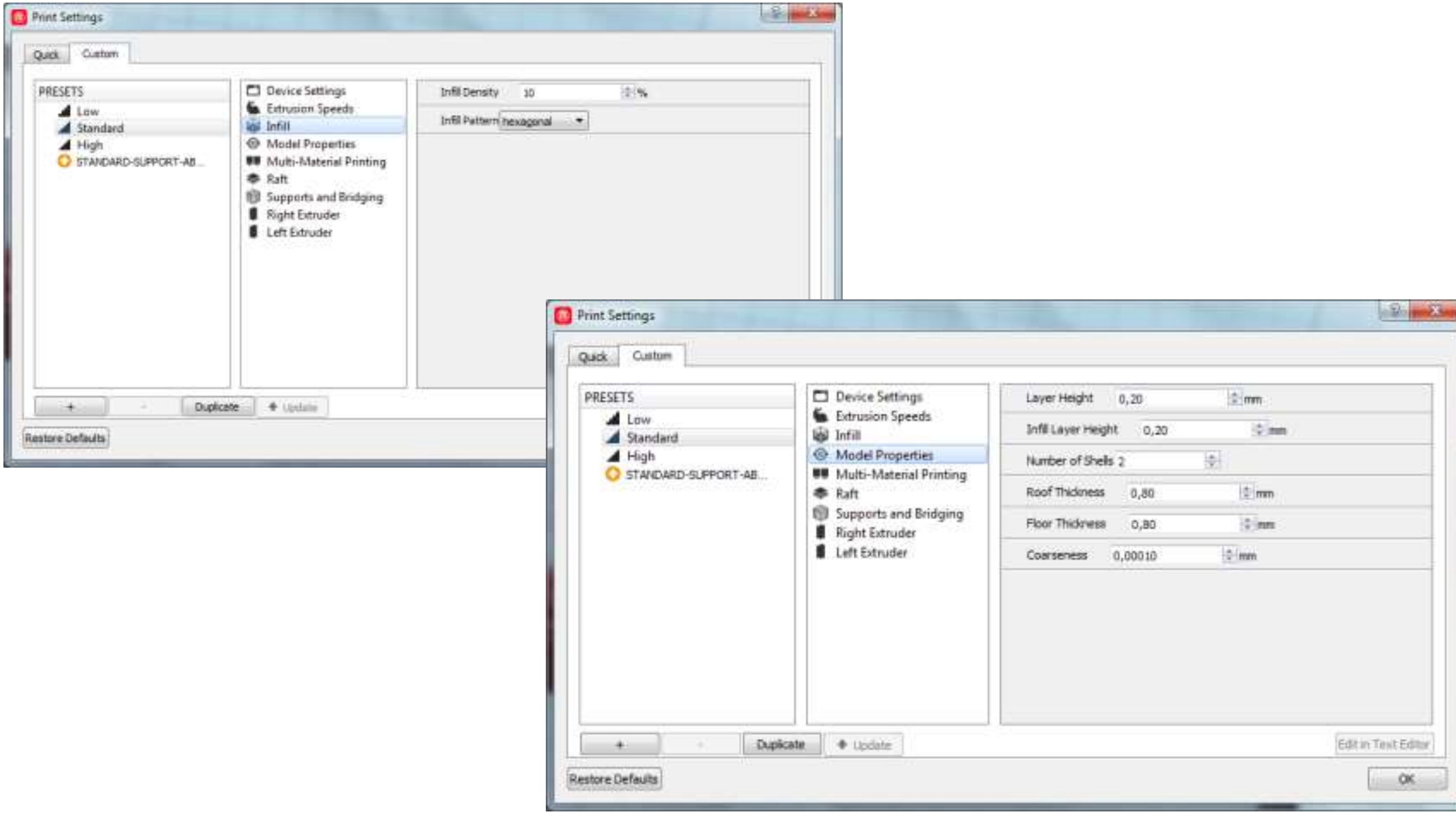
Makerbot Desktop 3D printing settings



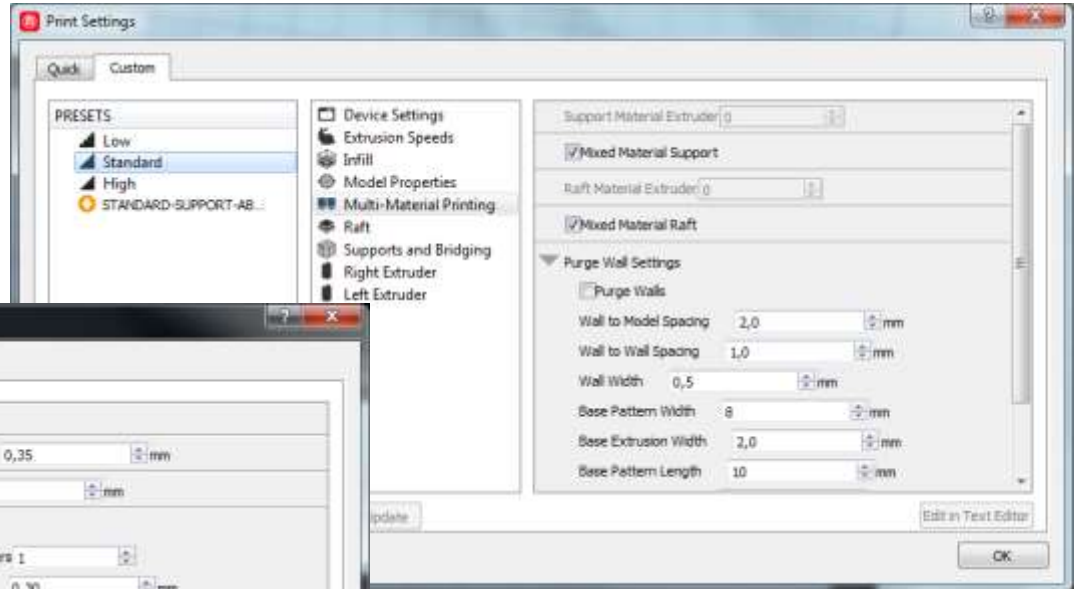
Makerbot Desktop 3D printing custom settings

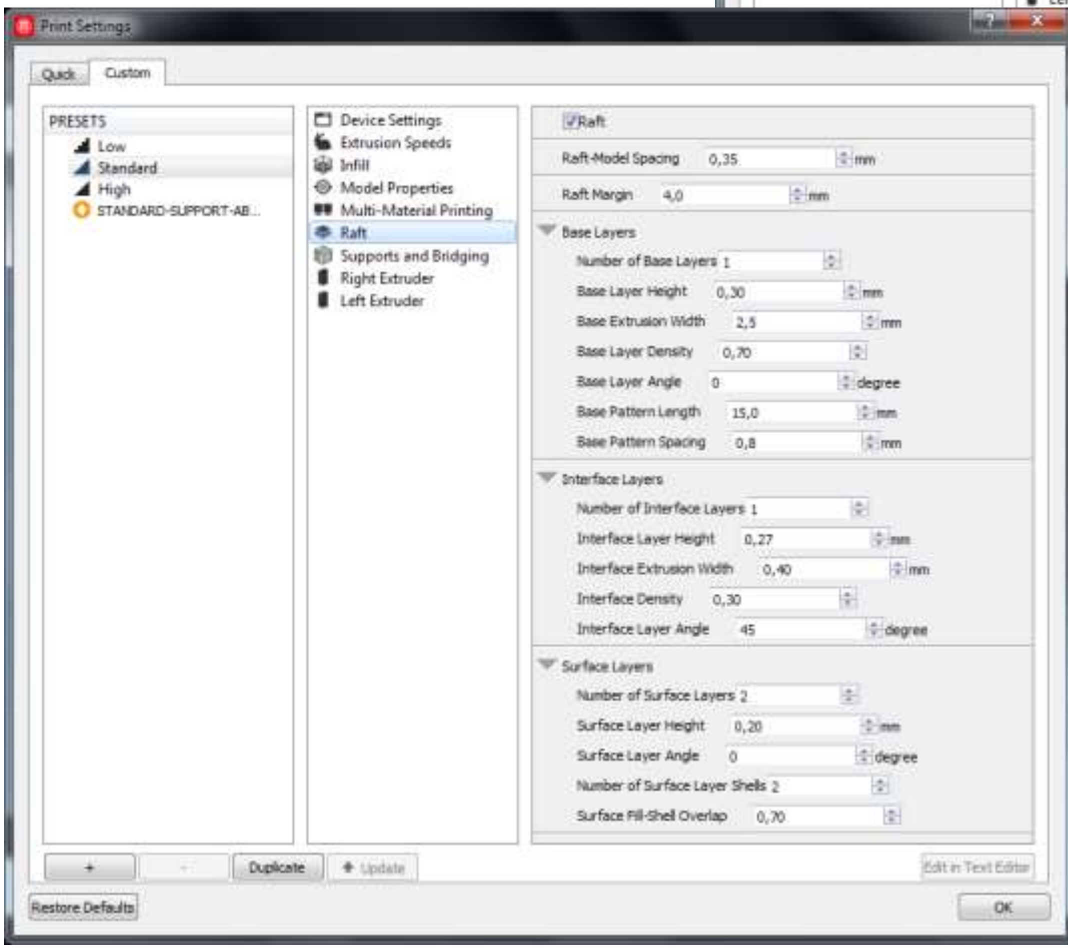


Makerbot Desktop 3D printing custom settings

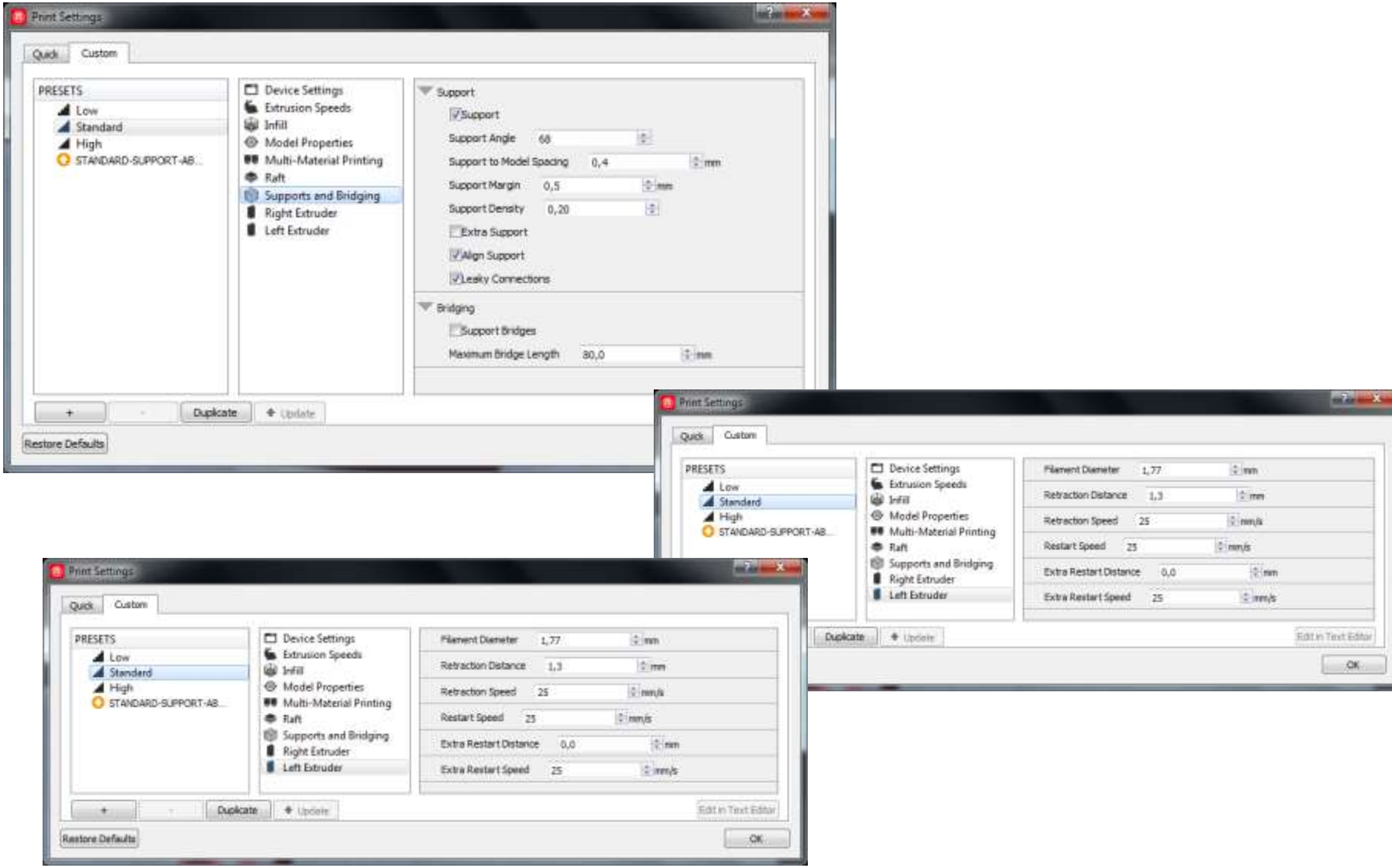


Makerbot Desktop
3D printing custom settings

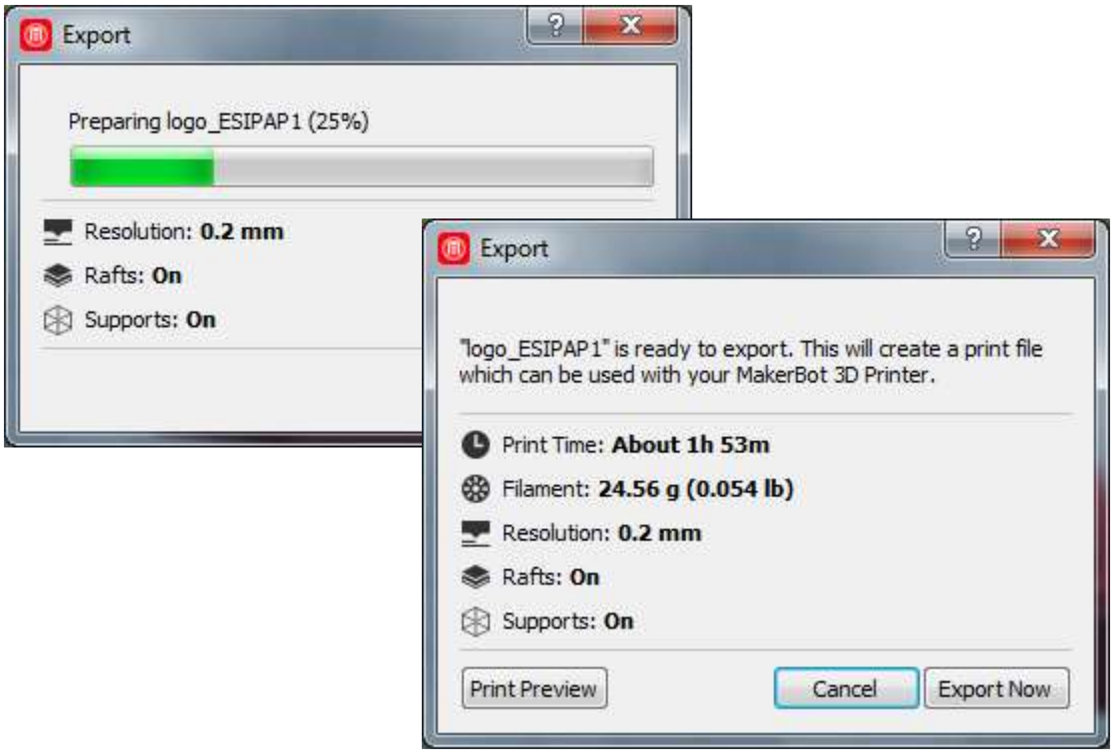




Makerbot Desktop 3D printing custom settings

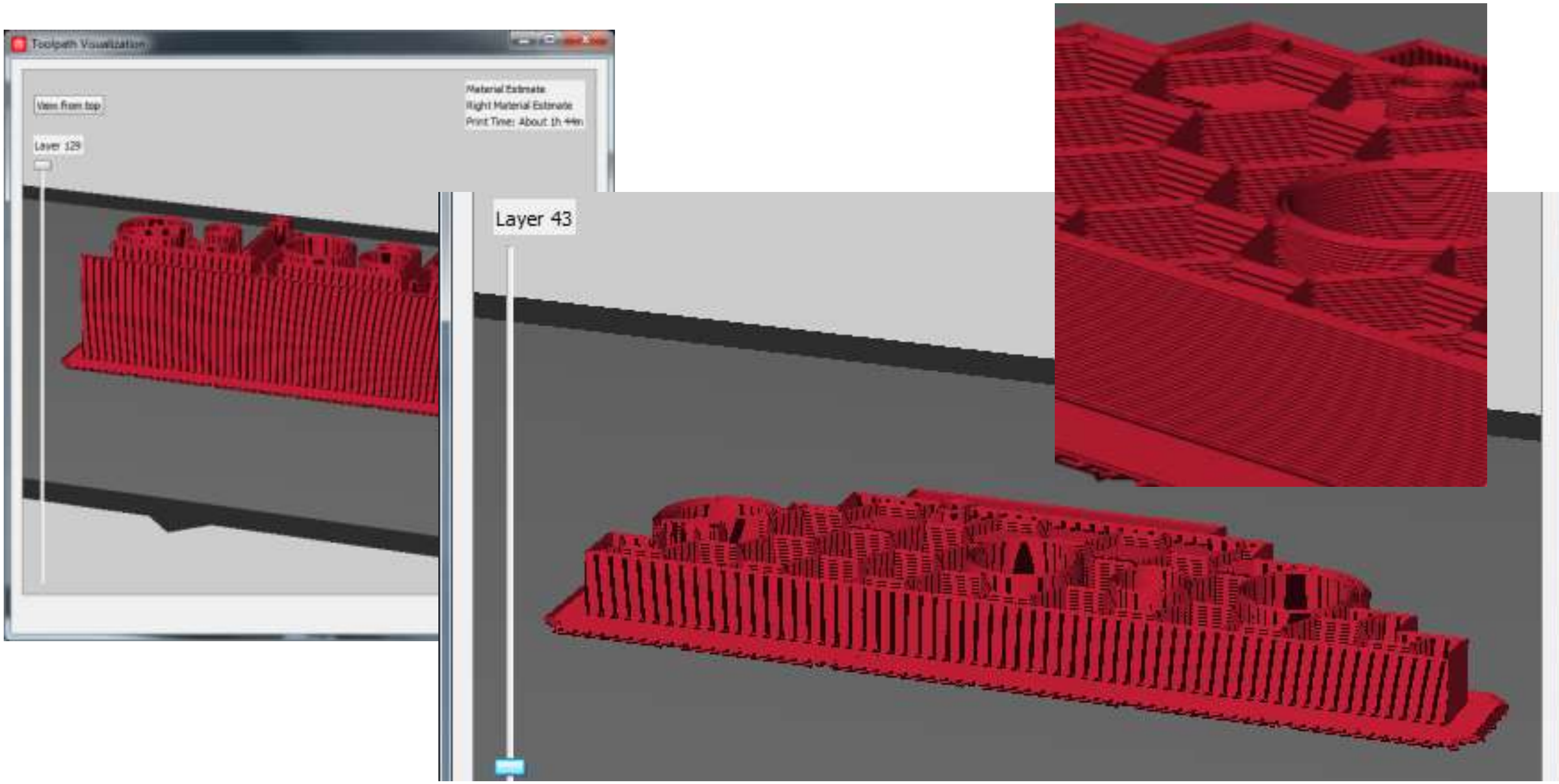


Makerbot Desktop 3D printing exportation

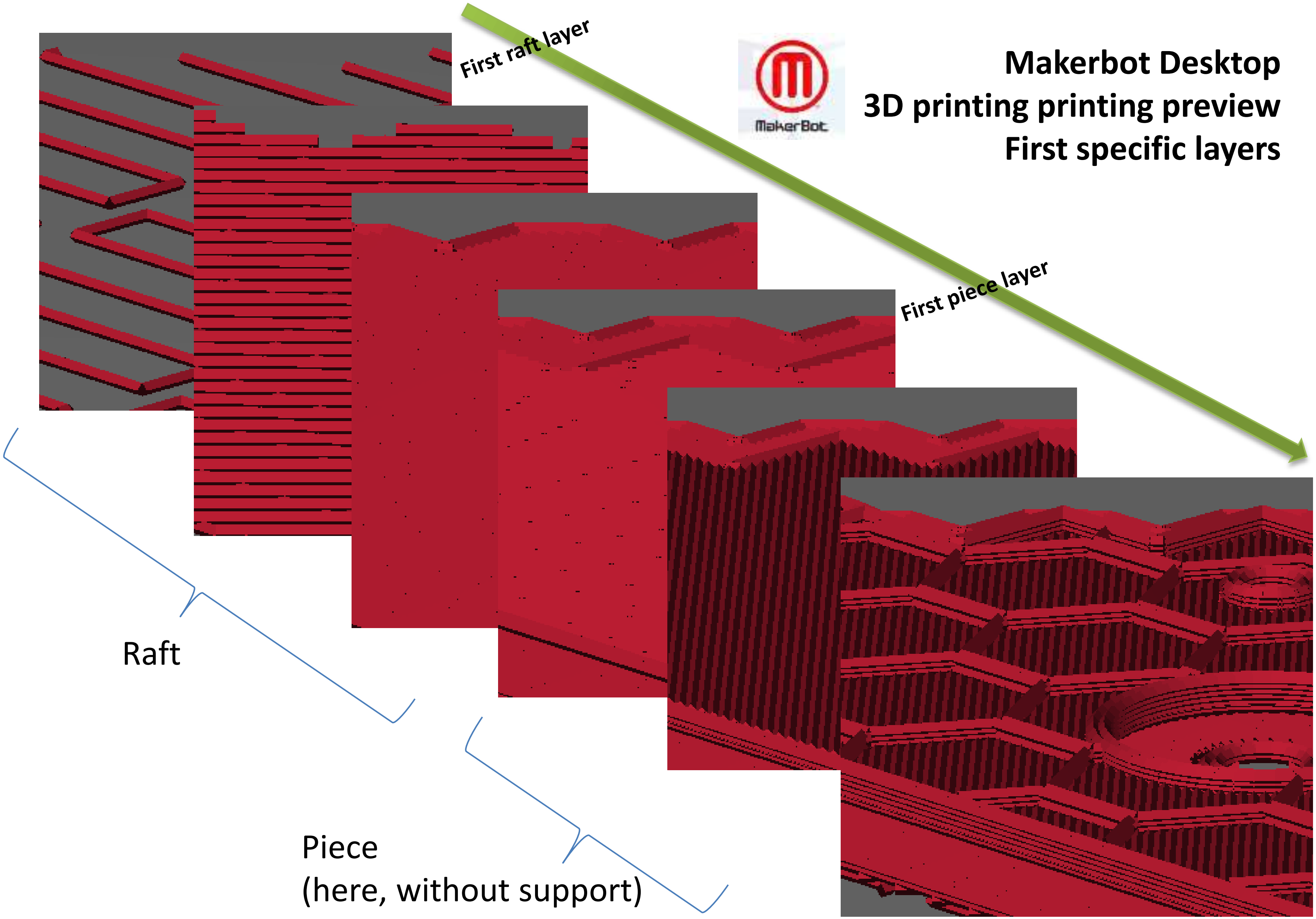


$\Rightarrow$ **.x3g**
Makerbot Replicator 2X specific file exporting

Makerbot Desktop 3D printing printing preview



Makerbot Desktop
3D printing printing preview
First specific layers



General FDM 3D printing run problems some solution

Incomplete bottom layer -> add additionnal bottom layers

Hanging strands -> change layer thickness and cooling (fan or ambiant temperature)

Too small holes -> use offsets

Burn marks on model -> clean or change nozzle

Irregular walls or material deficiency -> clean, change extruder cable or PCB, or change extruder

Layer shifting during print -> tighten screws on polleys

Unfinished part -> possible problem origins = material tangled u on spool, material running out or material blocked in the extruder

Extrusion problem -> change extruder cable, or change thermocouple and heater

Wraping (raft doesn’t stick to the platform) -> adjust distance between nozzle

Delamination of layers (layers split apart)
-> use material with low shrinkage level, print at a temperature more than 20°C.

7- Conclusion

6- Conclusion

1- Complementary manufacturing processes : machining and 3D printing

2- New items in 3D prining :
CAD, STL and AMF file format, design, topological and process optimisation, Finite Element simulations, Slicing, printing settings, safety, file protection,

3- New Additive Manufacturing machines with increased performances, new materials (plastic or metallic) and New services

Thanks for attention !

Source : http://www.ufunk.net/en/techno/3d-printed-flowers/

Source : http://www.123inspiration.com/3d-printed-architectural-structure-by-digital-grotesque/