RAPID PROTOTYPING

Brandenburg University of Technology

Cottbus

4.-5. February 2010

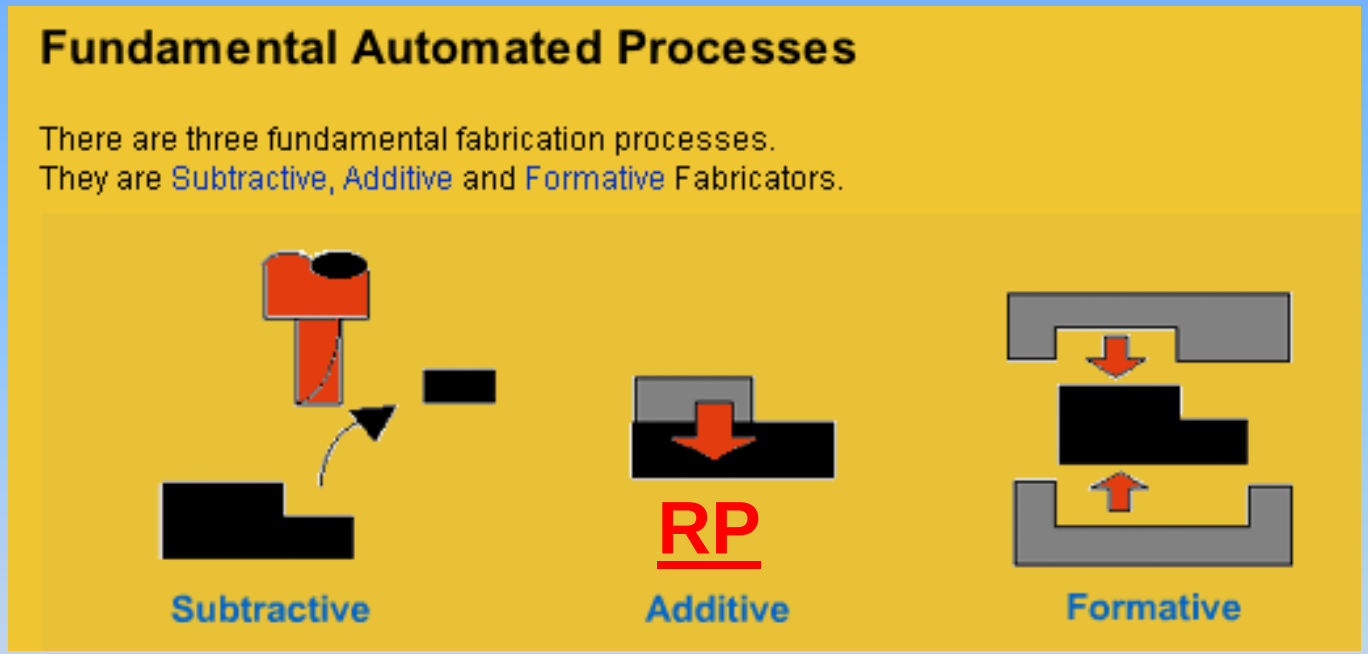
SEPPO AARNIO

THREE PHASES OF DEVELOPMENT LEADING TO RAPID PROTOTYPING

- **MANUAL PROTOTYPING**
- **SOFT or VIRTUAL PROTOTYPING**
- **RAPID PROTOTYPING (of physical parts)**

”***Solid freeform fabrication***”, ”***Desktop manufacturing***” or ”***Layer manufacturing Technology***”.

FUNDAMENTAL FABRICATION PROCESSES



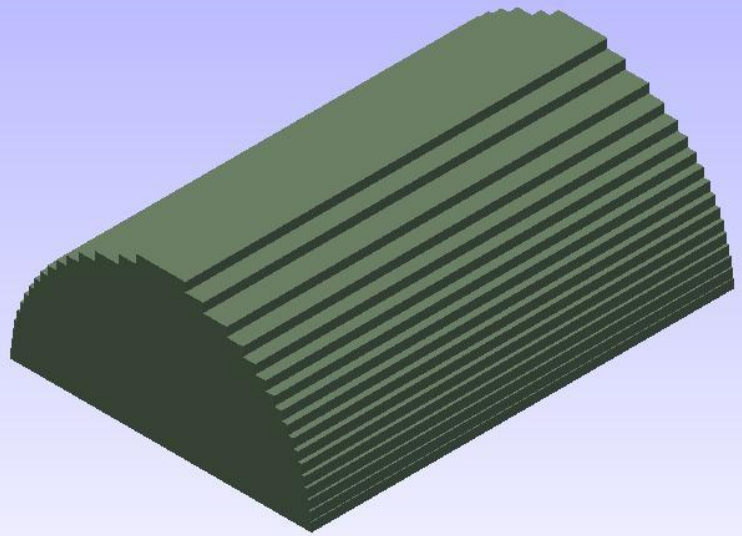
C K Chua, K F Leong, & C S Lim: Rapid Prototyping: Principles and Applications

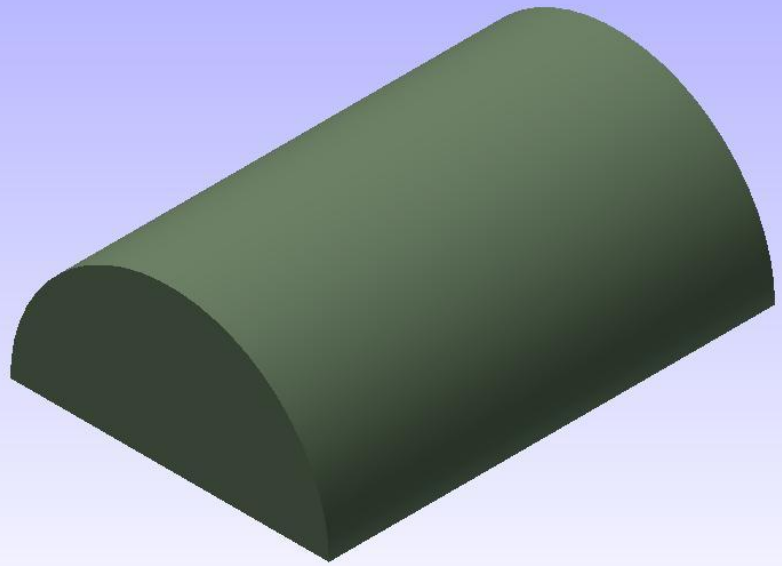
1. OVERVIEW OF RAPID PROTOTYPING

The term rapid prototyping (RP) refers to a class of technologies that can automatically construct physical models from Computer-Aided Design (CAD) data.
The main advantage of the system is that almost any shape can be produced. *Time and money savings vary from 50 – 90 %* compared to conventional systems.
Rapid prototyping techniques are often referred to *solid free-form fabrication*, *computer automated manufacturing* or *layered manufacturing.*
The computer model is sliced into thin layers and the part is fabricated by adding layers on to of each other.

Since 1988 more than twenty different rapid prototyping techniques have emerged.

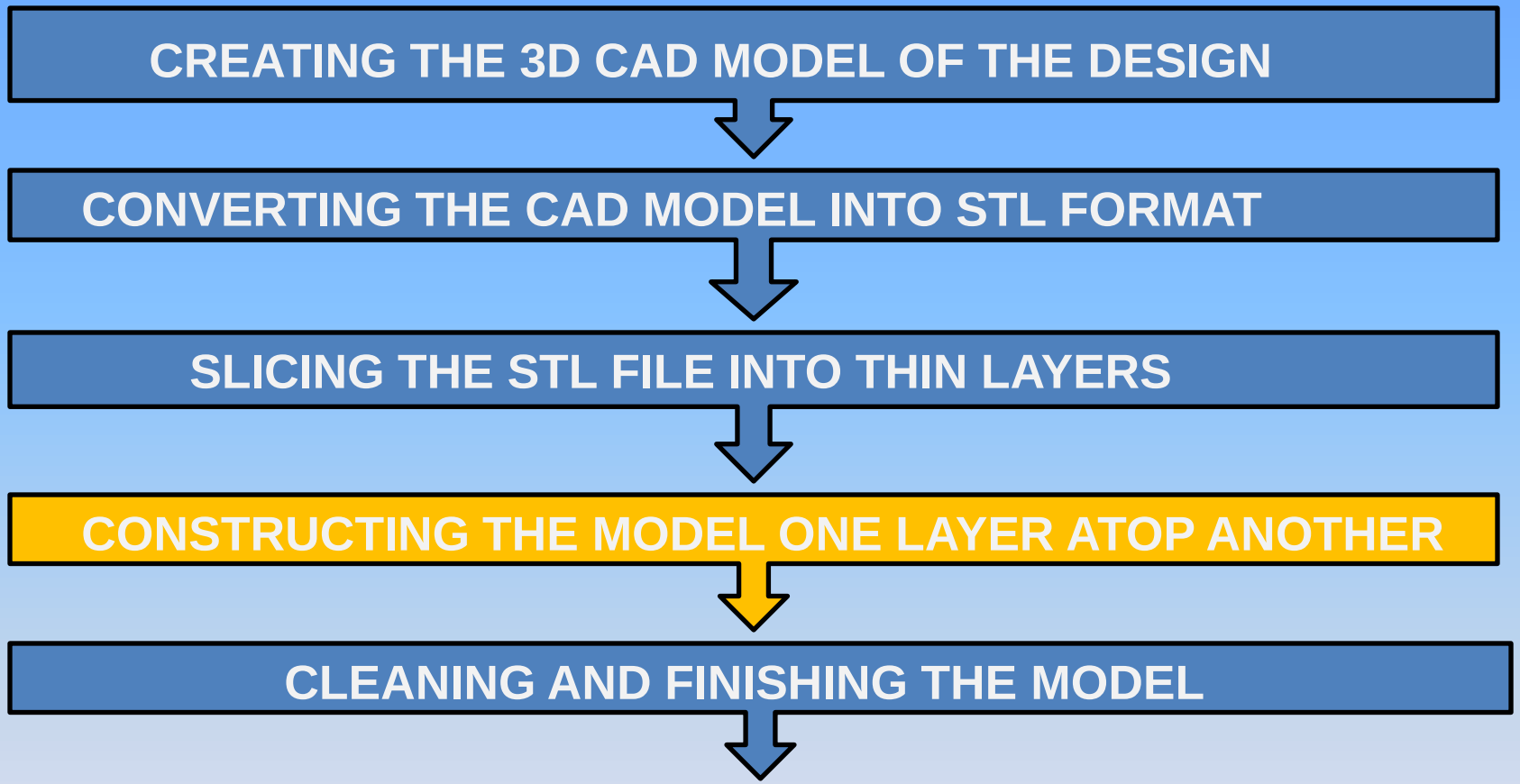
ADDITIVE PROCESS





Typical layer thickness could be ≈ 0,05 – 0,15 mm

2. THE BASIC PROCESS



2.1 CAD MODEL CREATION:

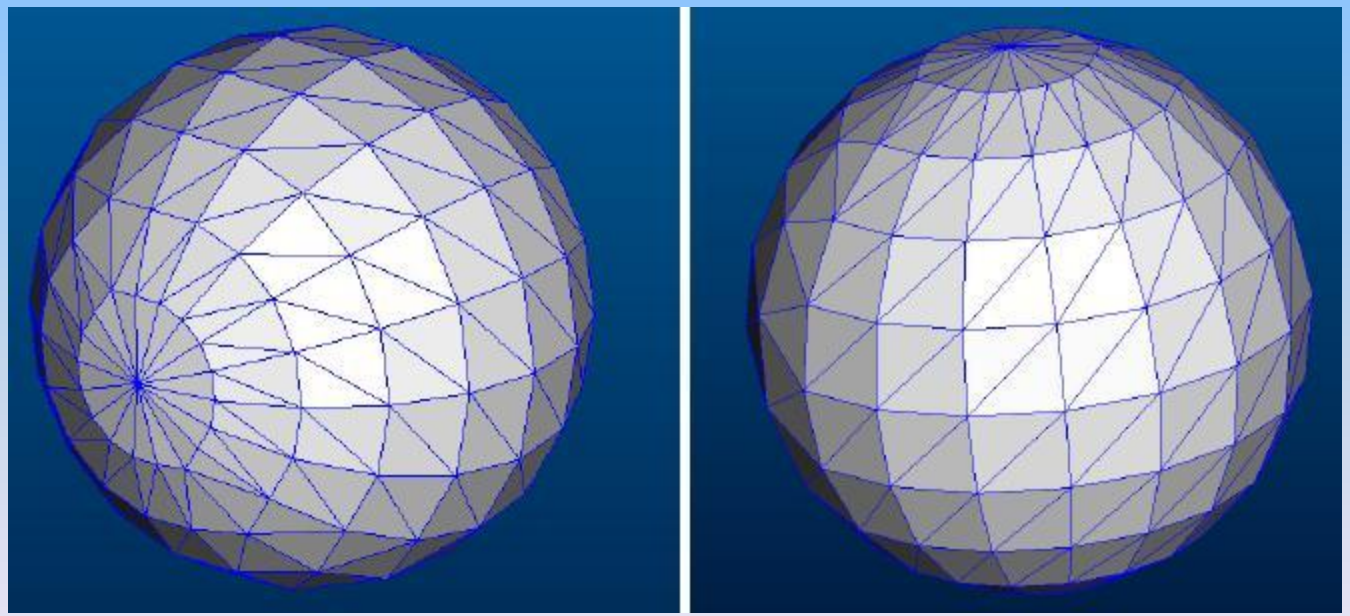
First the object to be build is modeled:

- using a ***CAD software package***
- or by using a ***laser scanner*** or a ***Coordinate Measuring Machine*** (CMM). (”Reverse engineering””)

2.2 CONVERSION TO STL FORMAT:

The standard data interface between CAD sofware and the machine is the STL-format (Stereolithography).

An STL-file approximates the shape of a part using triangular facets. Small facets produce a high quality surface.

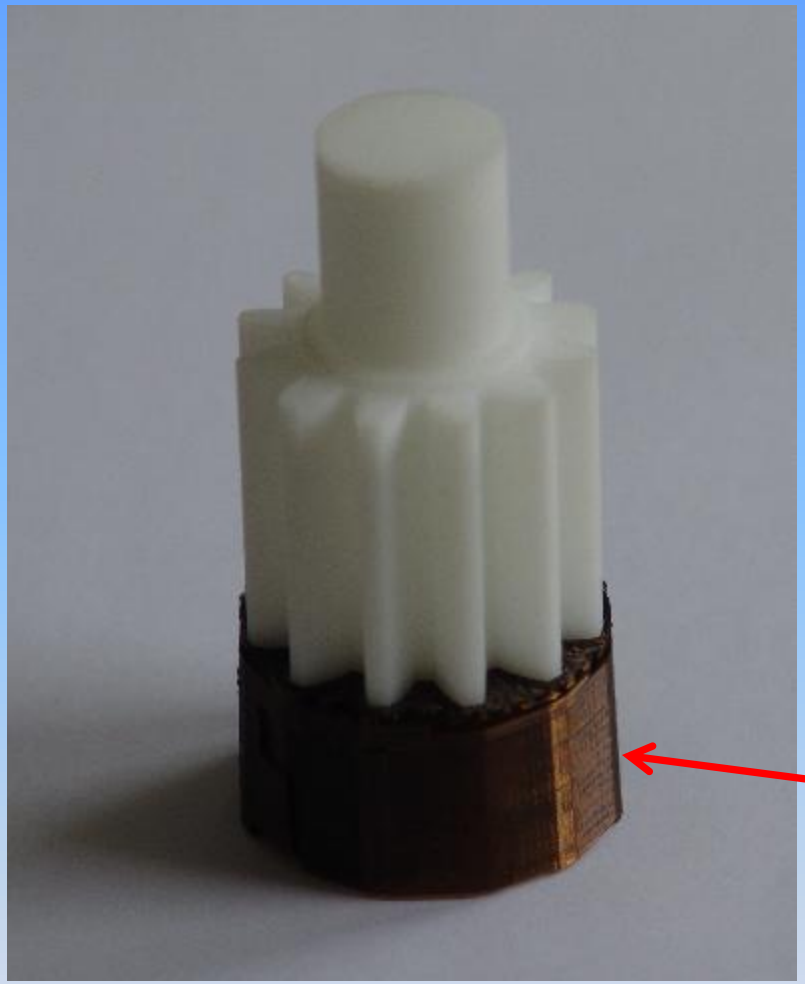


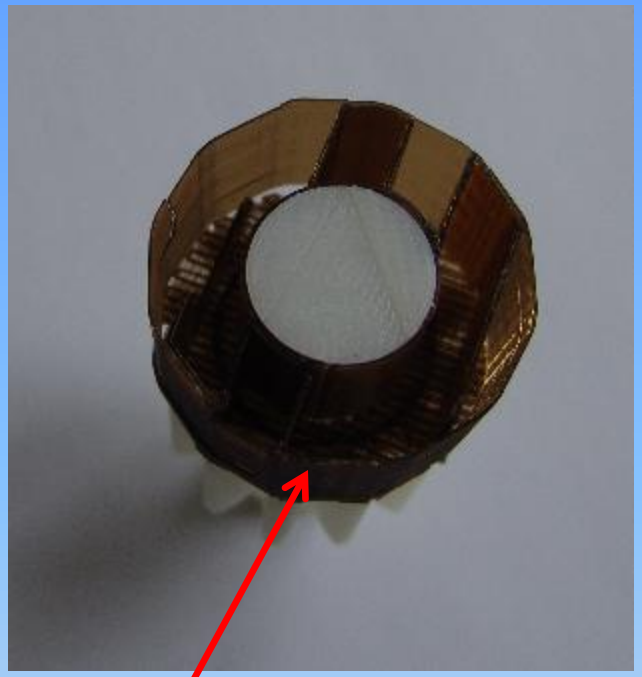
Since the .stl format is universal, this process is identical for all of the RP build techniques.

3.2 SLICE THE STL FILE:

http://www.youtube.com/watch?v=80aXU5q2Kgg

The program may also generate an *auxiliary structure* to Support the model during the build





SUPPORT MATERIAL

4.2 LAYER BY LAYER CONSTRUCTION:

The fourth step is the actual construction of the part. Using one of several techniques (described later) RP machines build the model layer by layer.

The material´s initial states are:

- LIQUID
- SOLID or
- POWDER

5.2 CLEAN AND FINISH:

- Removement of the part from the machine
- Detaching any supports
- Aftercure (some photosensitive materials)
- Cleaning and surface treatment
- Possible painting etc

3. GENERAL ADVANTAGES OF RP

- Almost any shape or geometric feature can be produced.
- Reduction in time and cost (could range 50 – 90%. Wohler)
- Errors and flaws can be detected at an early stage.
- RP/RM can be used in different industries and fields of life (medicine, art and architecture, marketing..)
- Discussions with the customer can start at an early stage.
- Assemblies can be made directly in one go.
- Material waste is reduced.
- No tooling is necessary.
- The designers and the machinery can be in separate places.
-

4. SOME DISADVANTAGES OF RP

- The price of machinery and materials.
- The surface is usually rougher than machined surfaces.
- Some materials are brittle.
- The strength of RP-parts are weaker in z-direction than in other.
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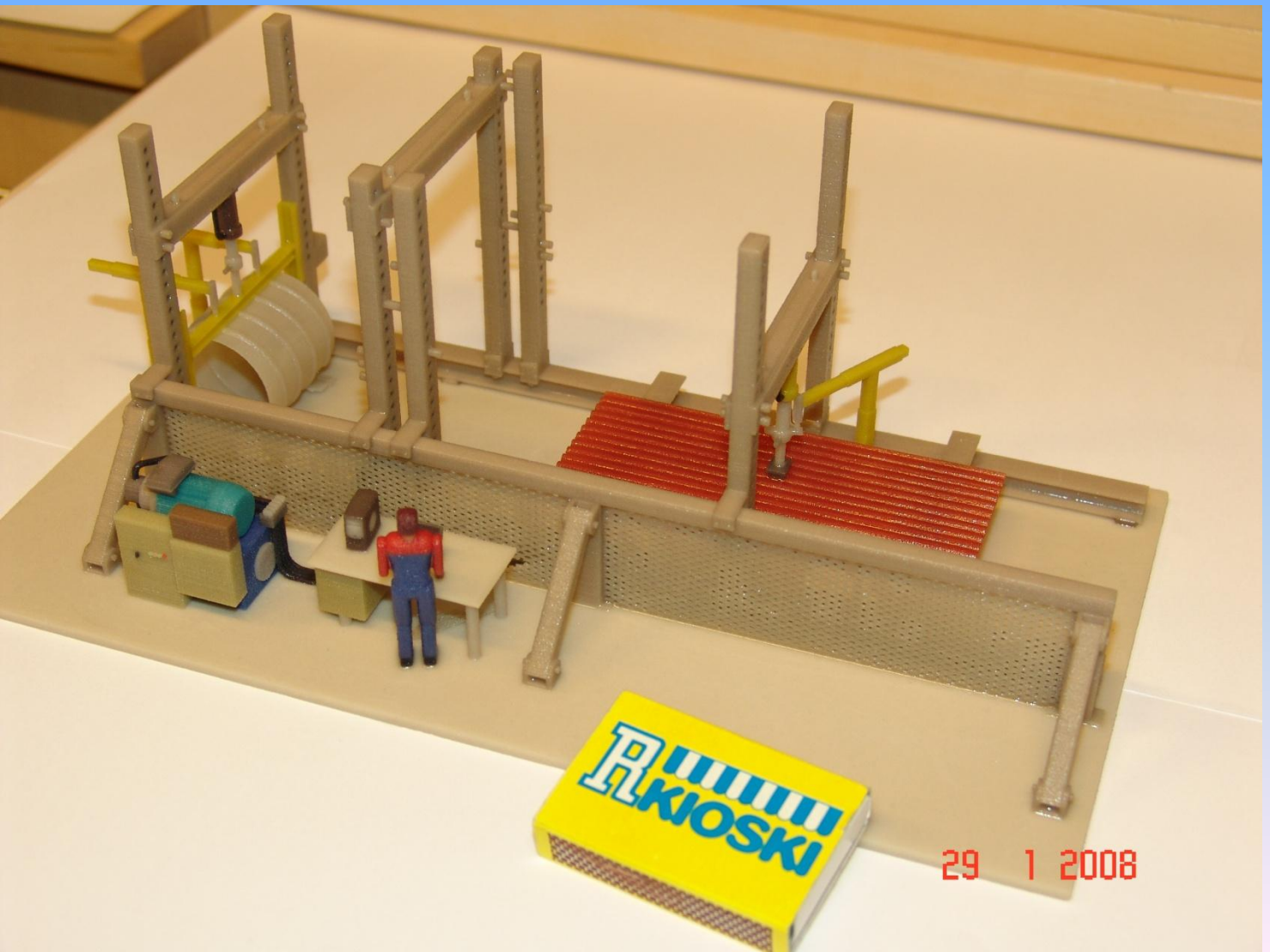
5. APPLICATIONS OF RP

Technology

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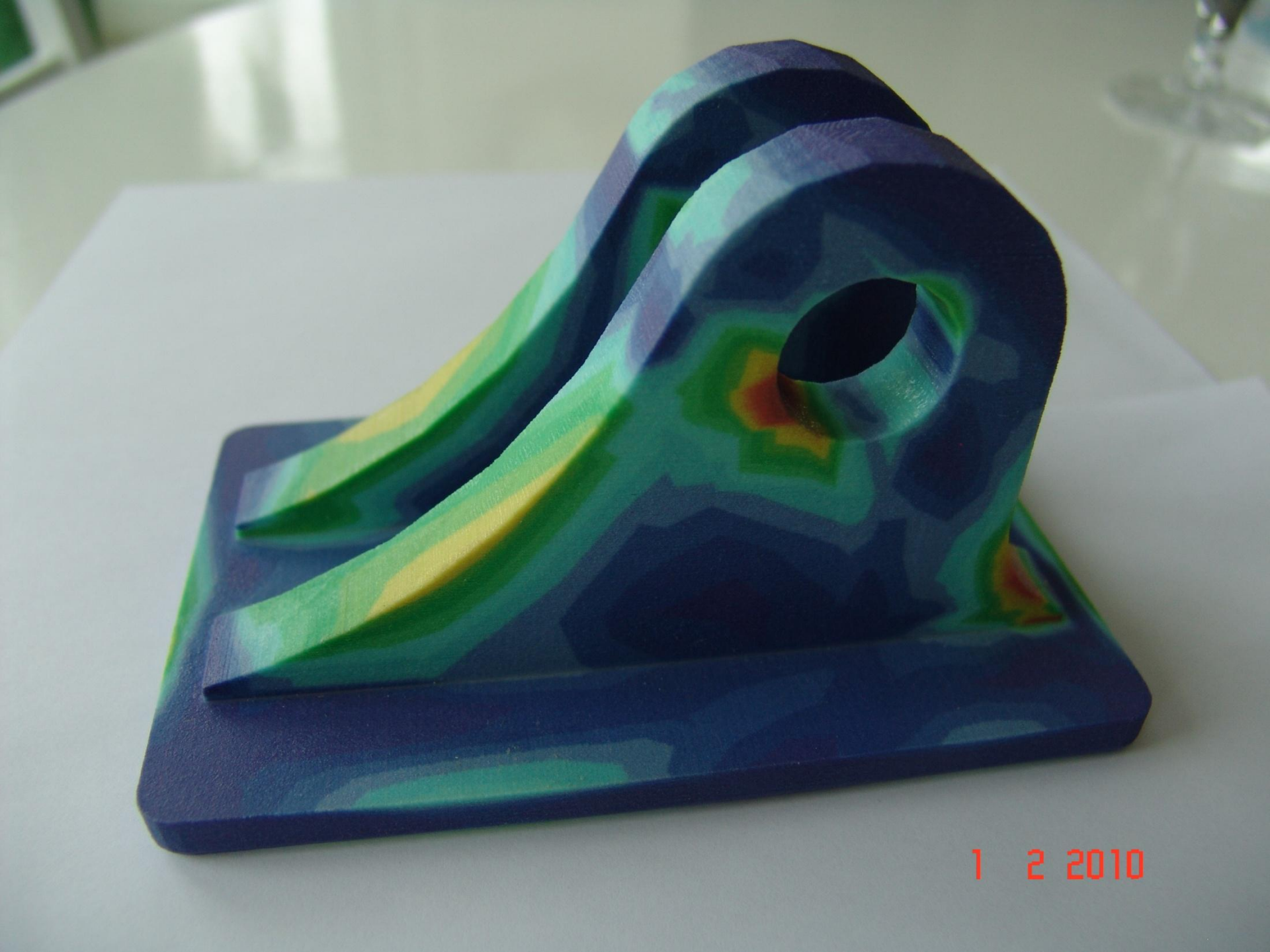
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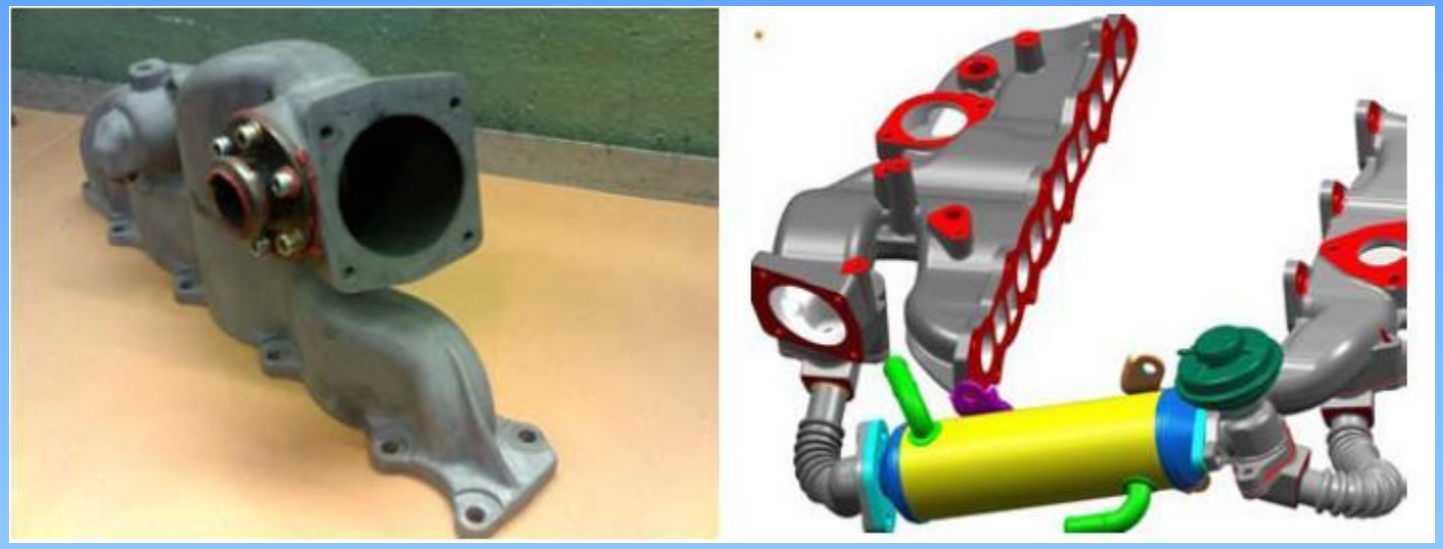
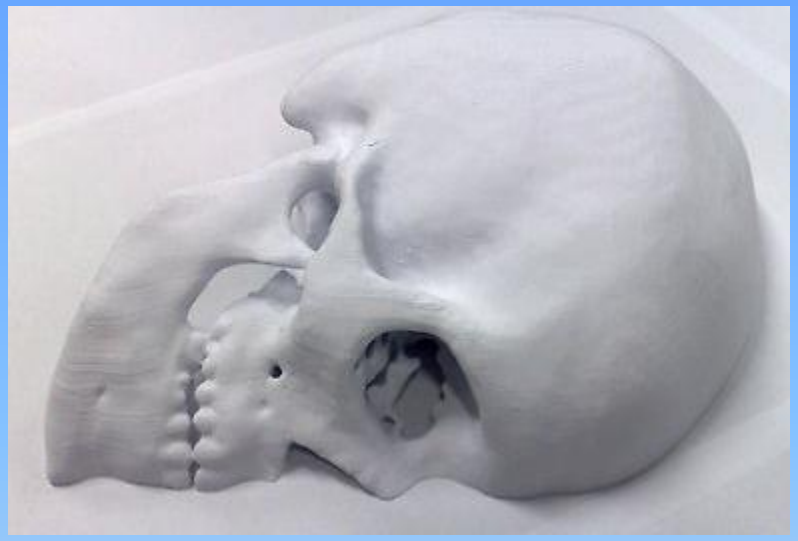


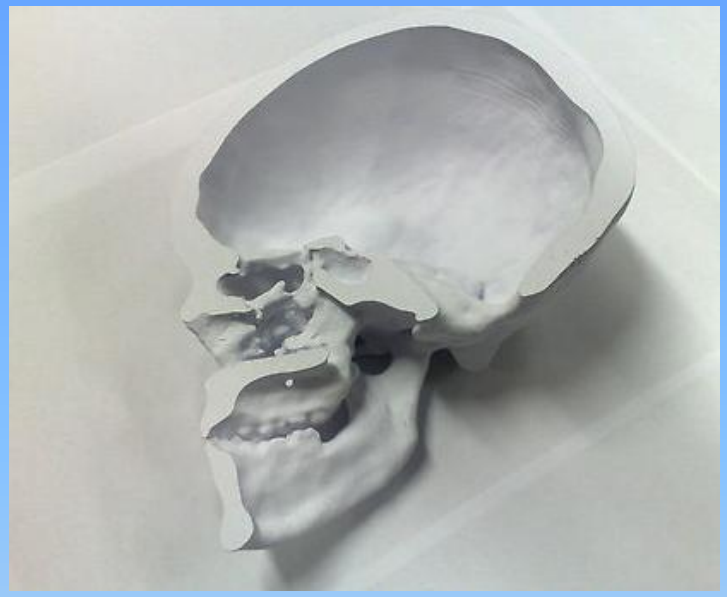
The task was to test different alternative INTAKE MANIFOLDS. The parts (three) were made of Windform XT with laser sintering. By using SLS the time from desktop to product took only about 10 % of the time earlier.

Wind tunnel tests

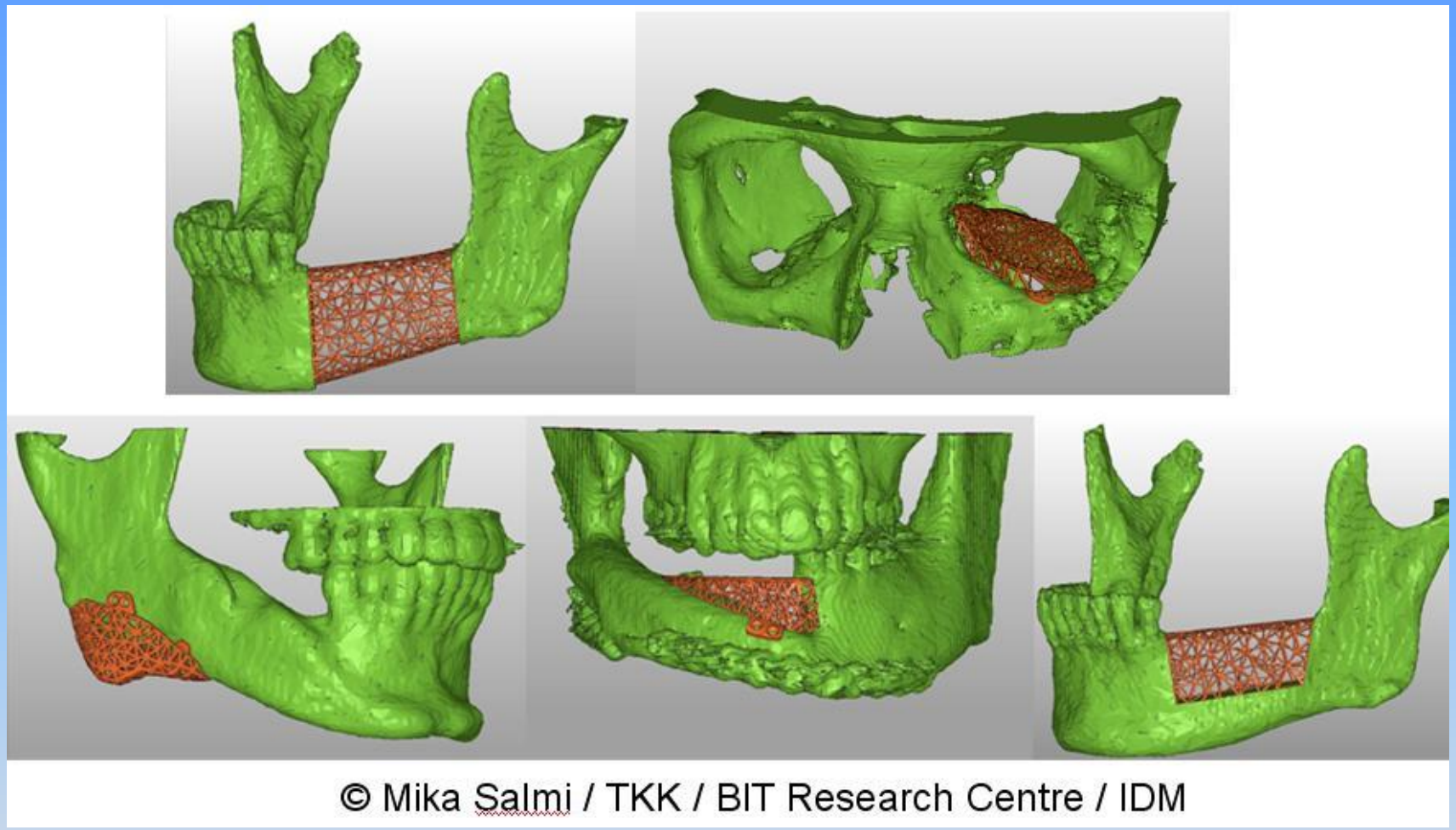

RedBull

Medicine





Models of skulls etc can be used for training of surgical operations



Parts made of titamium are used for replacements

RP modeling for surgical planning to separate Siamese twins.
(Courtesy, Biomedical Modeling, Inc.)

These siamese twins were succesfully separated. The operation was planned with models of the skulls.

Architecture

6. RP-TECHNOLOGIES

- Stereolithography (SLA)
- Fused Deposition Modeling (FDM)
- Selective Laser Sintering (SLS)
- Laminated Object Manufacturing (LOM)
- 3D Printing
- Direct metal laser sintering (DMLS)

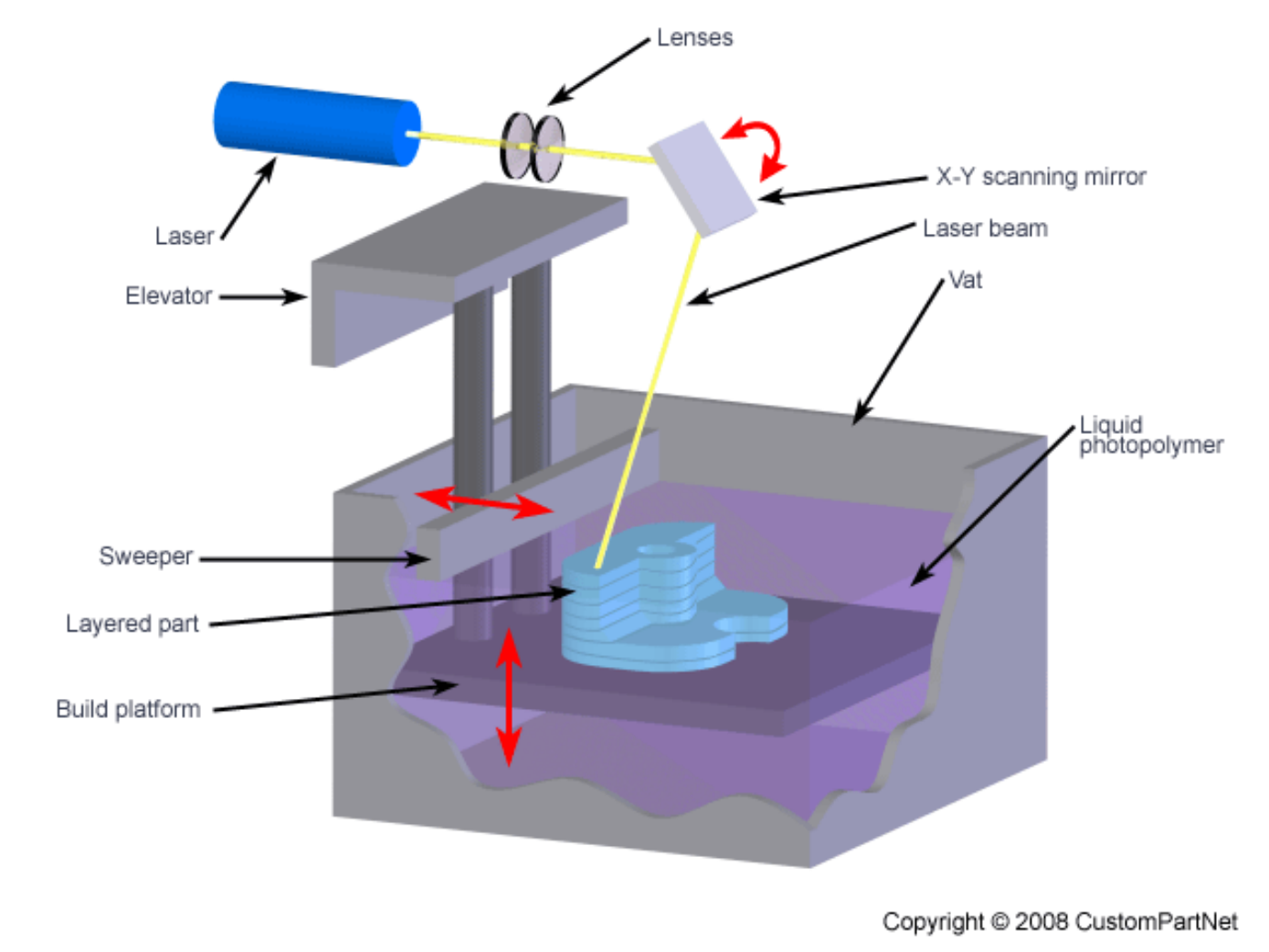
6.1 STEREOLITHOGRAPHY **SLA**

Stereolithography is the most widely used RP-technology. It can produce highly Accurate and detailed polymer parts. SLA was the first RP-process, introduced in 1988 by 3D Systems Inc.

SLA uses a low-power, highly focused UV laser to produce a three dimensional object in a vat of liquid photosensitive polymer.

Abbreviation:	**SLA**
Material type:	Liquid (Photopolymer)
Materials:	Thermoplastics (Elastomers)
Min layer thickness:	0,02 mm
Surface finish:	Smooth
Build speed:	Average
Applications:	Form/fit testing, Functional testing, Very detailed parts, Presentation models, Snap fits..

SLA



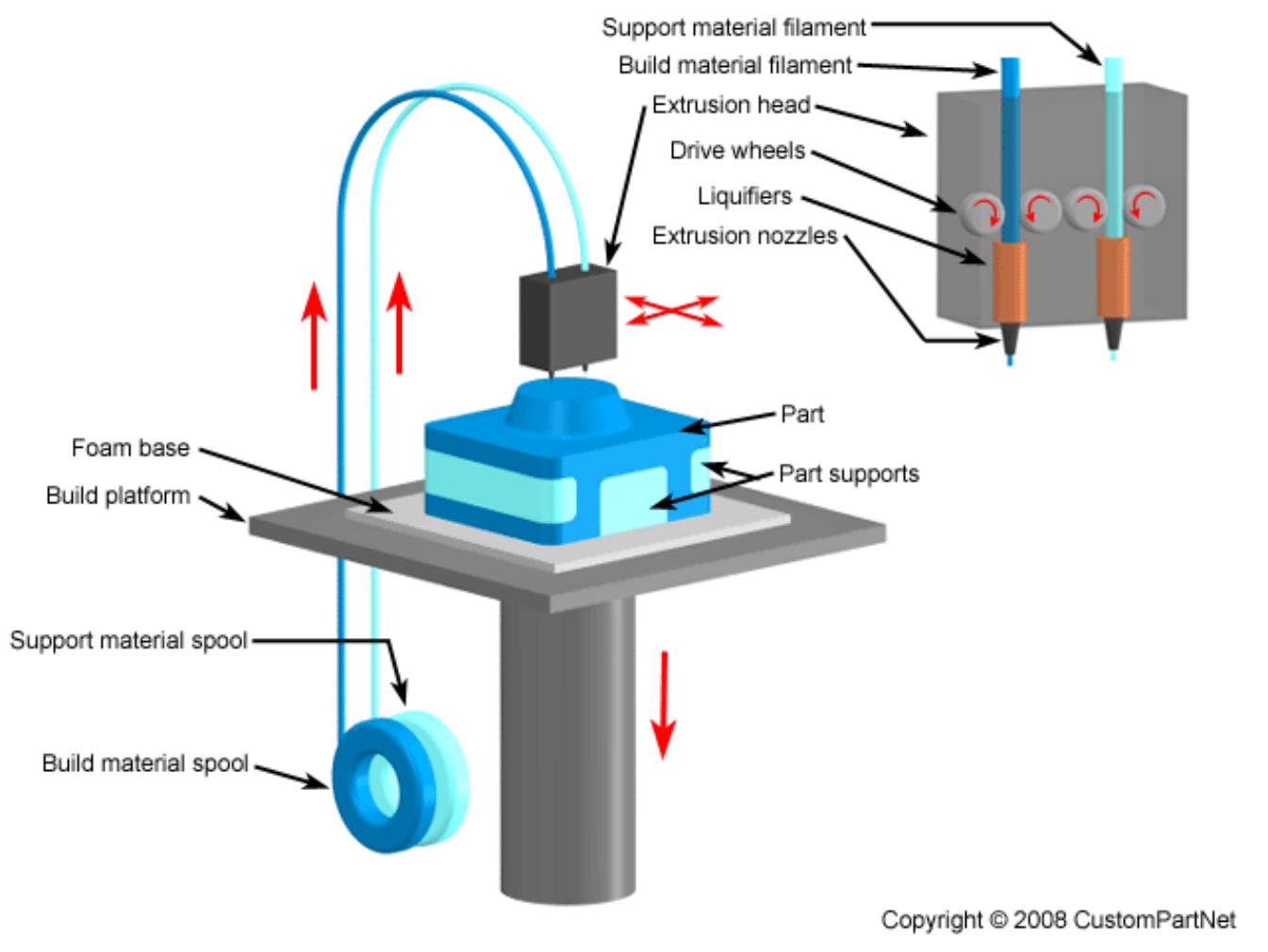
http://www.youtube.com/watch?v=eJ7s-1XvDFw&feature=related

6.2 FUSED DEPOSITION MODELING **FDM**

FDM was developed by Stratasys. In this process, a plastic or wax material is extruded through a nozzle that traces the part´s cross sectional geometry layer by layer

Abbreviation:	**FDM**
Material type:	Solid (Filaments)
Materials:	ABS, Polycarbonate, Polyphenylsulfonite; Elastomers
Min layer thickness:	0,15 mm
Surface finish:	Rough
Build speed:	Slow
Applications:	Form/fit testing, Functional testing, Small detailed parts, Presentation models…

FDM



http://www.youtube.com/watch?v=oYLjyI5honM&feature=related

6.3 SELECTIVE LASER SINTERING SLS

SLS was patented in 1989. *The basic concept of SLS is similar to that of SLA*. It uses a moving laser beam to trace and selectively sinter powdered polymer and/or metal composite materials. The powder is kept at elevated temperature. Unlike SLA, *special support structures are not required* because the excess powder in each layer as a support.

With the metal composite material, the SLS process solidifies a polymer binder material around steel powder (diameter ca. 0.1 mm) one slice at a time forming the part.

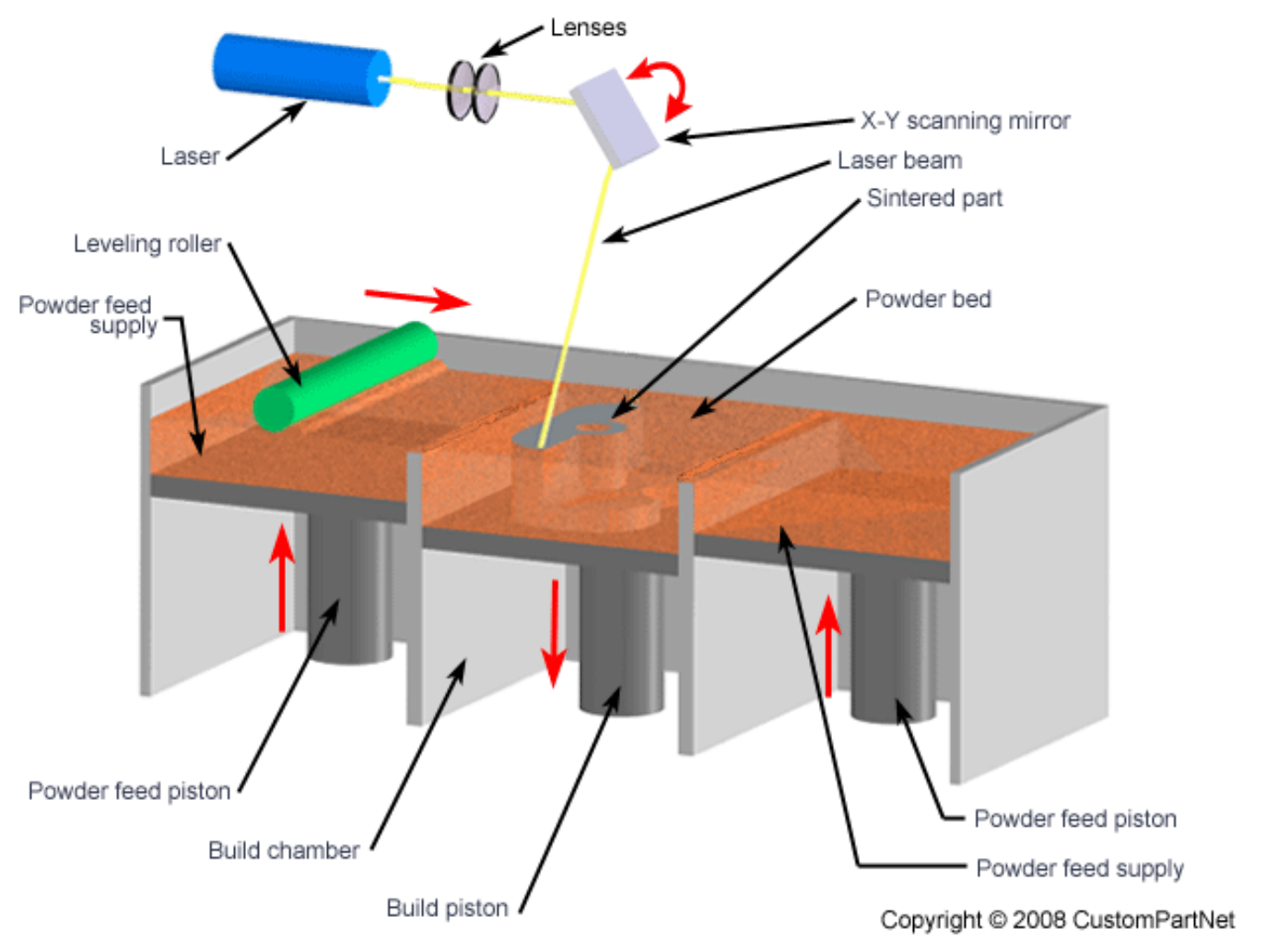
The part is then placed in a furnace (>900 °C), where the polymer binder is burned off and the part is infiltrated with bronze to improve its density.

SLS allows for a wide range of materials, including nylon, glass-filled nylon, Truform (investment casting) and metal composites.

SLS

Abbreviation:	SLS
Material type:	Powder (Polymer)
Materials:	Thermoplastics: Nylon, Polyamide and Polystyrene; Elastomers; Composites
Min layer thickness:	0,10 mm
Surface finish:	Average
Build speed:	Fast
Applications:	Form/fit testing, Functional testing, Less detailed parts, Parts with snap-fits & living hinges, High heat applications..

SLS



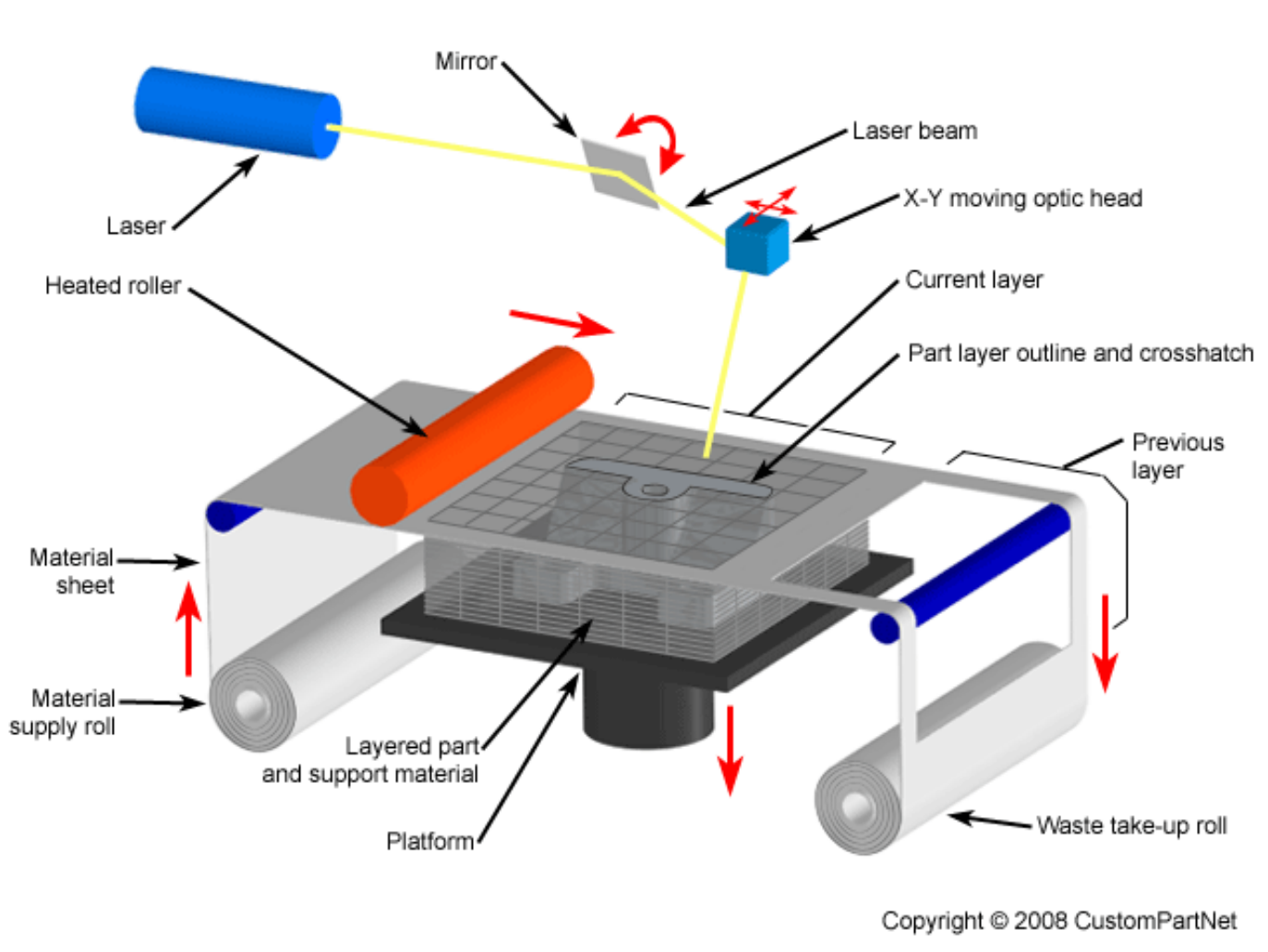
http://www.youtube.com/watch?v=ShX_qXSTj_E&feature=related

6.4 LAMINATED OBJECT MANUFACTURING LOM

The main components of the system are a feed mechanism that advances a sheet over a build platform, a heater roller to apply pressure to bond the to the layer below, and a laser to cut the outline of the part in each sheet layer. After each cut is completed, the platform lowers by a depth equal to the sheet thickness (0.05 – 0,5 mm). The laser cuts the outline and the process is repeated until the part is completed. After a layer is cut, the extra material remains in place to support the part.

Abbreviation:	LOM
Material type:	Solid (Sheets)
Materials:	Thermoplastics such as PVC; Paper; Composites (Ferrous metals; Non-ferrous metals; Ceramics)
Min layer thickness:	0,05 mm
Surface finish:	Rough
Build speed:	Fast
Applications:	Form/fit testing, Less detailed parts, Rapid tooling patterns…

LOM



http://www.youtube.com/watch?v=Z1WNA6tdfWM&feature=related

6.4 3D PRINTING **3DP**

Three Dimensional Printing (3DP) technology was developed at the MIT and licensed to several corporations. The process is similar to the SLS process, but instead of using a laser to sinter the material, an *ink-jet printing head deposits a liquid adhesive that binds the material.* Material options are somewhat limited but are inexpensive relative to other additive processes. 3D printing is *quite fast*, typically 2 – 4 layers/minute. However, the accuracy, surface finish, and part strength are not as good as some other additive processes.

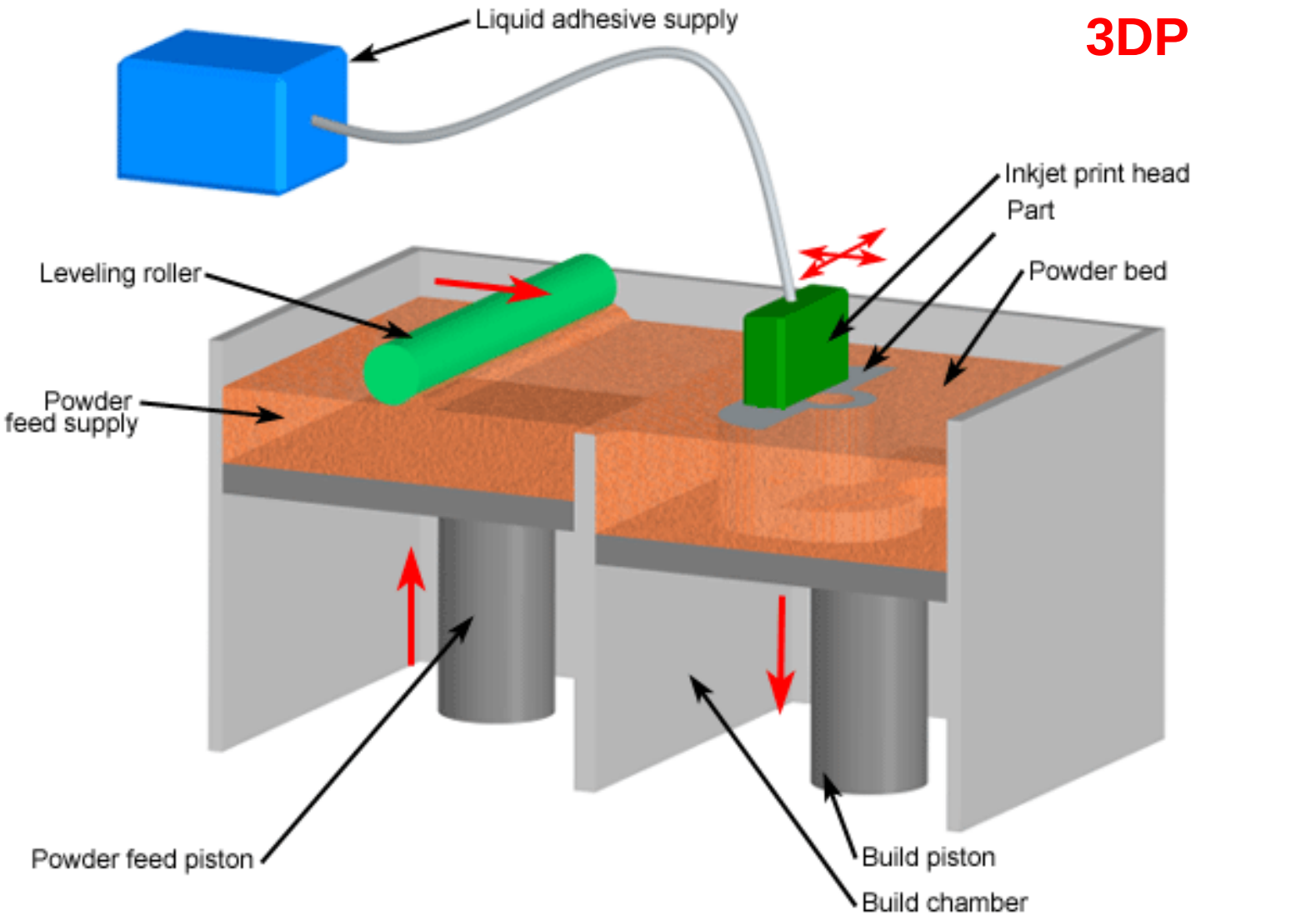
At the end the part is infiltrated with a sealant to improve strength and surface finish.

3DP

Abbreviation:	3DP
Material type:	Powder
Materials:	Ferrous metals such as Stainless steel; Non-ferrous metals such as Bronze; Elastomers; Composites; Ceramics
Min layer thickness:	0,05 mm
Surface finish:	Rough
Build speed:	Very Fast
Applications:	Concept models, Limited functional testing, Architectural & landscape models, Consumer goods & packaging

http://www.youtube.com/watch?v=uAt2xD1L8dw

3DP

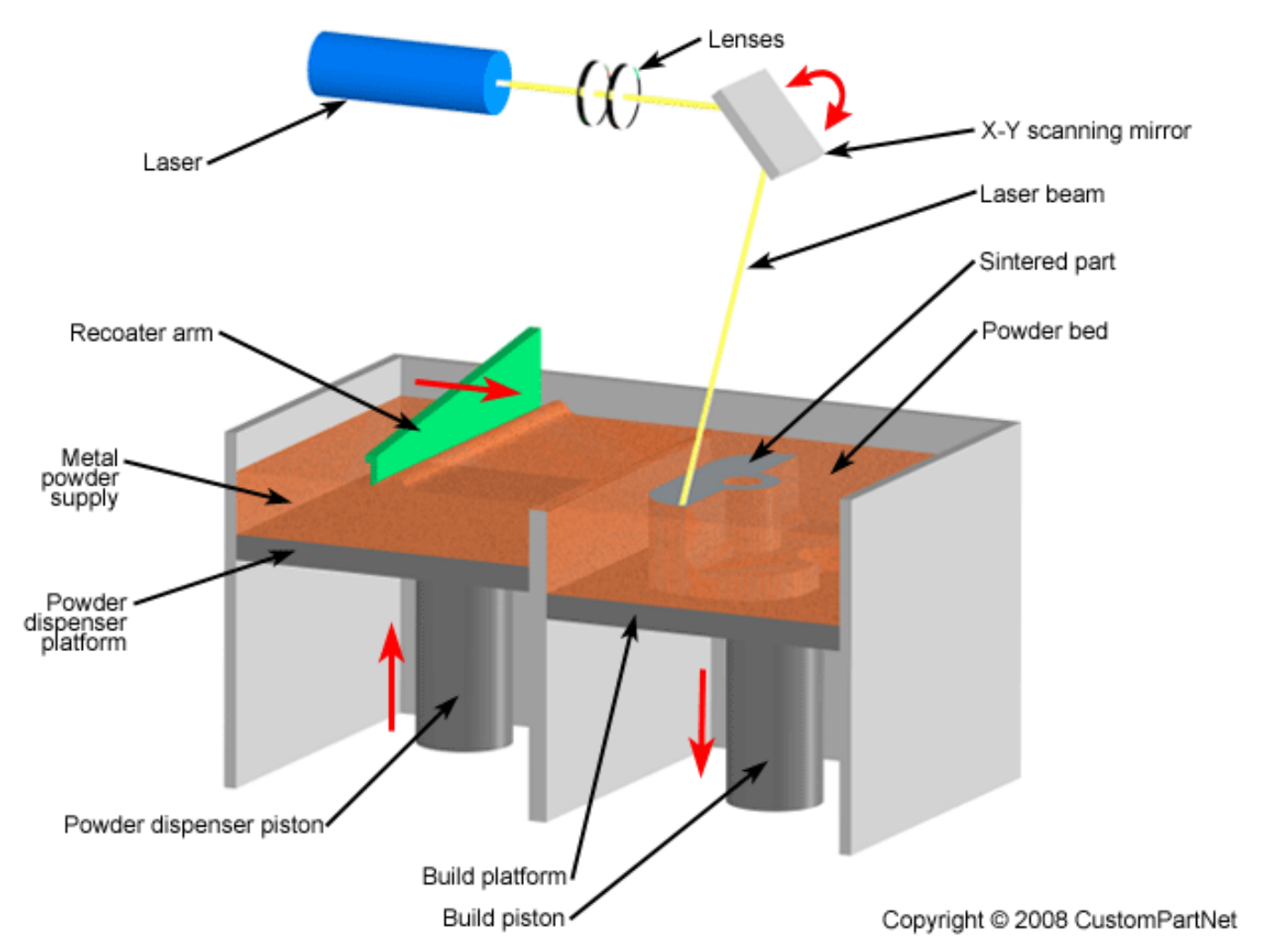

Liquid adhesive supply
Inkjet print head
Part
Powder bed
Leveling roller
Powder
feed supply
Powder feed piston
Build piston
Build chamber
Copyright © 2008 CustomPartNet

6.5 DIRECT METAL LASER SINTERING DMLS

DMLS technology was developed jointly by Rapid Prototyping Innnovations (RPI) and EOS Gmbh in 1994. *It was the first commercial RP-method to produce metal parts in a single process*. Metal powder (20 µm diameter) without binder is completely melted by scanning of a *high power laser beam*. *The density of a produced part is about 98 %.* SLS has about 70 %. One advantage of DMLS compared to SLS is the small size of particles which enables very detailed parts.

Abbreviation:	**DMLS**
Material type:	Powder (Metal)
Materials:	Ferrous metals such as Steel alloys, Stainless steel, Tool steel; Aluminium, Bronze, Cobalt-chrome, Titanium, Ceramics..
Min layer thickness:	0,02 mm
Surface finish:	Average
Build speed:	Fast
Applications:	Form/fit testing, Functional testing, Rapid tooling, High heat applications, Medical implants, Aerospace parts..

DMLS


Lenses
Laser
X-Y scanning mirror
Laser beam
Sintered part
Recoater arm
Powder bed
Metal powder supply
Powder dispenser platform
Powder dispenser piston
Build platform
Build piston
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