3D printing

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„It will be awesome if they don't screw it up" [1]

[1] Title of Michael Weinbergs book about 3D printing opportunities and risks

Agenda

(1) Introduction

a) What is 3D printing?
b) Benefits and downsides
c) Important stages
d) 3D printing technologies & processes
e) Related technology: 3D scanning
f) Charts

(2) Potential applications

(3) Concerns and future development

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3D printing is...

- the creation of 3 dimensional objects from a CAD[1] file
- a successive process adding material layer by layer on top of each other
- also called **additive manufacturing**

3D CAD model → 3D printer → 3D object

[1] Computer-Aided Design: the use of computer systems to assist in the creation, modification, analysis, or optimization of a design

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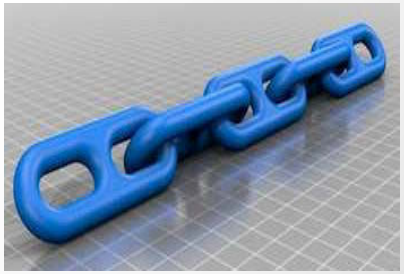
Key benefits

- can **safe costs** especially in manufacturing prototypes
- **reducing the waste** of material and therefore the environmental impact
- possibility to **personalize products** according to individual needs and requirements
- possibility to manufacture **interlocking objects**

Preventing waste at the source

Prototyping

Interlocked objects



But...

- the object has **first to be designed** with an according software
- design may require expert judgement of **physical feasibility** and structure
- **file conversion** into a 3D printer readable file type can be time consuming

Software knowledge

File conversion

Physical feasibility

→ 3D printing can require advanced knowledge of the technology

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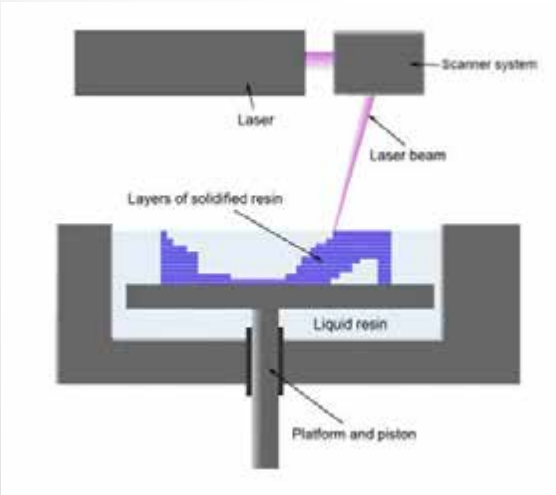
Important stages (1/2)

1984

first 3D printing technique "stereolithography" was invented



1992

first stereolithography machine was produced (by "3D Systems Inc.")

2002

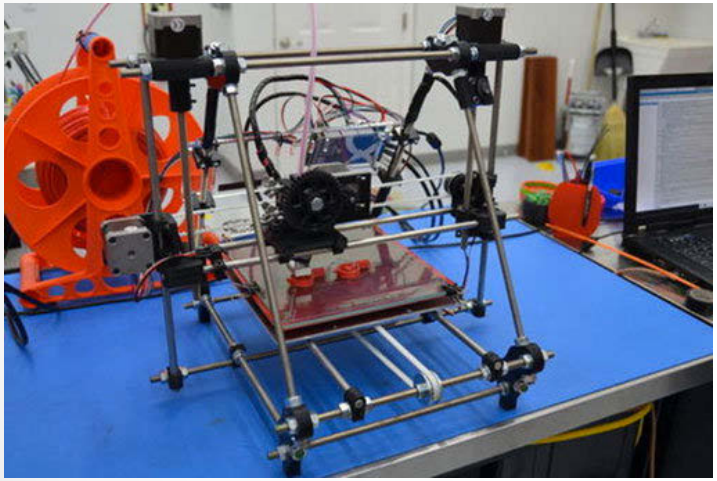
first working kidney was printed

3D printed kidney

Important stages (2/2)

2005

first self replicating printer (most of its parts)



2011

first 3D printed car called “Urbee" was introduced

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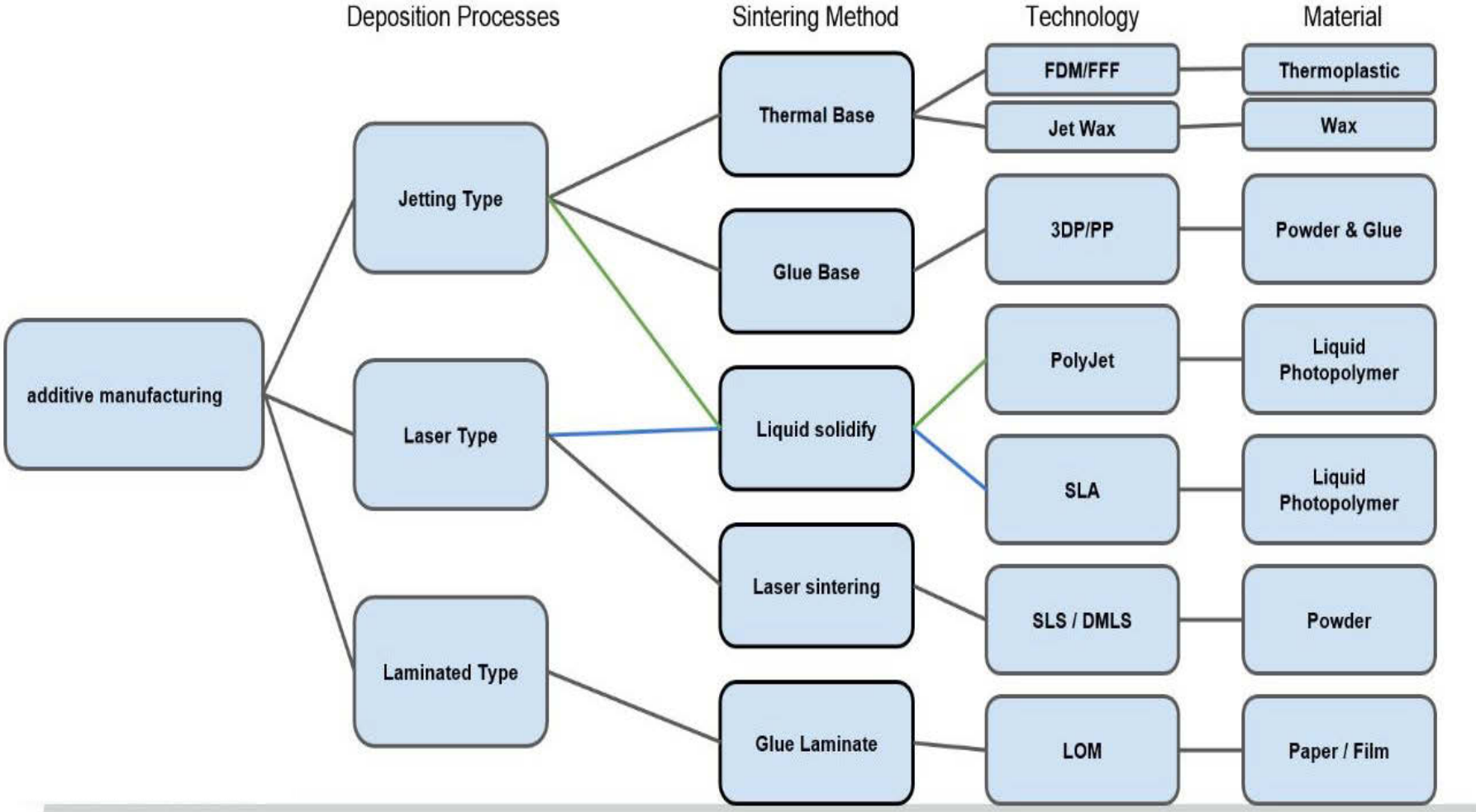
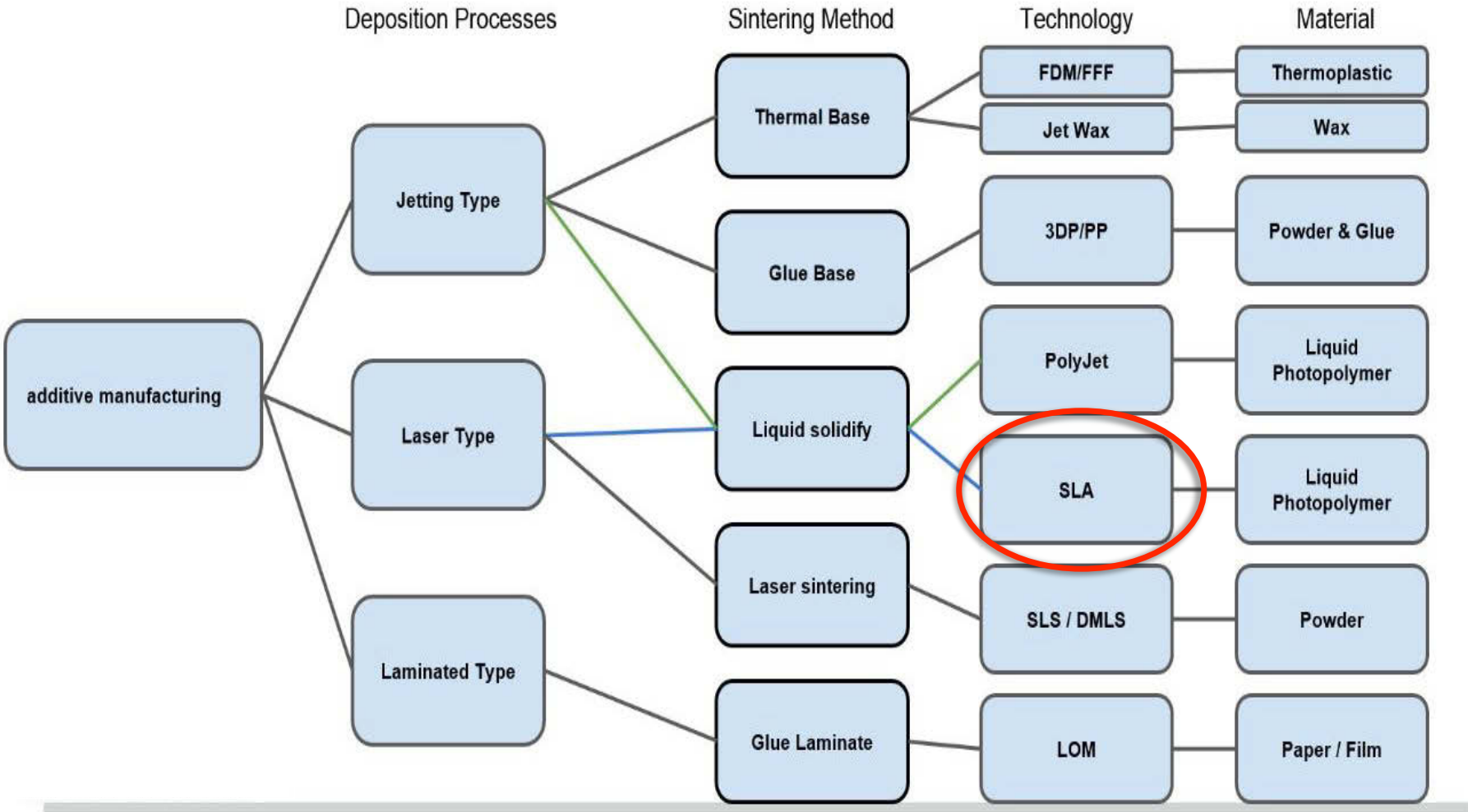
3D printing technologies

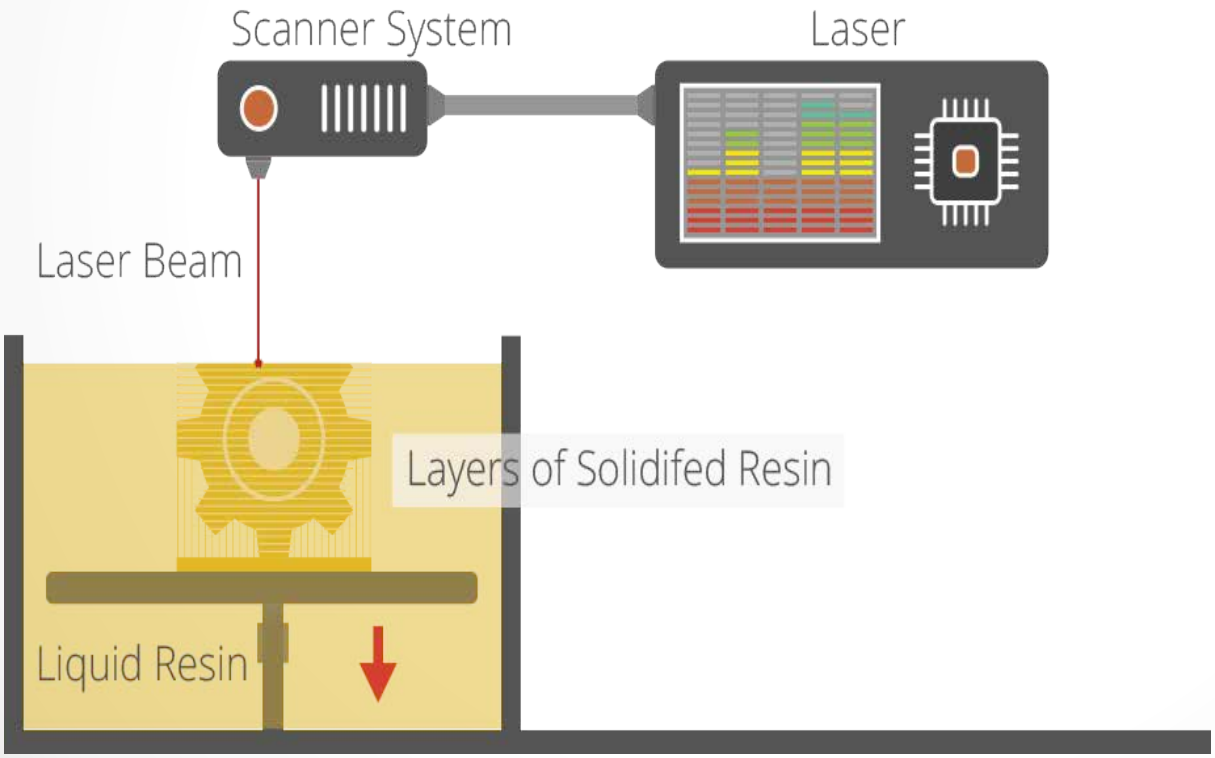


1. Stereolithography



1. Stereolithography

- first 3D printing process (1984)
- uses liquid photopolymers
- laser based



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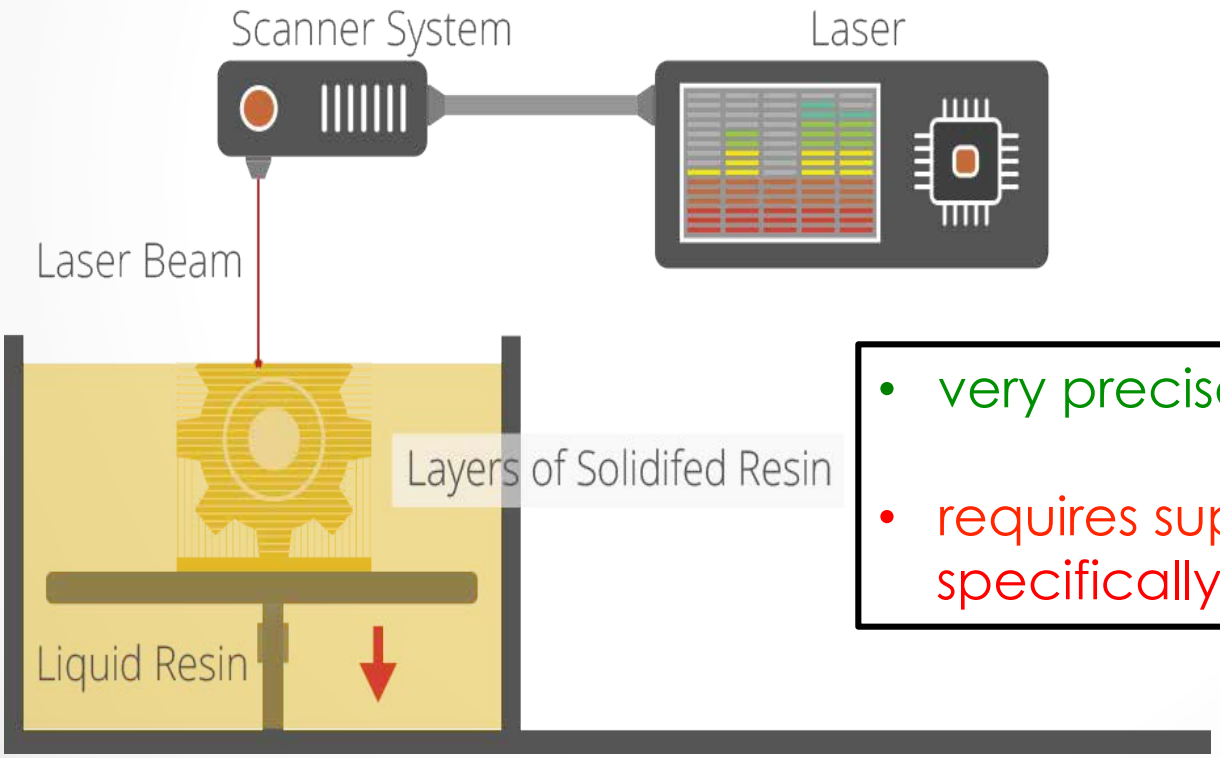
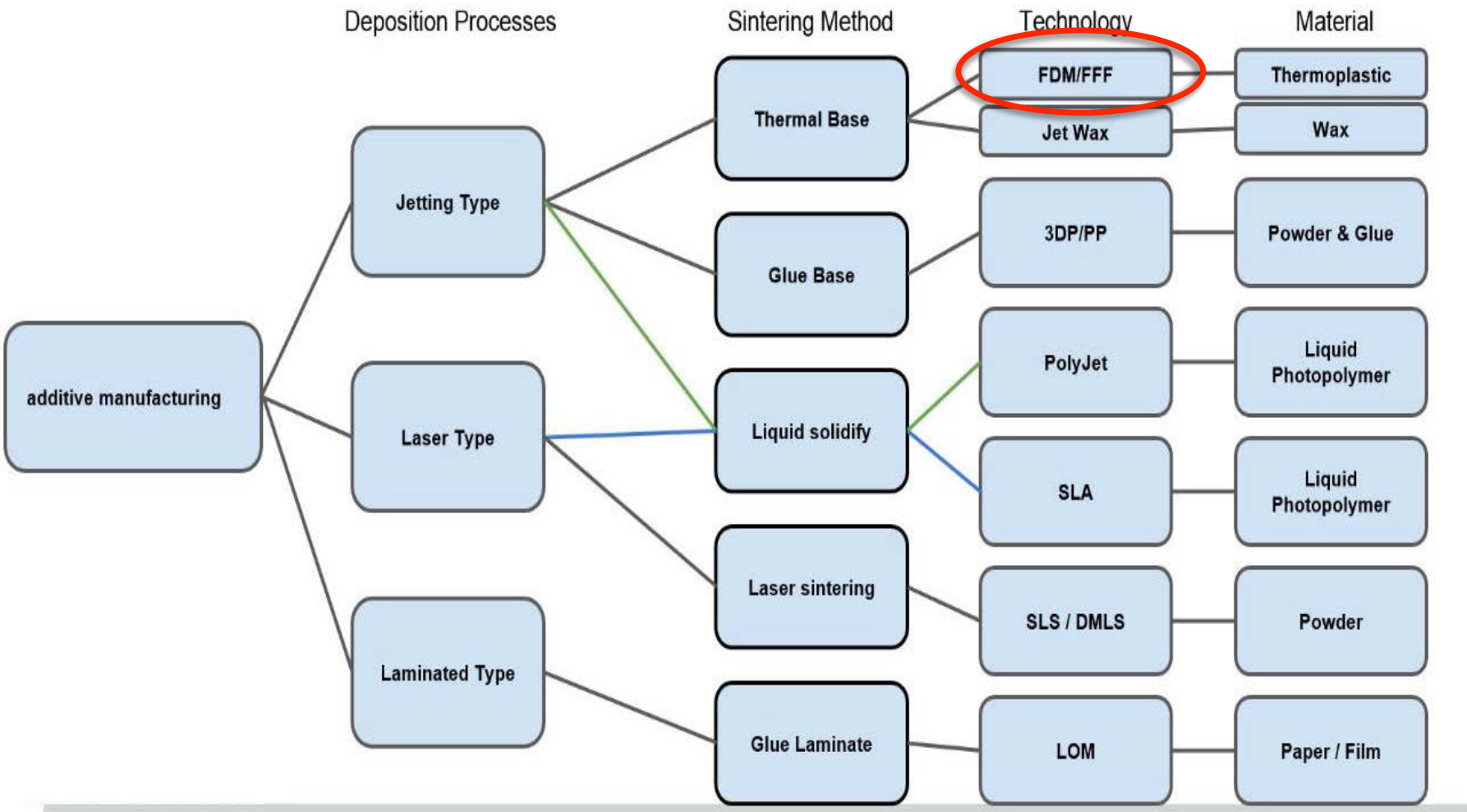


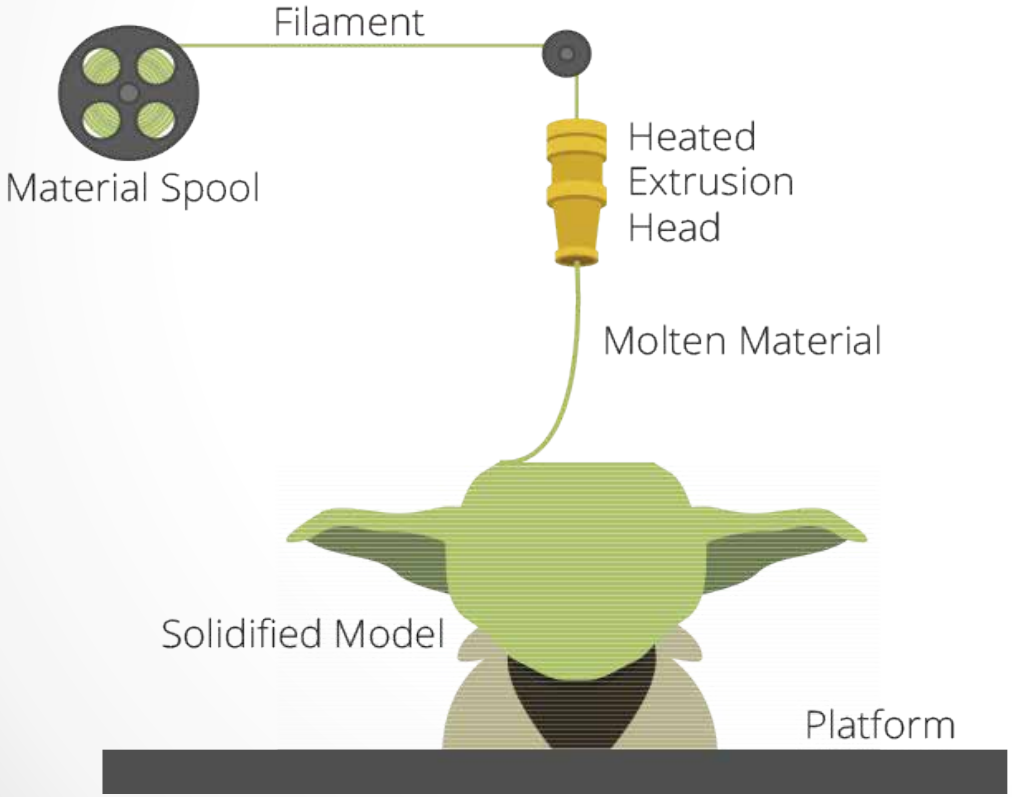
- very precise and accurate (+)
- requires support structures specifically for overhangs (-)

2. Fused Deposition Modelling



2. Fused Deposition Modelling

- thermal-based and uses extrusion of thermoplastic
- developed in the early 1990's by "Stratasys Ltd."



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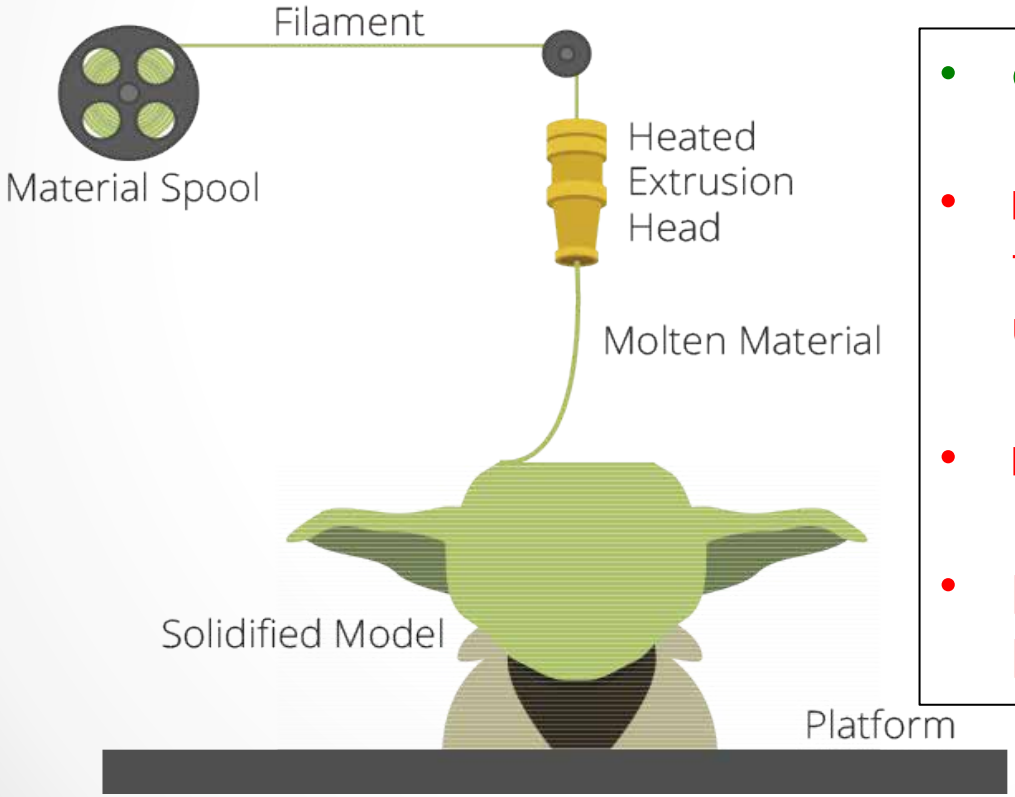
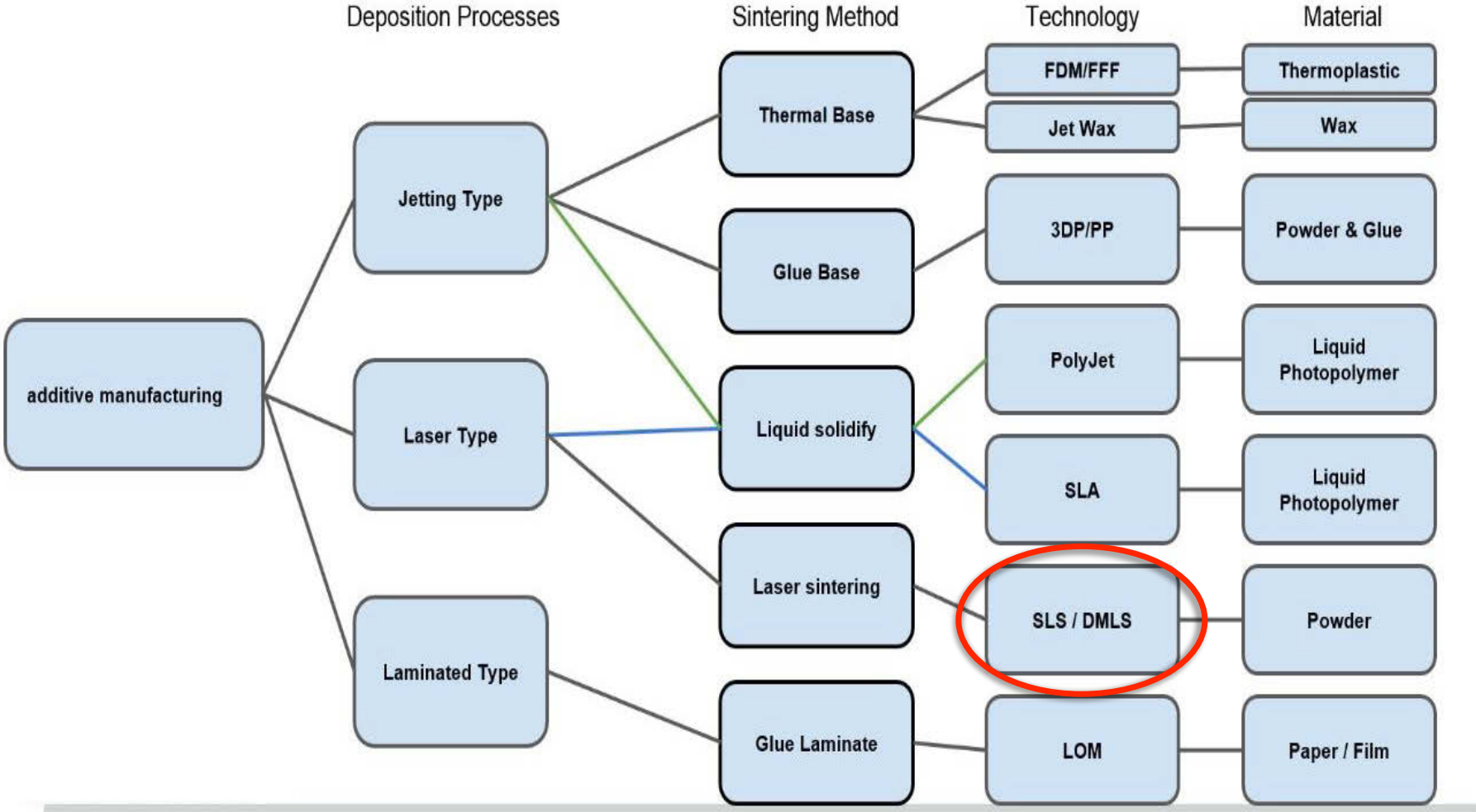


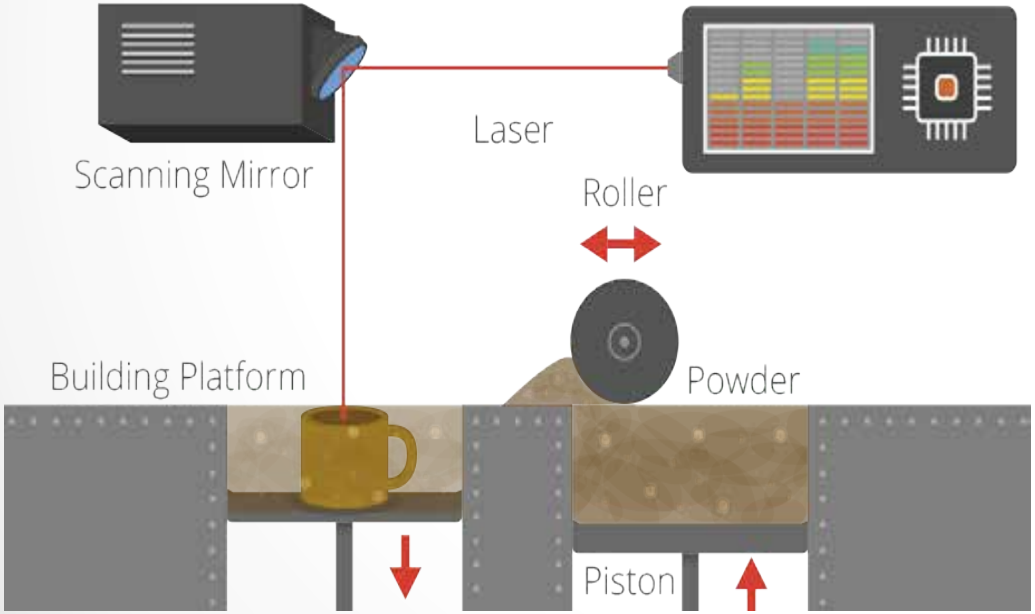
- accurate and reliable (+)
- requires support structures for overhangs and undercuts (-)
- relatively slow (-)
- problematic if waterproof parts are needed (-)

3. Selective Laser Sintering



3. Selective Laser Sintering

- a laser is traced across compacted powder
- the powder fuses due to the energy of the laser → solid is formed
- new powder is added for every new layer



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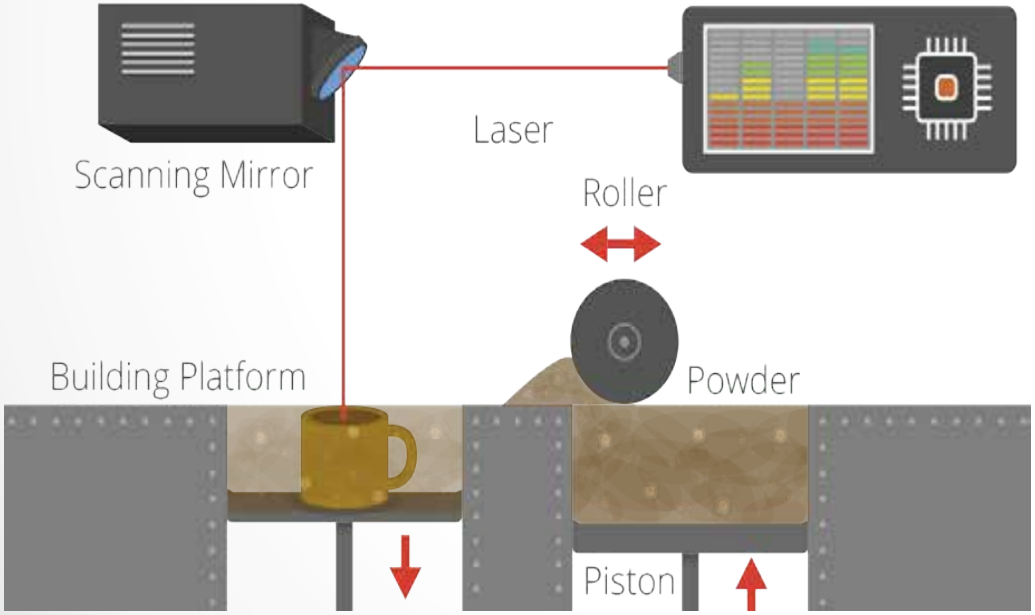

- works with **plastic, metal, ceramic or glass (+)**
- powder serves as support structure (+)
- complex shapes (+)

- May require cooling time (-)
- surface finish less detailed (-)
- less accurate (-)

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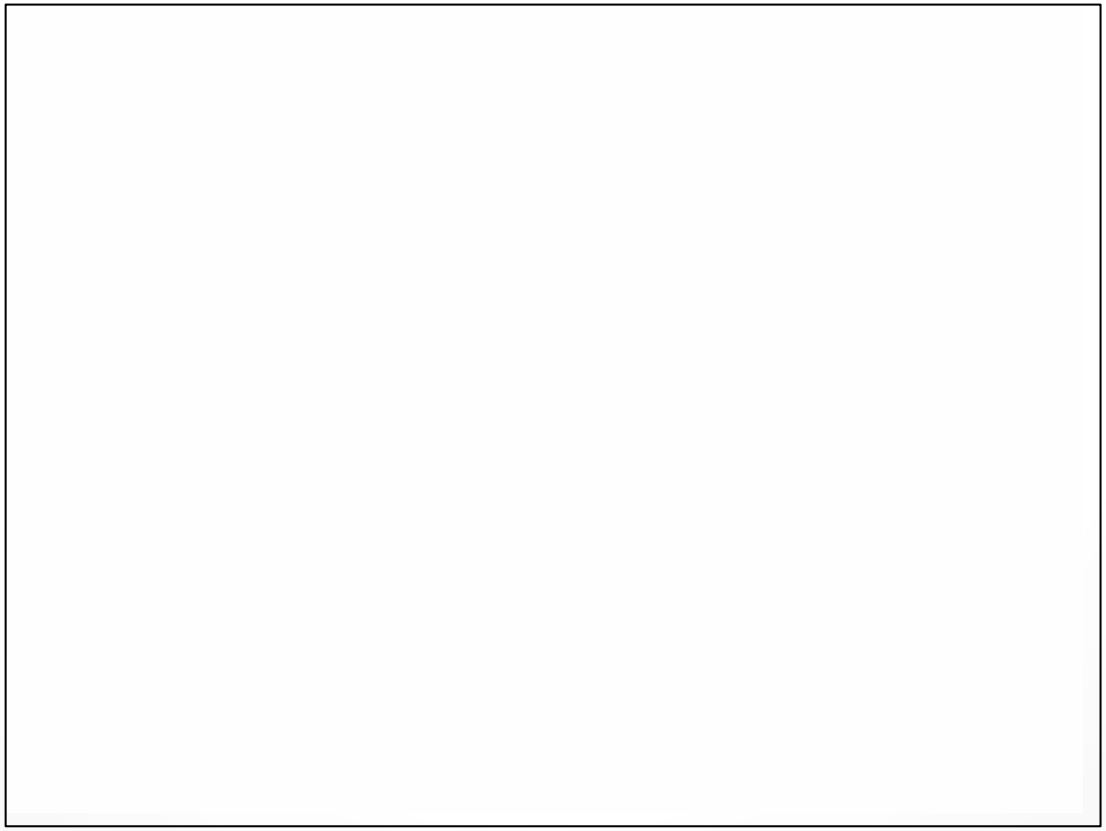
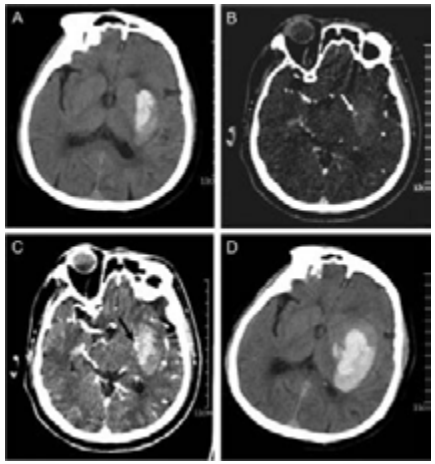
Related technology: 3D scanning

- digitalizing the surface of objects for e.g. animations, 3D measurement, archiving or 3D printing models



Related technology: 3D scanning

- Different technologies like
  - Contact 3D Scanning
  - Time-Of-Flight (laser) 3D Scanning
  - Triangulation (laser) 3D Scanning
  - Conoscopic 3D Scanning
  - Structured light 3D Scanning
  - Computed tomography (CT) 3D Scanning



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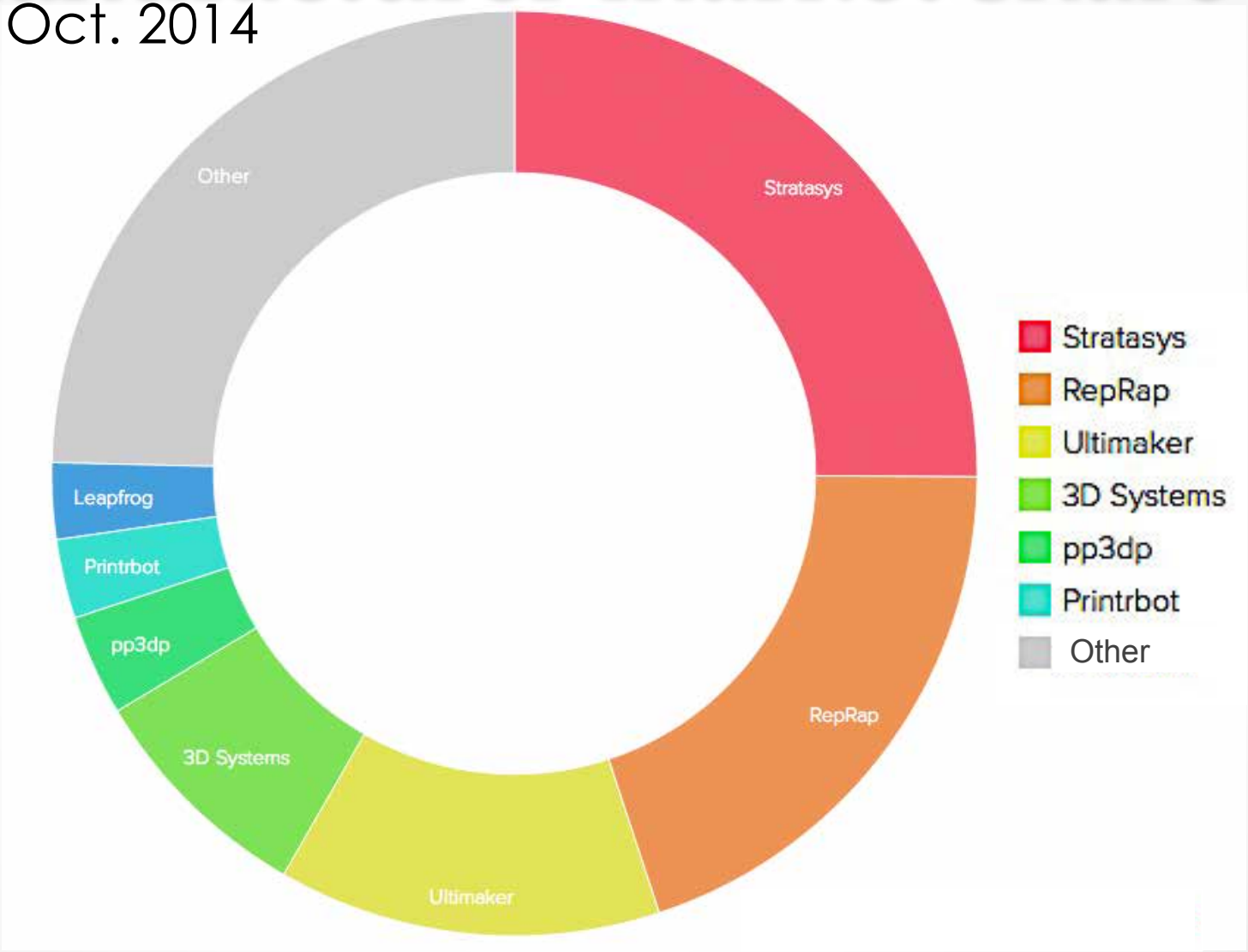
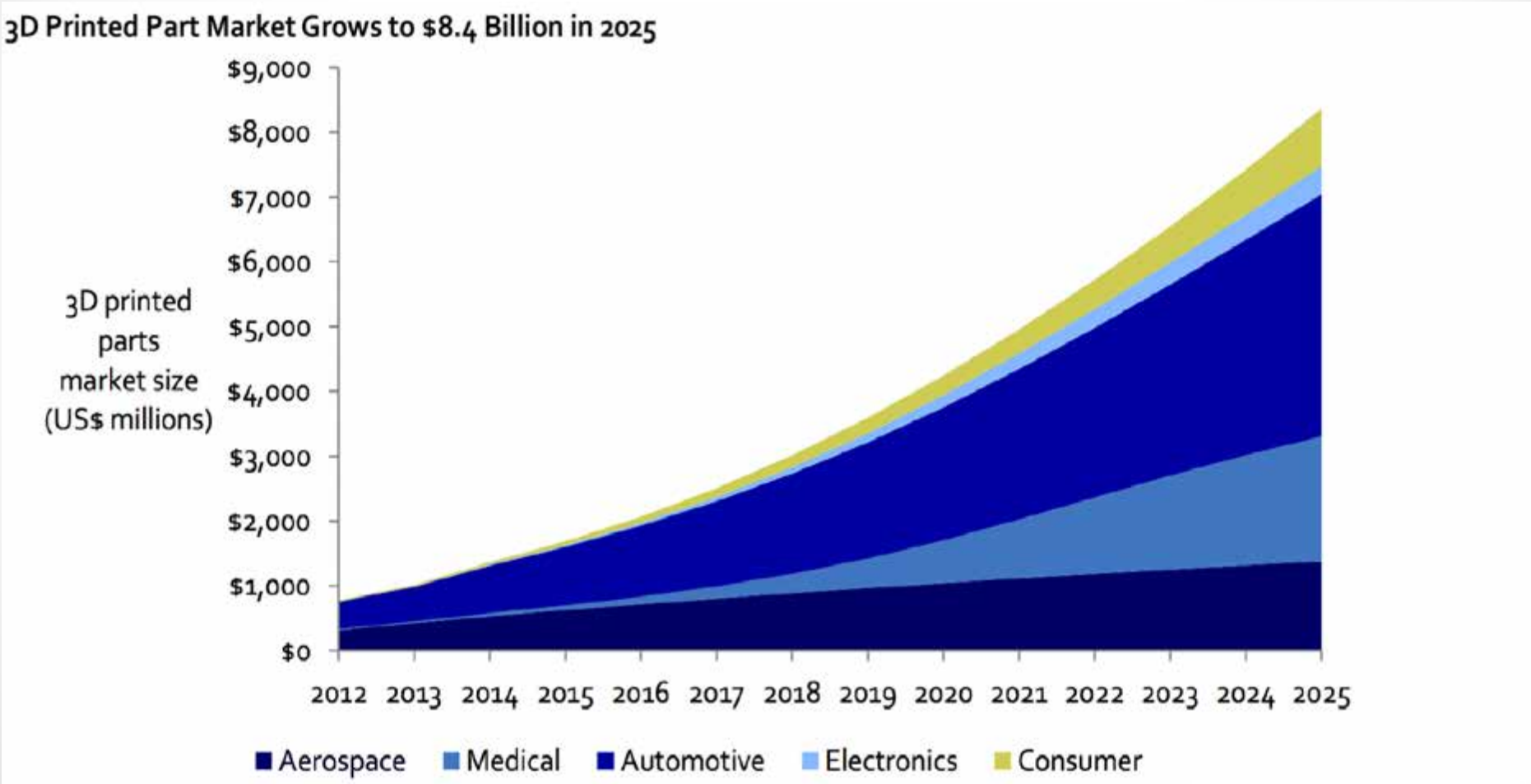
Manufacturer market share

Oct. 2014



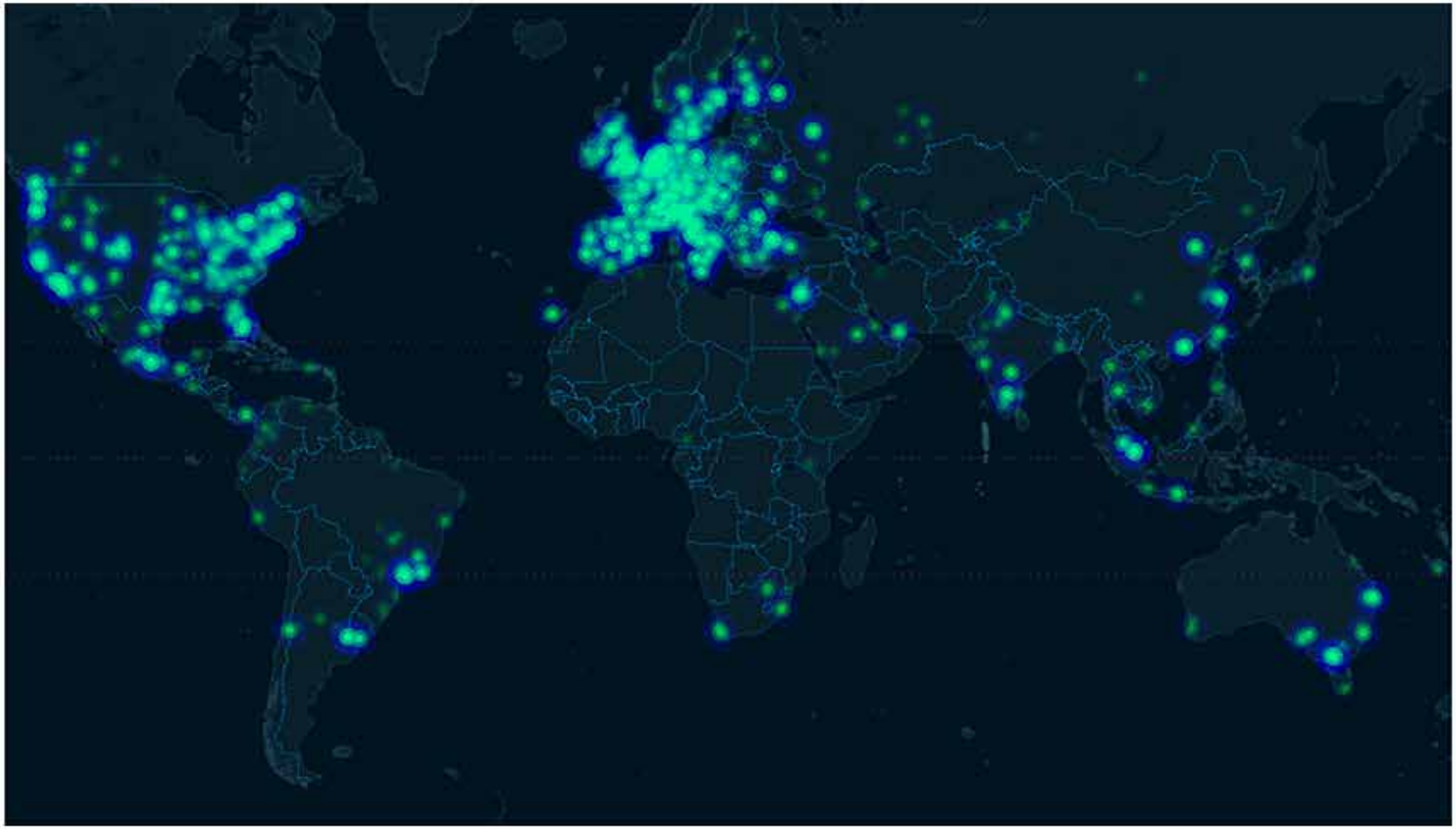
Note: RepRap is not a manufacturer but has been treated as such in this chart

Future market size estimation



3D printing world map

Geographical distribution of over 7500 printers registered on www.3dhubs.com



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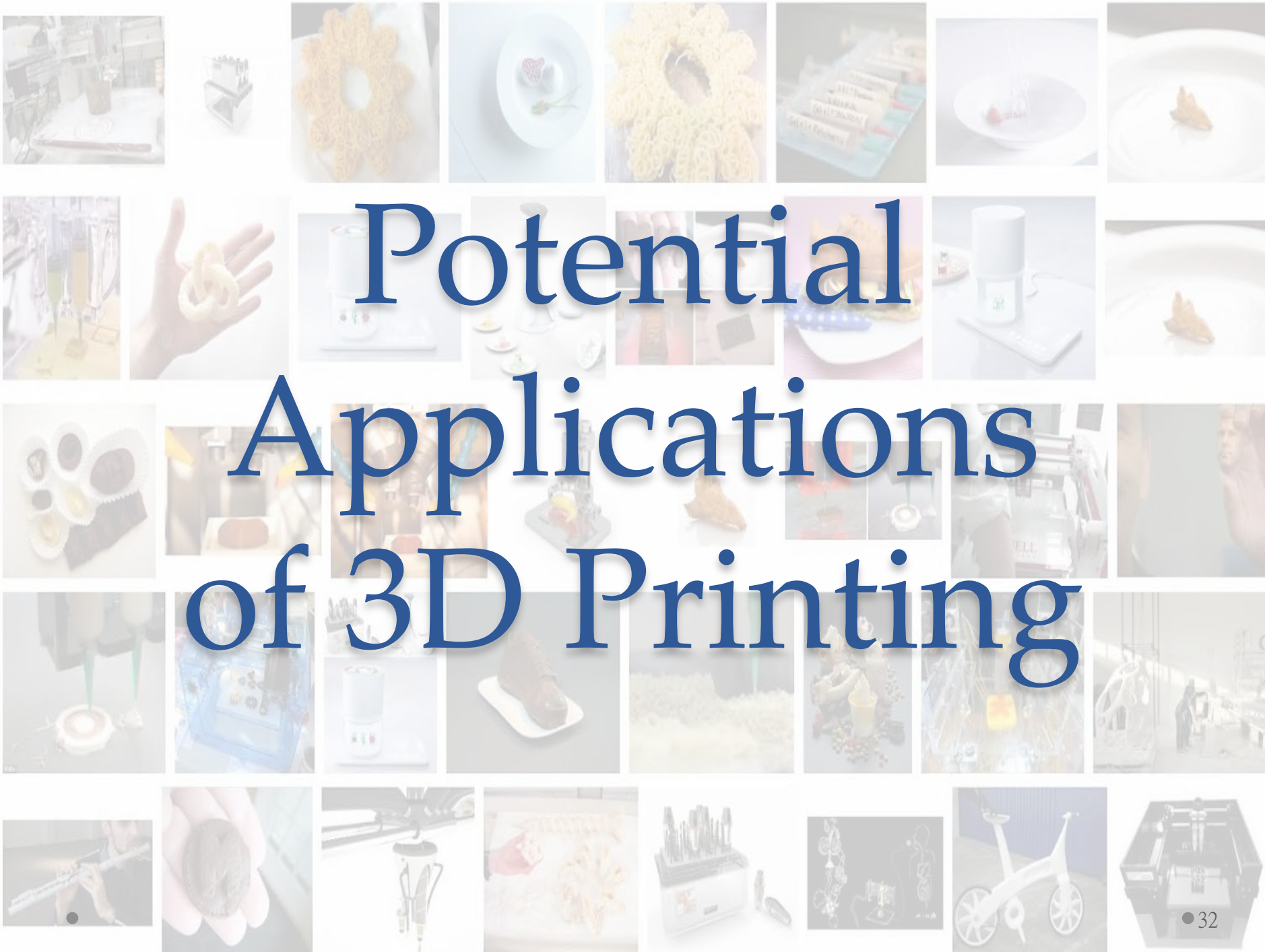


Potential Applications of 3D Printing

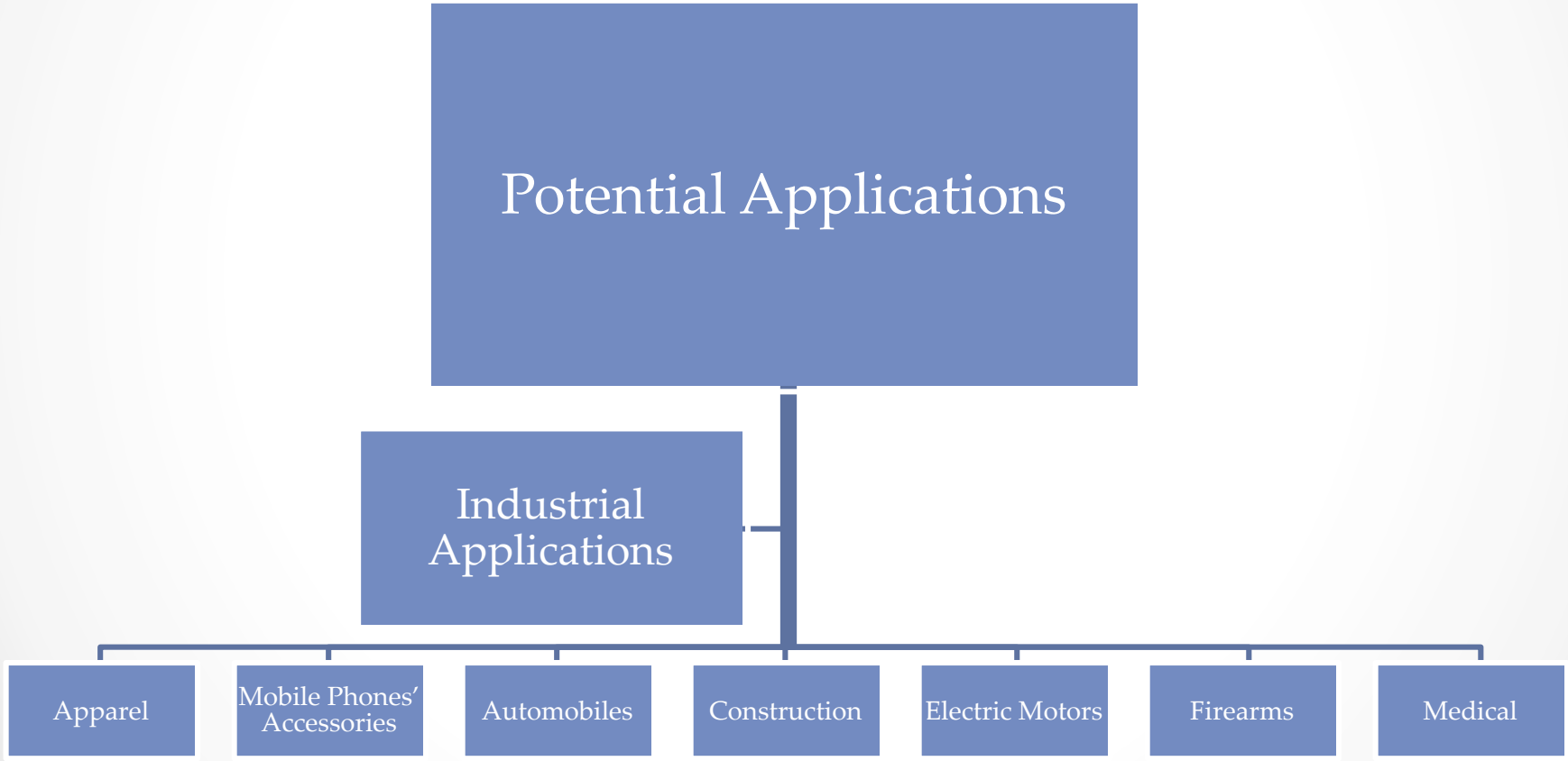
To be presented…

Potential Applications

Industrial Applications

Sociocultural Applications

To be presented…



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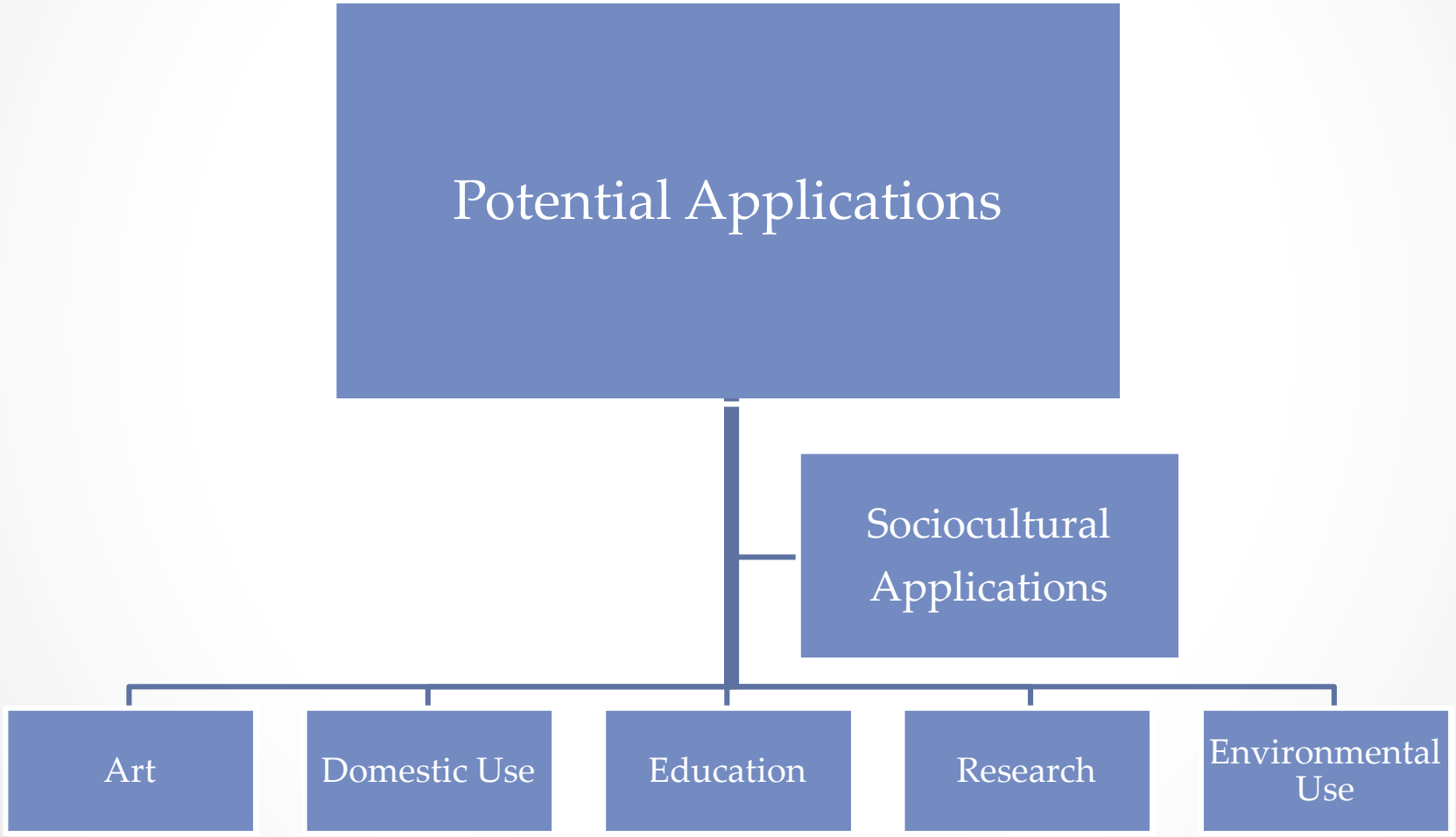

Potential Applications – Industrial Applications

Apparel

Mobile Phones' Accessories

Automobiles

Construction

Electric Motors

Firearms

Medical

Apparel

- Clothings such as:
- Bikinis
- Shoes
- Dresses
- Eyewear
- Hats

(1) 3D hat introduced by .MGX

(2) 3D printed dress coated in silicon

(3) Continuum Fashion: using solid nylon

(4) 4 different styles of shoes, using Cubify 3D printer

(5) People can customize their own 3D printed glasses

Apparel

- More to know:
- In March 2013
- New Balance manufactures 3D printed spike plates using soft SLS components
- SLS mimics the cushioning properties of foam midsoles
- Adapting to each athlete's personal preference

Potential Applications – Industrial Applications


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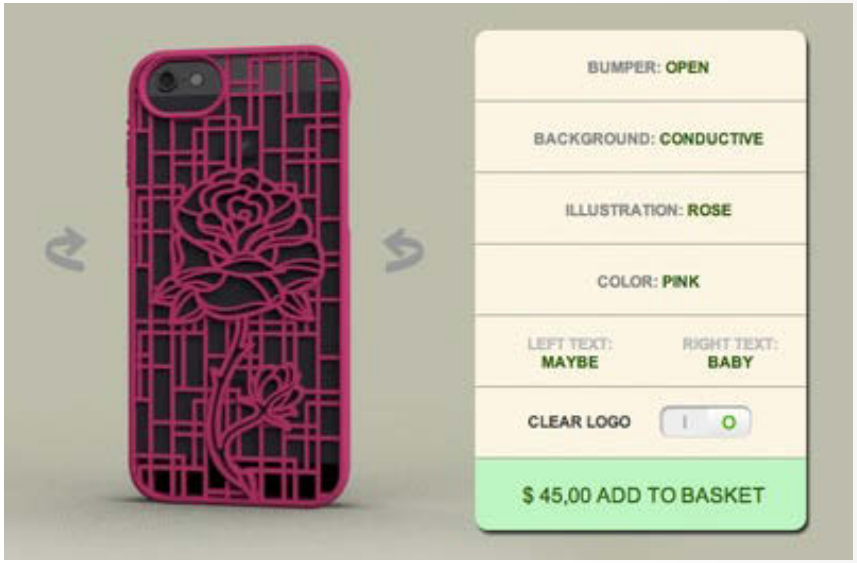
Mobile Phones' Applications

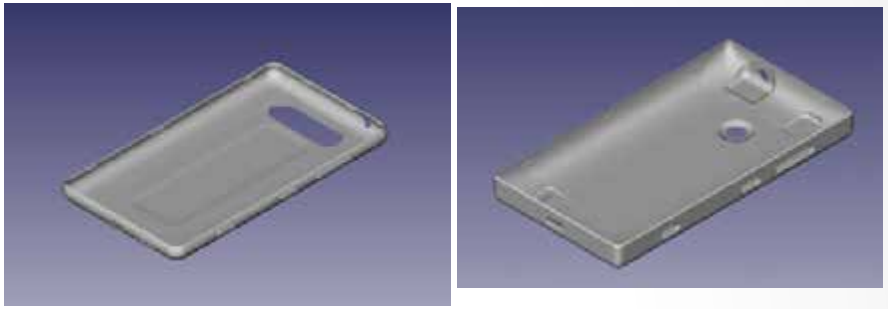
- Mobile Phone:
- 3D printed shells are available for selling
- We can also tailor-made with our own design – but it is of high difficulty to make it functional…



3D print service "Kees", personalised iPhone case for USD $45

Mobile Phones' Applications

- More to know:
- In January 2013
- Nokia allowed customers to customize their own phone's back shell for phones such as Lumia 520 and Lumia 820.



The Lumia 820 and Lumia 520 Shells

Potential Applications – Industrial Applications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Automobiles

- Vehicles:
- Nowadays, parts of the vehicles such as titanium exhaust components can be 3D printed
- For instance:
- Swedish supercar manufacturer Koenigsegg
- Produced the One:1
- Its titanium exhaust 3D printed takes three days to produce

A close-up of the exhaust tip

Automobiles

- More to know:
- In September 2014
- Officially at the International Manufacturing Technology Show (IMTS) in Chicago, Illinois
- The world's first finalized 3D printed car emerged, named "Strati"
- Electric with 2 seats

Potential Applications – Industrial Applications

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Automobiles

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Construction

- Buildings printings:
- Quicker construction
- Lower labor costs

- More to know:
- In China, the WinSun company based in Shanghai
- Using large 3D printers, ten demo houses were built
- Measuring 200 square meters
- In 24 hours, each costing US $5000
- 12 years to develop the large 3D printer
- 6.6 meters tall, 10 meters wide and 150 meters long

Materials used: construction waste mixed with cement

Construction

- More to know:
- In earlier 2014
- Amsterdam architects started building a full-sized 3D printed house
- Will be called "3D Print Canal House"
- Expected to take years to complete
- Using plastic heavily based on plant oil

Blueprints of the parts, to be combined like a Lego

Construction

- More to know:
- The "Canal House"
- 3D printed on a Kamermaker
- It is a large-scale movable 3D printer of 6-meter tall
- Printing on different types of plastic

Potential Applications – Industrial Applications


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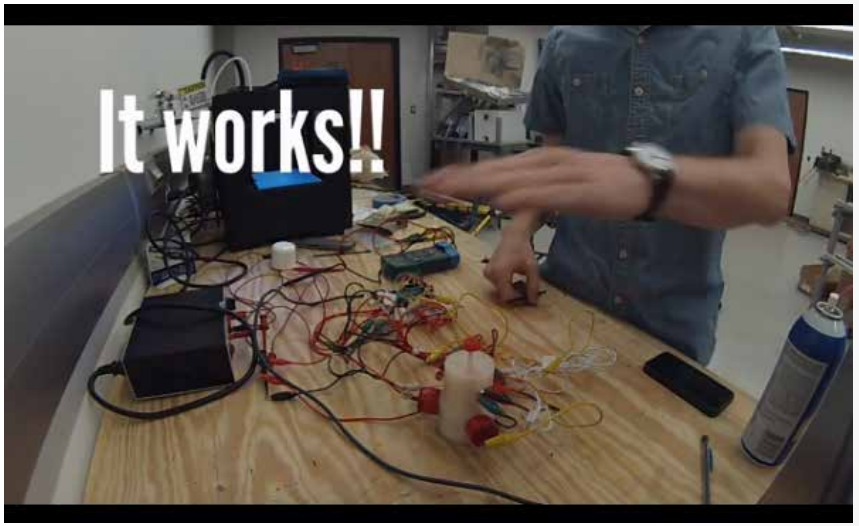
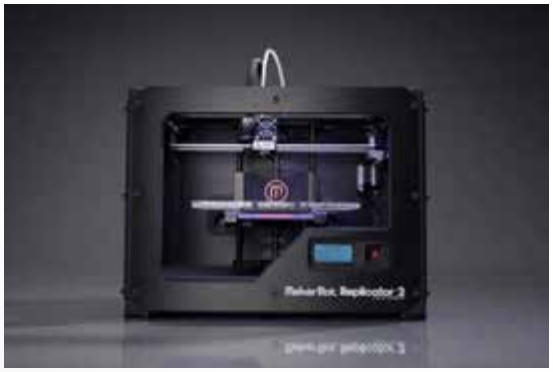
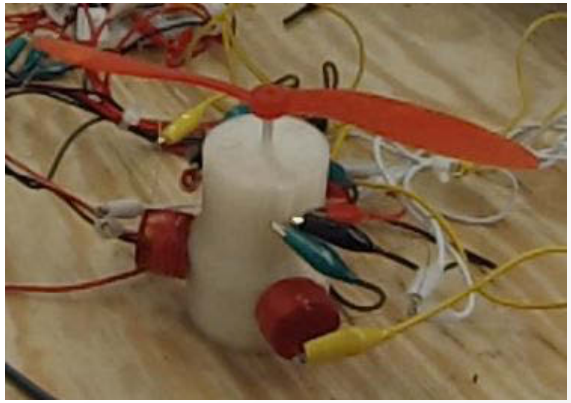
Electric Motors

- Electric Motors
- More to know:
- 3D printed Brushless DC Motor
- All parts 3D printed excluding magnets, solenoid wrapping wire, and hall effect sensors
- Using a Makerbot Replicator 2







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Firearms

- Plastic guns:
- Defense Distributed (DD)
- A non-profit organization designing 3D printable firearms

More to know:

- In May 2013
- Defense Distributed gave yield to the first successful design of a 3D printed plastic gun

Prototype 3D printed gun from Defense Distributed

Firearms

- United State Department of State ordered the removal of creation instructions from Defense Distributed's website

Potential Applications – Industrial Applications


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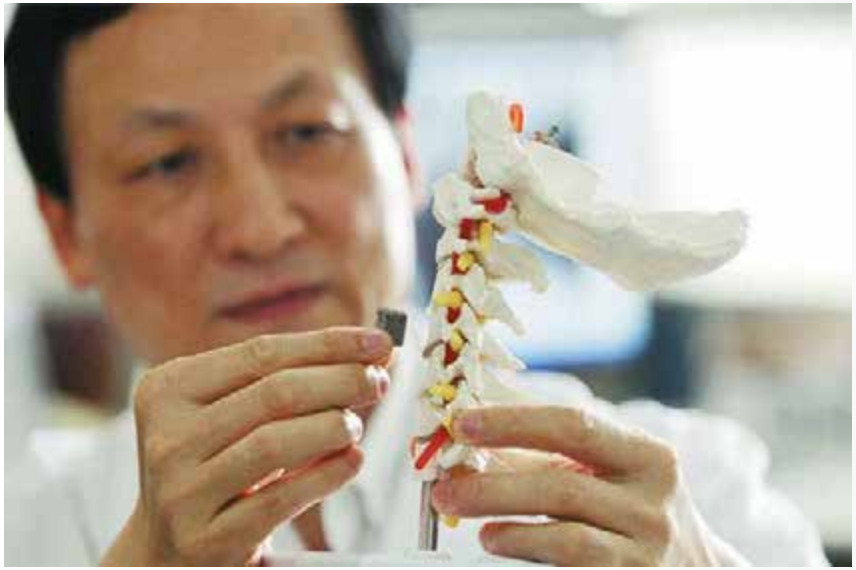
Firearms


Medical

Medical

- Implants and devices for medical use: Prosthetic implants of teeth or bones can be tailor-printed to fit a patient's need
- In August 2014
- The world's first 3D printed section of the vertebra of a 12-year-old boy was implanted
- By doctors at Peking University Third Hospital



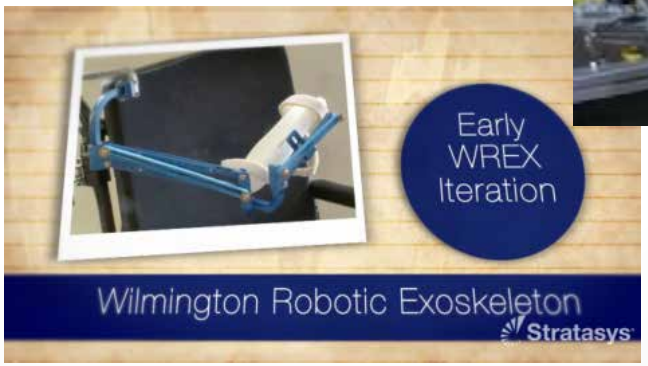
3-D Printed Vertebra
Director of Orthopedics at Peking University, holds the 3-D printed piece of vertebra

Medical

- More to know:
- In 2012
- A 4-year-old little girl, born with a disease called arthrogryposis multiplex congenita, a condition that leaves her joints stiff and muscles underdeveloped
- Because of the disease, she cannot lift her arms without support

Medical

- WREX (Wilmington Robotic Exoskeleton)
- Built with 3D printing with light materials
- Linear elastic bands are used both for balance and to assist movement in three dimensions against the effects of gravity



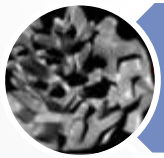
Potential Applications – Sociocultural Applications

Art

Domestic Use

Education

Research



Environmental Use

Art

- Work of arts:
- Apart from 3D printing with plastic materials;
- Laybrick, laywood and nylon can also be used as raw materials
- Resulting in a big variety of shapes and textures of pieces of work

Art

- More to know:
- Echoviren is the world's largest 3D printed art installation
- Two months (10,800 hours) of printing time to finish it
- The piece of art is believed to decompose back into the environment within 30 to 50 years.

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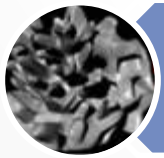
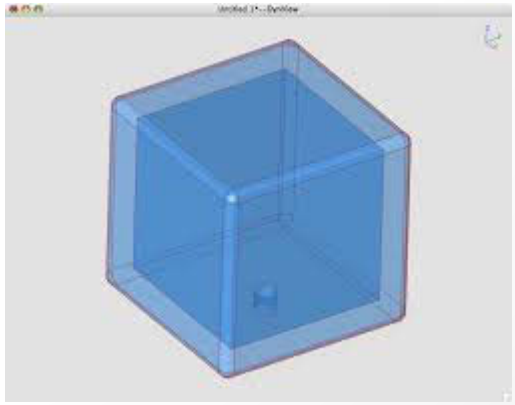


Environmental Use

Domestic Use

- Personal 3D printer:
- Choice of raw materials limited to plastic at the moment
- Only more advanced devices can create objects with various colors
- Normally limited to a single colour
- Limitations to shapes also occur, such as, a hollow cube



Sociocultural Applications – Domestic Use

More to know:

- Afinia H480 3D Printer

Costs only $1,299 USD → $10,067.25 HKD

Uses ABS plastic filament: from $31.99 USD/kg

Items produced: maximum size of around five cubic inches

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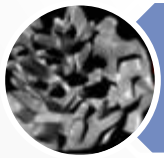

Environmental Use

Education

- Learning processes:
- Ranging from architectural planning to creation of historical artefacts
- 3D printing encourages imagination and creativity brought to the reality
- More to know:
- International Manufacturing Technology Show 2014
- Took place in Chicago
- Students were asked to use CAD modelling tools to produce wind turbine solutions – 3D printed

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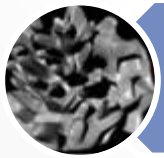
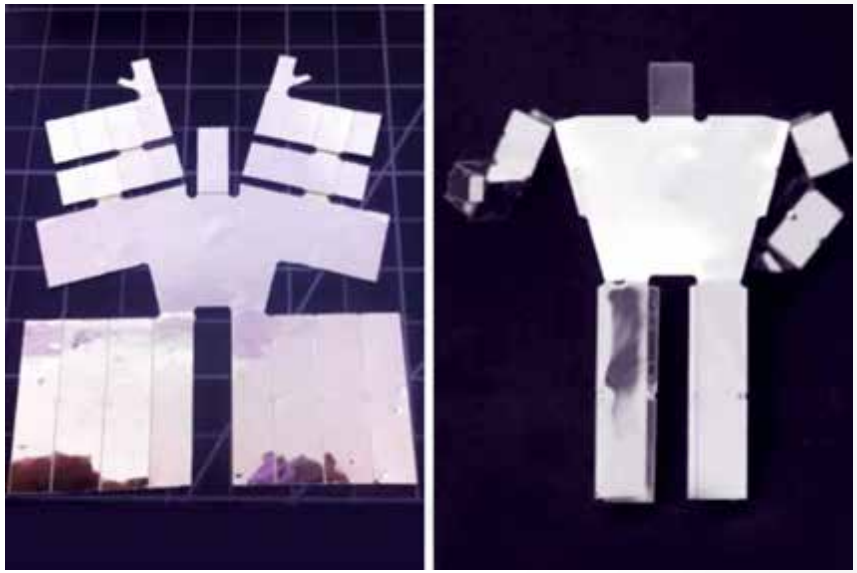


Environmental Use

Research

- Paths to new developments:
- Allows research in medical and technological areas
- More to know:
- At the 2014 IEEE International Conference on Robotics and Automation
- Held in Hong Kong in late May and early June
- An assembled future robot was presented
- The 3D printed robots could change shape once exposed to heat



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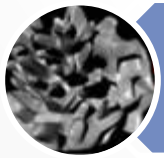
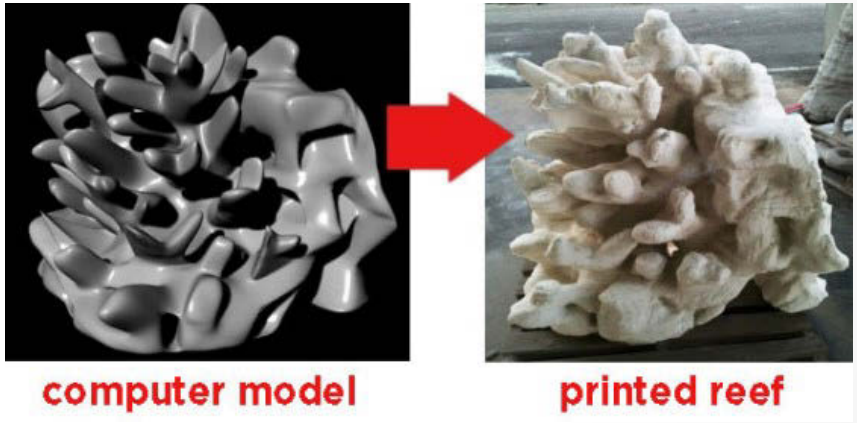


Environmental Use

Environmental Use

- Man-made structures to the environment:
- Humans are able to build 3D printed structures that assemble the ones found in Mother Nature
- More to know:
- Using sandstone-like materials
- Neutral pH coral-shaped structures are created to encourage coral reefs colonization
- Restore any damages previously found

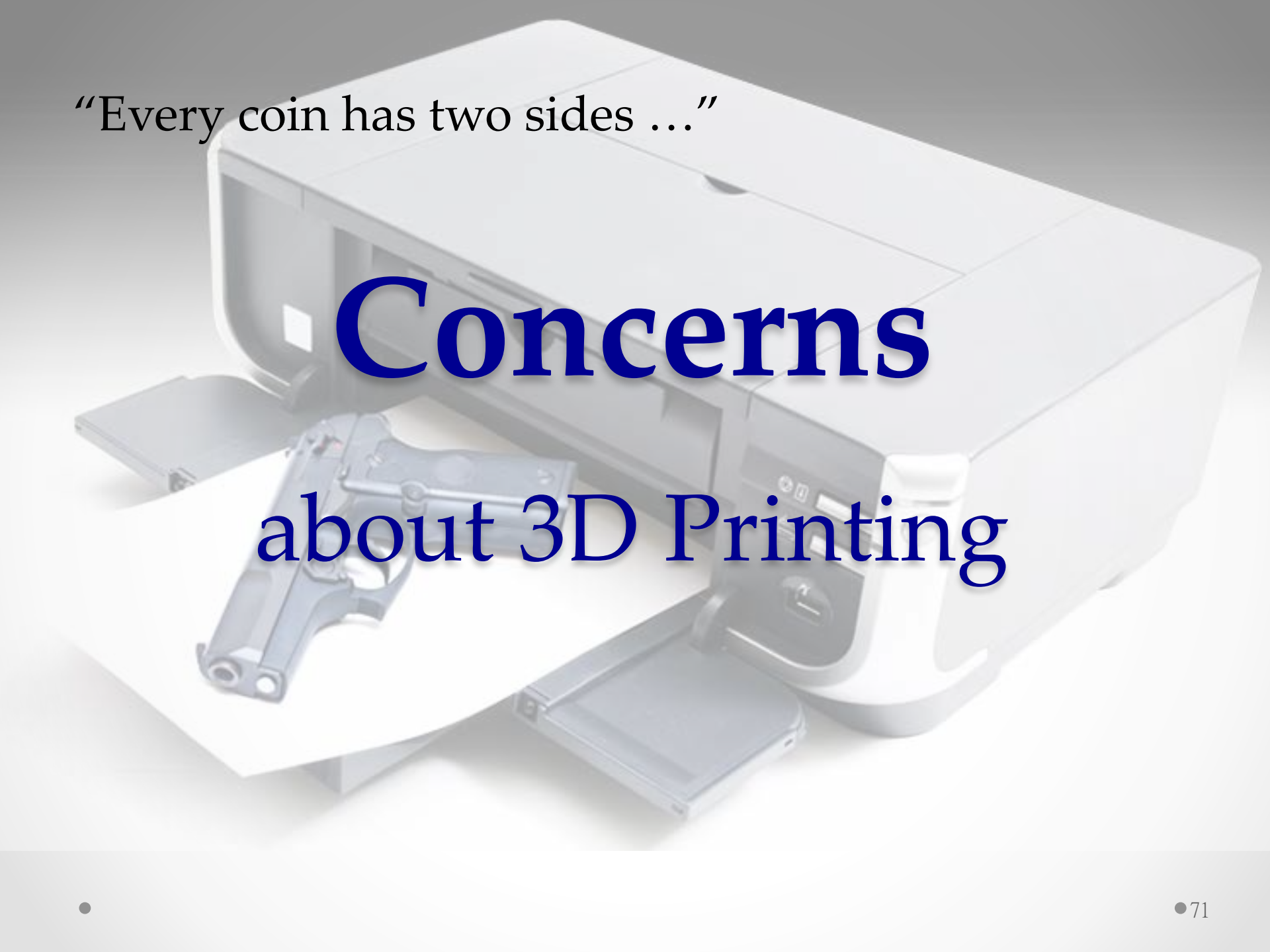


Agenda

(1) Introduction

(2) Potential applications

(3) Concerns and future development



"Every coin has two sides …"

Concerns

about 3D Printing

1. Legal Issues

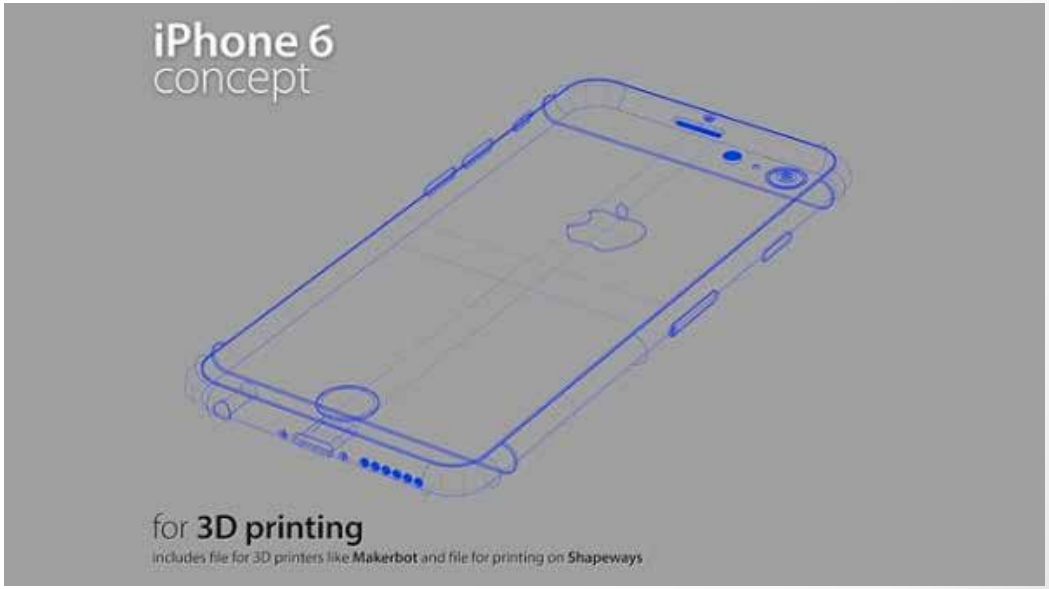
- Impact existing Intellectual Property(IP) regulations
- 3 major areas: Copyright, Patent and Trademark
- More easy to violate these protection laws with 3D printing

1. Legal Issues (Cont'd)

- Design blueprint files made available on the Internet for sharing
- Personal manufacturing of copyrighted objects are difficult to be detected, prevented or controlled.
- Discourage creative works

1. Legal Issues (Cont'd)

- A Japanese magazine, MacFan, had leaked pictures of the iPhone 6
- Two CAD artists immediately began selling CAD files of iPhone 6 mockups based on the pictures for people to 3D print at home



2. Criminal Issues

KeyMe App

3D Printed Key

2. Criminal Issues (Cont'd)

3D Printed Fake Goods

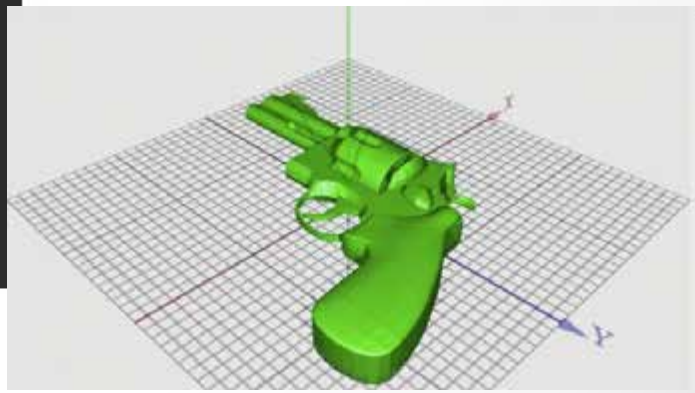
2. Criminal Issues (Cont'd)

3D Printed Face Mask

3. Weapons

The world's first 3D-printed gun

By Sebastian Anthony on July 26, 2012 at 10:56 am | 292 Comments



3. Weapons (Cont'd)

Now there are bullets that won't break your 3D-printed gun

709 SHARES

Share on Facebook | Share on Twitter | +

WHAT'S THIS?

Michael Crumling's 3D-printed gun and homemade ammo.

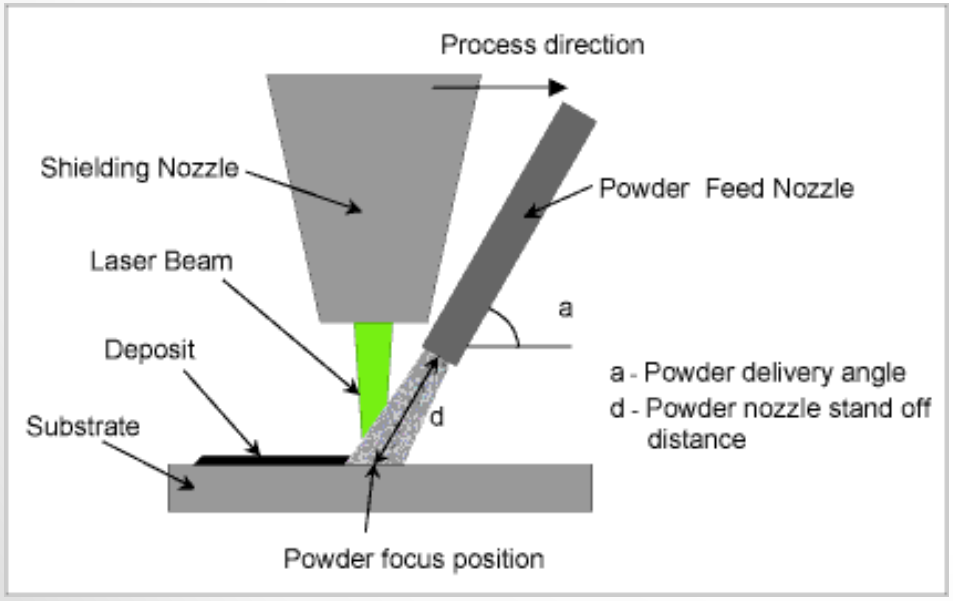
3. Weapons (Cont'd)

New: Japanese cops arrest man with five 3D printed guns at home

4. Environmental Issues

High Energy Consumption

- 3D printers consume about 50 to 100 times more electrical energy than injection molding to make an item of the same weight
- Laser direct metal deposition (where metal powder is fused together) used hundreds of times the electricity as traditional casting or machining



4. Environmental Issues (Cont'd)

Excessive Usage of Plastics

- Plastic filament is one of the mostly used materials in 3D printing
- ABS filament, the most commonly used type of plastic, is non-biodegradable
- As 3D printing becomes popular, it is predicted that many unused or unnecessary plastic products produced

5. Health Issues

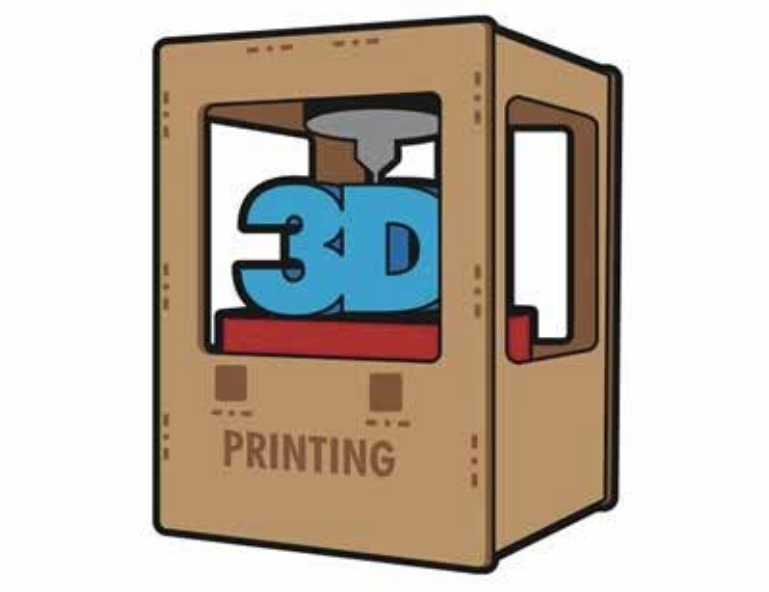
Unhealthy Air Emissions

- The emissions from desktop 3D printers are similar to burning a cigarette
- 3D printers using PLA filament emitted 20 billion ultrafine particles per minute, and the ABS emitted up to 200 billion particles per minute while heating the plastic and printing small figures

=

Future Development

of 3D Printing



1. 3D Printing as Service

- Changes in business model & consume pattern
  - Less good stores, less pre-produced goods
  - More 3D printing services stores that provide product printing on demand

Chicago 3D Printing Shop Opens for Business

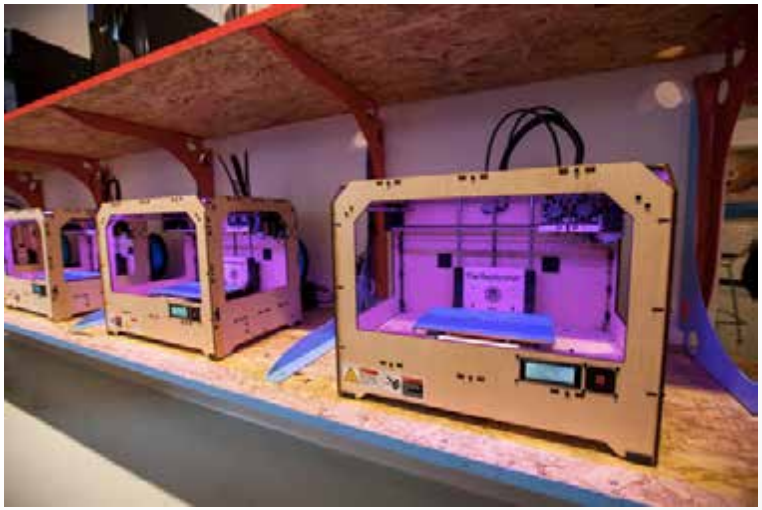
3D printing is coming to a city near you.

By Courtney Subramanian @cmsub | April 26, 2013 | 8 Comments

Share Like 702 Tweet 171 +1 18 Share 30 Pin it Read Later

The constant buzz surrounding 3D printer technology is finally making its way into the mainstream and a new company in Chicago is welcoming consumers to try out the revolutionary concept firsthand. The 3D Printing Experience, a new space that opened in Chicago Monday, is educating the public on how the technology works by offering a chance to watch or experience the printing process.

Customers can have their head scanned and replicated in a 3D portrait, create jewelry or smaller



2. 3D Copy Machine

- Big barrier of current 3D printing technology
  - Object Modeling
- 3D Copy Machine = 3D Scanner + 3D Printer
- 3D Scanner is a key element for successful future development of 3D printing
- Quick way to modeling an object

- Zeus 3D Copy Machine by AIO
- A fund raising project in KickStarter

2. 3D Copy Machine (Cont'd)

- Limitations on current 3D Copy Machine
  - Only copy the external appearance of objects
  - No internal structure or real functions

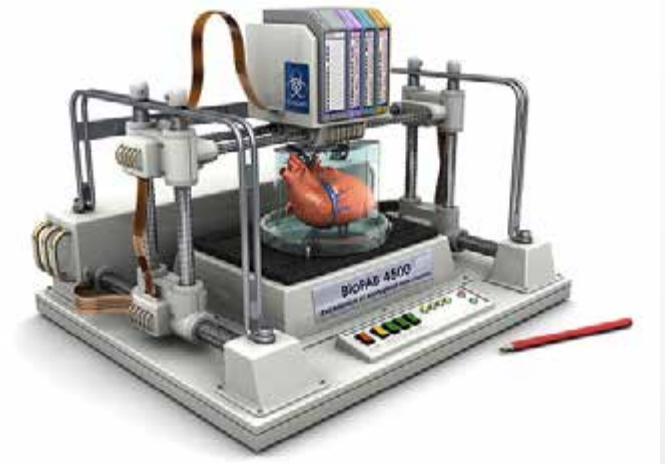
- Future Real 3D Copy Machine
  - Copy both external appearance and internal structure(e.g. Using X-ray?)
  - Copy the function of object as well

3. Material Detection & Multiple Printing Materials

- Most current 3D printers can only print objects with single pre-configured material (e.g. plastics)
- Real world objects consist of many diff. materials
- Key step for real 3D copy machine & object function copying
- New materials: wood, glass, elastic materials, etc…

4. 3D Bioprinting

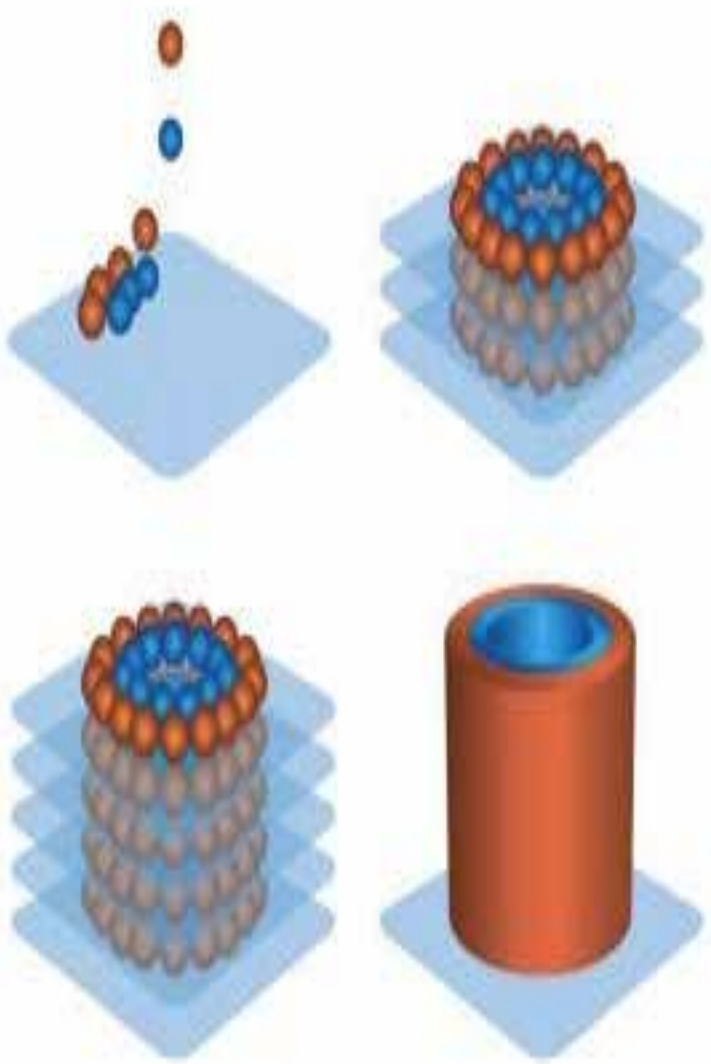
- 3D bioprinting is the process of generating spatially-controlled cell patterns using 3D printing technologies
- Applications: Build skin tissues, blood vessels, organs for transplantation
- Idea: Artificially construct living tissue by outputting living cells layer by layer
- Currently all bioprinters are experimental



4. 3D Bioprinting (Cont'd)

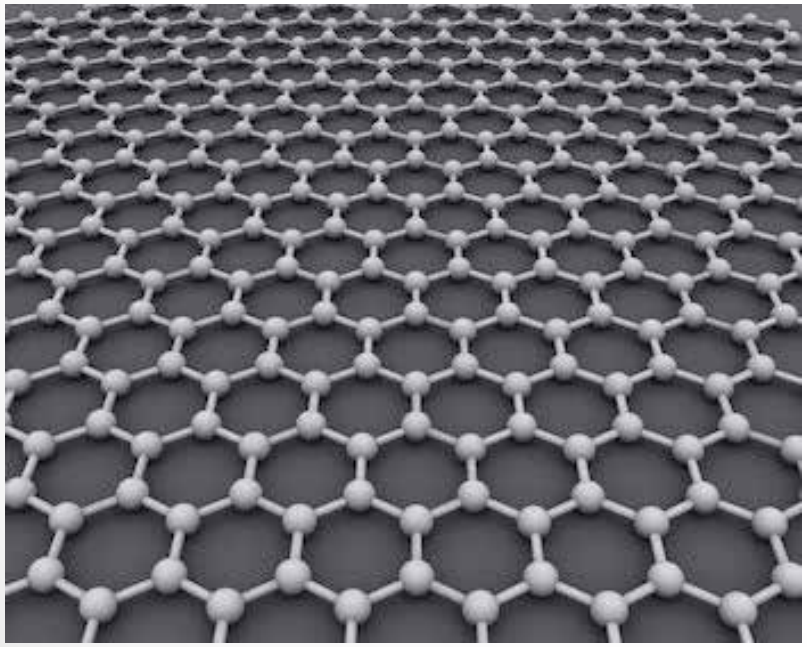
3D Bioprinting Process

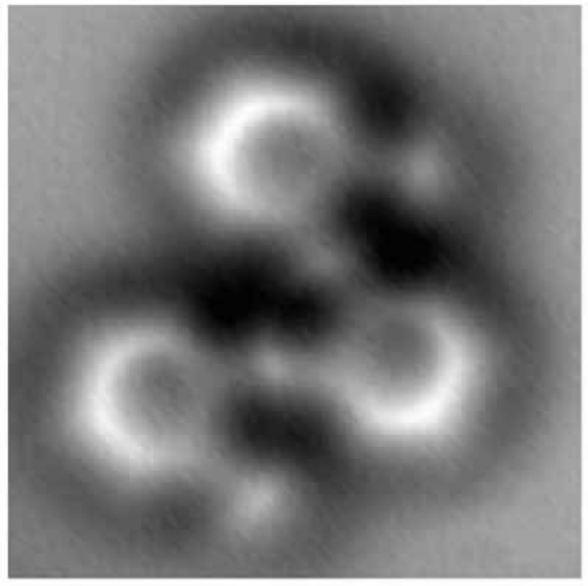
1. Take a person's cells and growing for enough cells
2. Form solid tissues by allowing the cells to attach with each others
3. Solid tissue is sucked into a glass tube that serves as printing material
4. Deposit the tissue one line at a time on top of a layer of gel
5. Over a few days, the cells will
   - merge into a single piece of tissue



5. 3D Printing Ultimate Goal – Atomic/Molecular Level 3D Printing

- Use element atoms or molecules as printing materials
- Can build any things theoretically
- Researchers are planning to build 3D printer that print Graphene

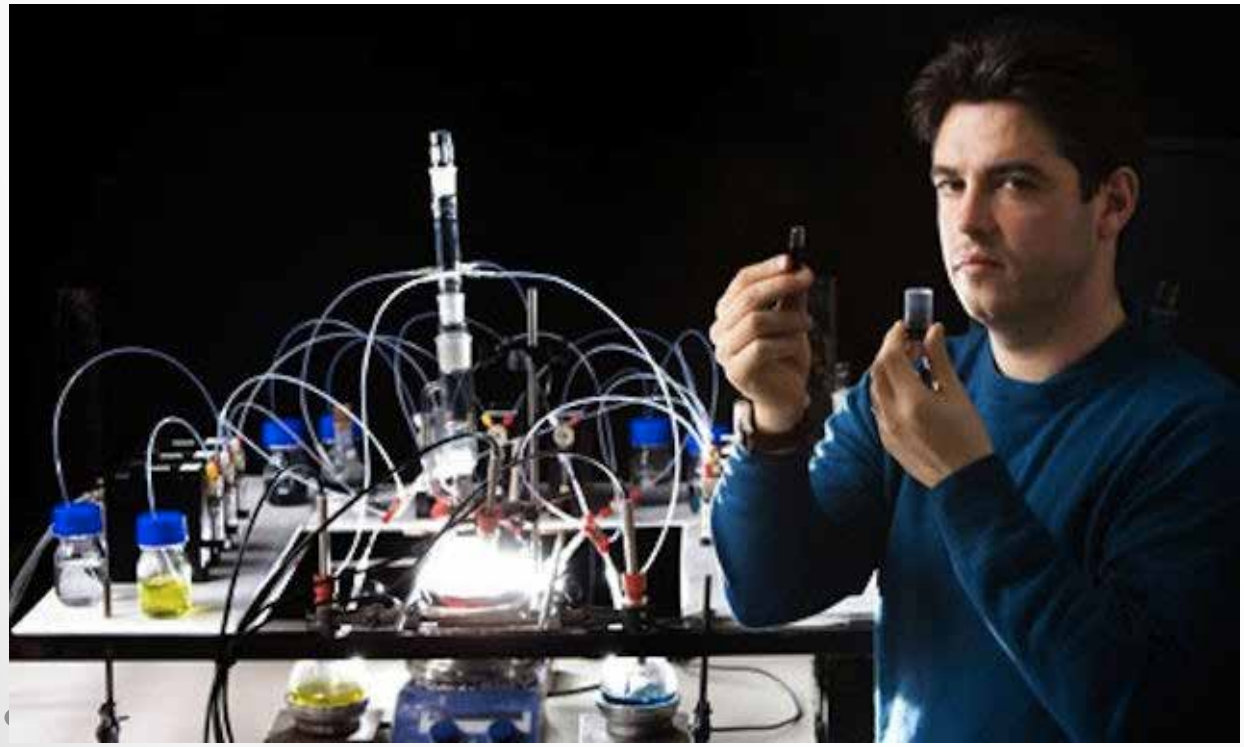




5. 3D Printing Ultimate Goal – Atomic/Molecular Level 3D Printing (Cont'd)

Printing Chemical Compounds - Drugs

- 3D Drugs Printed Project leaded by Lee Cronin from the University of Glasgow



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