3D – PRINTING

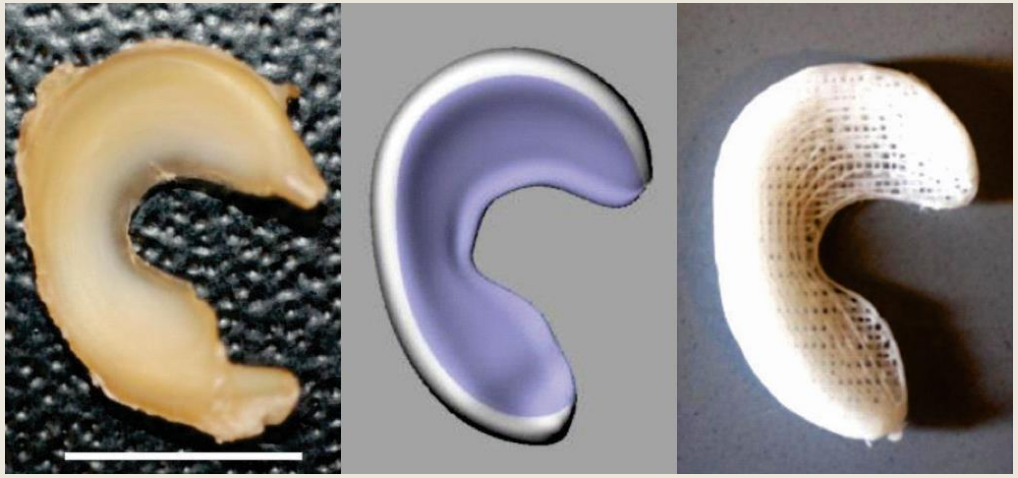
An Overview of the Science and its Applications

Hailed as a New Industrial Revolution [1-3,5-7]

- Game Changer for Industrial Mass Production and Socio-Economic affairs.
- Major Tech. Corporations (Hewlett Packard (HP), TOSHIBA, Google, Apple and others), invest large capitals on 3D printing technologies.
- It has affected most Industries as well as Visual Arts and Architecture.
- It aims at improving the quality and standard of living. Full benefits are yet to be materialised and appreciated.
- Also negative implications need to be considered.

Examples of Fabricated Structures[2, 10]

- Complex grids
- Aircraft/Automobile Components.
- Architectural designs and new trends in visual Arts.
- Biomedical Components and Implants



Important 3-D Printing Applications[3, 5]

- Small and Medium Scale Production Applications:
  - Replacement parts
  - Medical/Dental applications, e.g. vital organ replication e.g. kidney, human skin, prosthetics and many more
  - Food
- Large Scale Production Applications
  - Bridges/ Buildings, Automobiles and their components

Typical Materials in Use[1,2,6,7]

- Plastic/Polymers/ Nylon or Polyamide
  - Threaded (filament) or powder (granular) form.
- Metals and Alloys of Cooper/Cobalt/Stainless Steel.
  - Liquid or powder form
- Photopolymer Resin (liquid form).
- Ceramics/Paper/Biomaterials (made of cells).
- Edible materials.

Chronological Development of 3D-Printing [1,6,7]

- 1980, Japan: Dr Kodama Invented the concept of Rapid Prototyping Technology but did not file for a Patent!
- 1983-87, USA: Charles (Chuck) Hull. Patents the first commercial 3D-Printer: Apparatus for Production of Three-Dimensional Objects by **Stereolithography**
- 1987-89, USA: Carl Deckard at the University of Texas Patents a new method: **Selective Laser Sintering** (SLA)
- 1989-92, USA: Scott Crump Patents: **Fused Deposition Modelling** (FDM)

Chronology of 3D-Printing [1,6,7]

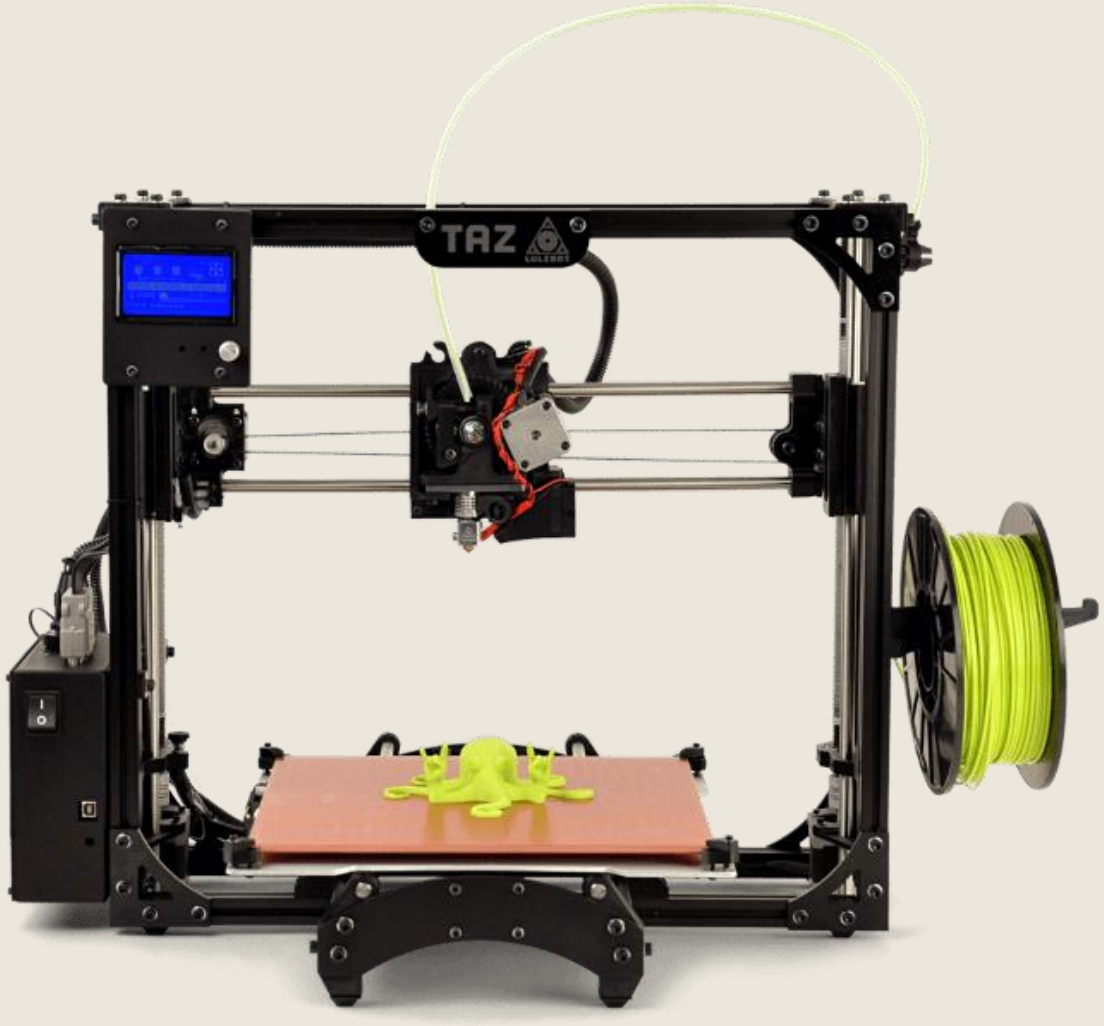
- 1990's: Throughout the 1990's and early 2000's a host of new technologies continued to be introduced, still focused wholly on industrial applications. Today more than 20 different techniques and technologies are available each with their pros and cons.
- At present time the size and cost of a printer have dropped to roughly 1/5 making them affordable to small businesses and individual ownership.

Chronology of 3D-Printing [1-3]

- 2007-09: First commercial desk-size 3D-printer appears for school applications and educational purposes at a price less £2,500.The **BfB RapMan 3D-printer**.[8]

Desk size 3D-Printer/Fused Deposition(FDM)[5-8]

- 2009 - 2016. Price of a desk 3D –printer for DIY costs less than £1000. [8]



Three Mainstream Technologies of 3-D Manufacturing

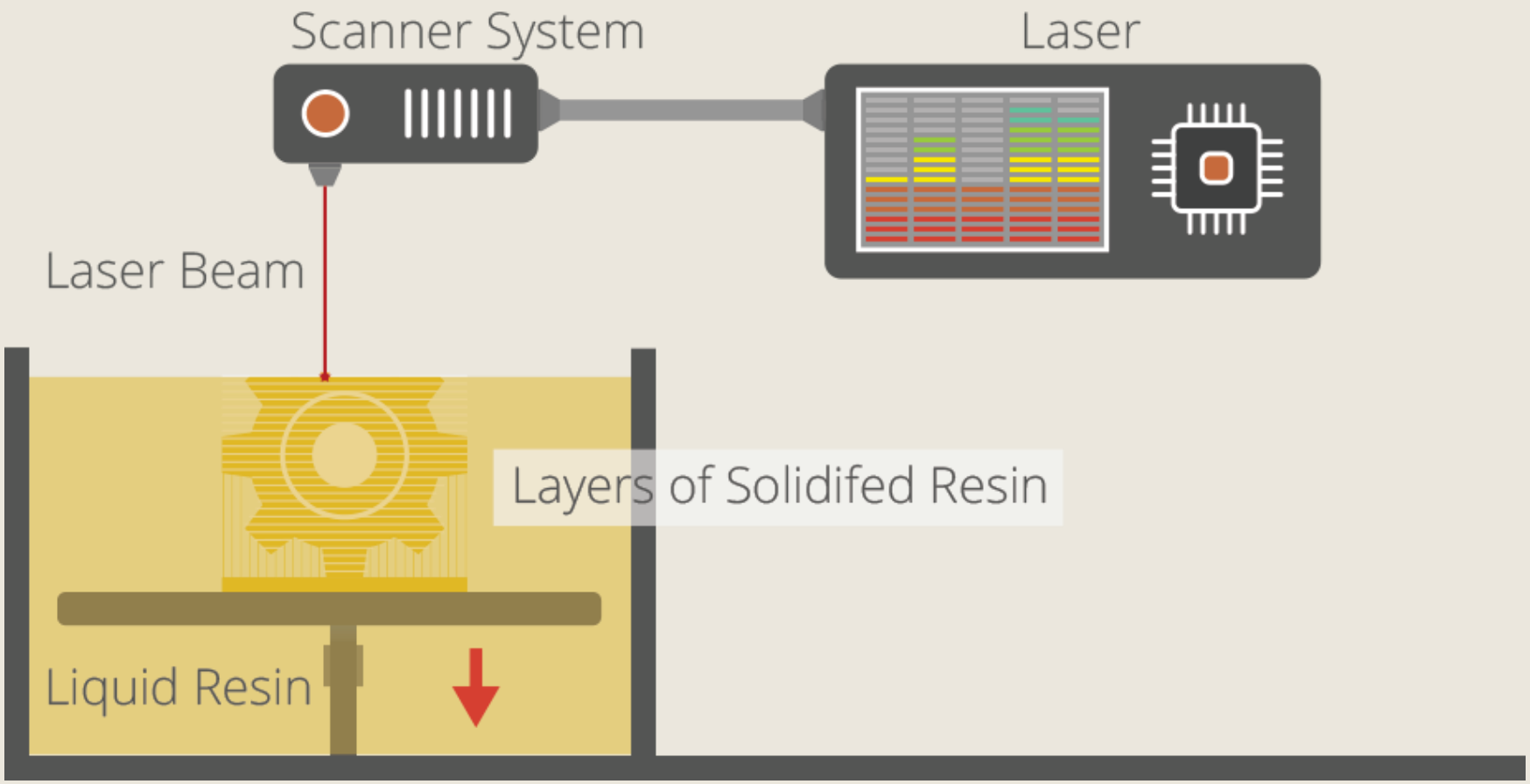
1. Stereo-litho-graphy
2. Selective Laser Sintering (SLS)
3. Fused Deposition Modelling (FDM)

1. Stereolithography [1, 4]

- “Stereolithography is an additive manufacturing process which employs a vat of liquid ultraviolet curable photopolymer "resin" and an ultraviolet laser to build parts' layers one at a time”.

- “For each layer, the laser beam traces a cross-section of the part pattern on the surface of the liquid resin. Exposure to the ultraviolet laser light cures and solidifies the pattern traced on the resin and joins it to the layer below”.

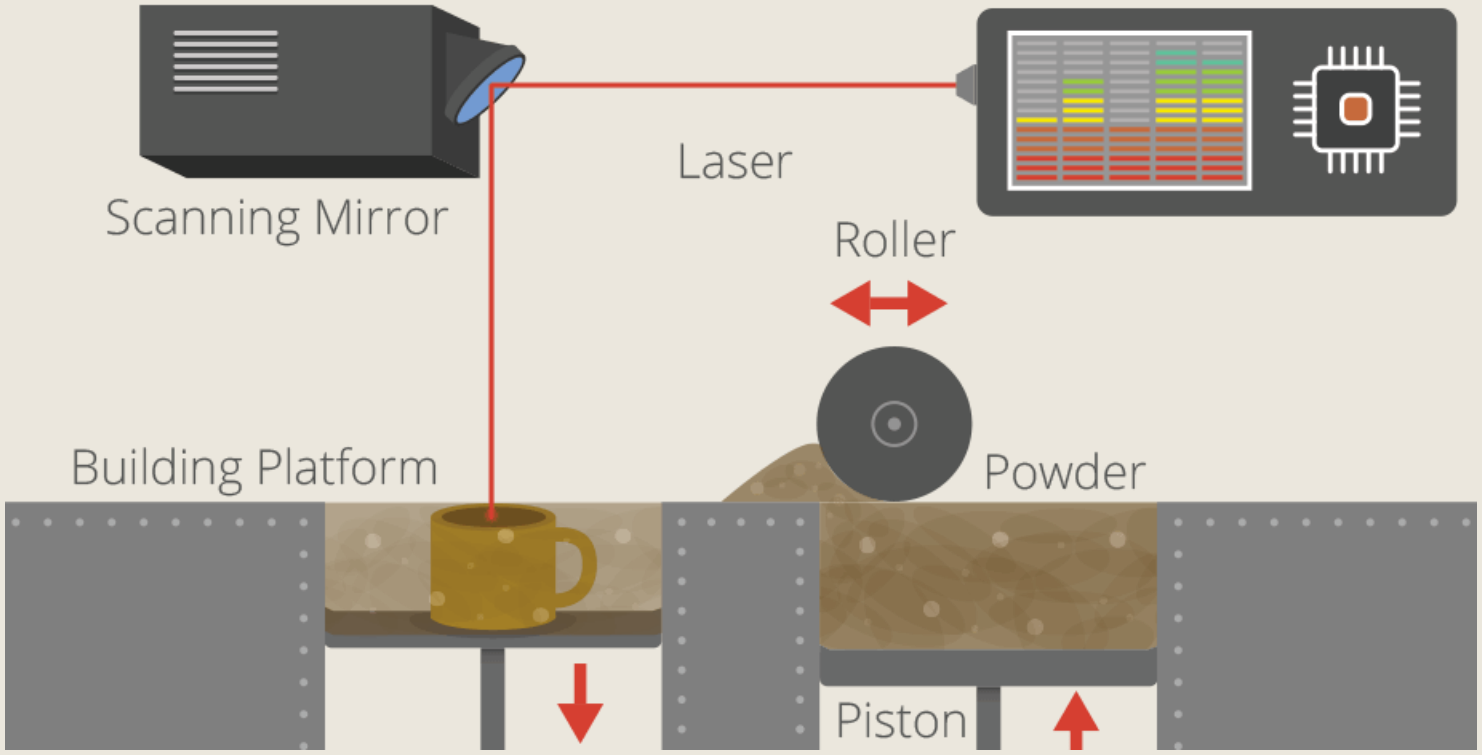
1. Stereolithography Apparatus (SLA) [1, 4]



2. Selective Laser Sintering (SLS)[4]

- “Selective laser sintering (SLS) is an additive manufacturing technique that uses a high power excimer laser (for example, a carbon dioxide laser) to fuse small particles of plastic, metal (direct metal laser sintering), ceramic, or glass powders into a mass that has a desired three-dimensional shape”.

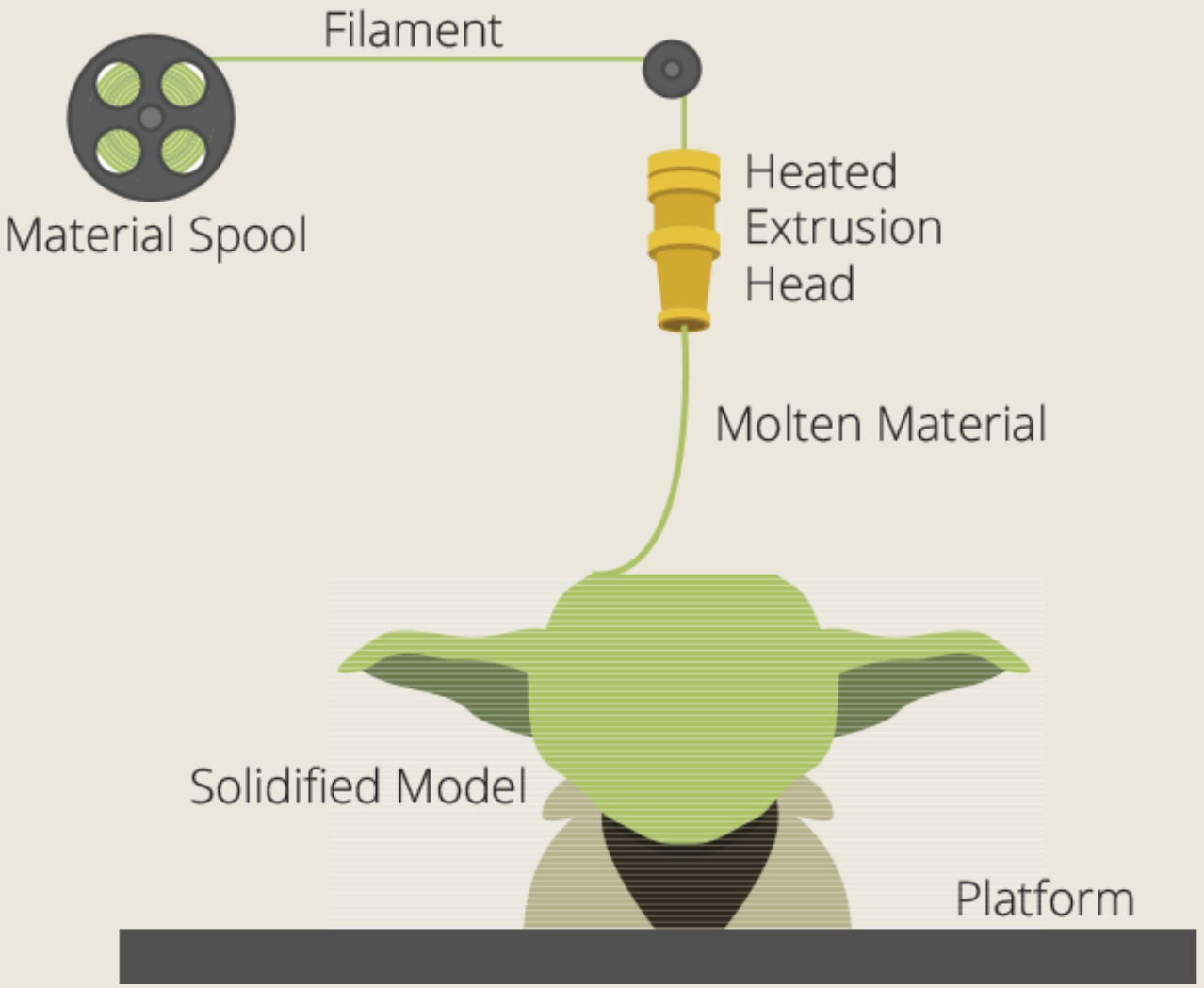
2. Selective Laser Sintering (SLS)[1]



3. Fused Deposition Modelling (FDM)[4]

- “FDM works on an "additive" principle by laying down material in layers. A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by a computer-aided manufacturing (CAM) software package”.

3. Fused Deposition Modelling (FDM)[1]



Main Advantages of 3-D Printing Versus Other Manufacturing Technologies [3]

- Can economically build custom products in small quantities as if mass production were used. Sources of cost effectiveness include:
  - No need for costly tools, moulds, or punches
  - Automated manufacturing
  - Use of readily available supplies
  - Ability to recycle waste material
  - Improved working capital management as goods are paid for before being manufactured

- Ability to easily share designs and outsource manufacturing
- Speed and ease of designing and modifying products

Current Limitations of 3-D Printing [3]

- Higher costs for large production relative to subtractive technologies.
- Reduced choice for materials, colours, and surface finishes.
- Materials have to be pre-processed to a given texture or form prior to being fed to the printer.
- Lower precision relative to other technologies.
- Limited strength, resistance to heat and moisture, and colour stability.

3D-Printing: Make Anything You want [9]

3D-Printing: What does the Future hold?

- Positive Socioeconomic Impact as the size-cost and efficiency become better.
  - Decrease in the amount of labour and number of labourers in industry (could also be negative?)
  - Advancing Medical Treatments to treat currently debilitating conditions.
  - Printing food to address famine in 3rd world countries?
  - Protect the environment by reducing waste material and emissions deposited to it.

3D-Printing: What does the Future hold?

- Ethical aspects as the size-cost-efficiency improves:
  - Technology advances at a much –much faster pace than policy frameworks needed to control and regulate it.
  - Individual ownership of 3D-Printers in the wrong hands can lead to replication of Guns/illegal drugs/forgery and counterfeiting to name but a few.

Effects to Global Economy could be a double edged sword

- If 3D –printing is adopted world wide:
  - Shift of production-distribution from the current model to localised production could potentially reduce the imbalance between export and import countries.
  - Create new industries and new more high skilled professions –those relating to designing, operating and supplying materials for 3D printers.
  - Traditional manufacturing jobs may be lost thus impacting the economy of developing countries.

References and Further Reading

[1] 3D-Printing Industry-The Free Beginners Guide. http://3dprintingindustry.com (25/01/2017).

[2] http://3dprintingfromscratch.com/common/types-of-3d-printers-or-3d-printing-technologies-overview/ (25/01/2017).

[3] 3-D Printing: The New Industrial Revolution, Barry Berrman- **Business Horizons, Vol. 55, pp 155-162** - Elsevier, SciVers ScienceDirect. (2012)

[4] **Report**: Domain Group 3D-Printing Workshop Notes. European Social Fund Malta 2007-2013. Malta Ministry of Education and Employment.

References and Further Reading

[5] Additive Manufacturing of Multi-directional preforms for composites. Opportunities and Challenges. Zhenzhen Quan et al. **Materials Today, Vol. 18 Number 9, pp 503-511** – Elsevier. (2015)

[6] Fabricated: The New World of 3D Printing, Hod Lipson, Melba Kurman, Wiley and Sons 2013.

[7] Makers – The New Industrial Revolution, Chris Anderson, pp 231-235, Random House 2013.

[8] http://www.coolthings.com/bfb-3000-3d-printer/ (25/01/2017)

[9] https://www.youtube.com/watch?v=G0EJmBoLq-g (25/01/2017)

[10] https://3dprint.com/tag/3d-printed-scaffold/ (09/10/2017)