



## 3D Printing of Particles Resource Sheet

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### Overview

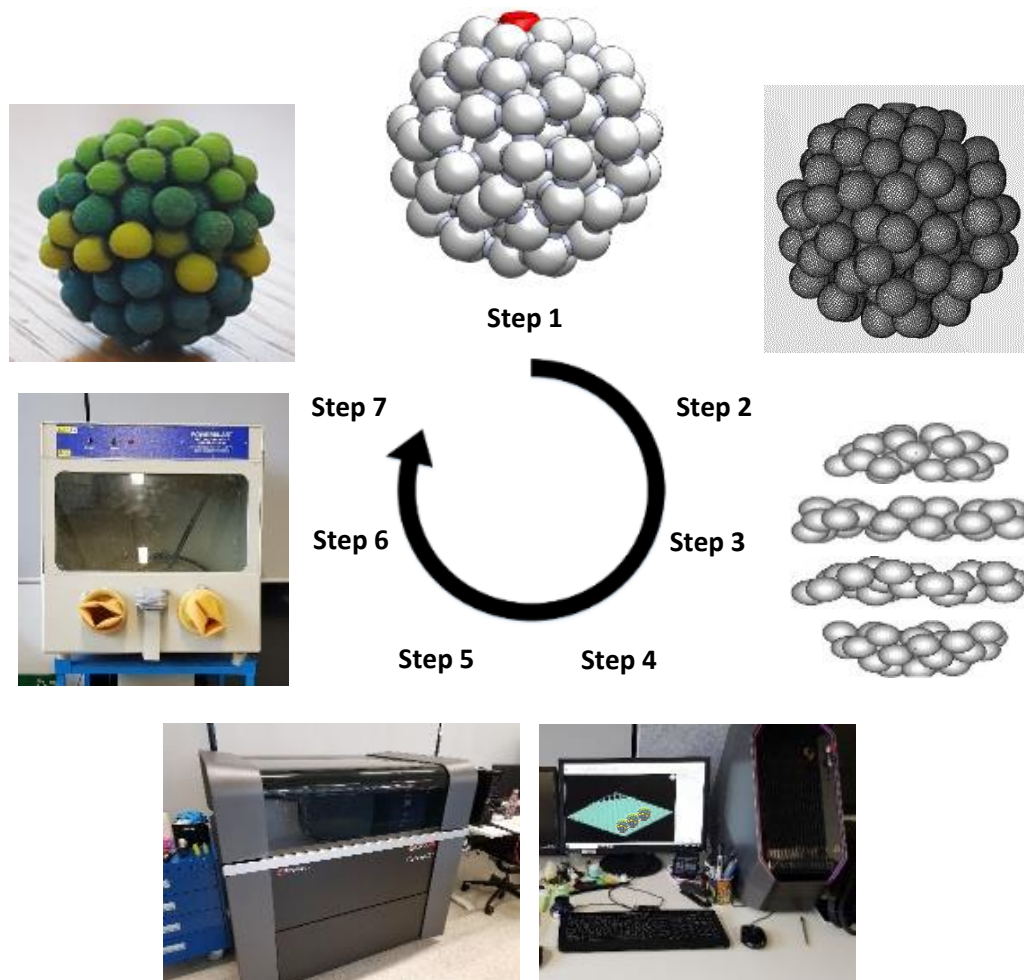
Conceptualisation of a digital source into a physical product is the underlying method to 3DP. According to the International Organisation for Standardisation and American Society for Testing and Materials International standard (ISO/ASTM 52900:2015) there are seven (7) main categories of 3D printing processes [1]. The general process for all categories are alike, printing in a layer-by-layer fashion. The specific method in which this is achieved varies for each category, whether that be by extrusion, lamination, jetting, photo-curing, or fusion of the materials [2]. A summary of the process description for the 7 categories are summarised in Table 1.

**Table 1. 3D printing process categories as outlined by the ISO/ASTM 52900:2015 standard [3]**

#	3D PRINTING CATEGORY	PROCESS DESCRIPTION
1	Binder jetting	The process where a liquid bonding agent is strategically deposited onto a powder bed to join the powder materials
2	Directed energy deposition	The process where focused thermal energy is used to fuse materials by melting the material as they are being deposited
3	Material extrusion	The process where material is selectively distributed through a nozzle or orifice
4	Material jetting	The process where droplets of the build material are strategically deposited
5	Powder bed fusion	The process where thermal energy is used to strategically fuse regions of a powder bed
6	Sheet lamination	The process where sheets of a material are bonded to form a single product
7	Vat photopolymerization	Liquid polymer in a vat is selectively cured via light activated polymerization

It is important to select the correct type of machine appropriate for the final application of the product. Considerations which can be taken to select the correct machine are; type of material

necessary for the build of product, material properties of the final product, need for support structure and the need for multi material components [4]. In order to produce a product there are several standard steps involved in the process, the generalised procedure is summarised in Figure 1.



**Figure 1. General step by step procedure for 3D printing from the initial 3D CAD model to the final 3D printed object**

## Step 1 – CAD design

The initiation of the process begins with developing digital representation of the product using Computer Aided Software (CAD) software. The exact dimensions of the final product are defined here. This step can be skipped and the user can directly make a mesh representation of the product in STL format– (begin from Step 2). Examples of software’s which can be used to develop a CAD representation of the product are; SolidWorks, Autodesk AutoCAD, Autodesk Inventor and Autodesk Fusion360. Almost all CAD software’s are able to export the final product design to STL format (.STL). Parameters to consider to improve accuracy of the design when converted to STL and consequently the print quality of the product are the chord height and angle of the design edges. In the case the



user wishes to 3D print a real particle, X-ray computed tomography of the structure can be imported to the machine.

## Step 2 – Conversion to STL

If a CAD software was not used to create a representation of the product, a direct mesh format can be created. Softwares such as Autodesk Maya and Autodesk Mudbox can be used to create a mesh form of the product in STL format. Pre-prepared STL designs are available for download and use from Thingiverse ([www.thingiverse.com](http://www.thingiverse.com)) and carry creative commons licence. If the final product design requires manipulation, software such as Materialise Magics can be used to alter the design. STL stands for Standard Tessellation Language and is a representation of the product and uses a series of linked triangles to create the product design. By increasing the resolution more triangles are used which in turn means the product surface will be a lot smoother, however, the file size will be much larger. Adjusting the resolution below or above a certain point is not recommended.

## Step 3 – Transfer STL file to 3D printer machine and file manipulation

The STL file needs to be transferred onto your 3D Printer machine. In order for it to be 3D printable, it will need to be sliced into layers, this could range from hundreds of layers to thousands of layers. The slicing process generates the tool path and converts the design into machine language (.GCODE). Parameters which are set in this step include but are not limited to; size of the nozzle, how often the nozzle prints, orientation and size of the design, number of parts to be printed, extrusion speed, head speed, temperature, use of fan, wall thickness, fill patterns etc. Typically, every 3D printer has a recommended compatible software that should be used for manipulating the file and creating the tool path. Examples of software's which can be used to slice the design are Netfabb engine, Simplify3D, Repetier and Slic3r.

## Step 4 – Machine set up

Once the digital format of the product is ready and transferred to the machine, the machine needs to be prepared to ensure sufficient materials i.e. polymers, binders etc. are installed. Once the machine has been checked to ensure it is in working order, the build can commence.

## Step 5 - Build

The automated build commences and will require some time to finish. The time can vary from minutes to many hours, depending on the conditions set in the machine and the design of the product.



## Step 6 – Removal & Post Processing

On completion of the build, safe removal and necessary post processing procedures of the product take place. In the instance the product contains a waxy support material, a high pressure waterjet cleaner can be used to wash the support material or the material can be immersed in appropriate solution in a heated water bath to remove the support material. In the instance the product was printed in a powder bed, the surrounding loose powder must be vacuumed away inside the 3D printer, being careful to not vacuum the printed product. An air brush should be used to gently wipe away excess powder immediately surrounding the product followed by gently transferring the product out of the machine. The product should be sprayed with an epoxy resin as recommended by the manufacturer or Epsom salt and water solution to strengthen the structure and then air dried.

## Step 7 – Final Product

The product is now ready for use. There are alternative ways of 3D printing without the need of going through steps 1-6, it is possible to create the design and print your product by Shapeways at a cost (<https://www.shapeways.com/>).

## Acknowledgements

The authors would like to thank Josh Tuohey for providing assistance.

## References

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