

Selective Laser Sintering

A Design of Experiments

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Abstract: Additive Manufacturing (AM), also commonly known as 3D Printing or Rapid Prototyping, is a method of manufacturing that provides for the ability to make intricate internal features and easily customizable parts. The concept is to break a Computer Aided Design (CAD) file into a series of thin layers that are sent to the machine and laid down one layer at a time.

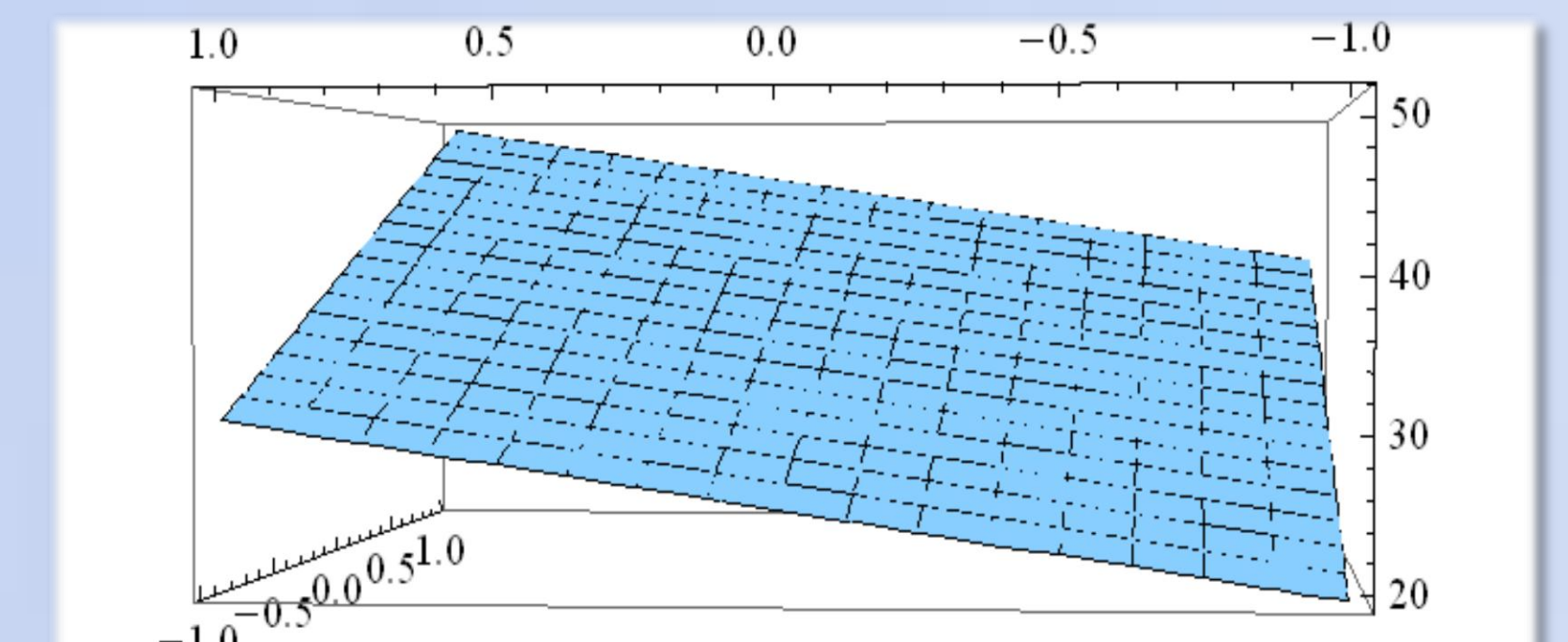
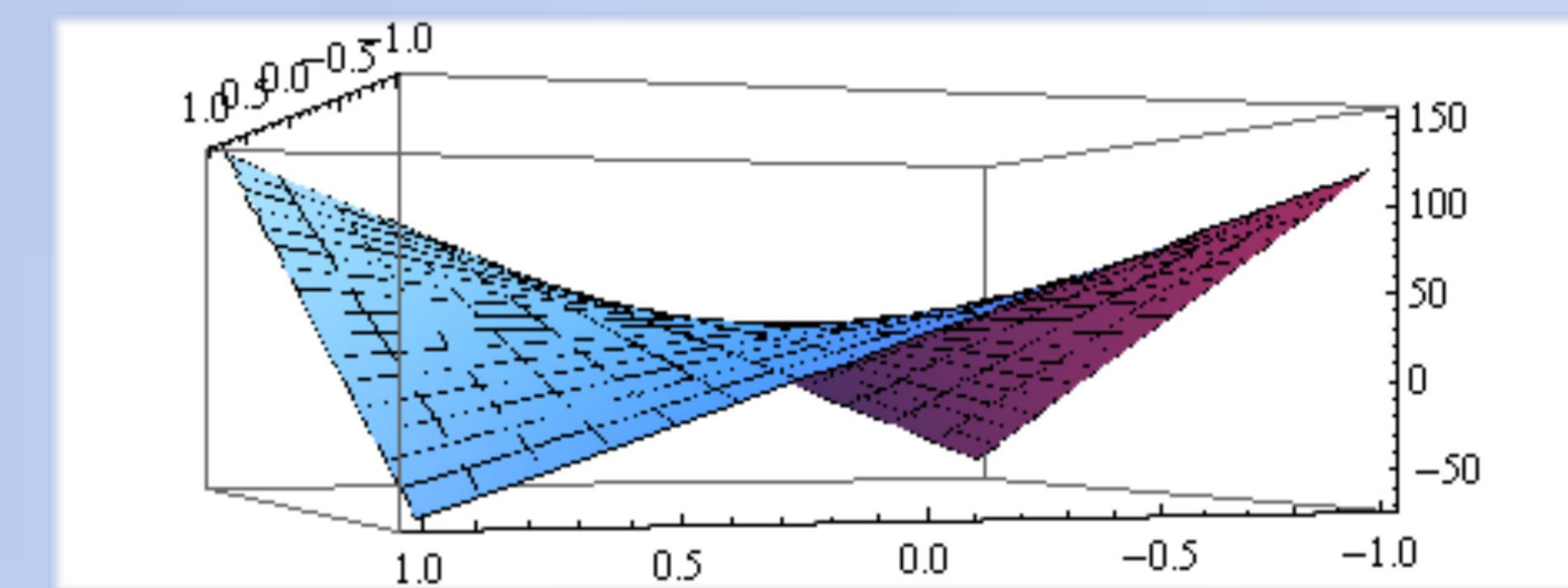
Just like any other form of processing, material properties can alter by undergoing this process. Manipulating various parameters of the AM process can allow for different properties to be achieved. For this reason, an in depth study will be done by Lawrence Livermore National Laboratory to discover what parameters are relevant, how those parameters interact with one another, and what affect those parameters have on the material.

Background

Designing the Experiment

Analysis

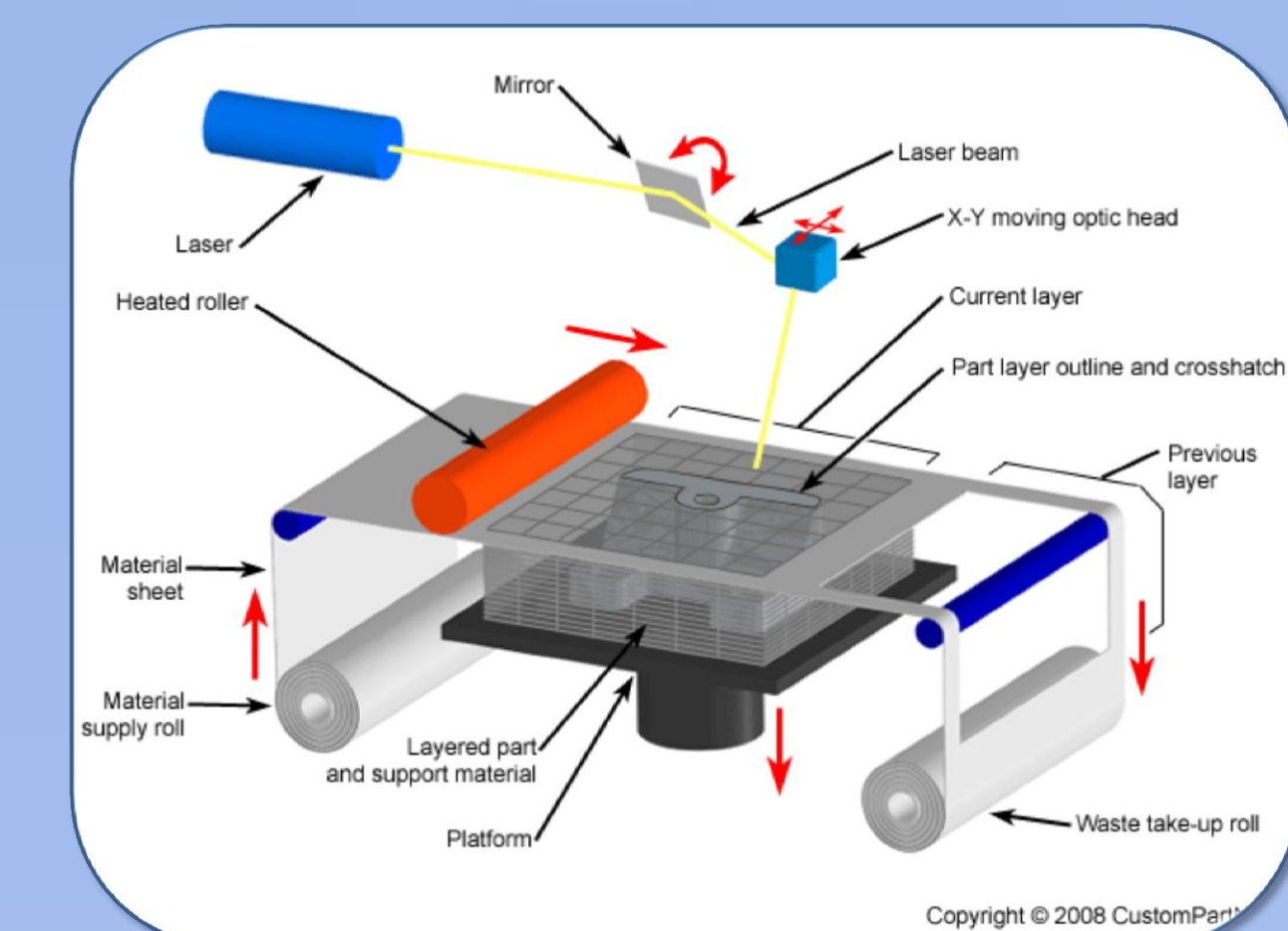
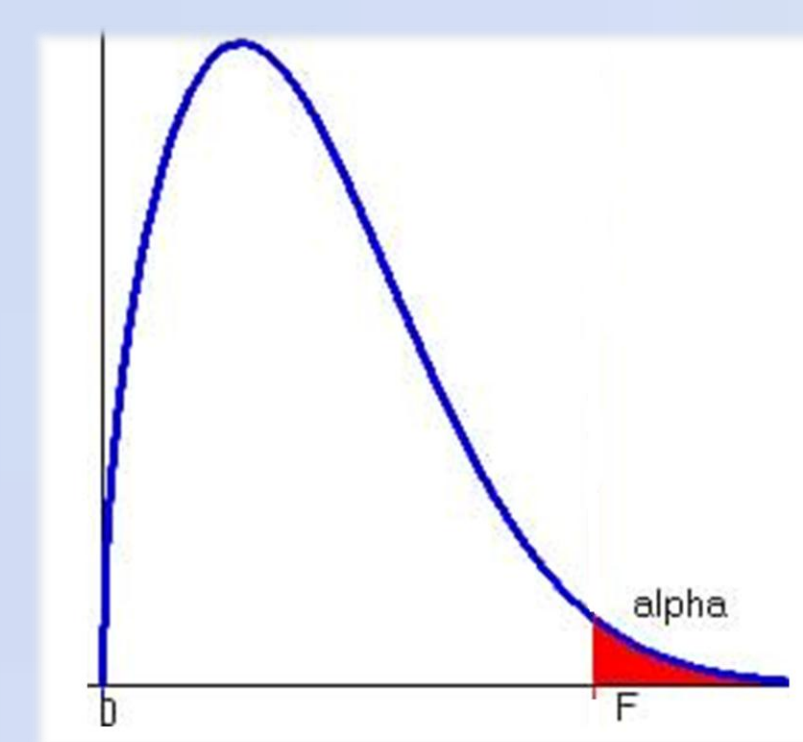
- Define the problem
 - What are the properties of a material produced by the additive manufacturing process?
- Select the response variables
 - Geometric precision
 - Density
 - Ultimate strength
 - Toughness
 - Thermal/electrical conductivity
- Determine the parameters that affect the response variables.



Response surfaces representing the effect caused by two interacting parameters can be generated by using a lower order regression representation. The surface above on the left represents two parameters that interact significantly, while the surface on the right represents two parameters that have little or no interaction.

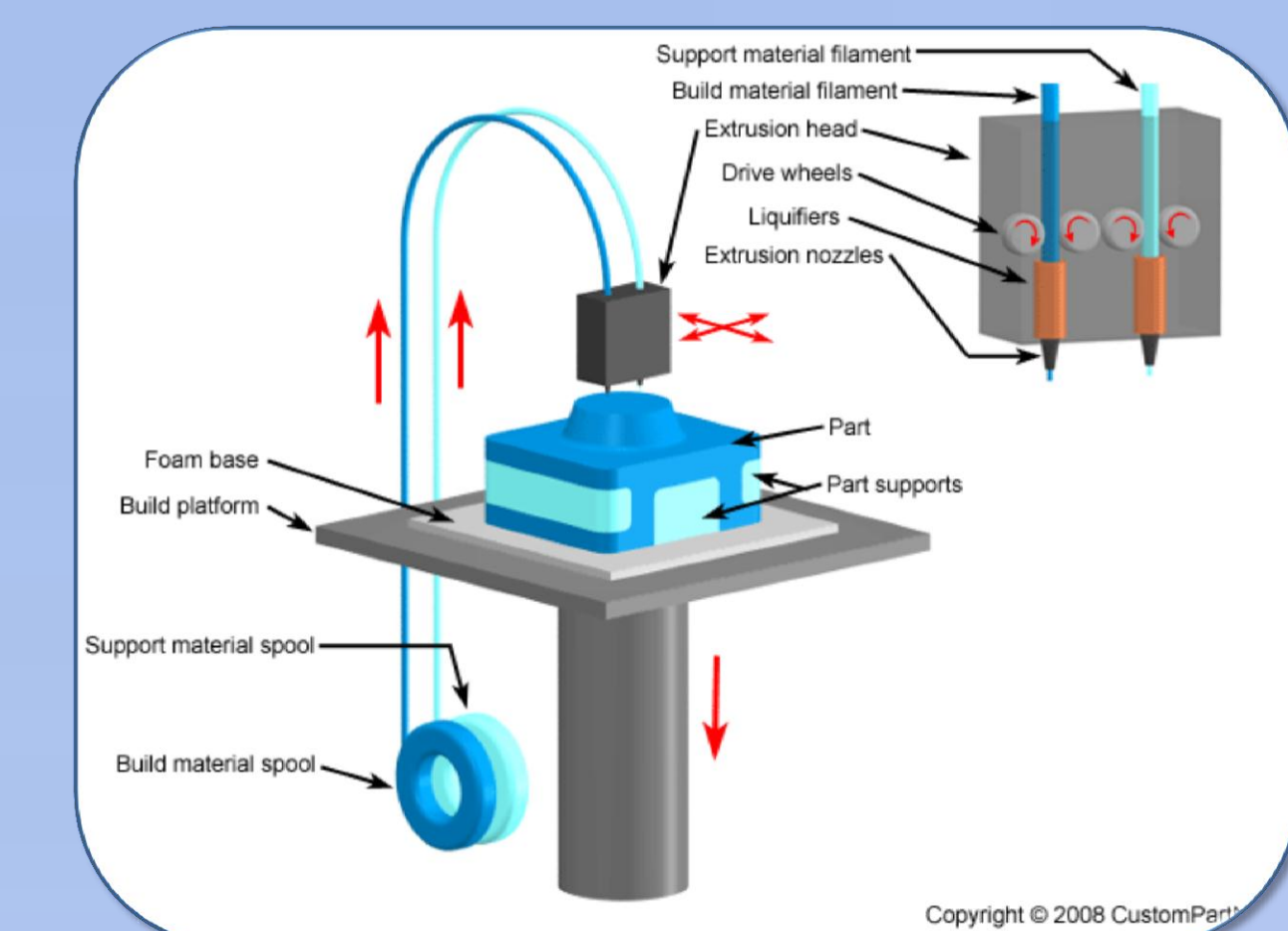
Once data has been collected and each case has been repeatedly tested, an f-test can be performed using the variance between and within groups. This Analysis of Variance (ANOVA) can be used to compare the parameters and to rank them in order of their impact on the response variables.

$$f = \frac{\text{"between - group" variability}}{\text{"within - group" variability}}$$



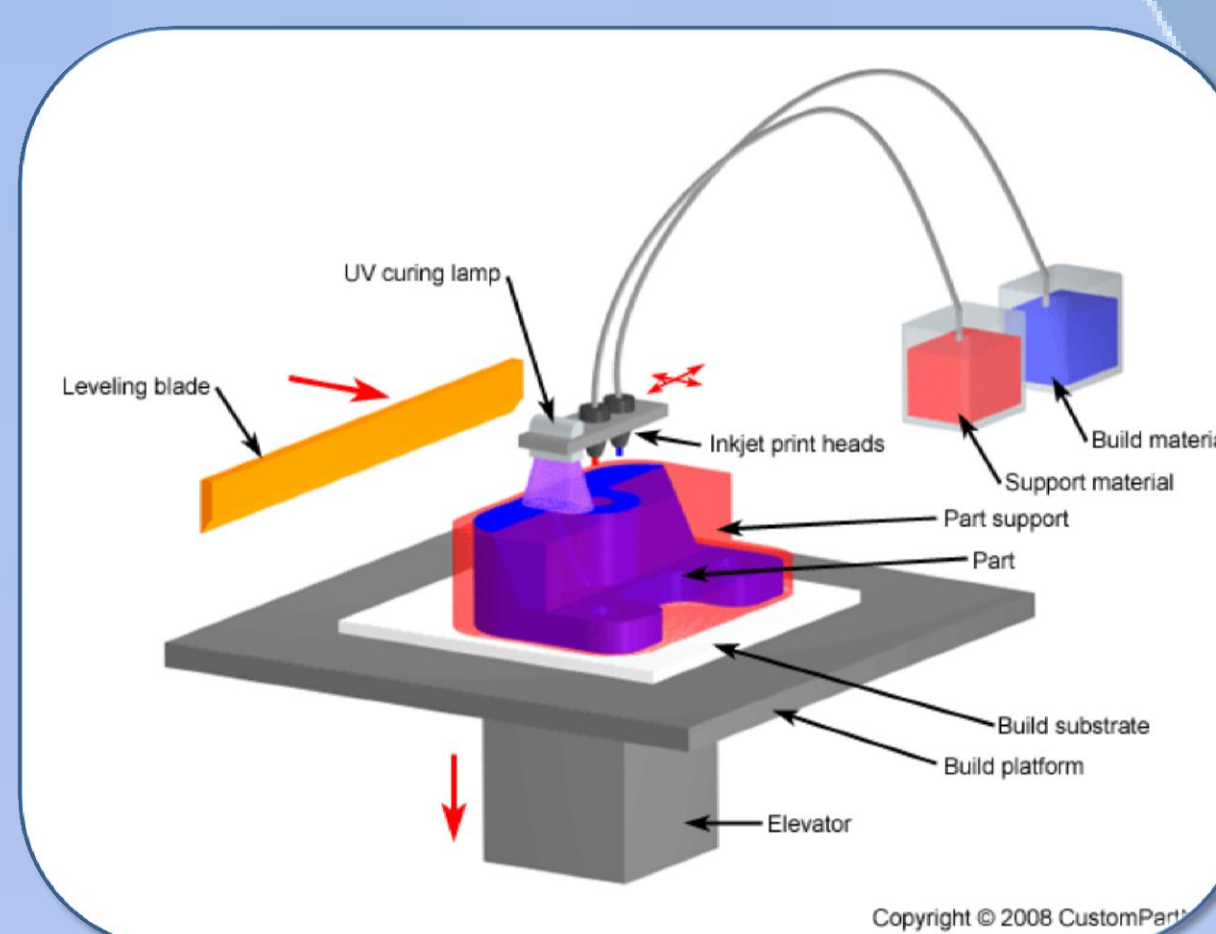
Laminated Object Manufacturing

- Sheeted material adhered to lower layer and cut out



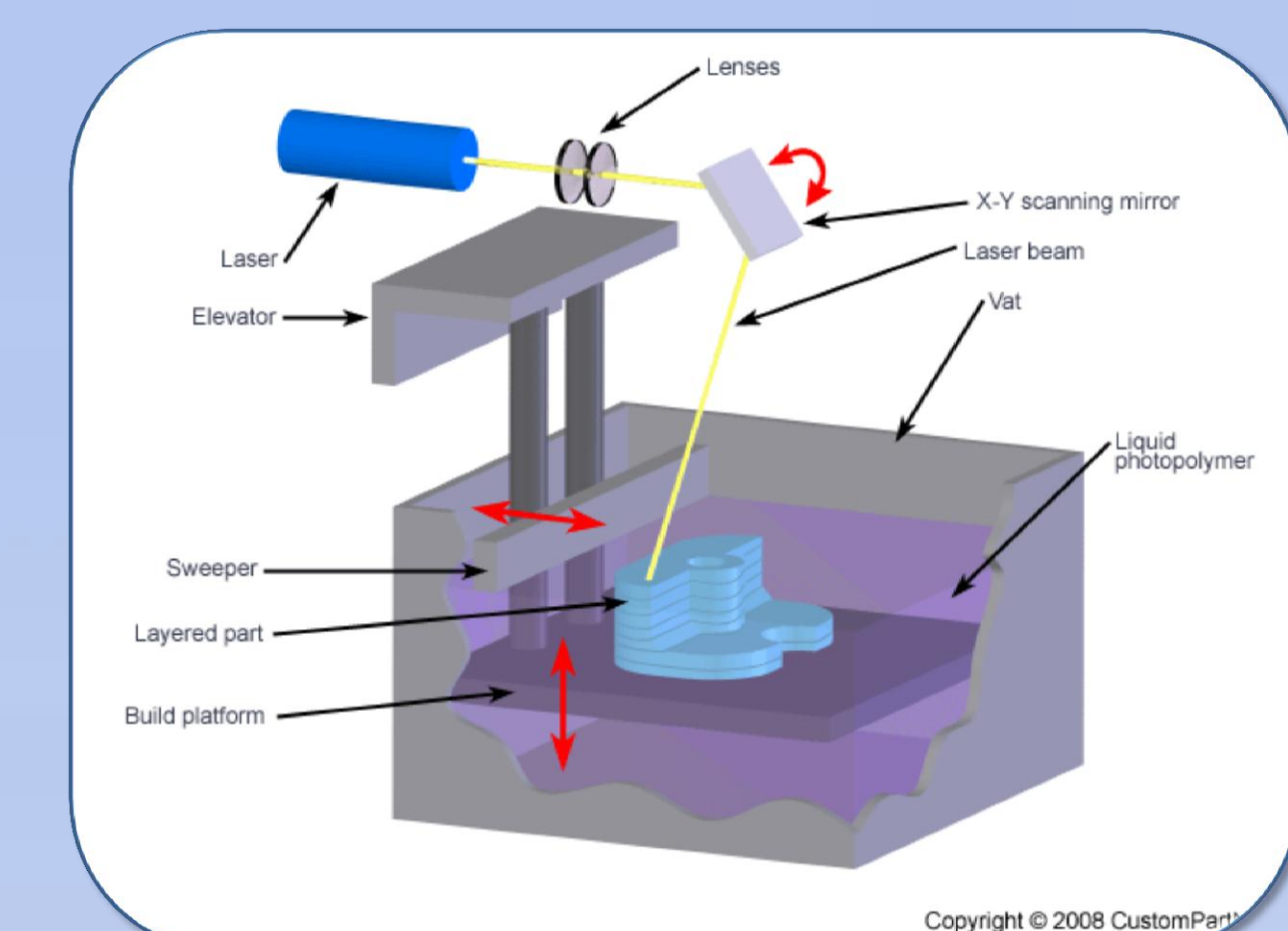
Fused Deposition Modeling

- Spooled polymer "printed" in layers



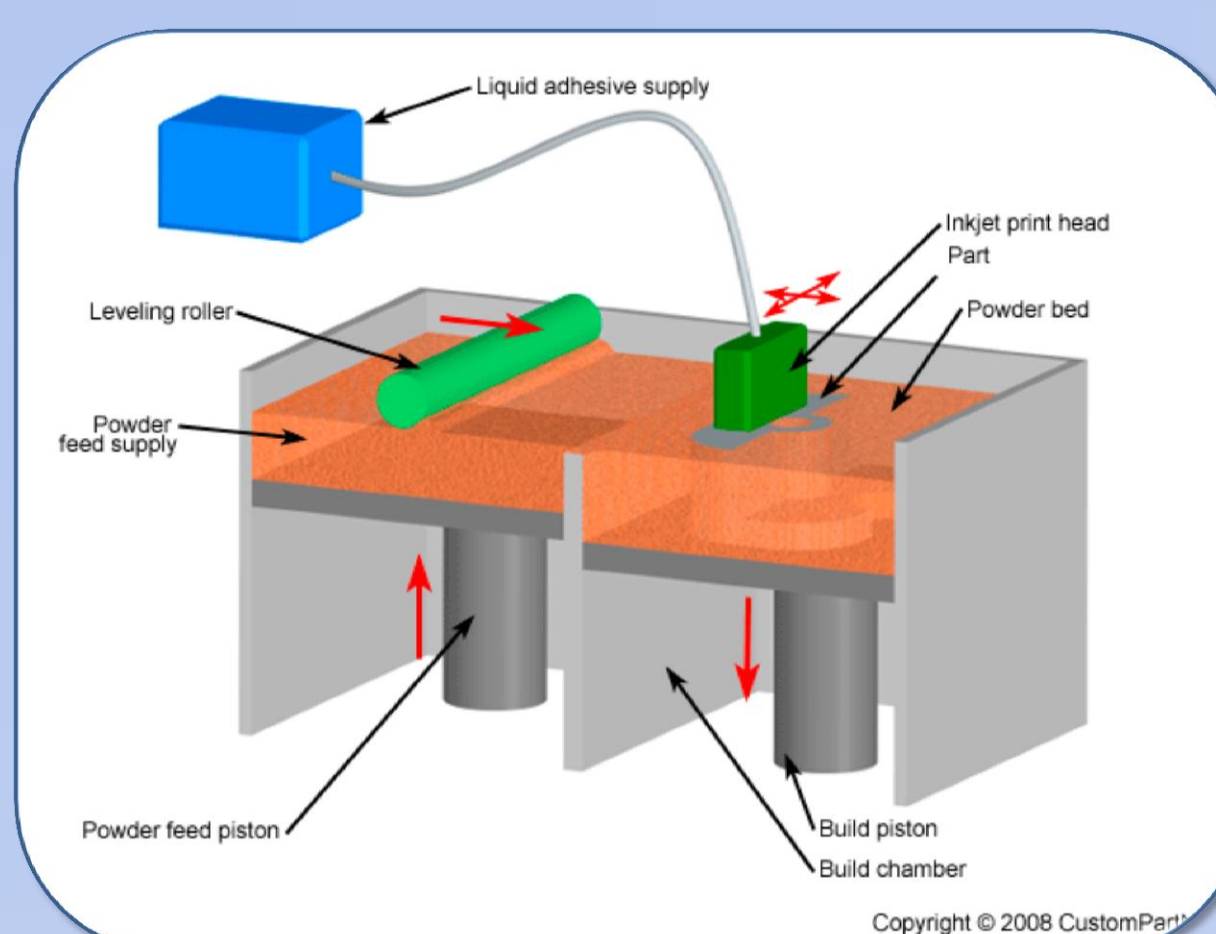
Inkjet Printing/Jetted Photopolymer

- Liquid polymer "printed" and cured



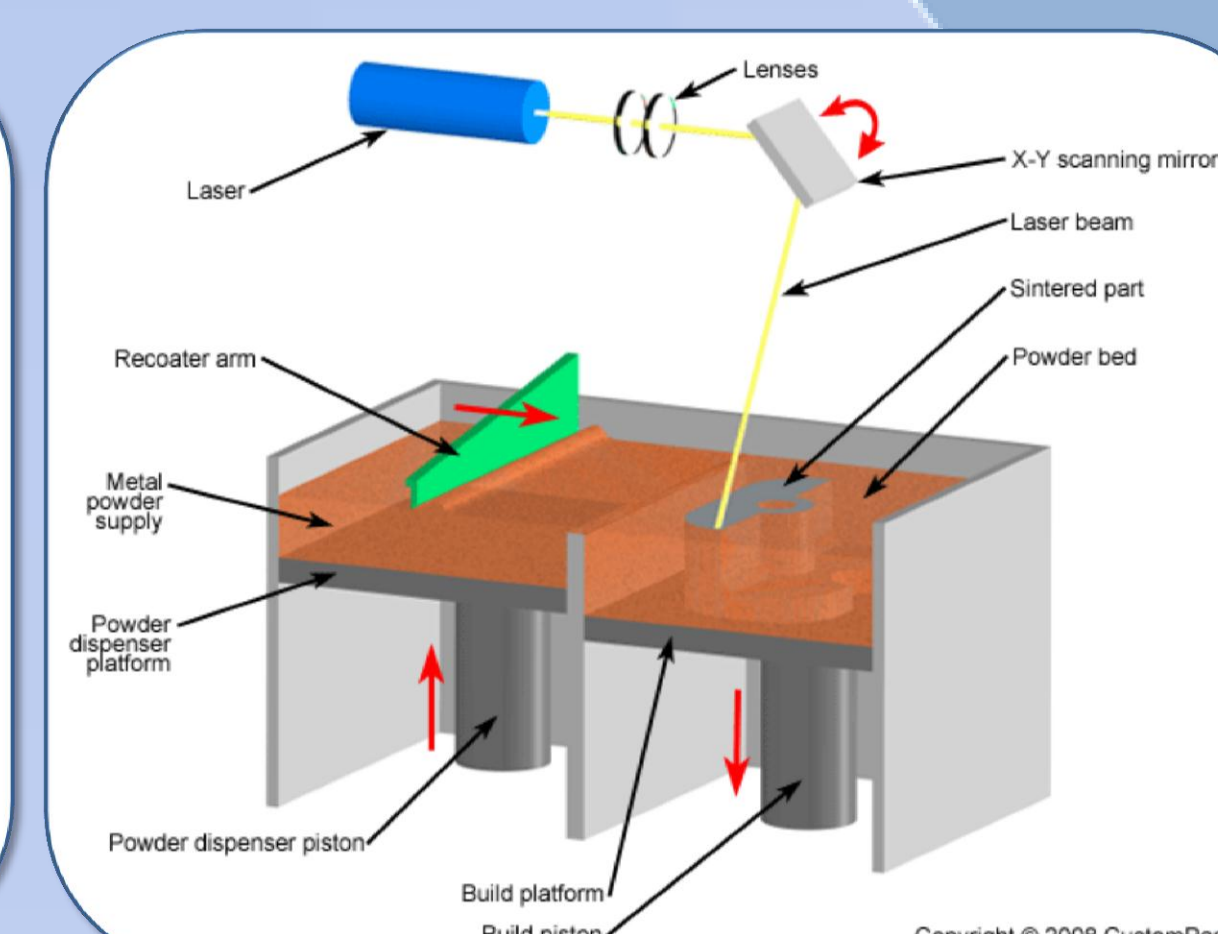
Stereolithography

- Liquid Polymer Cured by a UV Laser



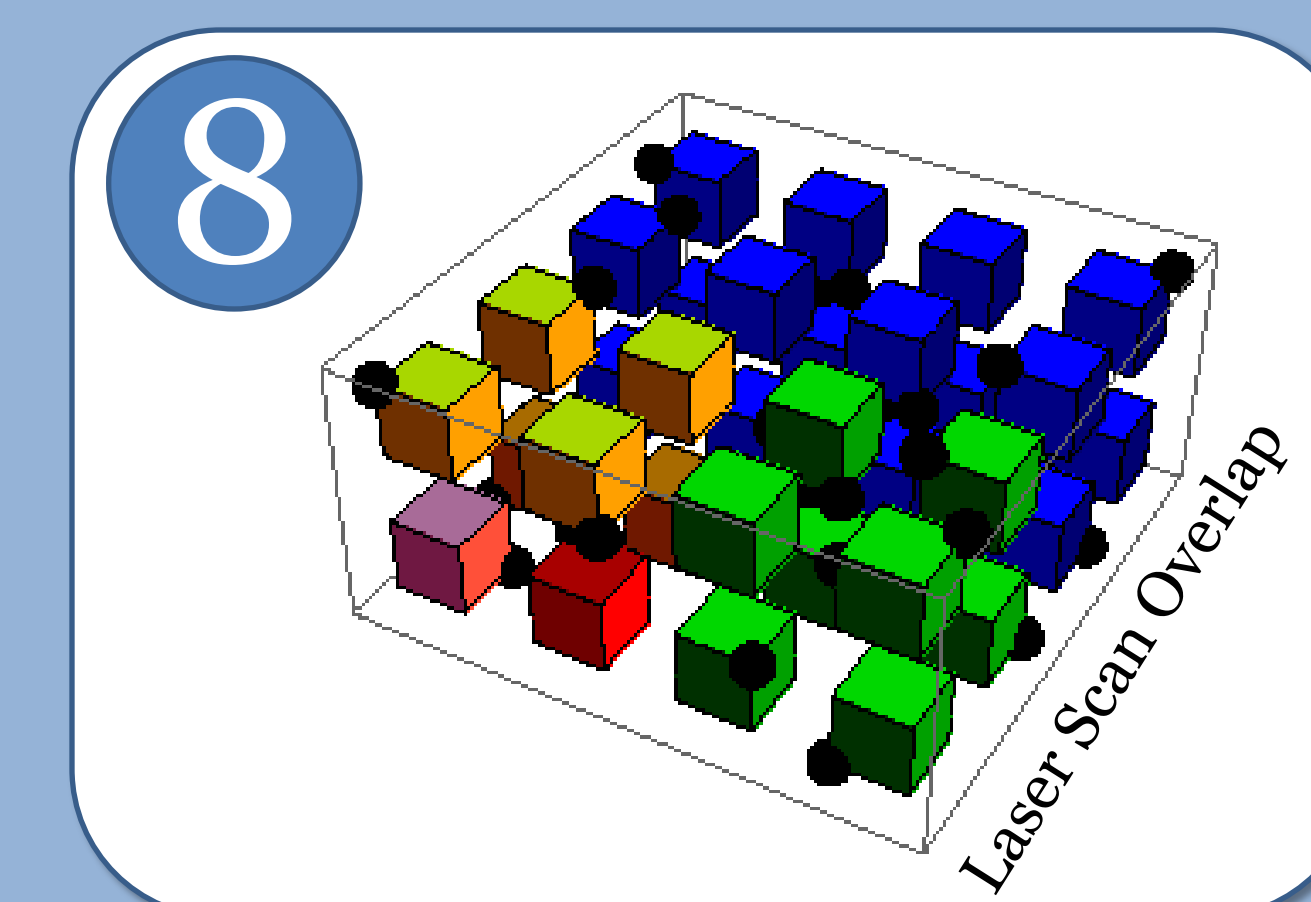
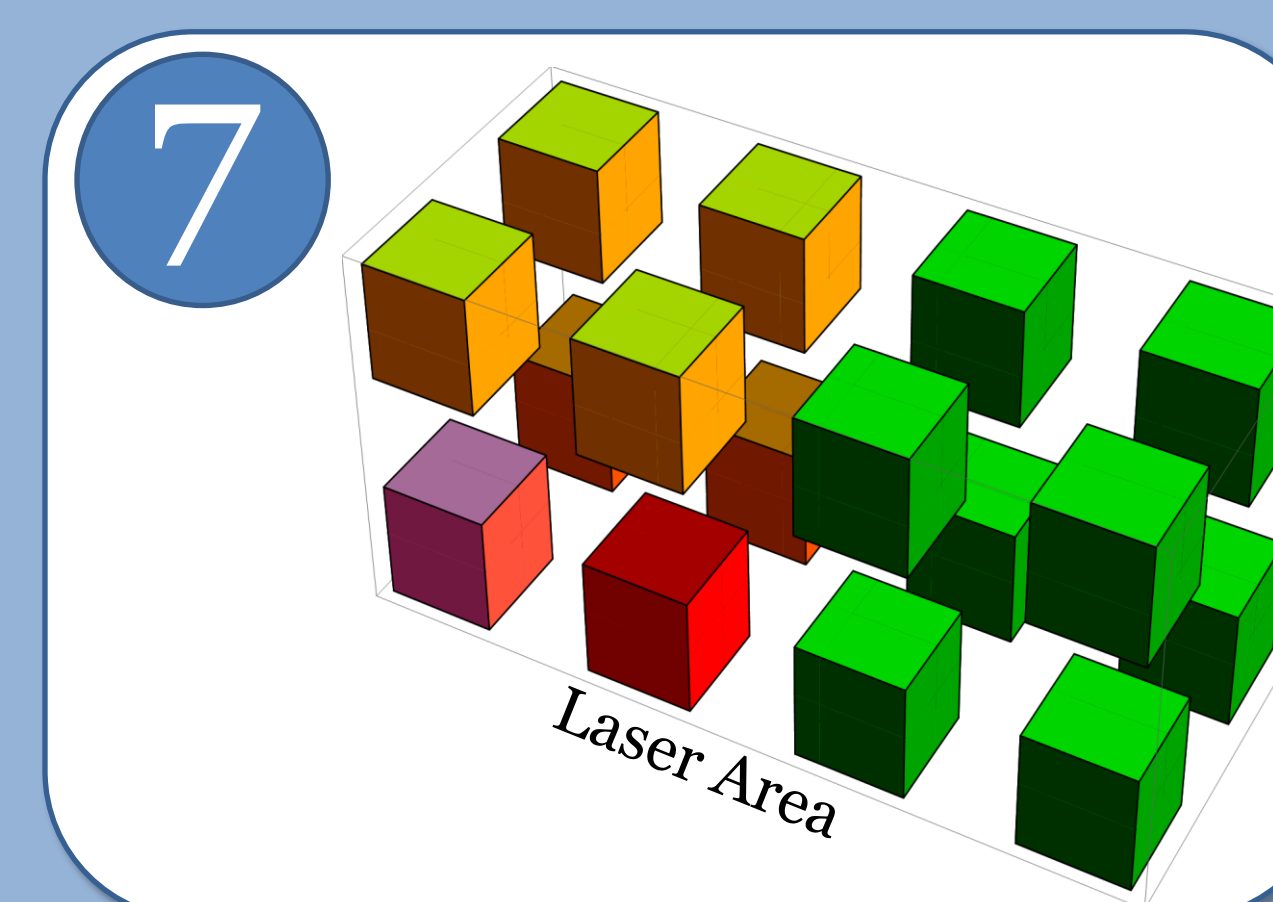
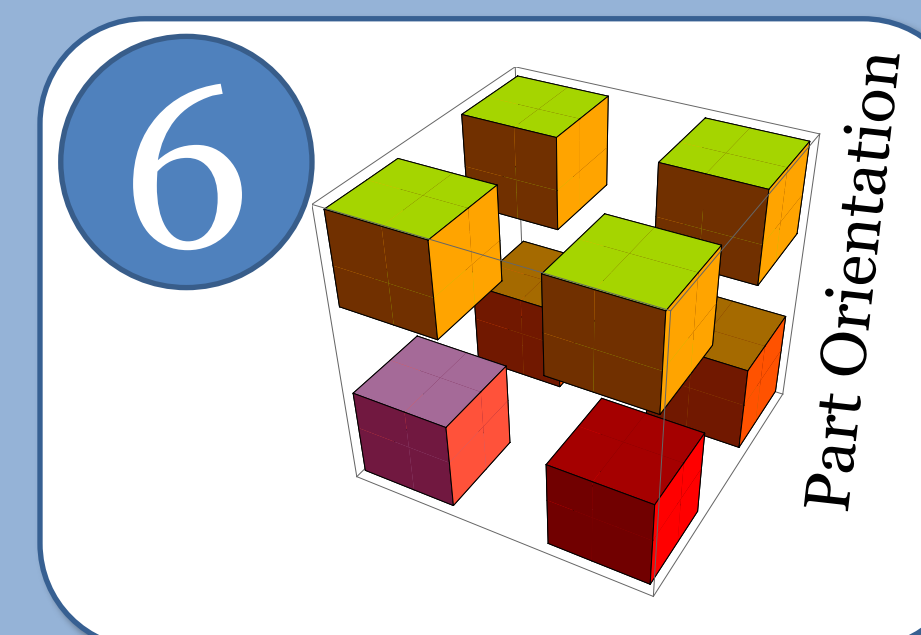
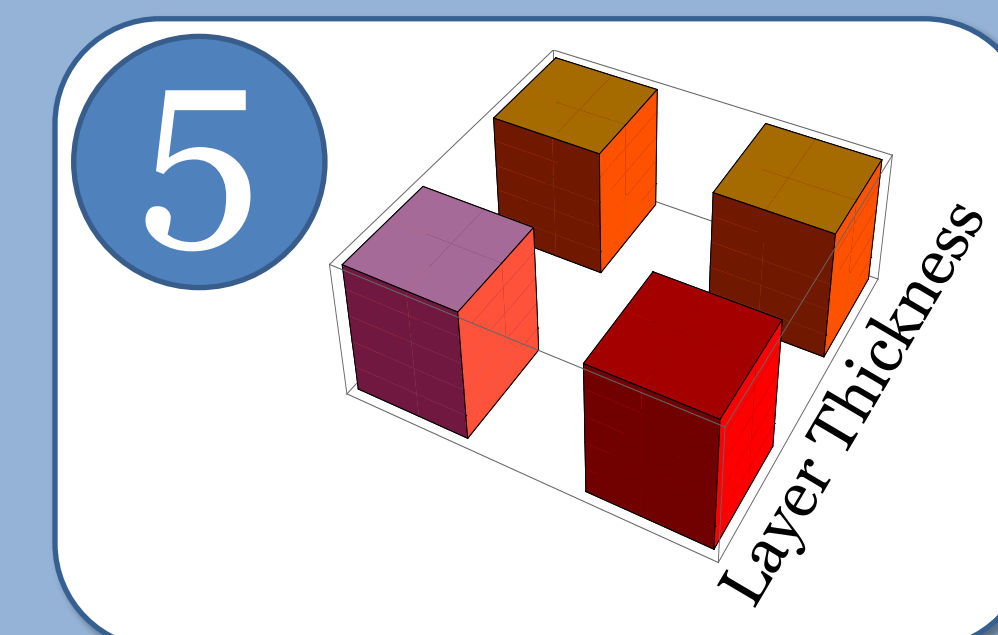
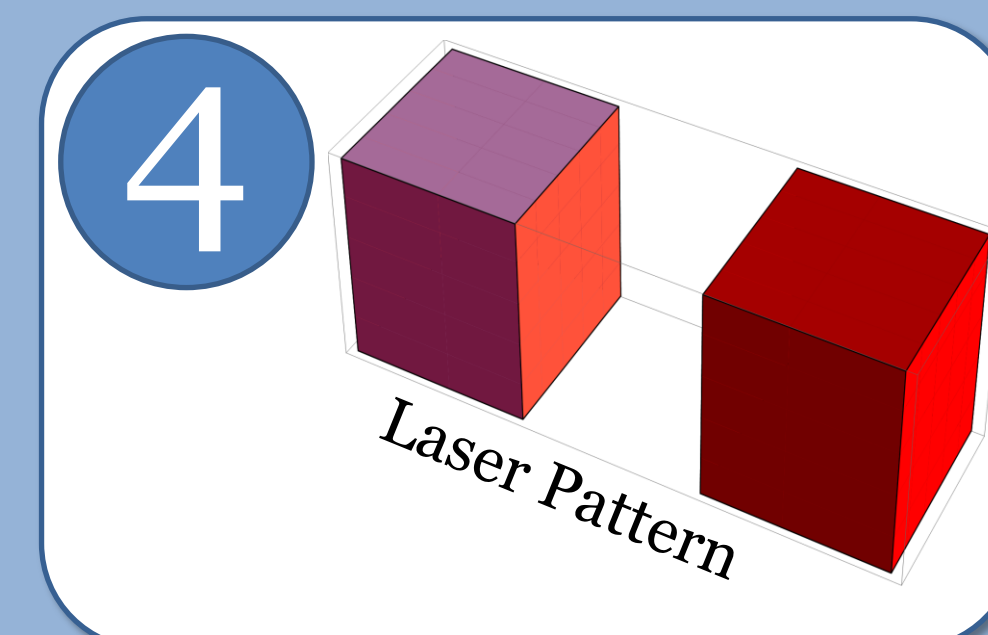
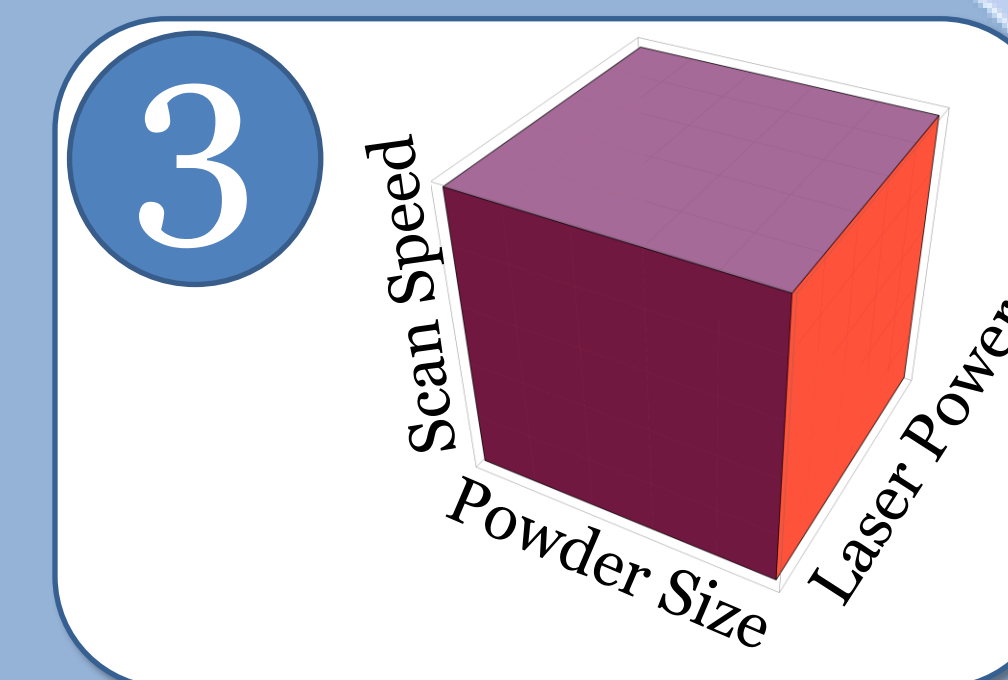
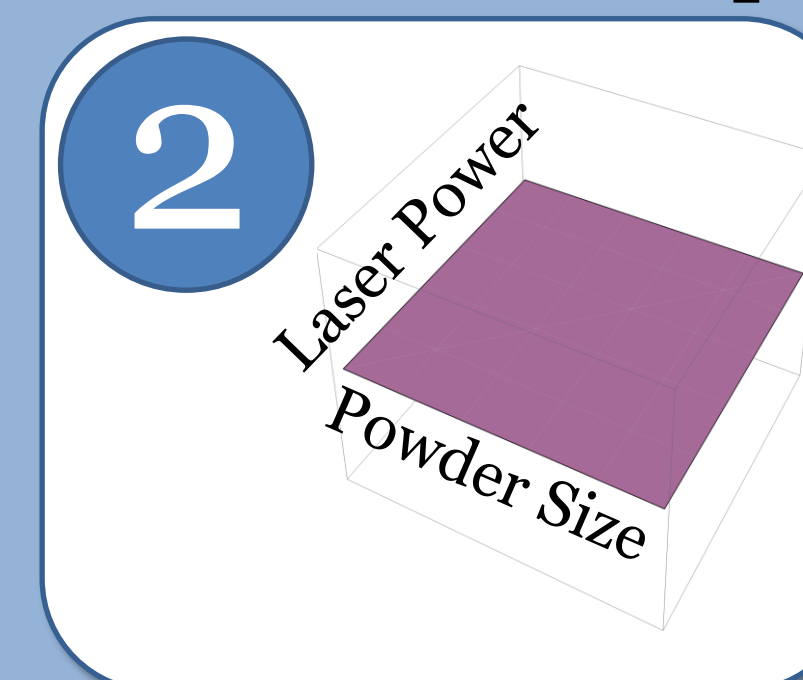
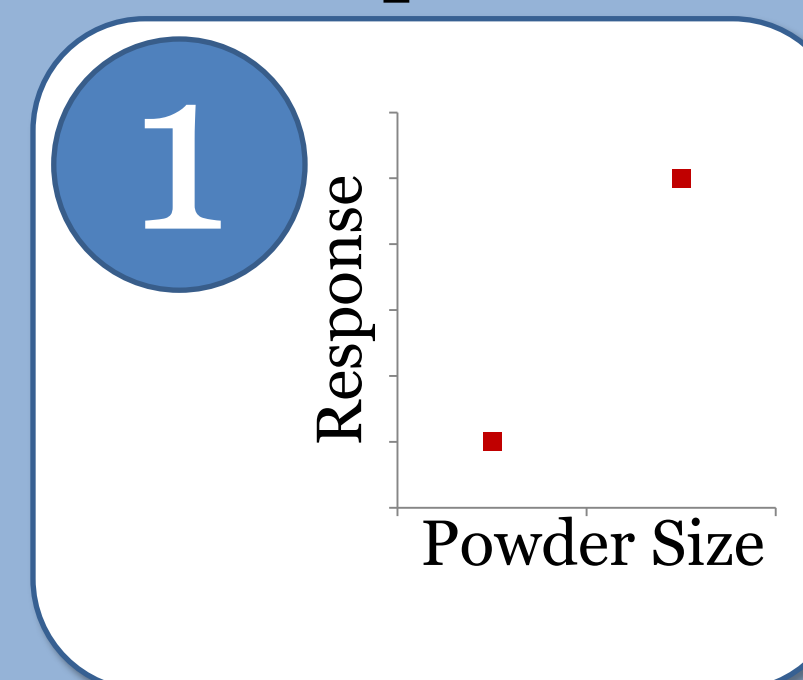
3DP

- Binder "printed" to adhere powder



Selective Laser Sintering

- Powdered material fused by a high powered laser



Each new parameter is represented by a different dimension/color, meaning that each corner represent s a possible test case. Of the original 15 parameters identified, 8 suspected significant parameters were selected for further analysis, leading to 2^8 (256) test cases. A fractional factorial design was used to reduce the number of tests to 32 cases which are represented as black spheres in the full hypercube.

Acknowledgements:

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