M.Tech
Digital Manufacturing

BITS Pilani
Pilani Campus

Jayakrishnan J
Guest Faculty

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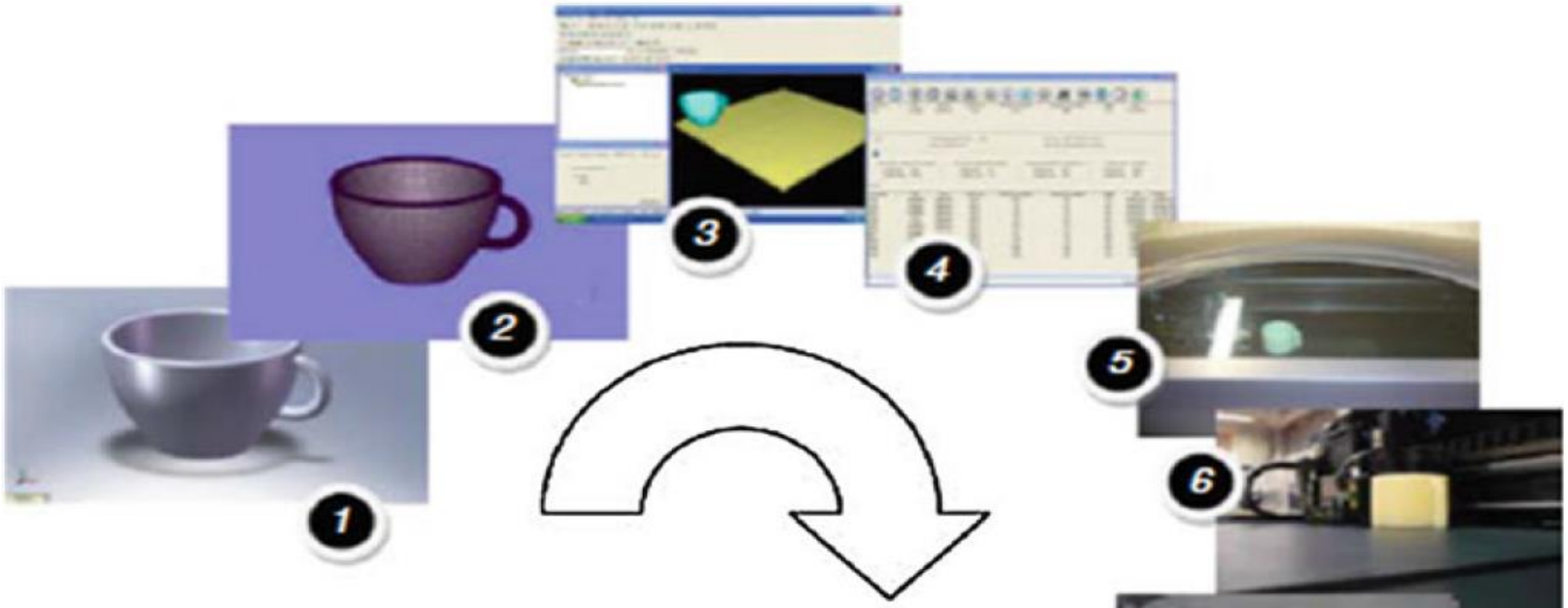
DMZG521- Design for Additive Manufacturing
Session 4 & Lecture 7-8

Eight stages of AM process



1 CAD
2 STL convert
3 File transfer to machine
4 Machine setup
5 Build
6 Remove
7 Post-process
8 Application

AM Process Planning

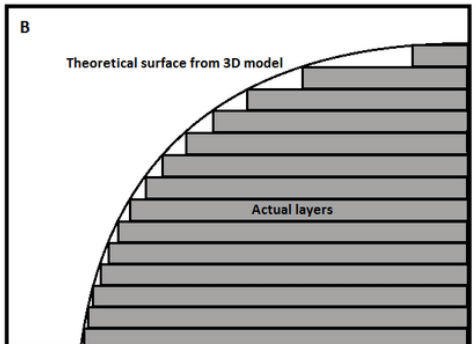
- Part Orientation
- Support Generation
- Slicing
- Path Planning
- Print the Model
- Post Processing

Part Orientation

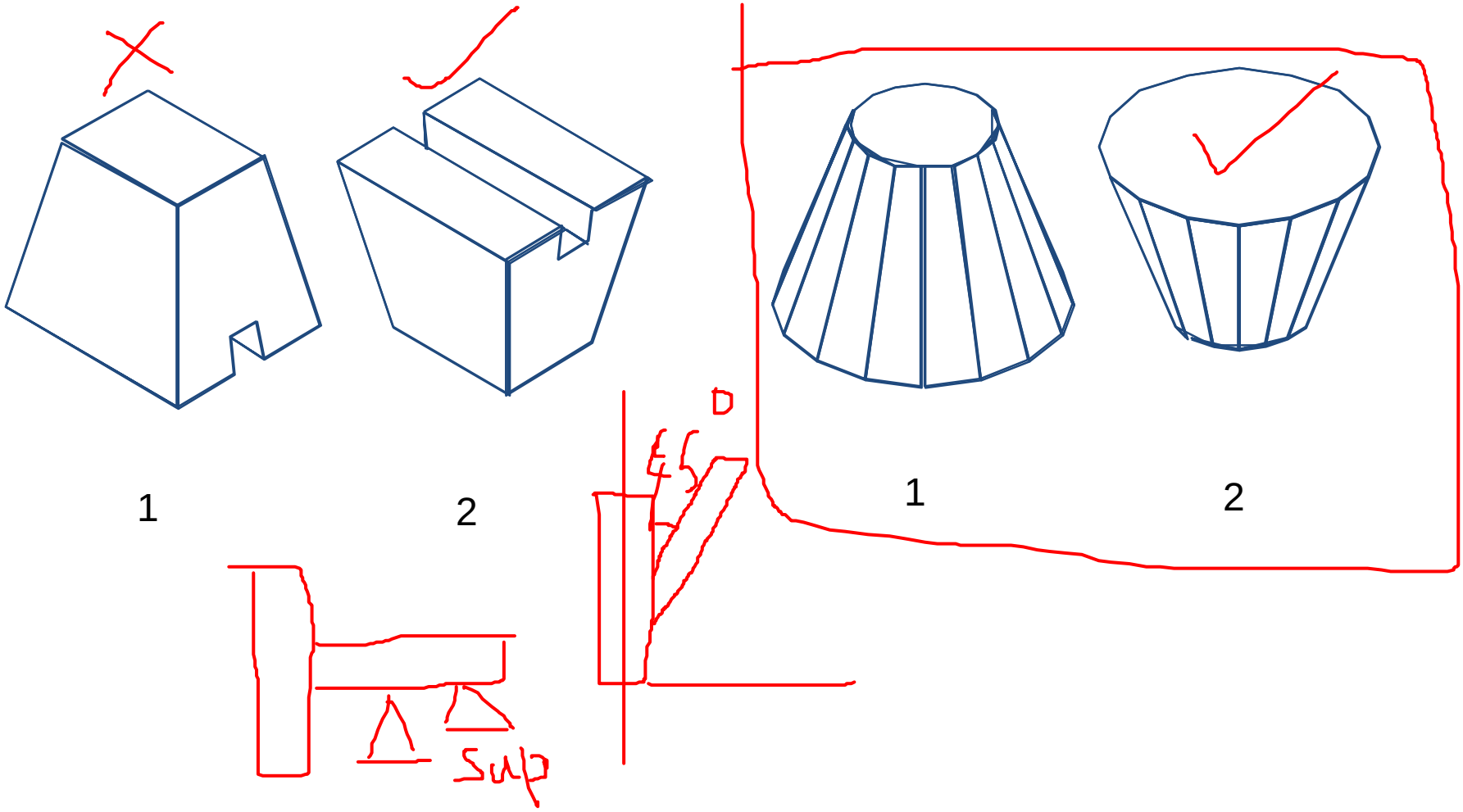
- Part accuracy
- Surface finish
- Build time
- Part strength
- Support structure

Effects of part orientation

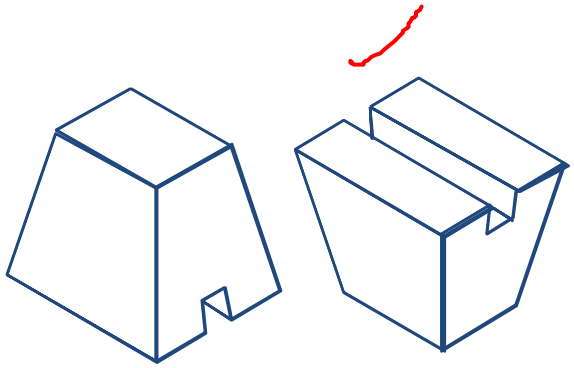
- Cost
- Build Time
- Stair step error
- Trapped Volume
- Support structure
- Curling and Warpage
- Assembly consideration

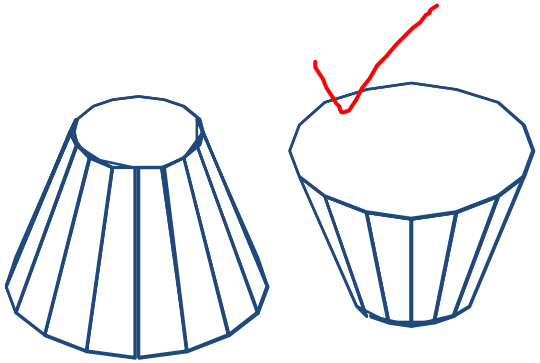


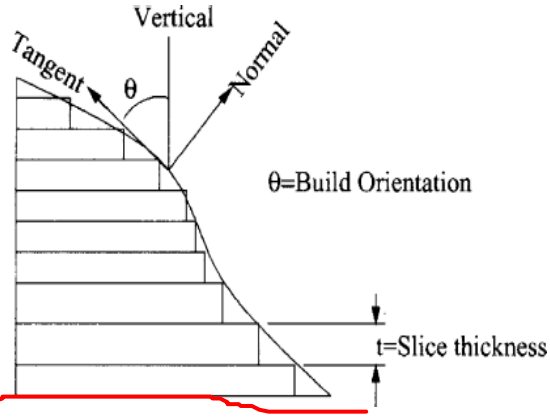
Which is best orientation?



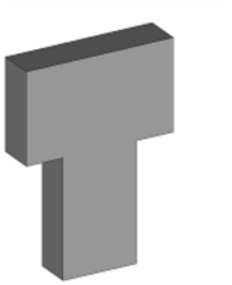
Design guidelines for Part Orientation



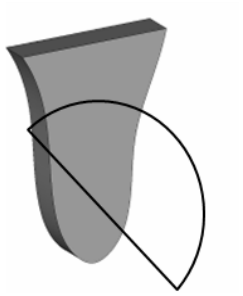


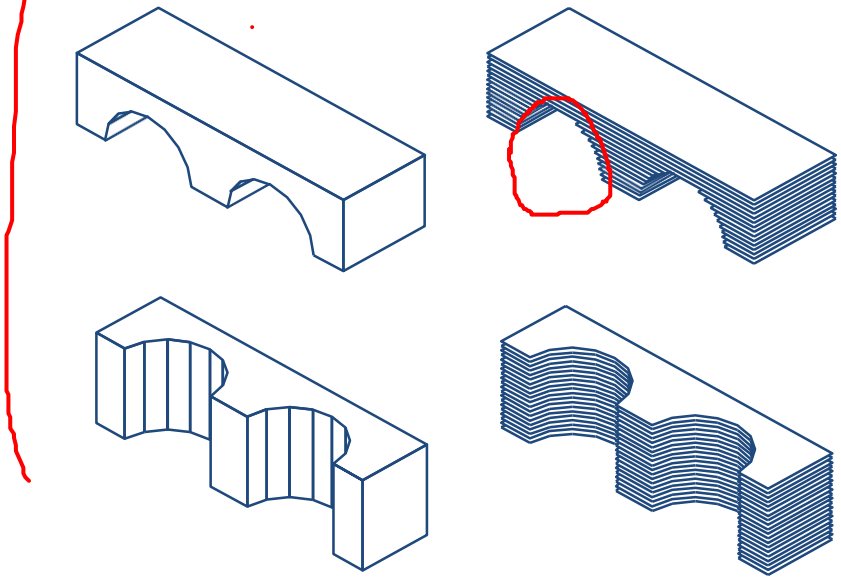


Good Part

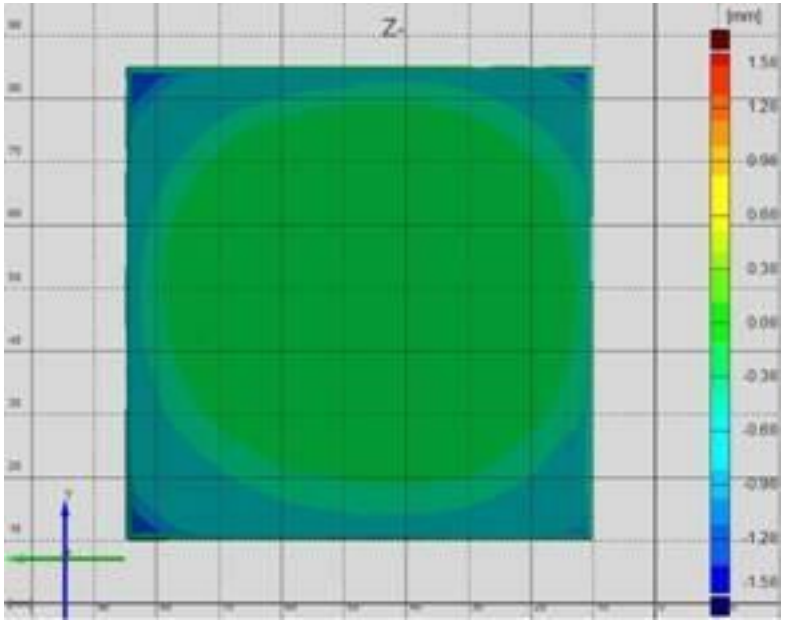


Bad Part

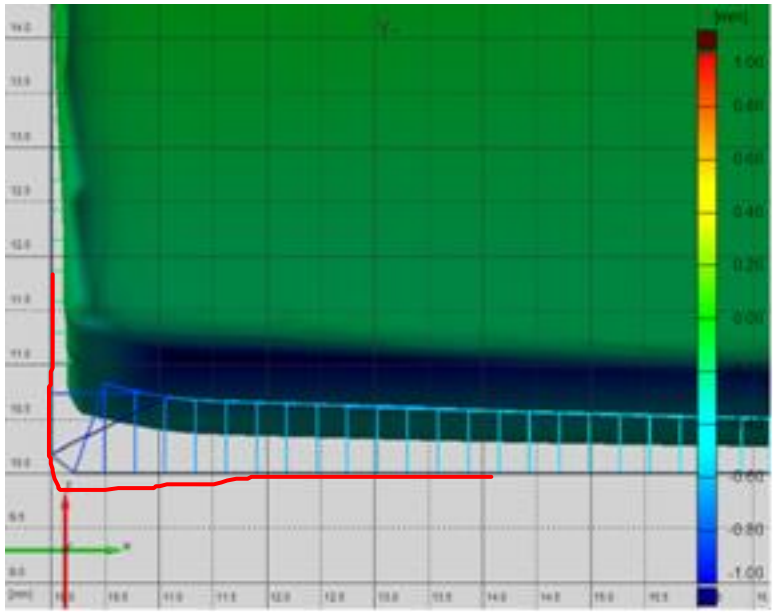




Curling and Warpage



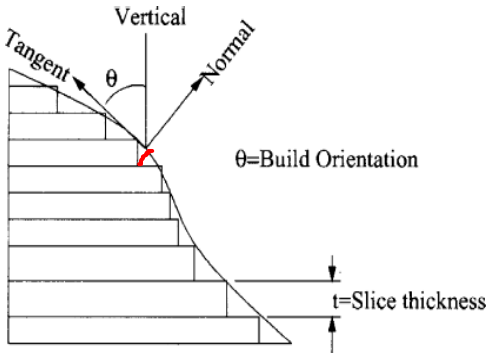
Bottom surface



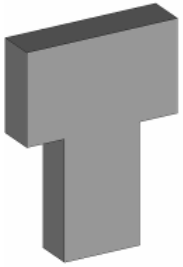
Corner of the part

Avoid highly curved surfaces in the design

Highly curved surfaces causes ‘stair-step effect’ due to finite layer thickness during slicing

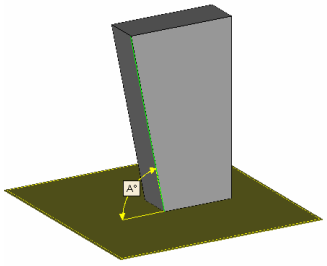


Good Part

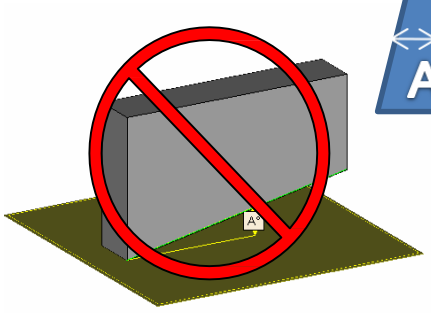


Bad Part

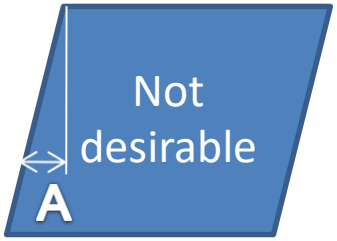
Good Orientation

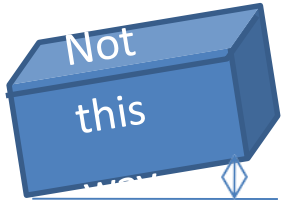


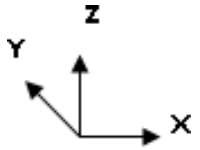
Bad Orientation



In design







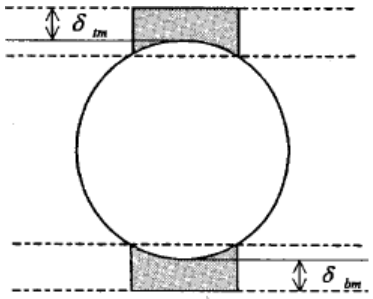
Orient axis of cylindrical surfaces perpendicular to the building plane.

Staircase effect

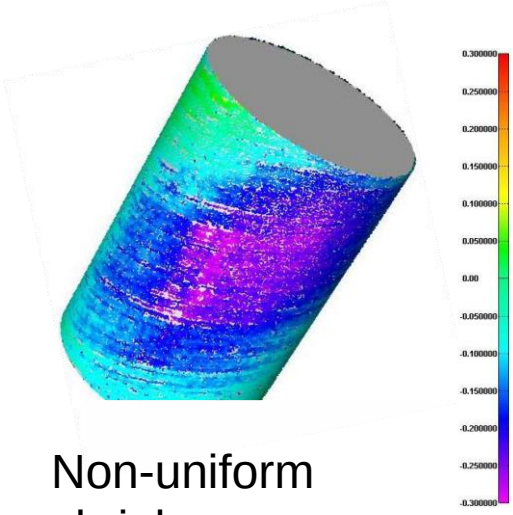
Mismatch of features

Non-uniform shrinkage

Mismatch of features

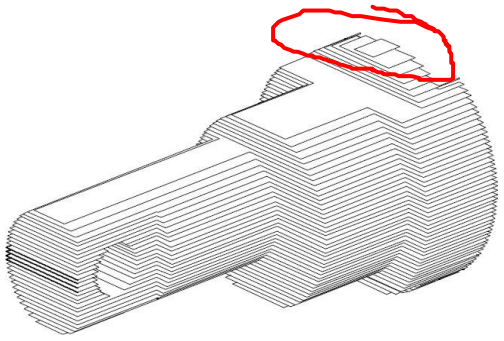


(Pham and Dimov, 2001)

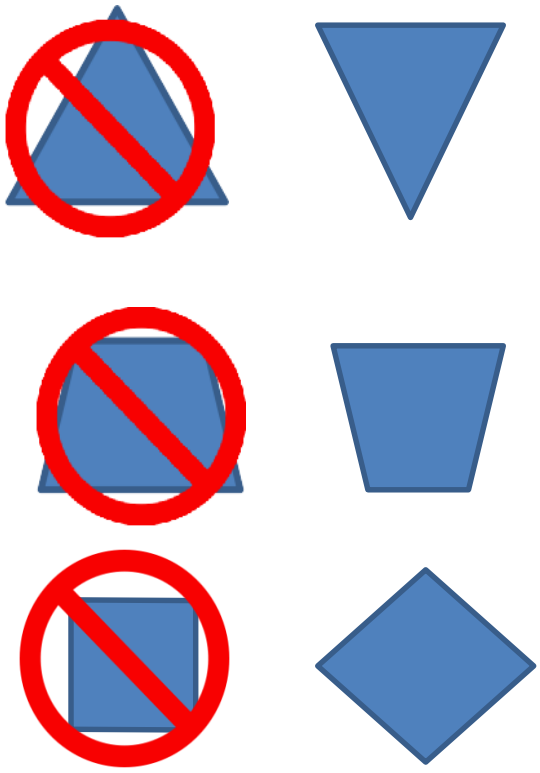


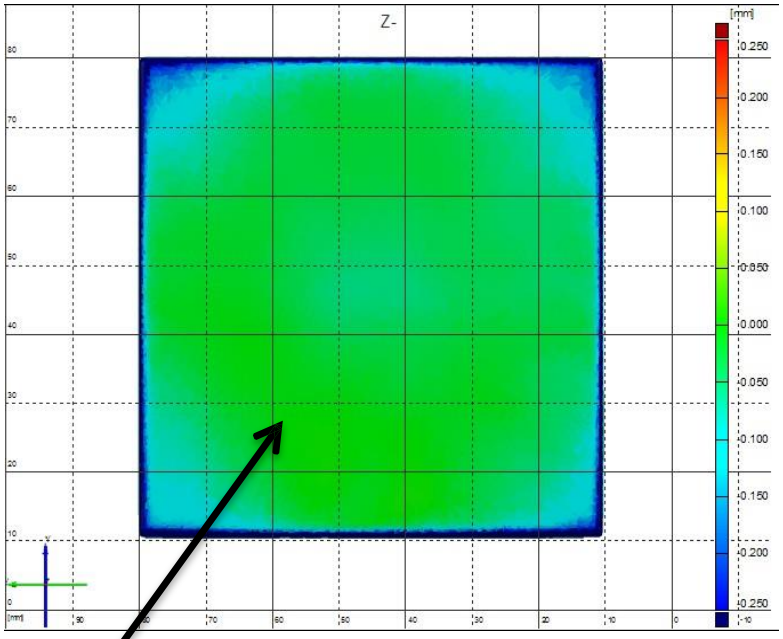
Non-uniform shrinkage

Stair step effect

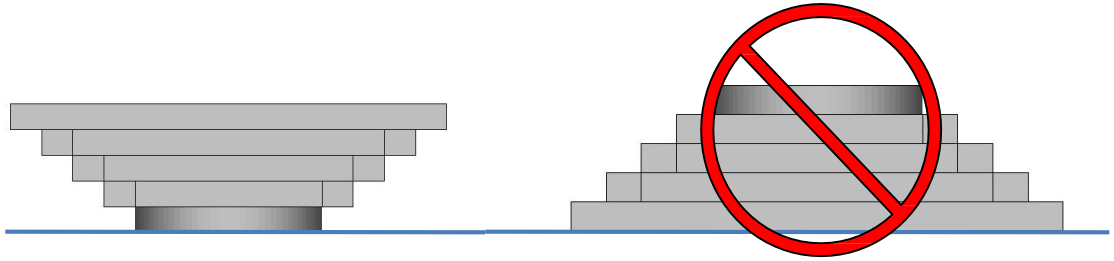


Avoid large flat area as the first layer



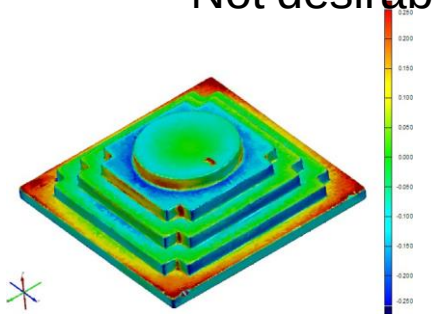


Deviation for a flat bottom of a part oriented to be the first layer



Desirable

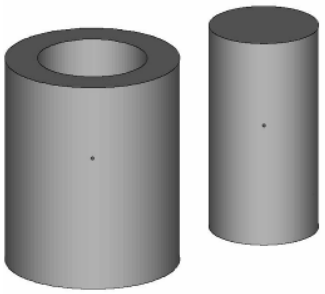
Not desirable



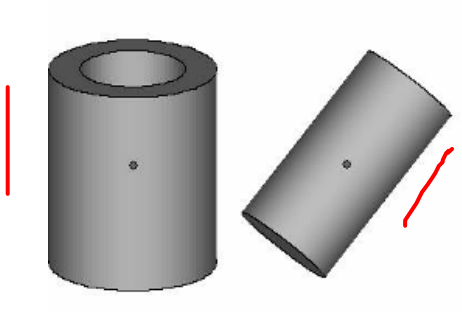
Assembly Consideration

Assembly Consideration:
If two cylindrical parts are to be assembled, orient the part axes parallel in build chamber.

Good Orientation

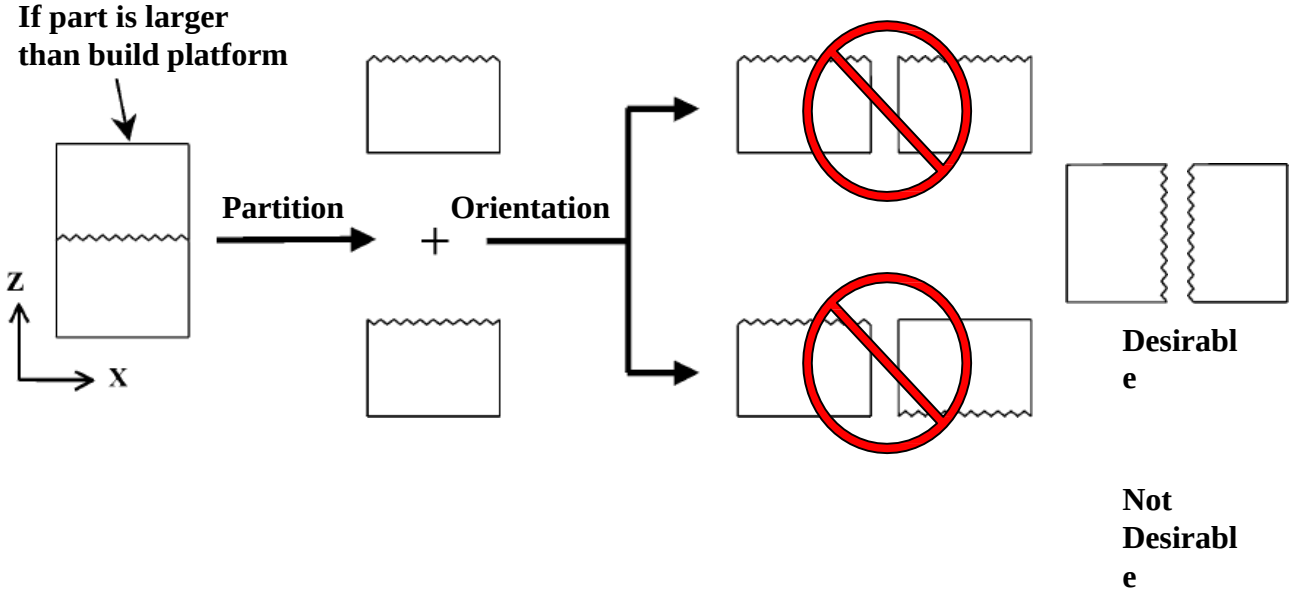


Bad Orientation

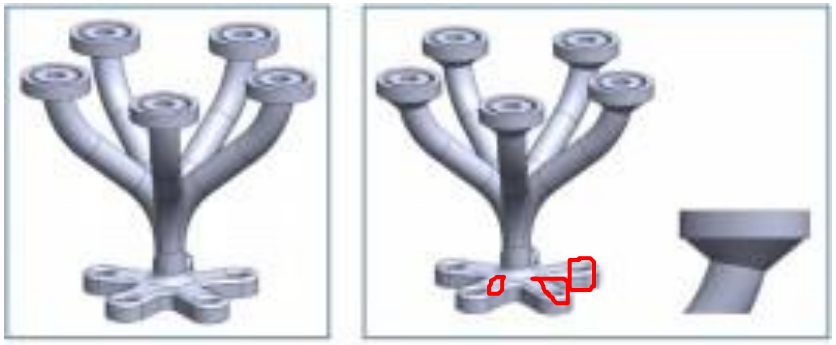


Due to stair step effect, clearance of a bush and shaft is high, when their axes are not oriented parallel in the build chamber.

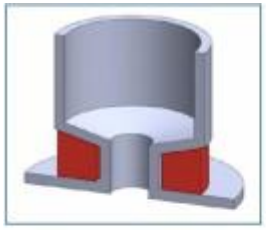
Partitioned surface should be oriented parallel in the build chamber



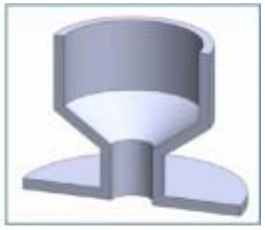
Design Guidelines



Add chamfers or fillets to overhanging geometry to make it self-supporting



Angles <30°: non self-supporting



Angles 30°-45°: self-supporting with rough surface finish

Angles >45°: self-supporting with smooth surface finish

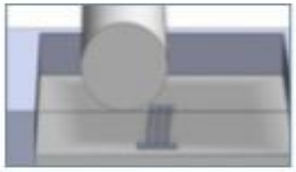
Fill

Lattice

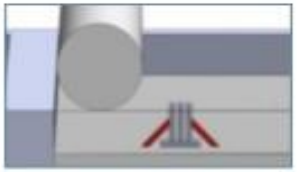
Offset

Gusset

Design rules



Force from the roller may cause tall, narrow parts to shift in the build

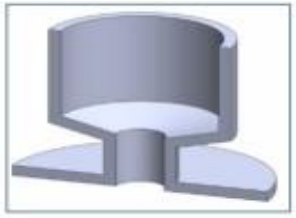


Support structures prevent parts from shifting in the build

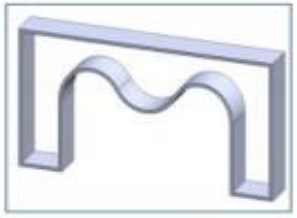
Overhang geometry may require support structures to successfully build using DMLS:

Horizontal surfaces

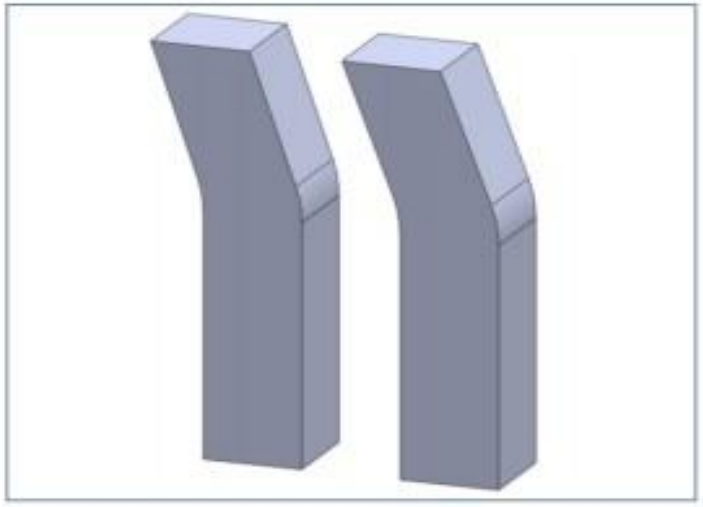
Large holes on the horizontal axis



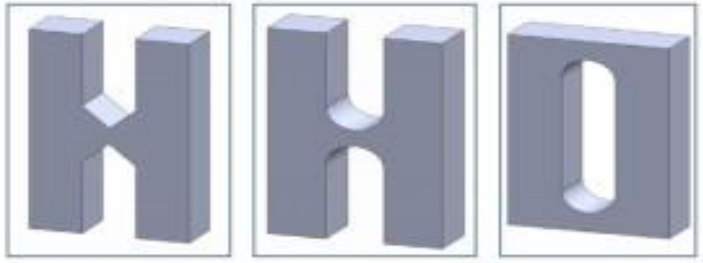
Angled surfaces <30°



Arches and overhangs

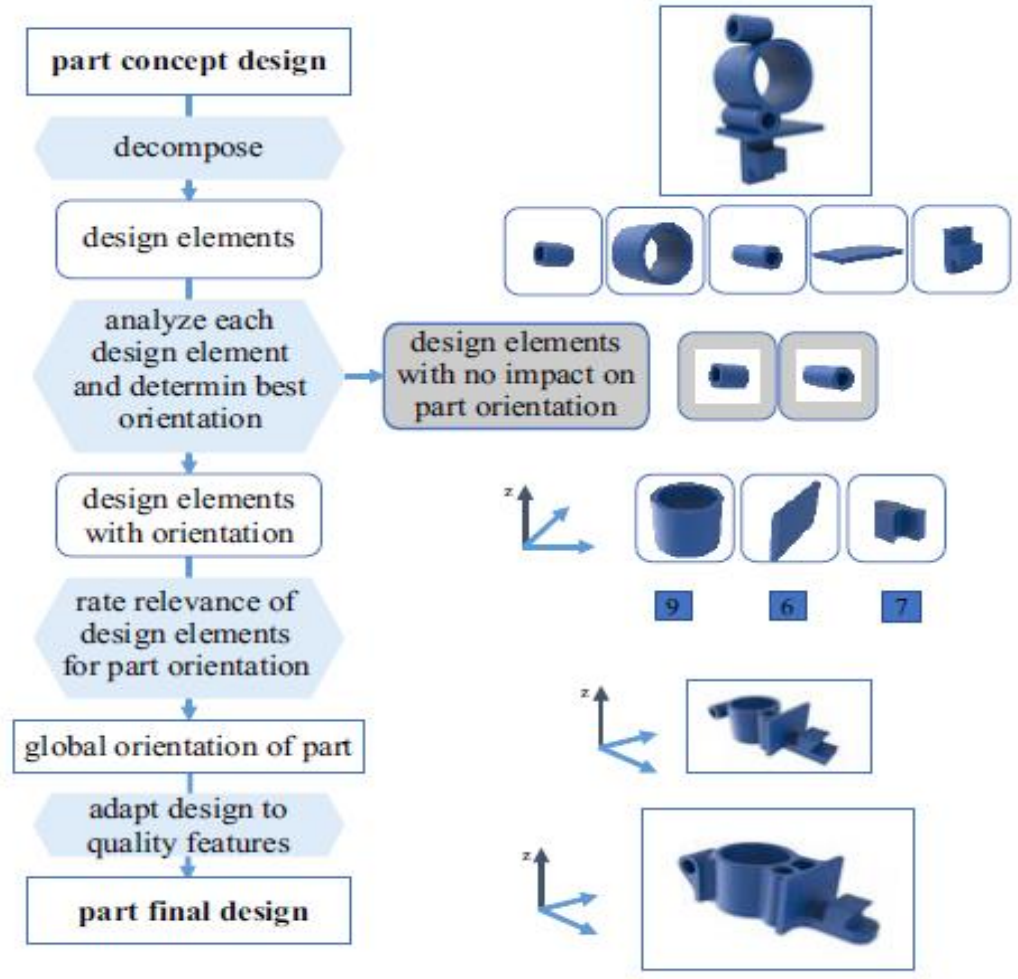


Example of warping on a tall, thin part without support structures



Examples of potential design improvements to prevent warping

part orientation in early design stage



Optimum orientation using Autodesk Netfabb

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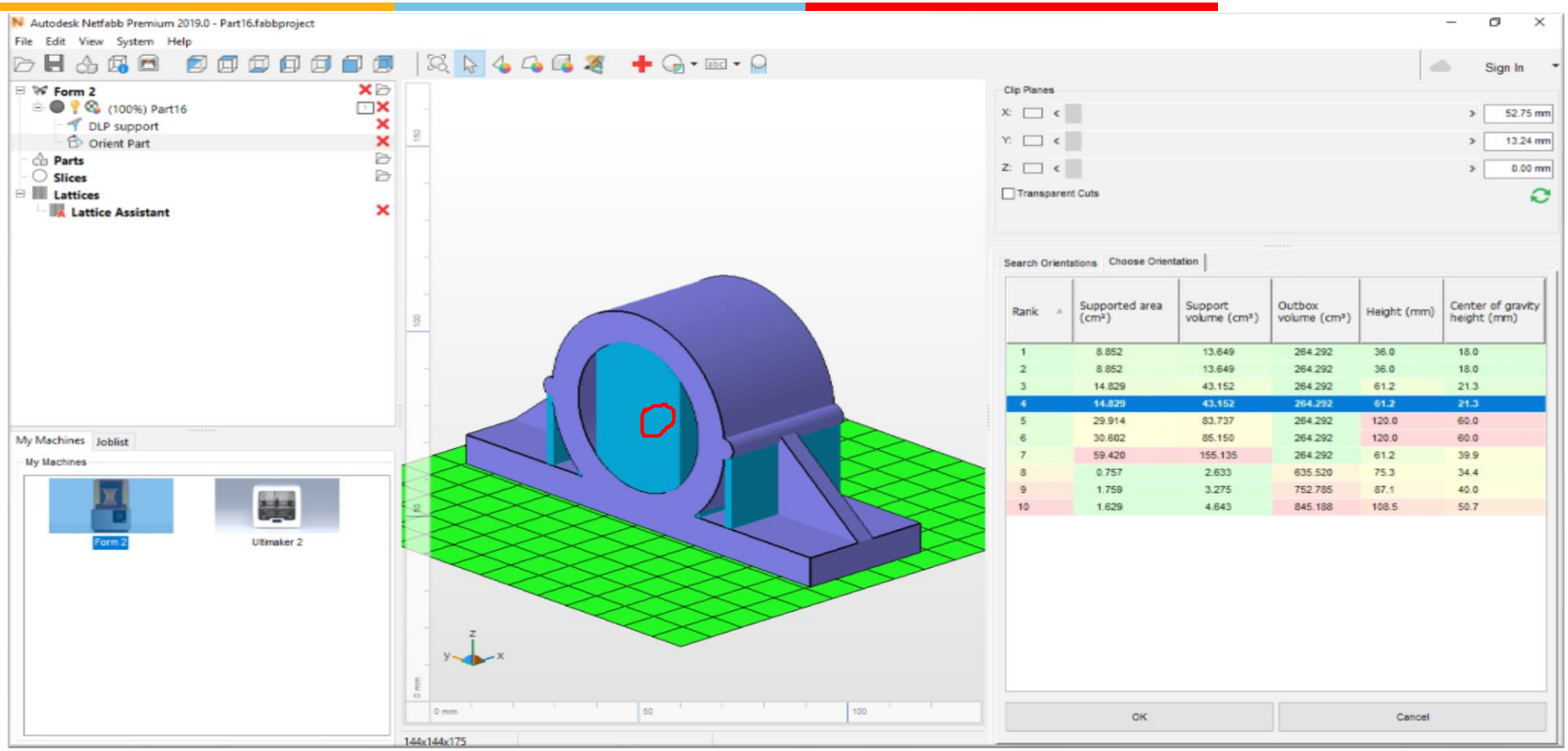
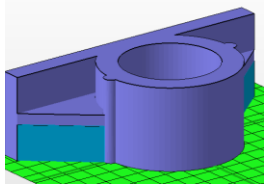
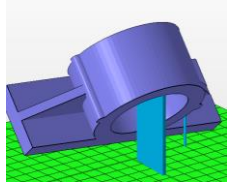
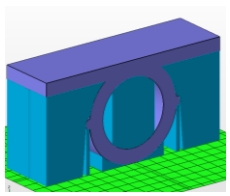
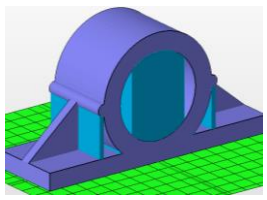


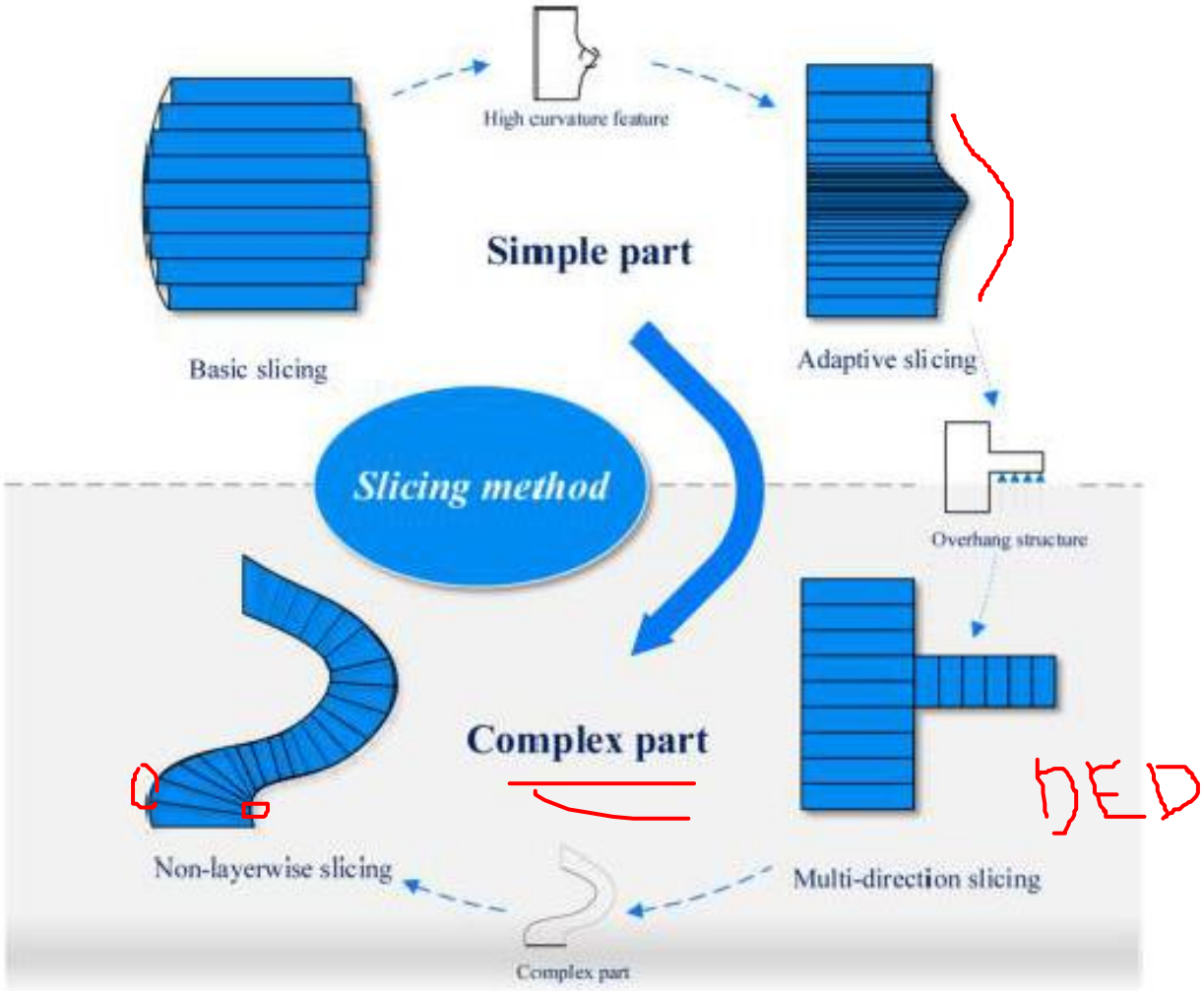








Slicing Strategy

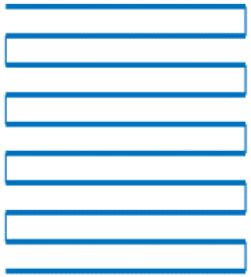


Slicing software

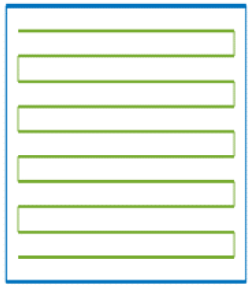
- Cura
- Slice3r
- Autodesk Netfabb
- Meshmixer
- Meshlab
- MatterControl 2.0

Path Planning

Raster

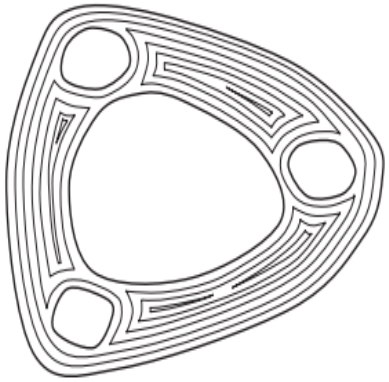


Zig-Zag

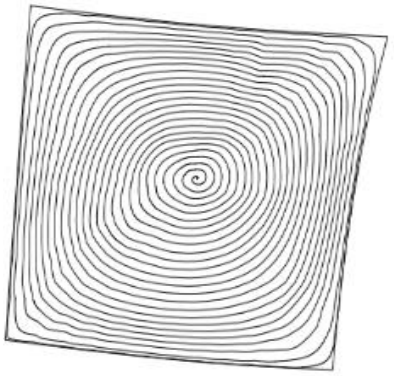


Hybrid

Continuous



Contour



Spiral

Part Consolidation

Part consolidation is nothing but reducing the no of parts by grouping the different parts with out compromising the functionality of the system.

Benefits of Part Consolidation

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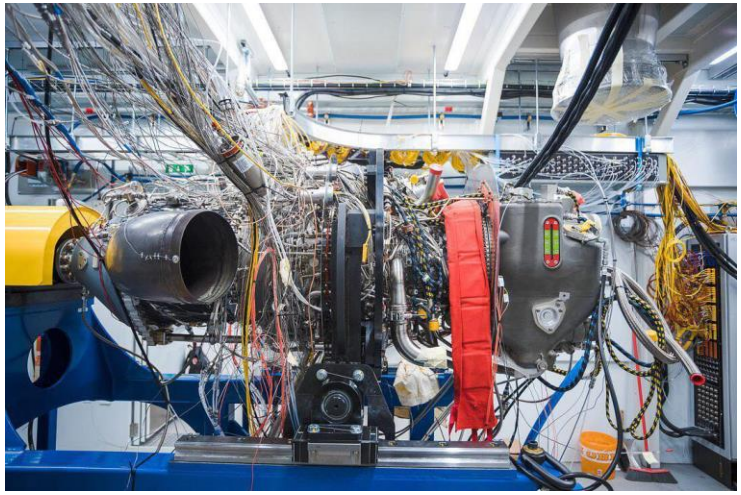
- Lower overall production costs
- Less material
- Lower overall risk
- Better performance
- Reduction in supply chain



Source:
https://3dprinting.com/tips-tricks/designing-for-additive-manufacturing-dfam/

Part Consolidation rules

(1) **Relative motion (R1)**: “CF_RelativeM”;

(2) **Material variance (R2)**: “CF_MaterialV”;

(3) **Assembly access (R3)**: “CF_AssemblyX”

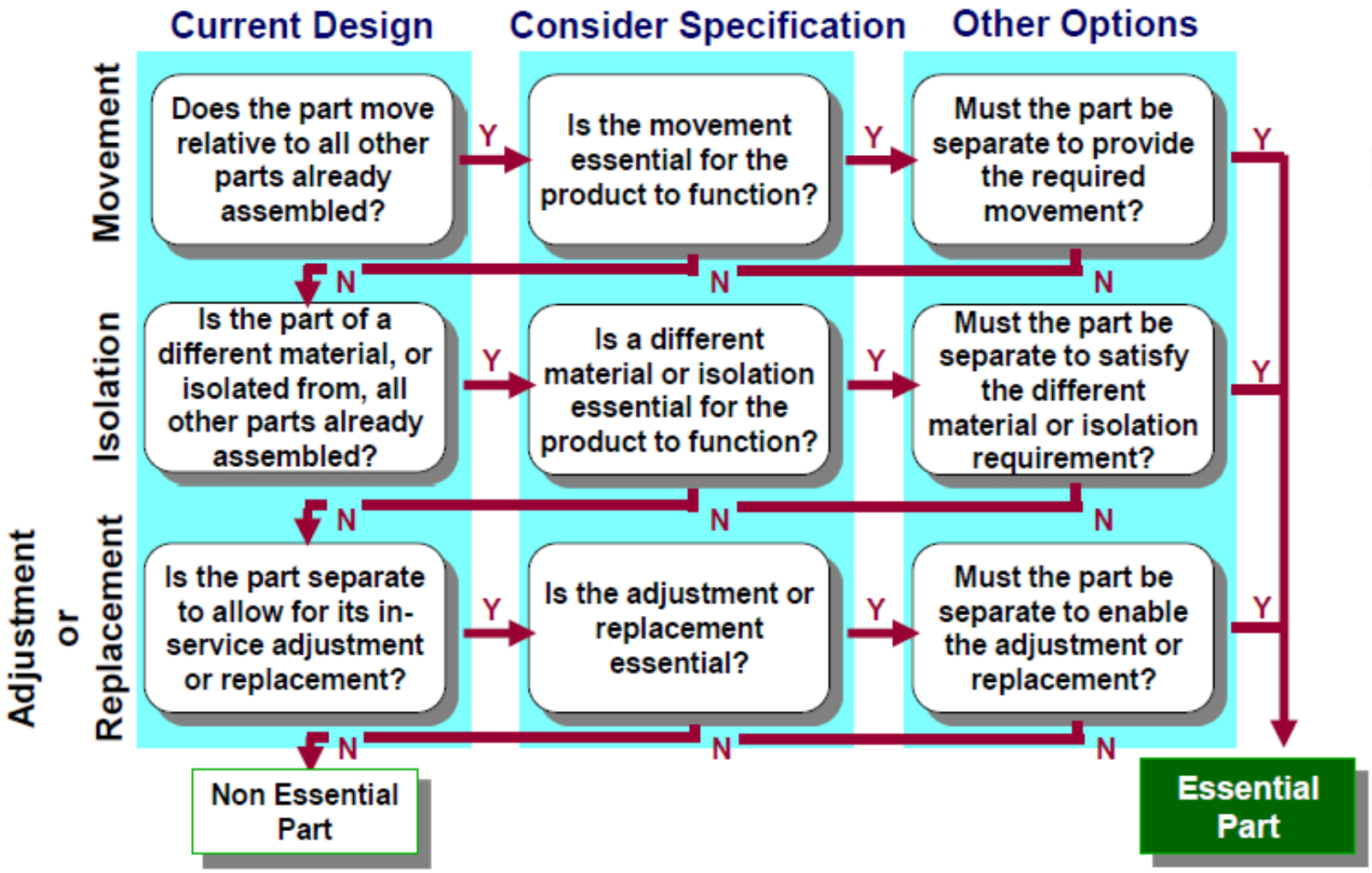
(4) **High-quality electronic/standard device (R4)**: “CF_StandardD

(5) **Size limitation (R5)**: “CF_SizeLimit”

(6) **Material availability (R6)**: “CF_Material0”

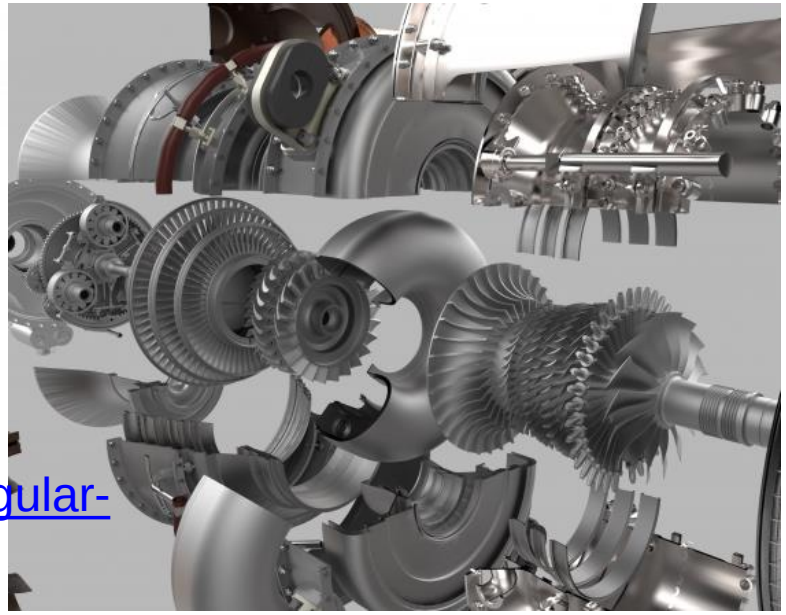
(7) **Maintenance frequency difference (R7)**: “CF_MaintenanceDiff”

Rule for Part Consolidation



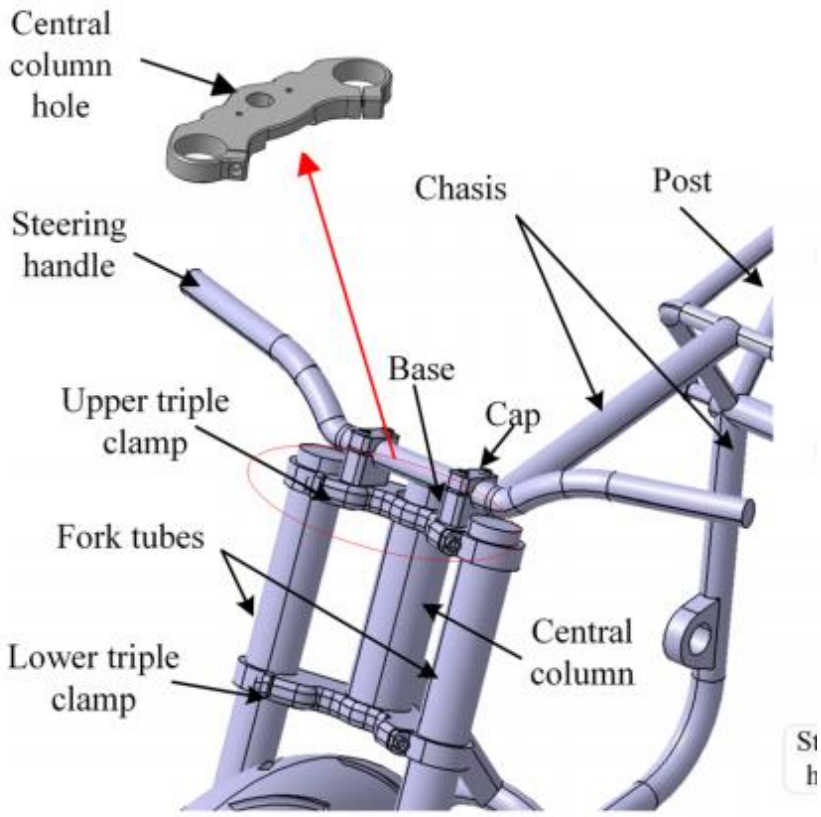
Case studies

GE Turboprop engine 855 to 12 Parts



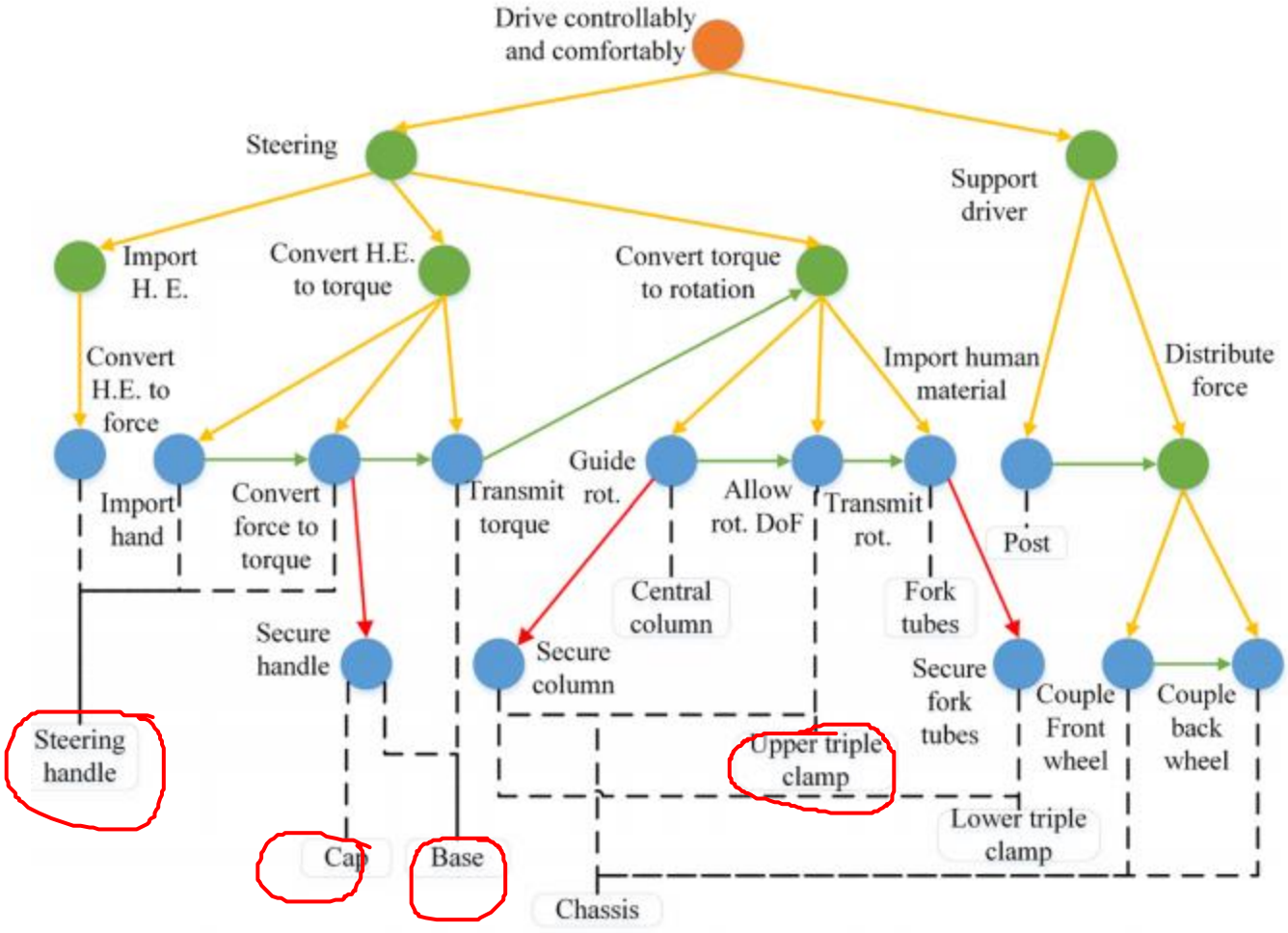
Source: http://www.leolane.com/blog/multiple-singular-consolidating-parts-additive-manufacturing/

Throttle Pedal PC

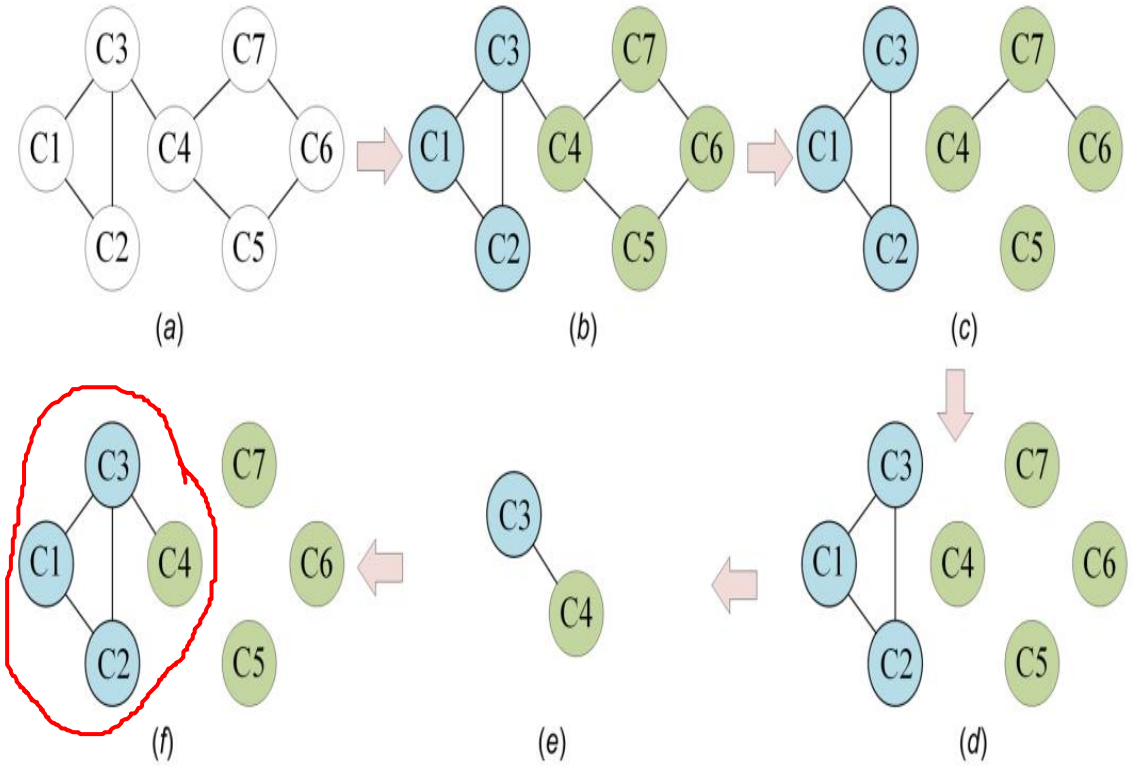


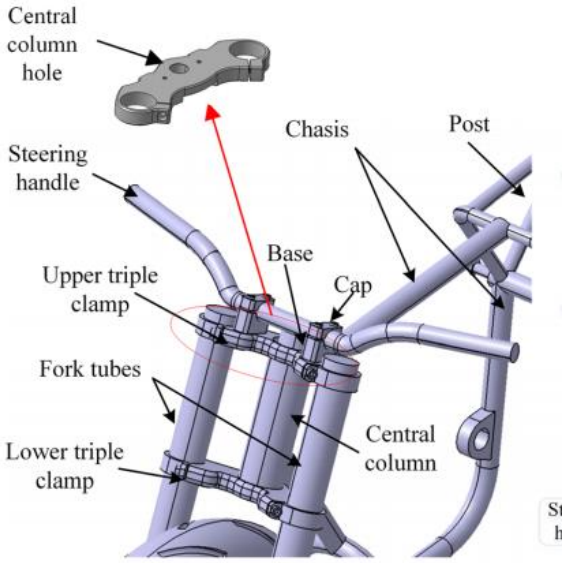
Source:
https://asmedigitalcollection.asme.org/mechanicaldesign/article/140/3/031702/367606/Additive-Manufacturing-Enabled-Part-Count

Function-Function carrier view



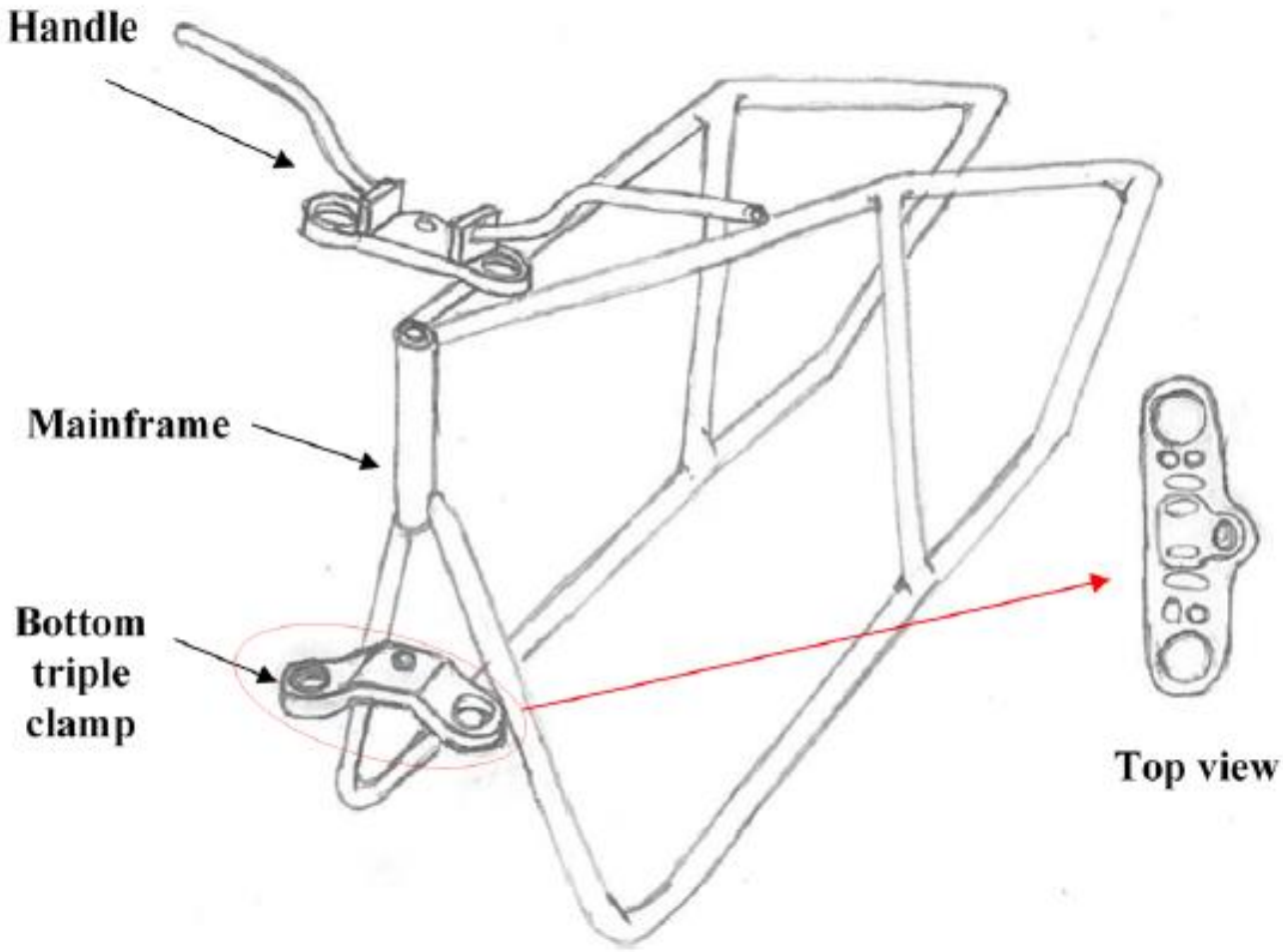
Level 1 Screening





C1 – Steering Handle, C2- Cap, C3- Base, C4- Upper triple clamp
C5- Fork Tubes, C6-Lower Triple clamp, C7- Main Frame

Consolidated Part



innovate achieve lead

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End of Lecture 7-8