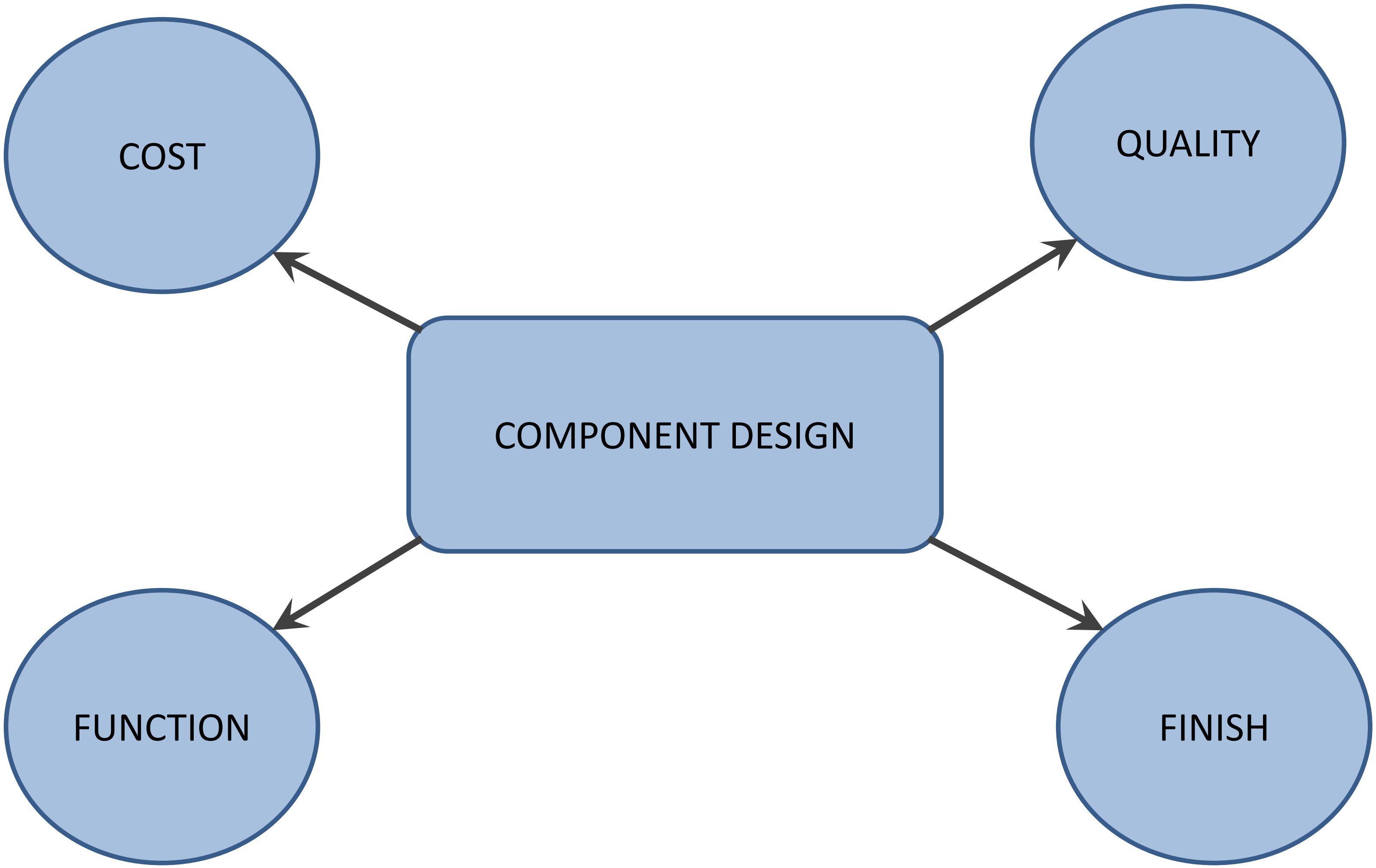
Designing for Additive Manufacture – an introductory guide

A Guide from Aben – September 2018

Technology Drivers



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Common AM Technologies

Technology	Materials	'Relative' Cost per g†
Stereolithography	Acrylic and epoxy photopolymer resins. Some contain fillers, e.g. ceramics	50
Selective Laser Sintering	Mainly nylons, many with fillers, e.g. carbon fibre/graphene – glass or metal powders	20
Fused Deposition Modelling	POM, ABS, PC, ULTEM, Nylon, PPSF	50
Direct Metal Laser Sintering	Steels, Bronze, CoCr,	200
Powder/binder technology	Starch, various plastic powders	20
Inkjet material systems	Photopolymer Resins	40
Ballistic Particle Manufacturing	Plastics (under development)	80

†This is very approximate and will depend upon the geometry of the parts

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Traditional Manufacturing

- Traditional manufacturing
  - Pouring liquid into a mould (and solidifying)
    - Injection Moulding, casting, concrete etc
  - Extrusion
    - Plastic or metals forced through die
  - Pressing flat sheets between tools
    - E.g. car bodies
  - Cutting
    - Milling, turning grinding, EDM

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Traditional Manufacturing Rules

- Low cost requires tooling
- Tooling tends to be expensive
- Complexity adds cost
- Can be specific manufacturing limitations:
  - Undercuts, draft requirements, wall thickness requirements, corners may need to be rounded, etc etc.

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Traditional Manufacturing Costs

- Part Cost =
  - + Amortised design + development cost
  - + Amortised tooling cost
  - + Tool Set-Up charge
  - + Moulding machine running costs
  - + Material cost
  - + Post Processing time
  - + Finishing cost
  - + Overheads

As numbers manufactured increases the cost per part drops due to amortisation but also due to ‘buying power’ relating to materials and to machine utilisation.

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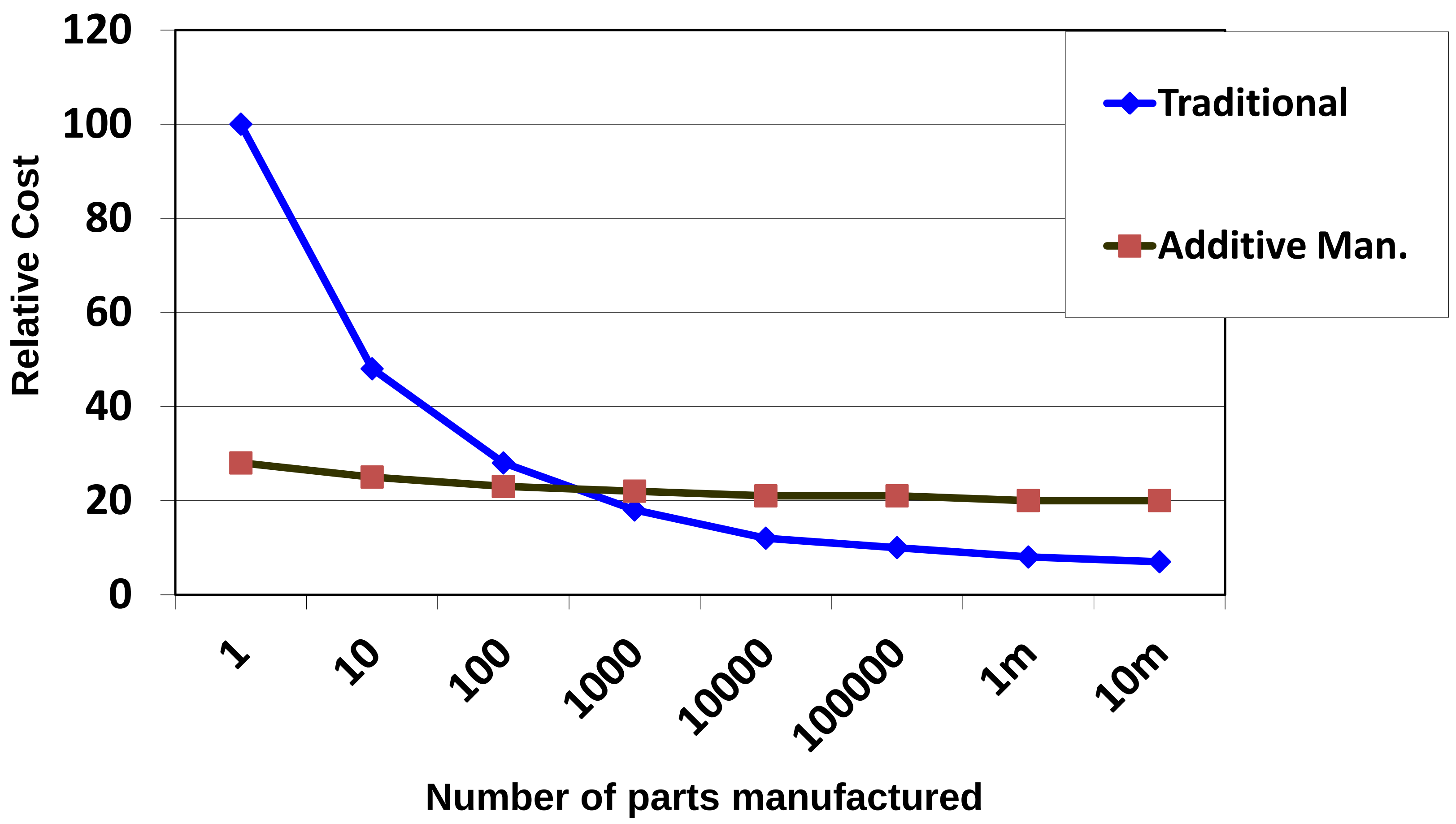
AM Manufacturing Costs

- Part Cost =
  - \+ Amortised design + development cost
  - \+ Material cost
  - \+ AM machine running costs
  - \+ Post Processing time
  - \+ Finishing cost
  - \+ Overheads

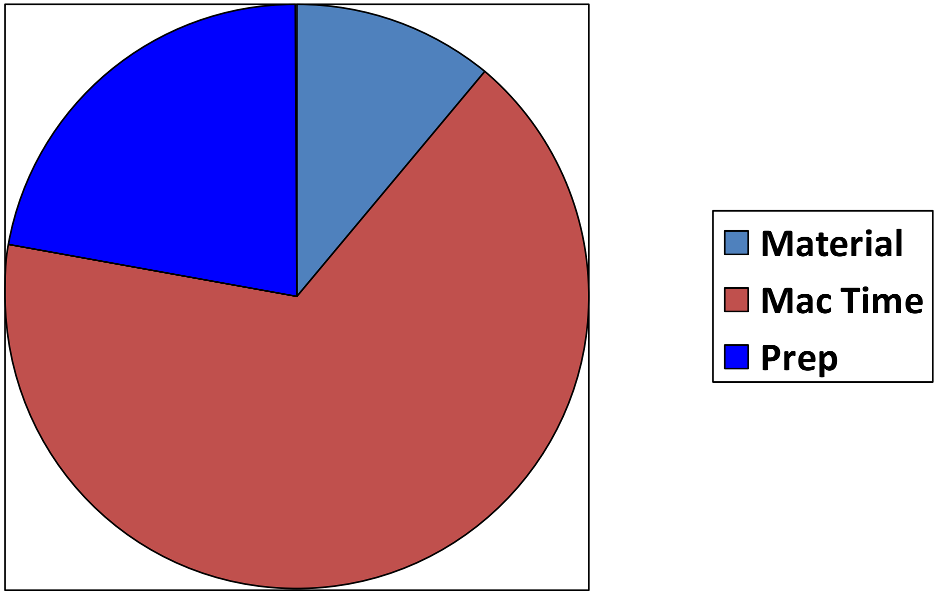
Cost per part does not vary much as numbers increase.

Comparison of Costs



How parts are costed

- SLA, FDM, DMLS, (Typical model)
  - Part cost = material + machine time + (finishing costs) + preparation fee



Longer it takes to build the part – the more expensive it is.

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Costing Issues for SLA, FDM,DMLS

- Time it takes to build part depends upon:
  - Mass of Part
  - Height of Part
  - Amount of support structure
- Prep time depends upon:
  - Quality of supplied SLA file
  - Amount of support structure to put on and remove afterwards

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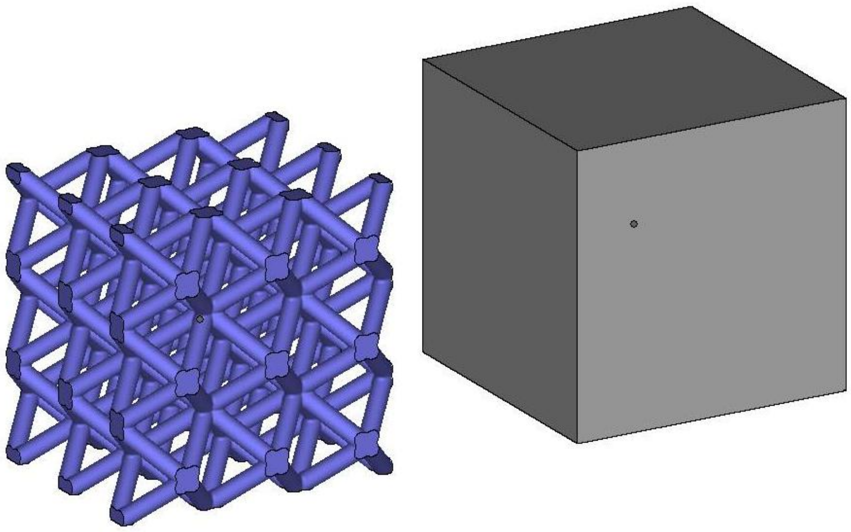
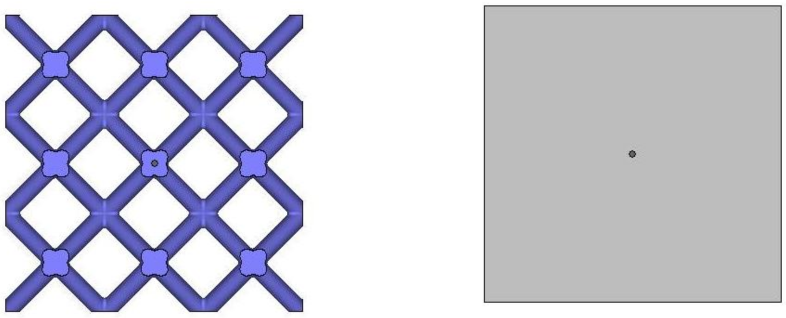
Design Tip 1 – Remove material wherever possible!

- Complex parts don't cost any more to build & usually cost less, as long as they don't require



The lattice is cheaper to build (less mass) as long as it doesn't need lots of support



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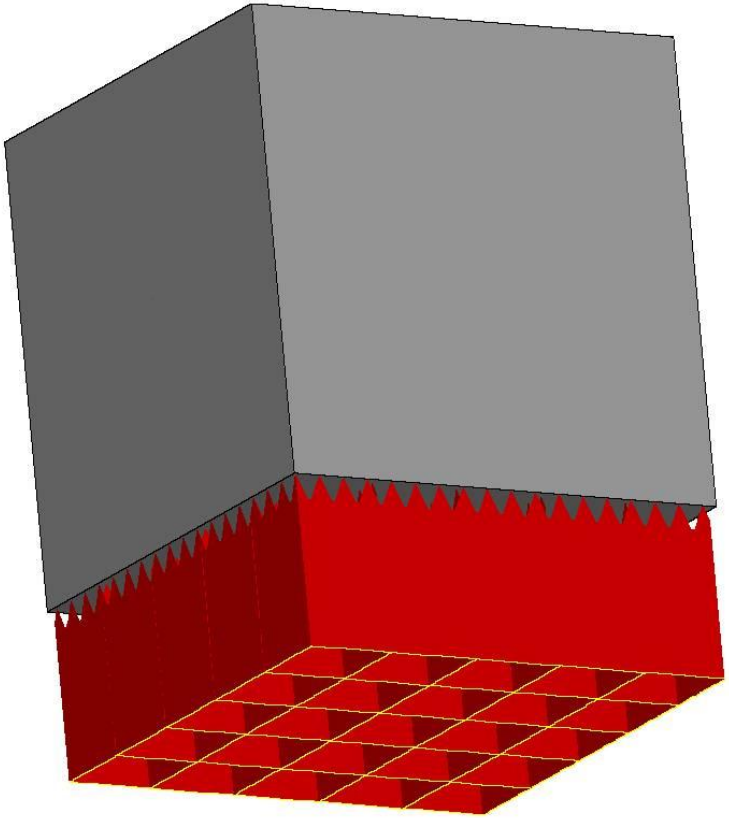
Support Structure

- Many AM processes (DMLS, SLA etc) require that parts are 'supported'



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Technologies Requiring Support Structure

Additive Manufacturing Technology	Support Structure Required?
Stereolithography	YES
Selective Laser Sintering	NO
Fused Deposition Modelling	YES
Direct Metal Laser Sintering	YES
Powder/binder technology	NO
Inkjet material systems	YES
Ballistic Particle Manufacturing	YES
Paper Manufacturing System	NO

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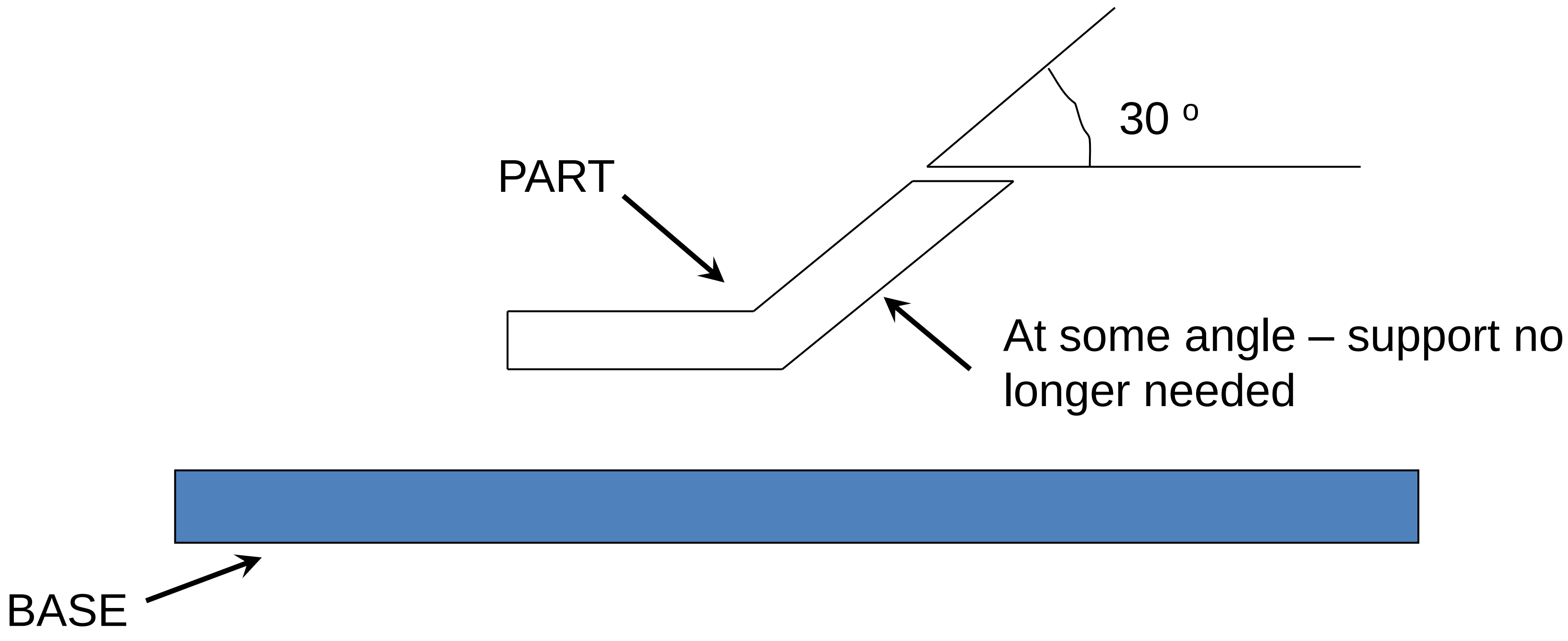
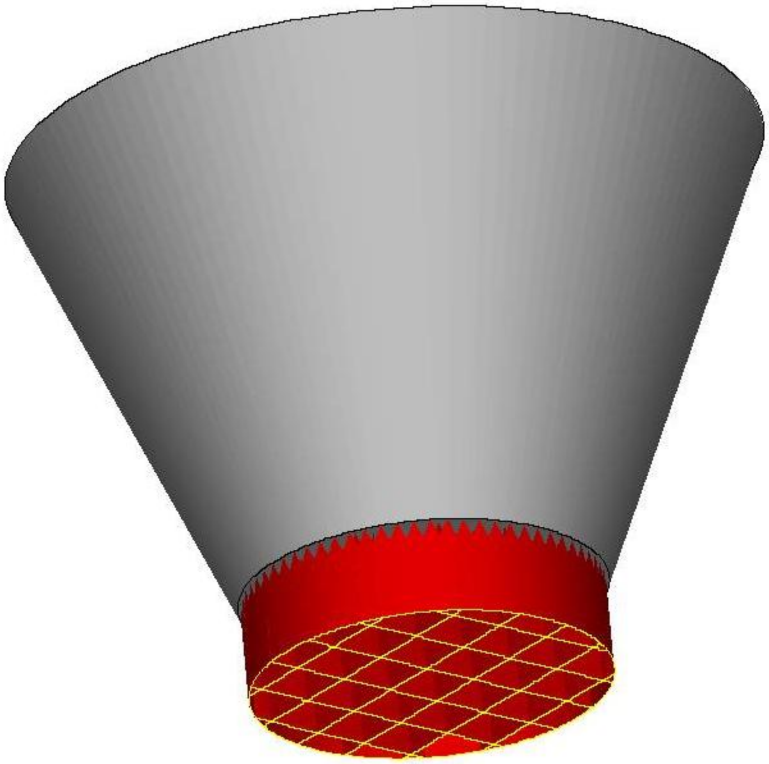
Unsupported Surfaces



Example - cup

- Less support
  - Easier finishing
  - Less labour
  - Less material use
  - Quicker builds
  - Cheaper parts!



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Controlling support needs

- Cosmetic requirements
  - Support always leaves cosmetic damage which needs repair
  - Support needs labour to remove it
  - Support can be difficult to remove
  - Surfaces can appear ‘pillowy’

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Cosmetic quality of parts

UP-FACING

GRADE ‘A’ Quality

Try to have this for visible surfaces

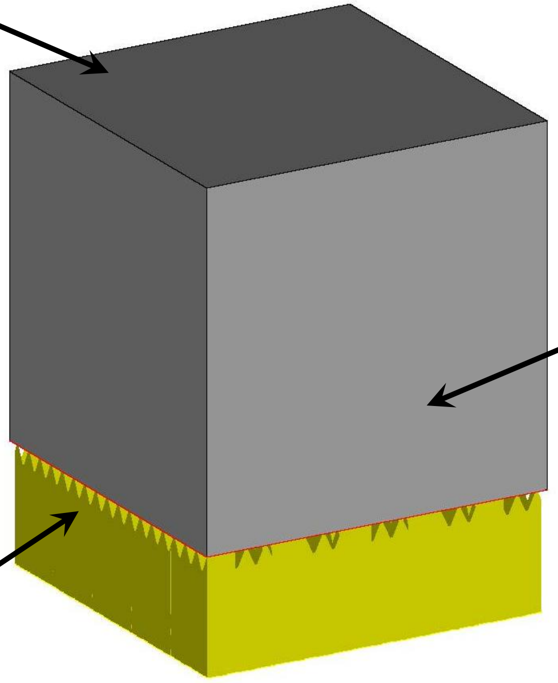
Try to have these parallel to build platform

AVOID gentle slopes!

SIDE WALLS

GRADE ‘B’ Quality

May be acceptable for visible surfaces



DOWN-FACING

GRADE ‘C’ Quality

‘Hidden’ surfaces

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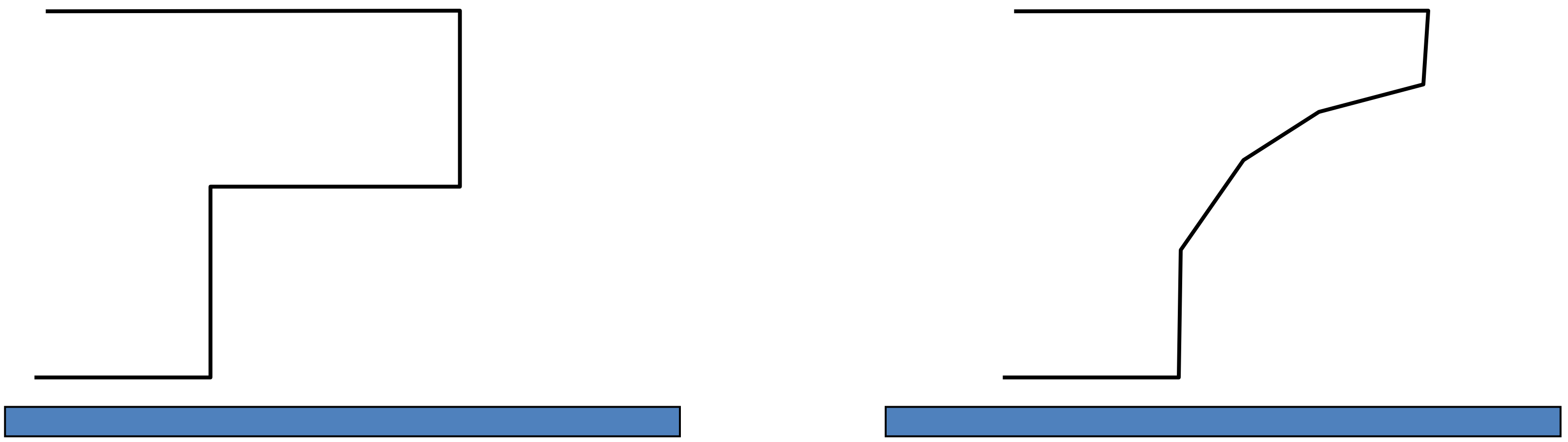
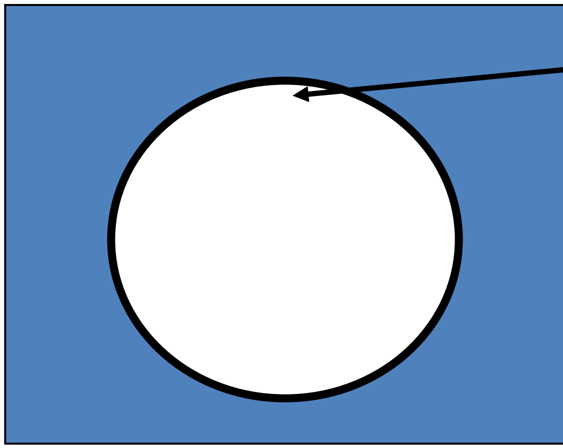
Design Tip 2
Strategies for dealing with support

- Overhangs

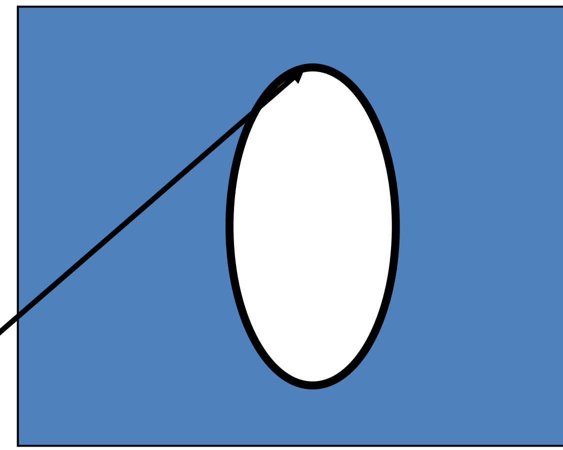


Try to avoid horizontal down-facing surfaces

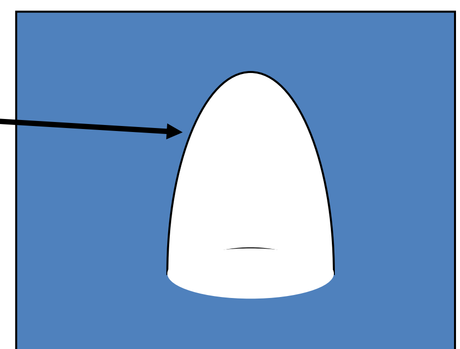
Design Tip 3
Large bore horizontal holes



Large bore horizontal holes may need support at the top of the hole



To counter this, try to reduce the Radius of Curvature at the top by using an ellipse or rounded triangle



Design Tip 4
Wall Thickness

Each process has a minimum useable wall thickness

Process	Minimum wall (x-y) mm	Minimum wall (z) mm
SLA	0.5 – 0.7	0.8
SLS	0.8	0.8
DMLS	0.4 -0.7	0.3
FDM	1.0	0.8

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Design Tip 5
Traditional rules which can be broken

- No draft needed
- No rounded corners (watch out for stress raisers though!)
- No ejection points needed
- Thick and thin walls can be mixed
- Re-entrant shapes fully allowed
- Any complication you like (watch out for support!)
- No shrinkage issues
- Saving weight is no problem

Design Tip 6

- Accuracy (X-Y)

Process	Absolute	+%
SLA	± 0.15	± 1.0
SLS	± 0.2	± 1.5
DMLS	± 0.05	± 1.0
FDM	± 0.05	± 2.0

Note - Z accuracy usually slightly worse.

Design Tip 7

- Design to Mean Material Condition
  - Machine errors are random
  - The machines can not be set to build parts to Minimum Material or Maximum Material conditions
  - Best results are always found by designing CAD to Mean Material Condition, and using tolerance control to ensure function of parts will not be impaired by the machines inaccuracies

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Design Tip 8
File Sizes

- The scanners (print heads) of the machines usually work to a grid of about 12 ‘pixels’ per mm. (about a 0.08 mm grid)
- Your STL file does not need to be significantly more accurate than this, i.e. do not set the point collection grid to 1 micron.
  - If you do you will create huge STL files which are difficult to process and the resulting part will be no more accurate, indeed it can be worse due to scanner ‘dwell’

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Strength of Parts

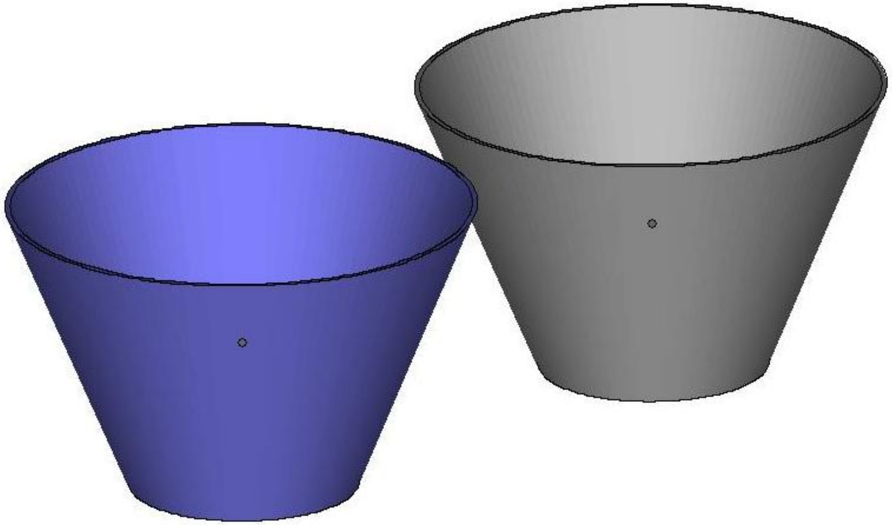
- The mechanical properties of ALM parts are not uniform
- If the recoater operates in the 'X' direction then in terms of reducing performance the axes are:
  - Y (best)
  - X (next)
  - Z (worst)

Special Issues for SLS

- SLS is a slightly different process as
  - It does not need support structure
  - Can build 3D arrays of parts

Reducing part costs with SLS

- With SLS the mass of the part is not really a driver of part cost
- Example - containers



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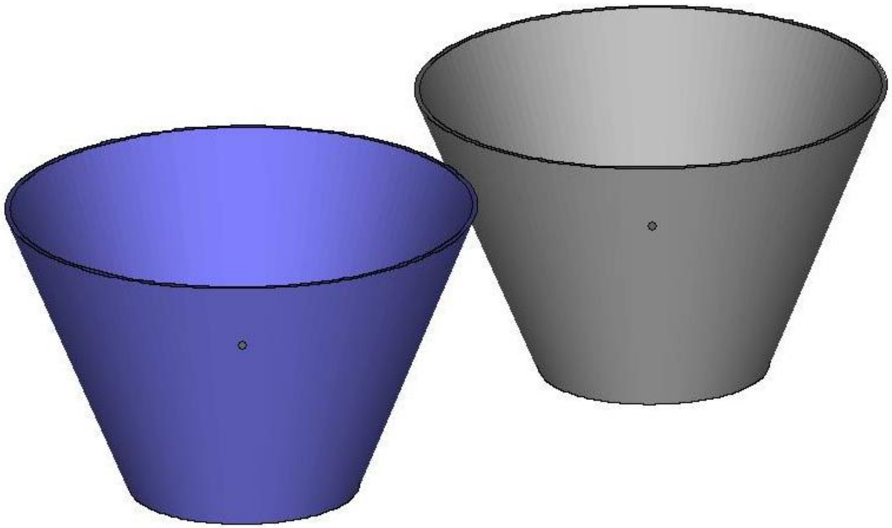
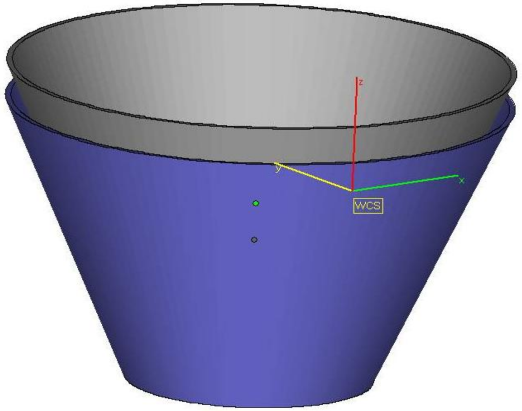
Reducing part costs with SLS

CONFIGURATION 'A'



CONFIGURATION 'B'



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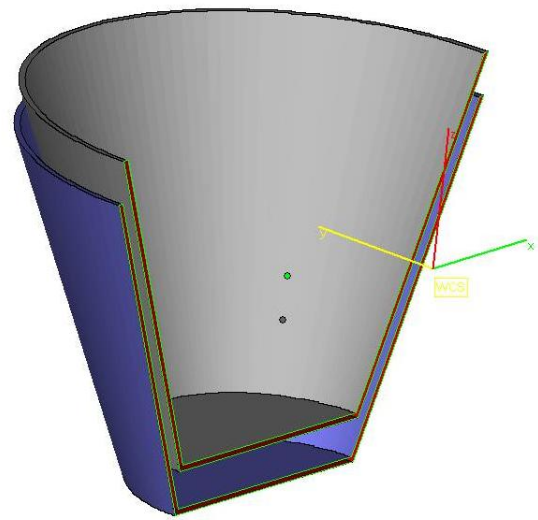
Design Tip 9 – Nest SLS parts or families of parts if possible

- Configuration A is almost twice as expensive to build as SLS parts as Configuration B
  - Note – this only works when there is no support structure (SLS Binder/powder systems)



CONFIGURATION 'B'

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