PADT
3D Printing

Design Guidelines for 3D Printing Parts and Tooling

Agenda

PADT 3D Printing

- Things to Consider
- Defining 3D Printed Parts
- Examples
- Resources

Success with Design for 3D Printing

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Actually Designing for End Use Parts

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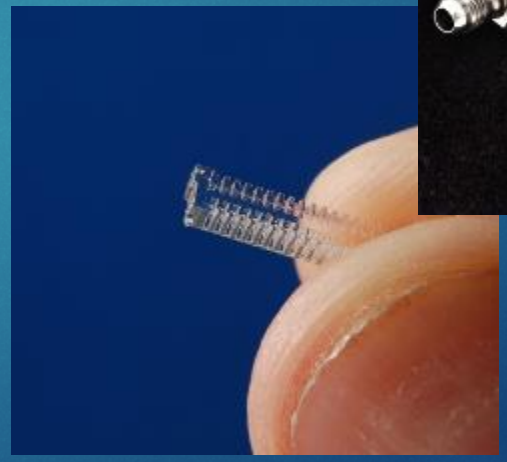
- End Use Parts:
  - Made to be used outside of prototyping
  - Test Fixtures
  - Tooling Fixtures
  - Product Parts
- Prototype parts are one time, throw away
  - Don’t need to be rigorous
  - Good enough is good enough
- End Use 3D printed is the same as End Use milled or injection molded.



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Things to Consider

STUFF THAT IS DIFFERENT, THAT YOU NEED TO TAKE INTO ACCOUNT

Materials

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- Each technology offers multiple material options
- Dozens of plastics
  - Goal was for prototyping
  - Now its about functional material
  - Workhorse for end-use is FDM ABS and ABS-like SLA and Polyjet
  - Newe: color, clear, rubberlike, nylon, Polycarb, Polypropylene, Ultem
  - Wide range of operating temperatures
  - Better UV protection
  - New materials come out about twice a year
- Metal
  - Standard powder metal
  - Aluminum, Cobalt-Chrome, Titanium, Steels, Nickel Alloys

Material Selection

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- Always consider:
  - Strength
  - Stiffness
  - Poison's Ratio
  - Environment
    - UV
    - Temperature
    - Chemicals
  - Aesthetics
- To Study, make samples of typical geometry
  - The flat coupons may not be representative
  - Make parts in several materials and test

Supports

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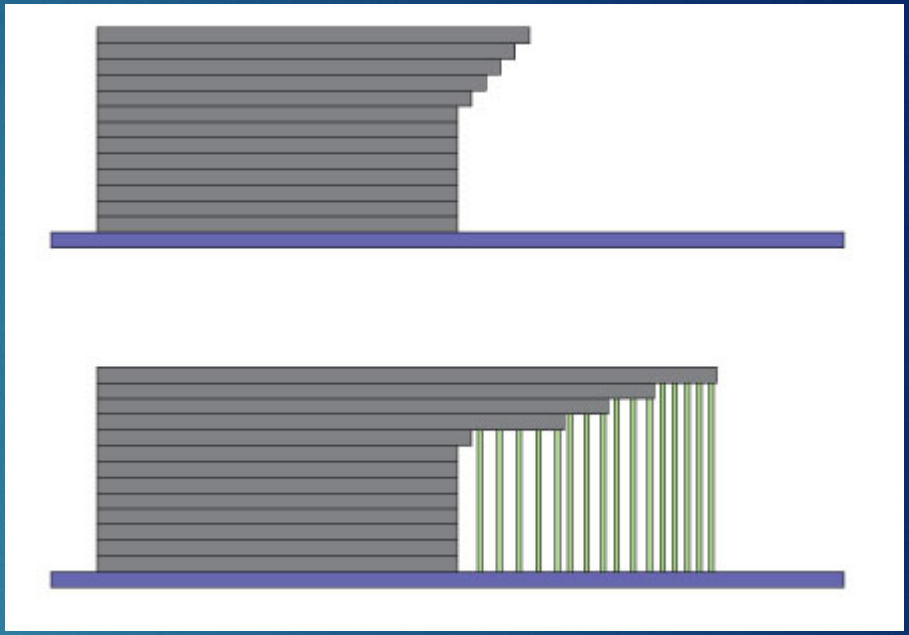
- Every manufacturing method has something you need to work around
- For AM, the issue is **supports**
  - As you put down a layer, there must be something to hold an overhang up
    - Powder in powder bed processes
    - Support material in Polyjet & most FDM
    - Build material in other systems
- Each process has an overhang angle that requires some support
- Metal powder based need supports
  - Warping, thermal management
- All powder needs a way to get powder out of internal features



Supports: FDM

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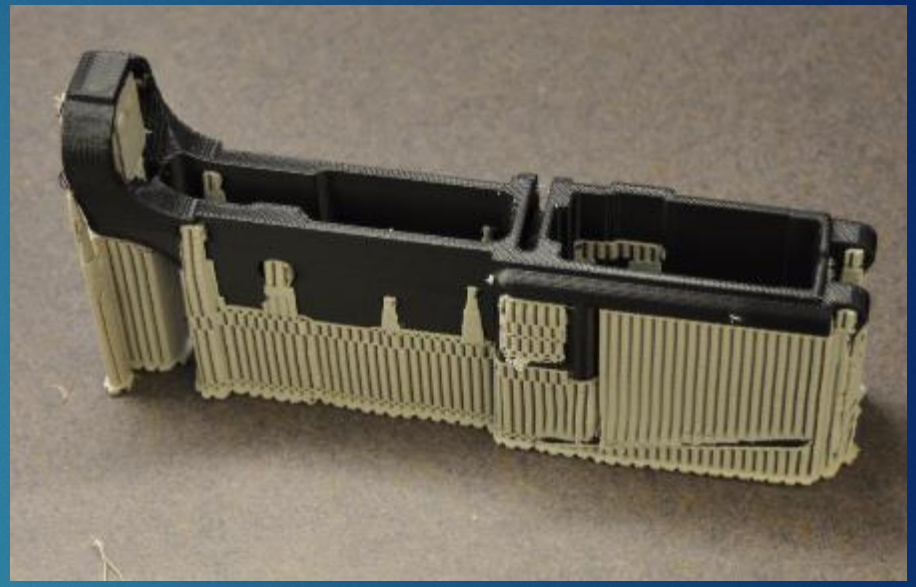
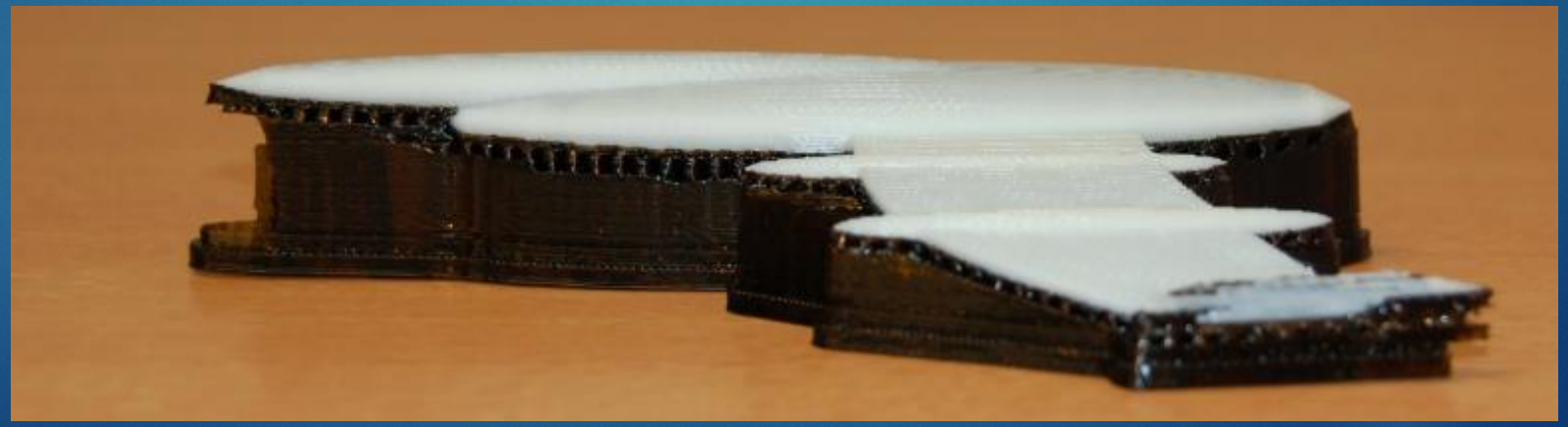
- Breakaway or soluble
- Soluble is the least bothersome and has little impact on part
- Design for removal:
  - Features need to survive breakaway removal
  - Features need to survive warm turbulent water bath for soluble
  - In soluble, water needs to be able to get to support material – holes and channels big enough





Supports: SLA

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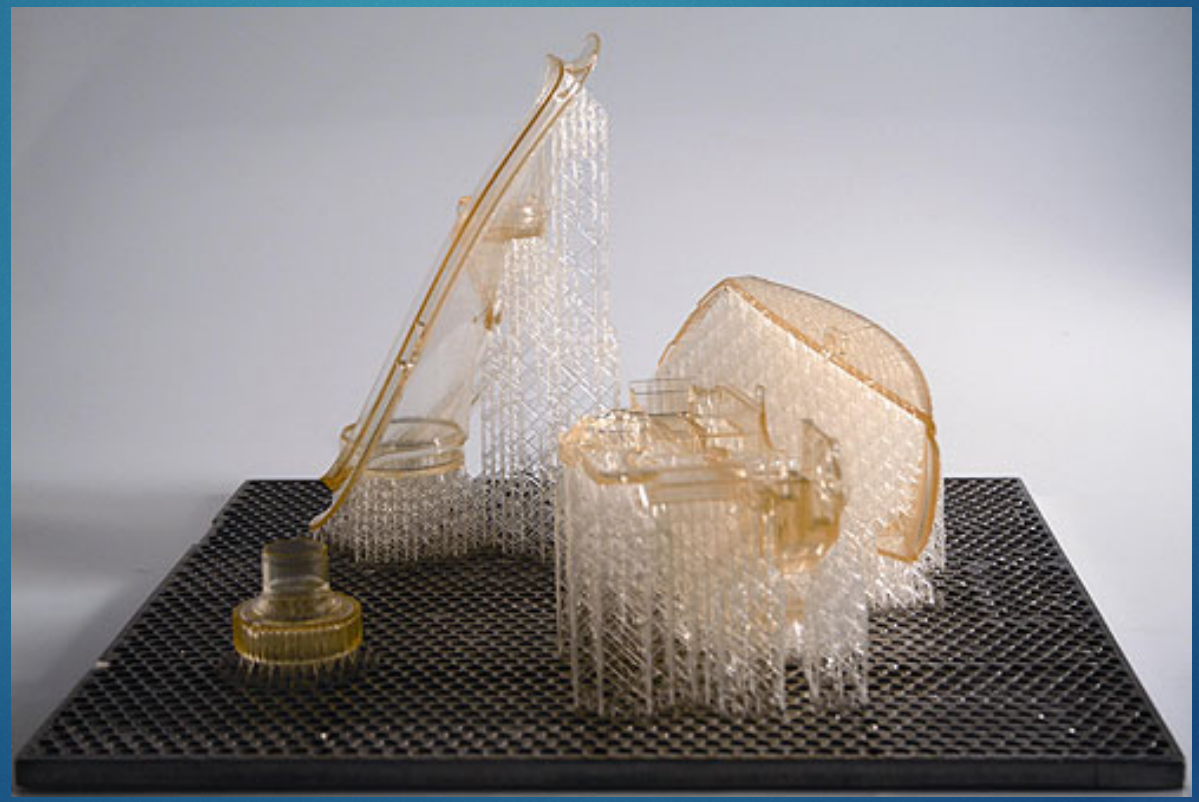
- Cut off with sharp knife
- Downward surfaces need to be sanded



Supports - Metal

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- Hold the part to a base plate and keep it from warping
- Conduct heat away from the build surface
- Material must be cut with Wire EDM or Machined off
- Surface may need further machining, grinding
- Need to be able to get at the supports inside

Orientation – Design for it

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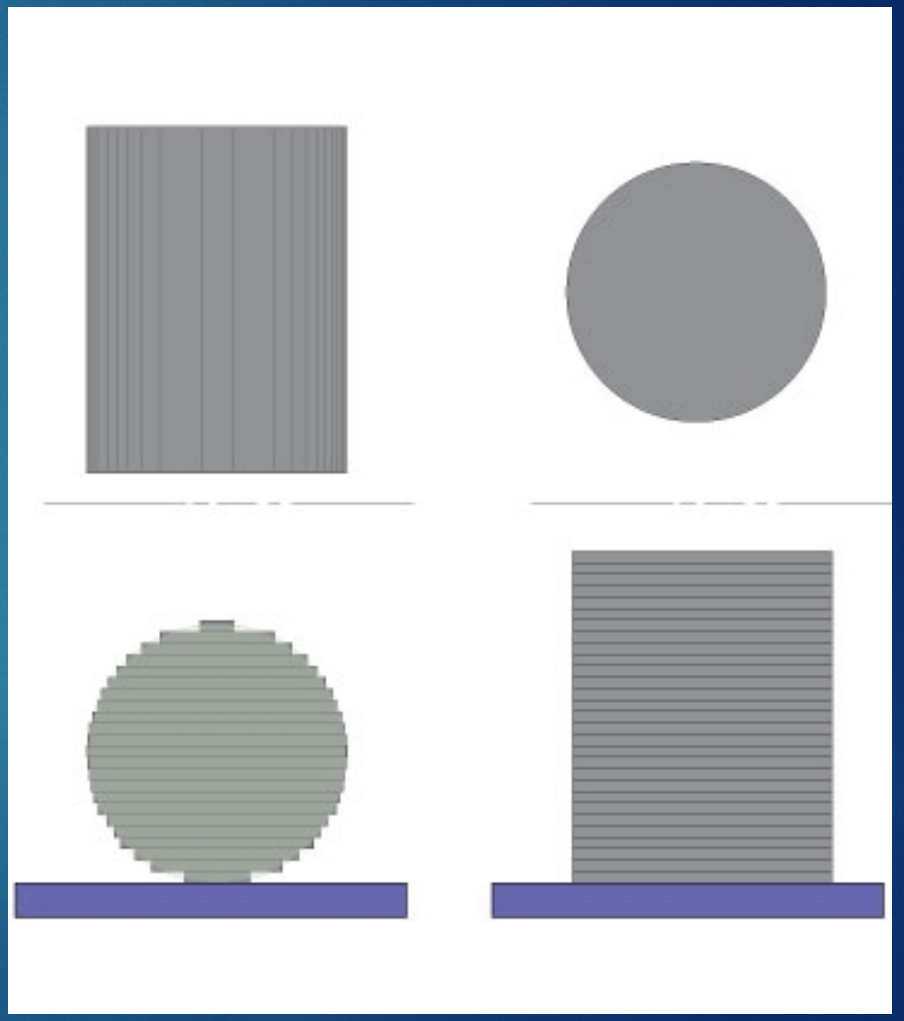
- Remember, you are building up one layer at a time
  - Strength varies in Z vs X and Y
  - Min tolerance is the min layer thickness +/- process tolerance
  - Process creates stair steps, orientation determines where they are on a part
  - Some features are easy in X and Y, but hard in Z
  - Supports
  - Warpage is usually warping of the X-Y plane
- The orientation of the part in the machine is a design consideration
  - Design to take advantage and avoid short comings
  - Self supporting if possible, or at least minimize the need for support



Supports – Design Issues

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- How Supports are removed is important
  - Manual for most processes - Cost
  - Impacts surface finish where supports touch part
  - Need access to get supports out even if powder or soluble
  - Removal may damage the part or change its shape

Machine Constraints

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- Remember – Layers and droplet/beam/bead thicknesses
  - Not like machining where you can have any value +/- tolerance
  - Dimensions are discrete
    - Layer thickness for Z direction
    - Resolution of thing making material on the X-Y plane
- Tolerances are not as tight as traditional
  - Little secret:
    - Stated tolerance is usually over an inch on the X-Y Plane
    - Tolerance from one end of the build area to another is much less accurate.
    - Shrinkage in curing/heat treat, residual stresses, machine accuracy
    - Creep
- Design parts so that you do not care about discrete distances
  - Easy to say, hard to do
- Use machining of critical surfaces/holes if needed

Large parts can be assembled

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- Your build area is not a limit on size, just on size per build
- Very large parts can be quickly assembled
- You can glue/weld/braise multiple parts together
- Suggestions
  - Ask vendor for suggestions on bonding that is best for the material you are using
  - Make joints: dovetails work well
  - Make fixtures
    - Maybe even 3D Print them

Complex Parts can be single parts

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- Assemblies that needed to be assemblies to get made can be made as one part
- Be careful about supports and gap tolerances
- Ideal for:
  - Braised parts with internal features
  - Internal flow parts
  - Mechanisms that require difficult assembly
  - Complex internal passages
- Could be a significant cost saver

Critical Dimensions and Features

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- Most technologies can be machined
  - Especially metal
- Think casting
  - Leave stock
  - Come back and get critical features
- You need datums – AM surfaces are not datums
  - Single biggest source of parts not fitting
  - Design so you will have usable datums
- You can use inserts for critical features
  - Threaded inserts just like any plastic/soft metal part
  - But be careful about tolerances
    - Don’t assume holes are round or perpendicular to datum

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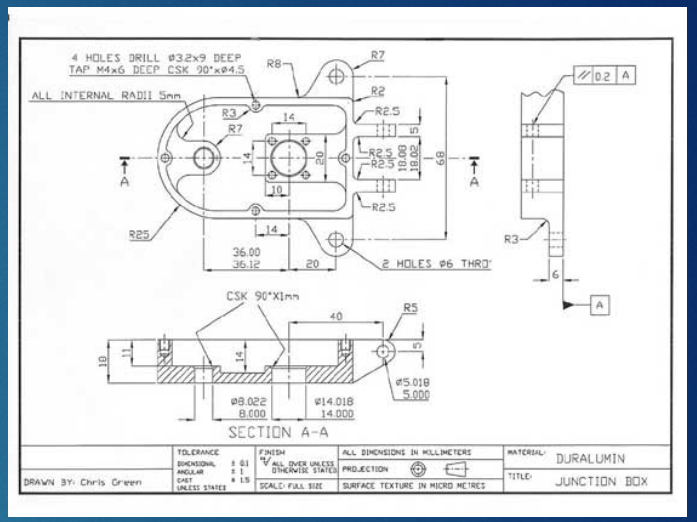
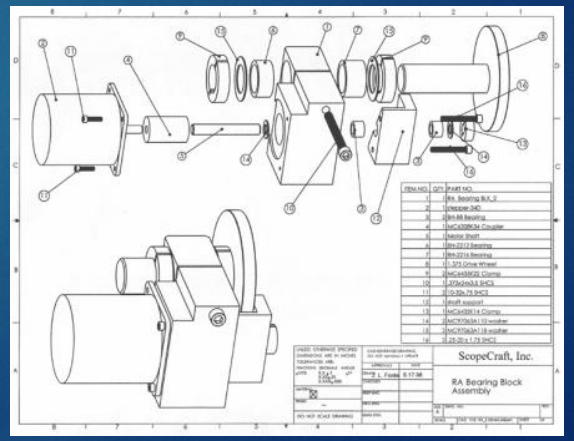
Defining 3D Printed Parts

YOU STILL NEED DRAWINGS

Part Definition

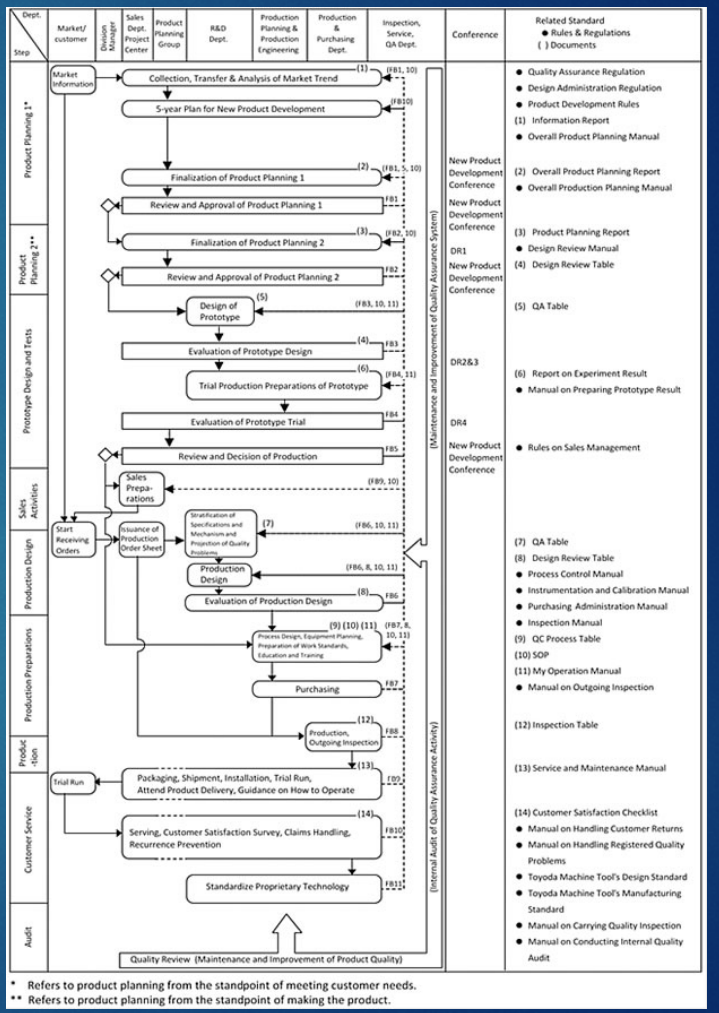
- Direct from computer to printer gets people thinking about no drawings
- Remember what drawings are for:
  - Capture information that manufacturing and quality need to make the right part
- End use parts need full documentation
  - Solid geometry is required to run the machine
  - Can be a drawing
  - Can be a text document
  - Need some pictures to identify critical features/dimensions
- Don’t forget assemblies for joined parts





Standards are your friend

- You should develop a drawing standard for AM Parts
  - Develop shop floor standards and reference those in notes
  - Develop inspection standards and call those out
- Assume a stranger is making the part, **everything** they need to know must be on the drawing
  - The STL file and the drawing should fully define and control the part from creation to shipping
- Manufacturing should develop standard for process planning
  - Standardized routers for each technology, including pre- and post-processing
- Important: the build instructions (tool path) should be a controlled document, just like CNC code.
  - Repeatability and tractability.



Drawings What to Include

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- Material specification
- Orientation!
- Support parameters
- Acceptable machine parameters
  - Or specific parameters to use
  - Based on assumptions in design
- Post processing
  - Support removal
  - Washing
  - Final curing
  - Sanding/grit blasting, etc…
- Heat Treat
- Storage constraints (temp, humidity, etc…)
- Surface finish

- Painting/coating
- Dimensions
  - Datums
  - Inspection points for acceptable warping/distortion
  - Key features – especially machined features
- Part marking
- Lot documenting instructions
  - Group by machine build, material lot, and/or production run
- Other tractability
  - Material lot info
  - Parameters used in build
  - Location of each part in build volume

Design Checklist

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- ✓ Material
- ✓ Supports - minimize and removal
- ✓ Orientation - Build time, strength, stair stepping
- ✓ Layer Thickness
- ✓ Min Wall Thickness
- ✓ Critical surfaces/holes
- ✓ Surface Finish
- ✓ Operating Environment
- ✓ Capture requirements in a drawing

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Examples

REAL WORLD

Design Example

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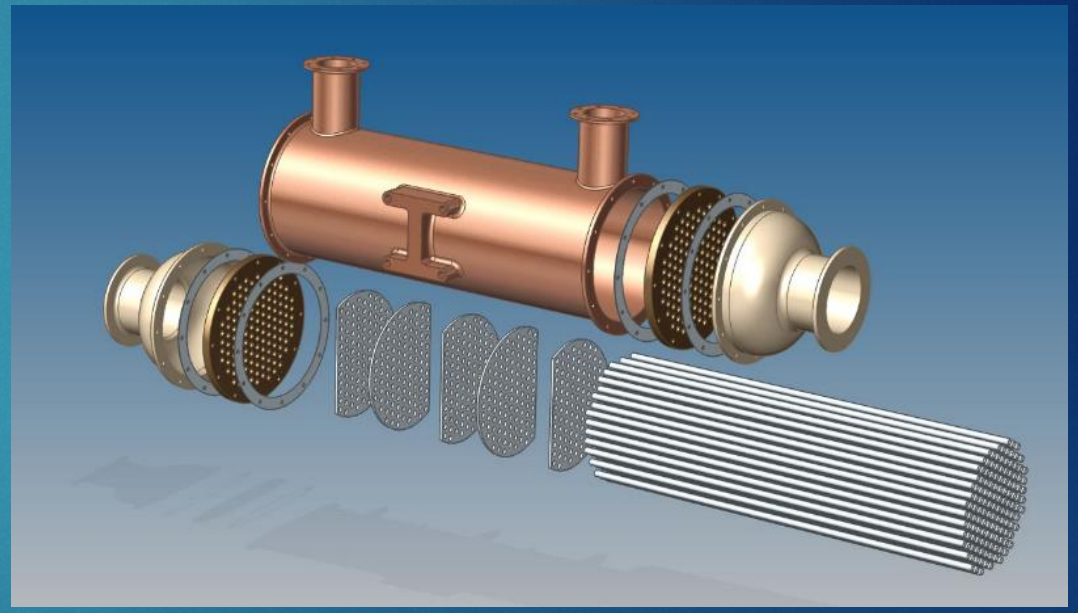
- Heat Exchanger
  - Two fluid – fuel cooling oil
  - 14 parts not counting tubes or bolts
  - Cast or weldment housing
  - Sealing issues (gaskets, torque process)
  - Assembly is time consuming, especially tubes and baffles
  - Baffle placement inflexible



Design Example

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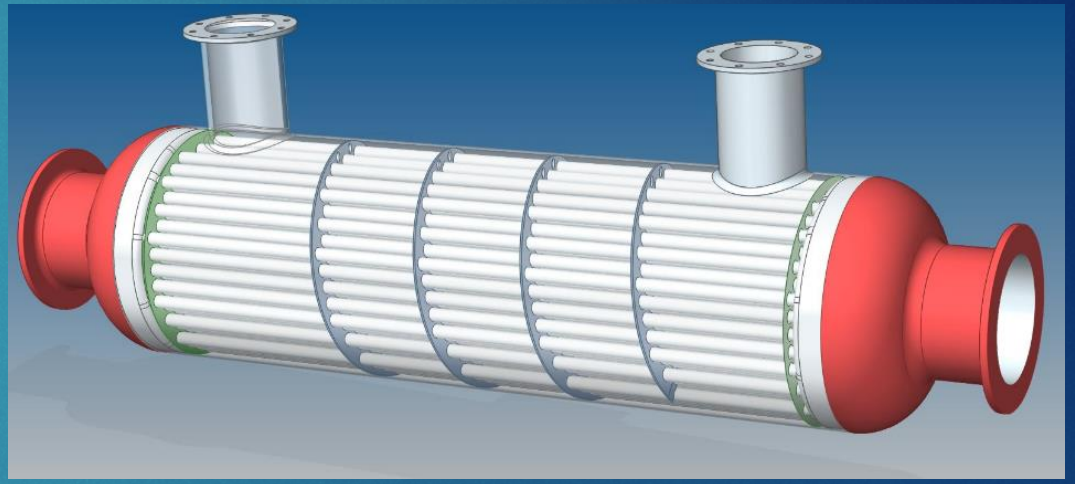
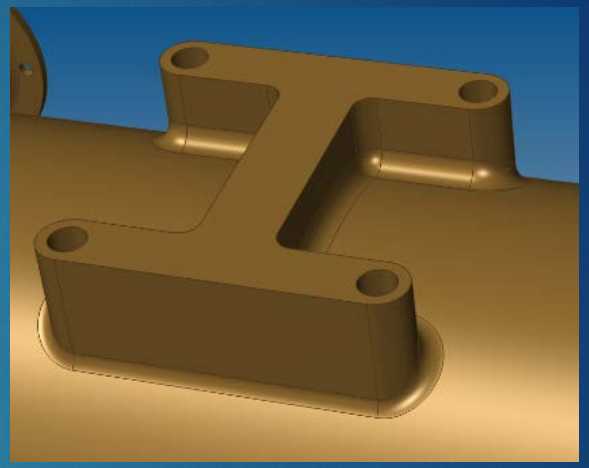
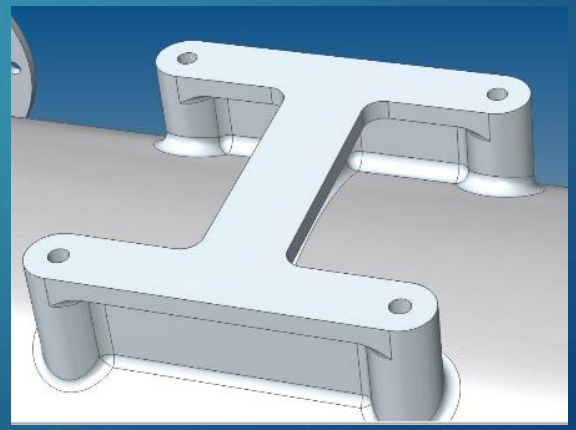
- One single piece
- No assembly, no gaskets, no bolts except at interface if needed
- More efficient helical flow baffles
- Only manual is support removal and machining of interface surfaces/holes
- Copy of design, optimized for AM would be even better
  - Minimize supports
  - Maximize heat transfer flow
  - Any weird shape

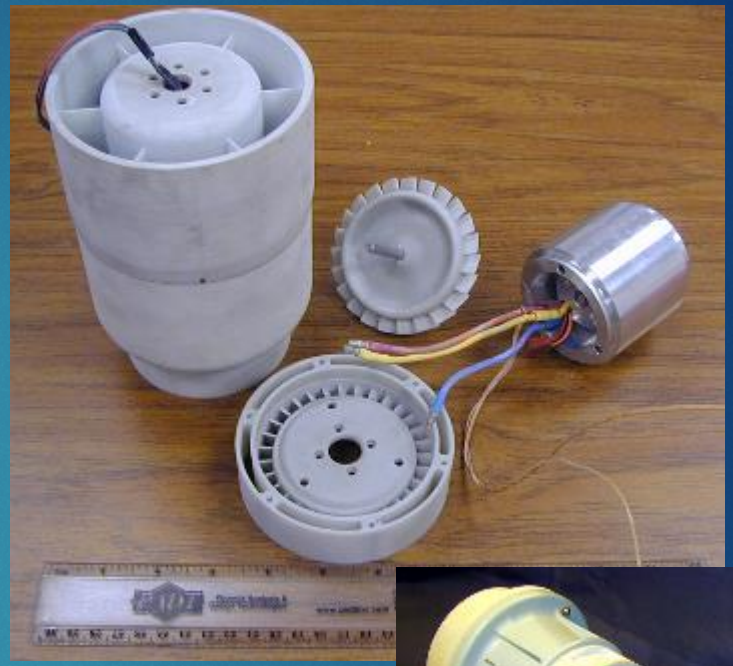


Design Example - Mount





Design Example – CAB



Example – GE Bracket Challenge

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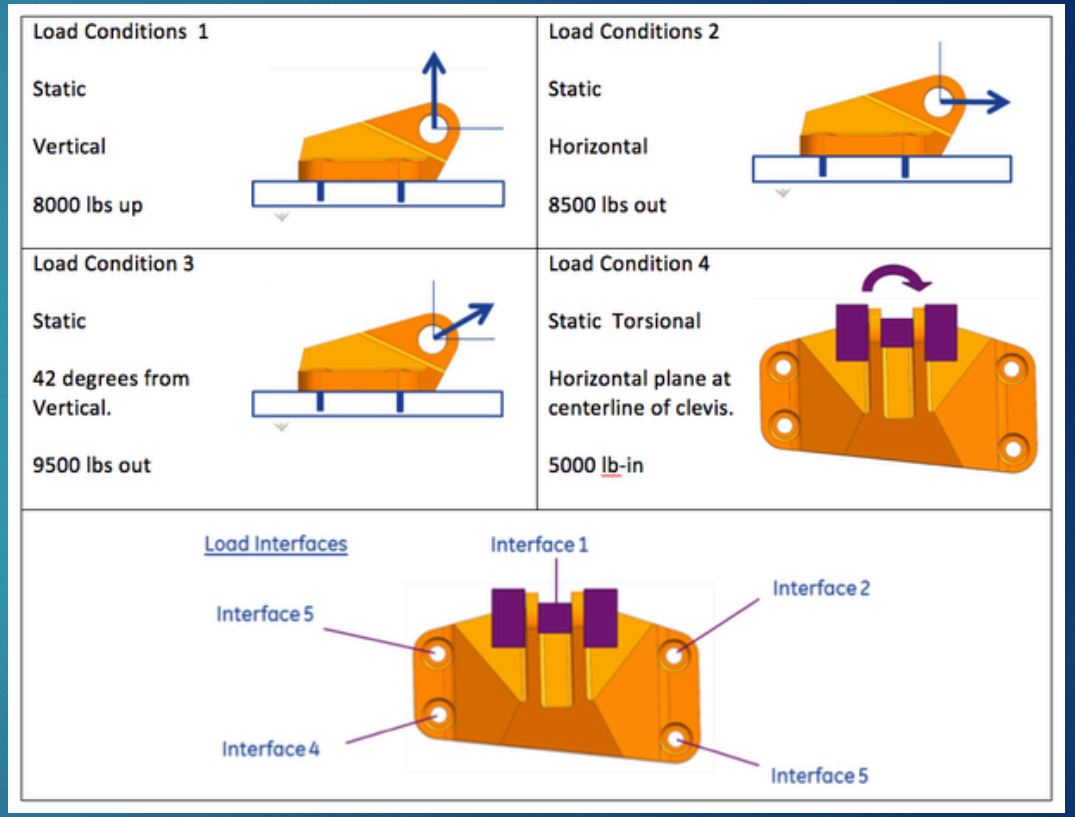
- Redesign a bracket to meet strength but reduce weight



GE Bracket Challenge - Winners

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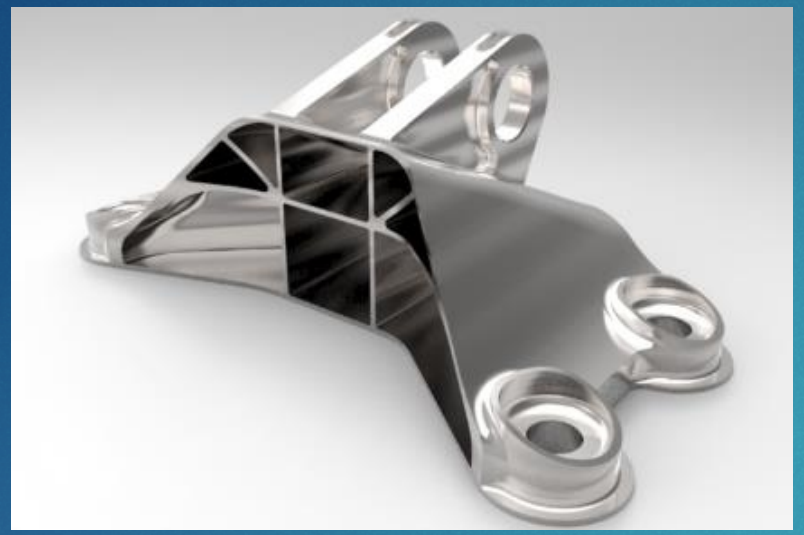

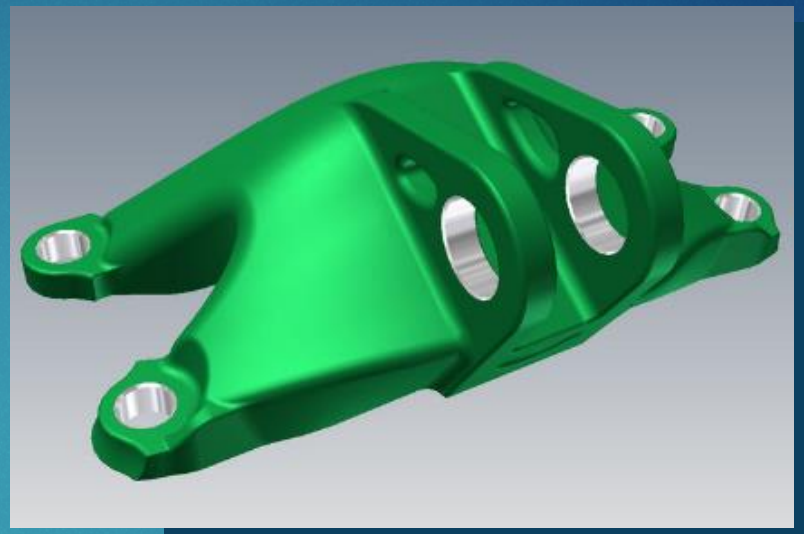

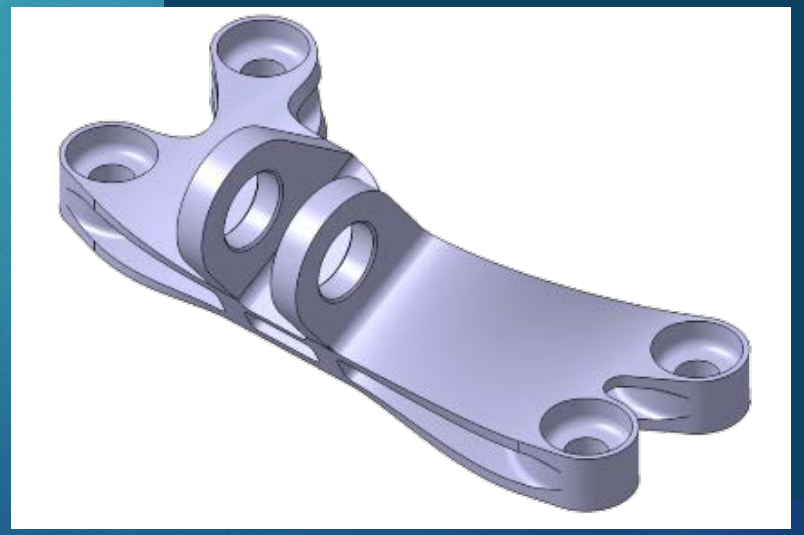

Example – Composite Layups

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