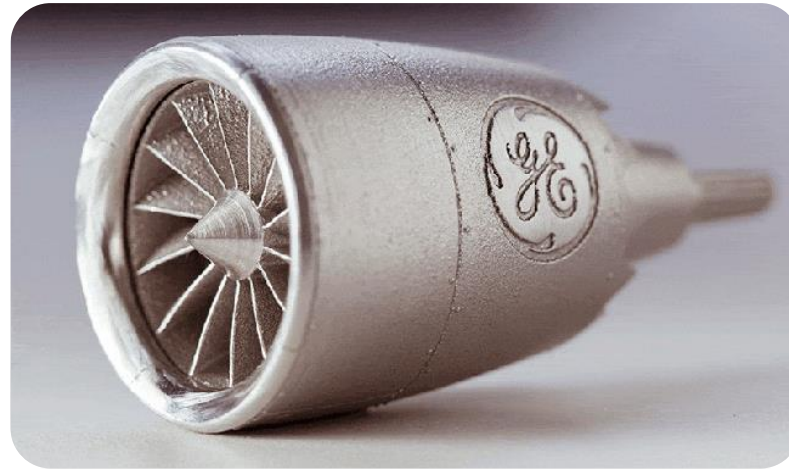


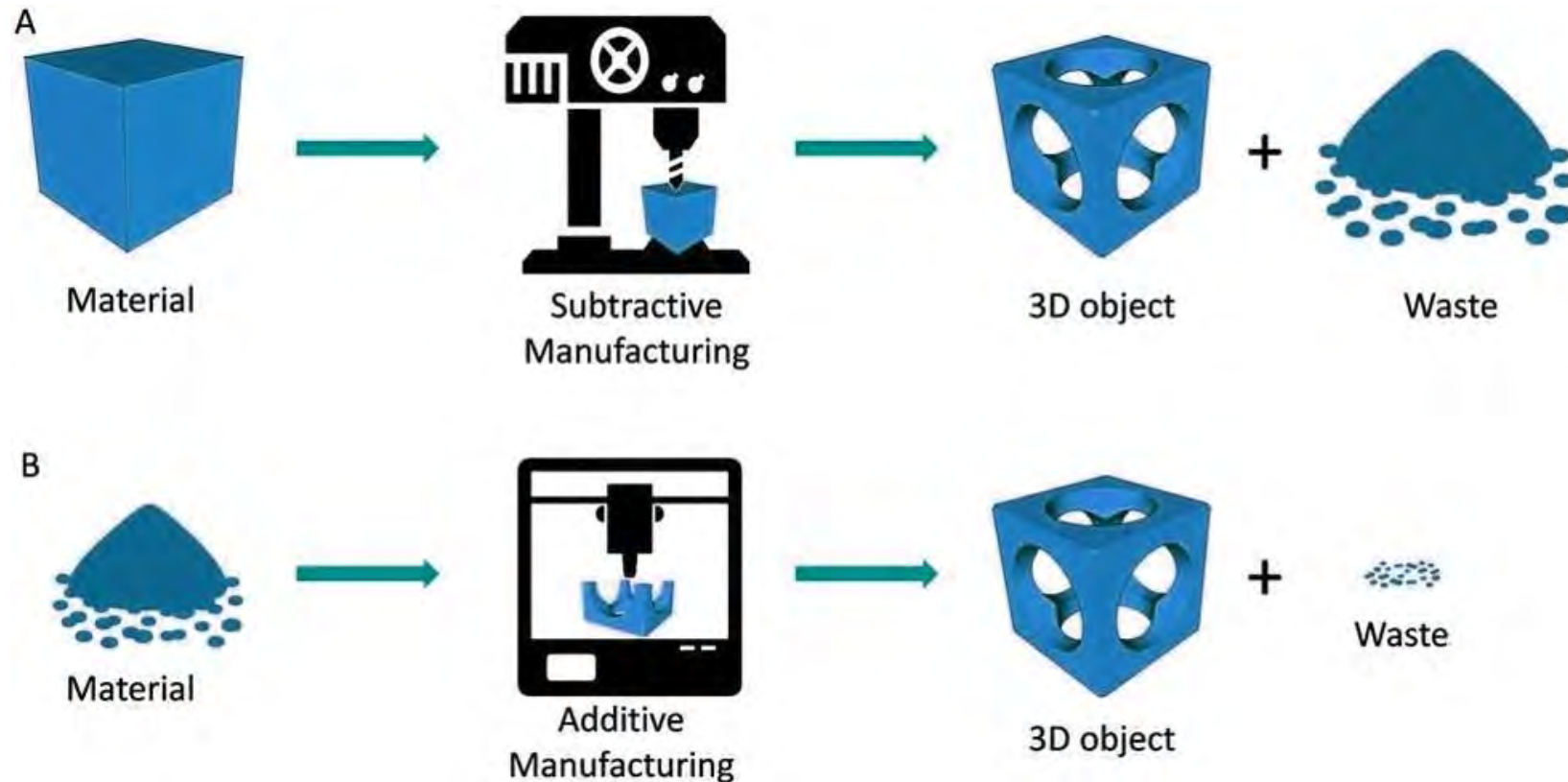
ADDITIVE MANUFACTURING THE GOOD, THE BAD, AND THE UGLY



Additive Manufacturing Overview



Additive vs Subtractive Manufacturing



ADDITIVE MANUFACTURING TECHNOLOGIES





Vat photopolymerization



Material extrusion



Material jetting



Binder jetting



Powder bed fusion

Cured with laser

Cured with projector

Cured with LED & oxygen



SLA

Stereolithography



DLP

Digital Light Processing



CDLP

Continuous Digital Light Processing



FDM

Fused Deposition Modeling



MJ

Material Jetting



NPJ

NanoParticle Jetting



DOD

Drop On Demand



BJ

Binder Jetting



MJF

Multi Jet Fusion



SLS

Selective Laser Sintering



DMLS / SLM

Direct Metal Laser Sintering
Selective Laser Melting



Plastic



Plastic



Plastic



Composite Plastic



Plastic



Metal



Wax



Gypsum, Sand Metal



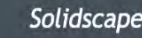
Plastic

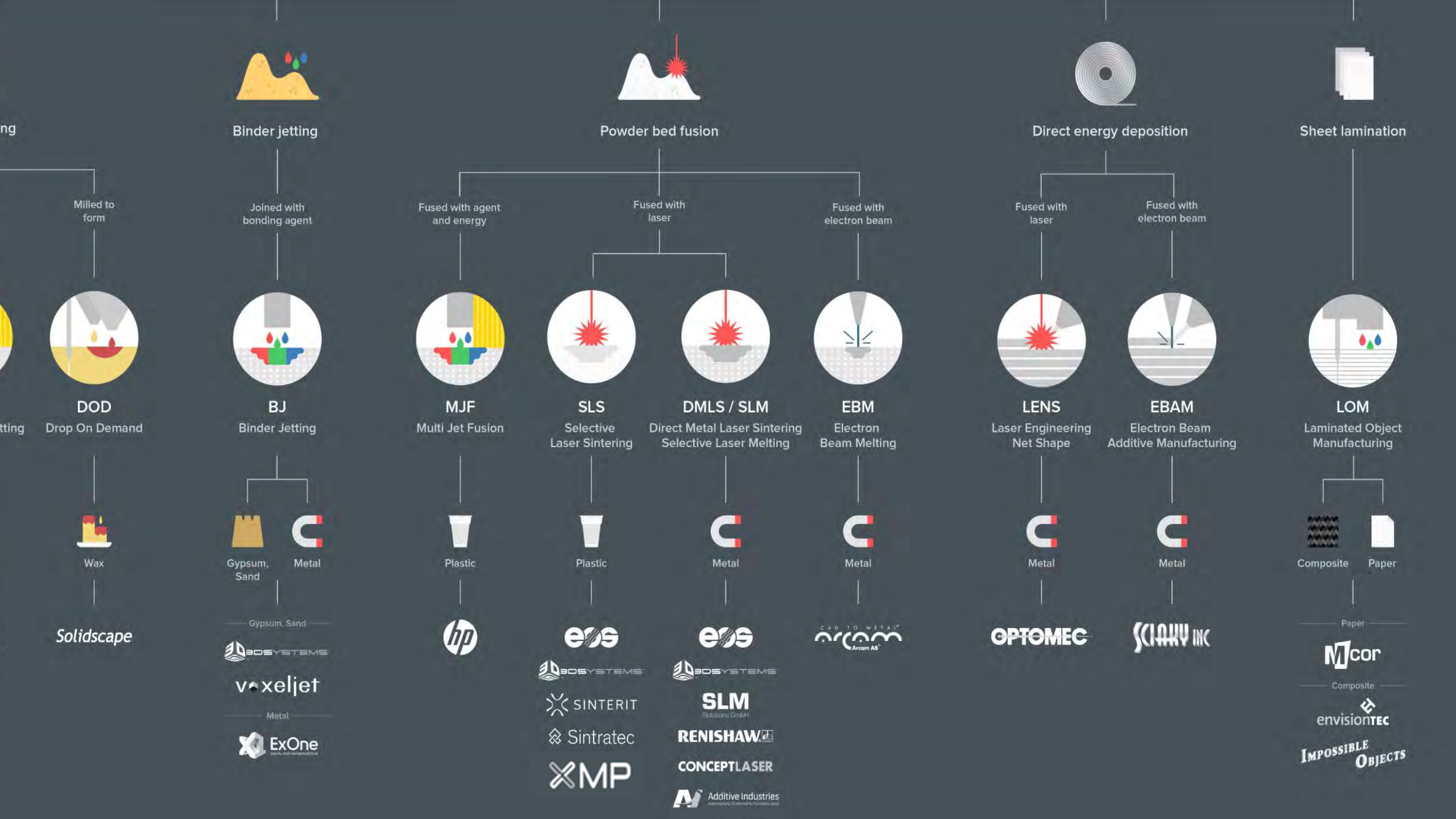


Plastic



Metal





The Good



The Potential For AM



Additive Manufacturing Opportunities

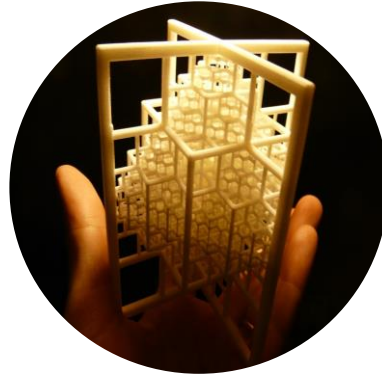
- ▶ Design Freedom
 - ▶ “Free” complexity
 - ▶ Topology Optimization
 - ▶ Weight Reduction
 - ▶ Mass customization
- ▶ Rapid part production
 - ▶ Digital manufacturing
 - ▶ Rapid prototyping



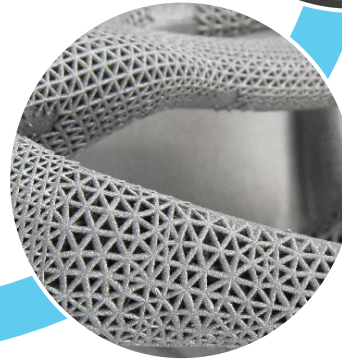
Design Freedom



“Free”
Complexity



Weight
Reduction

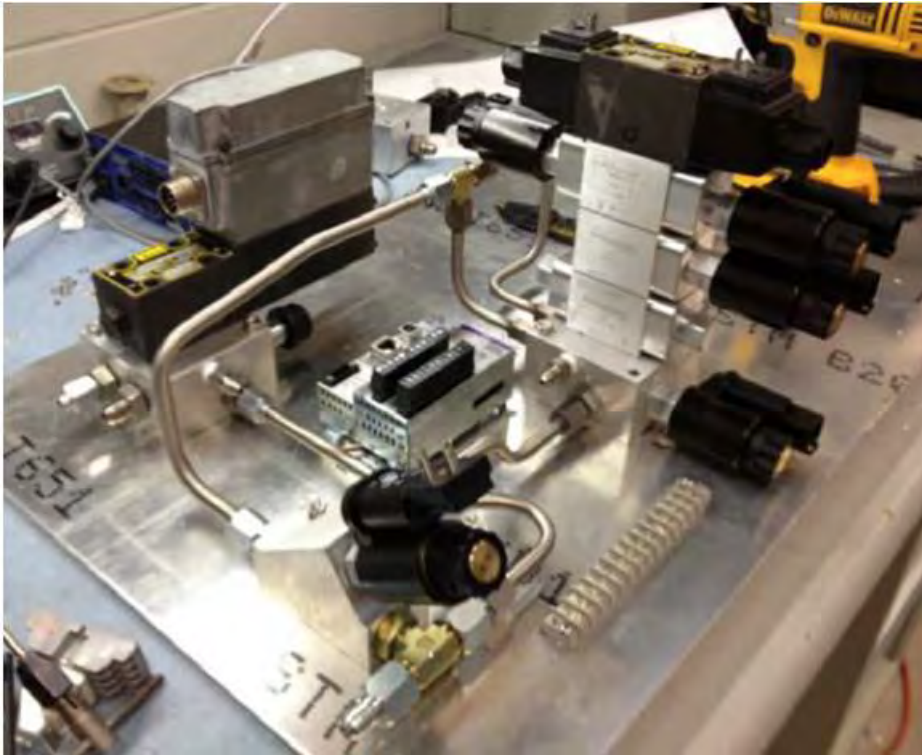


Topology
Optimization



Mass Customization

Part Consolidation - Hydraulic Manifold

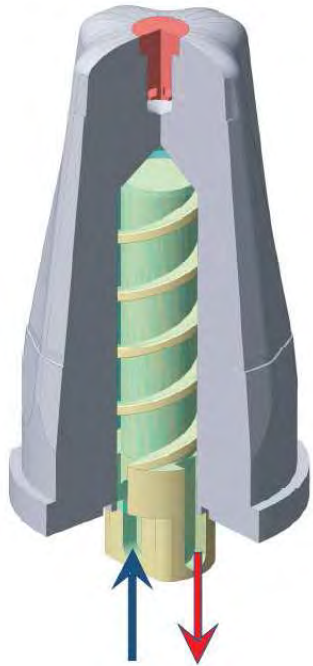


60% lighter weight
53% shorter height



Courtesy of NAVAIR Lakehurst

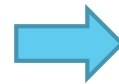
Greater Productivity from Conformal Cooling Channels



Original



Additive Version



40% Faster Cycle Time
70% Greater Productivity

The Bad and The Ugly



Room for Improvement



Speed



Scale



Material Capabilities



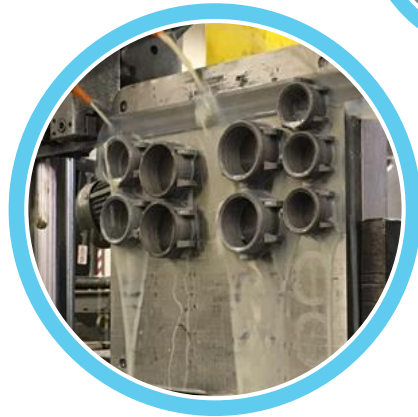
Cost



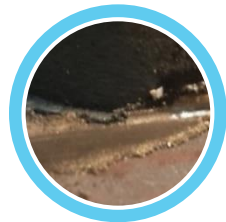
Reliability

What you didn't know about AM

Post Processing

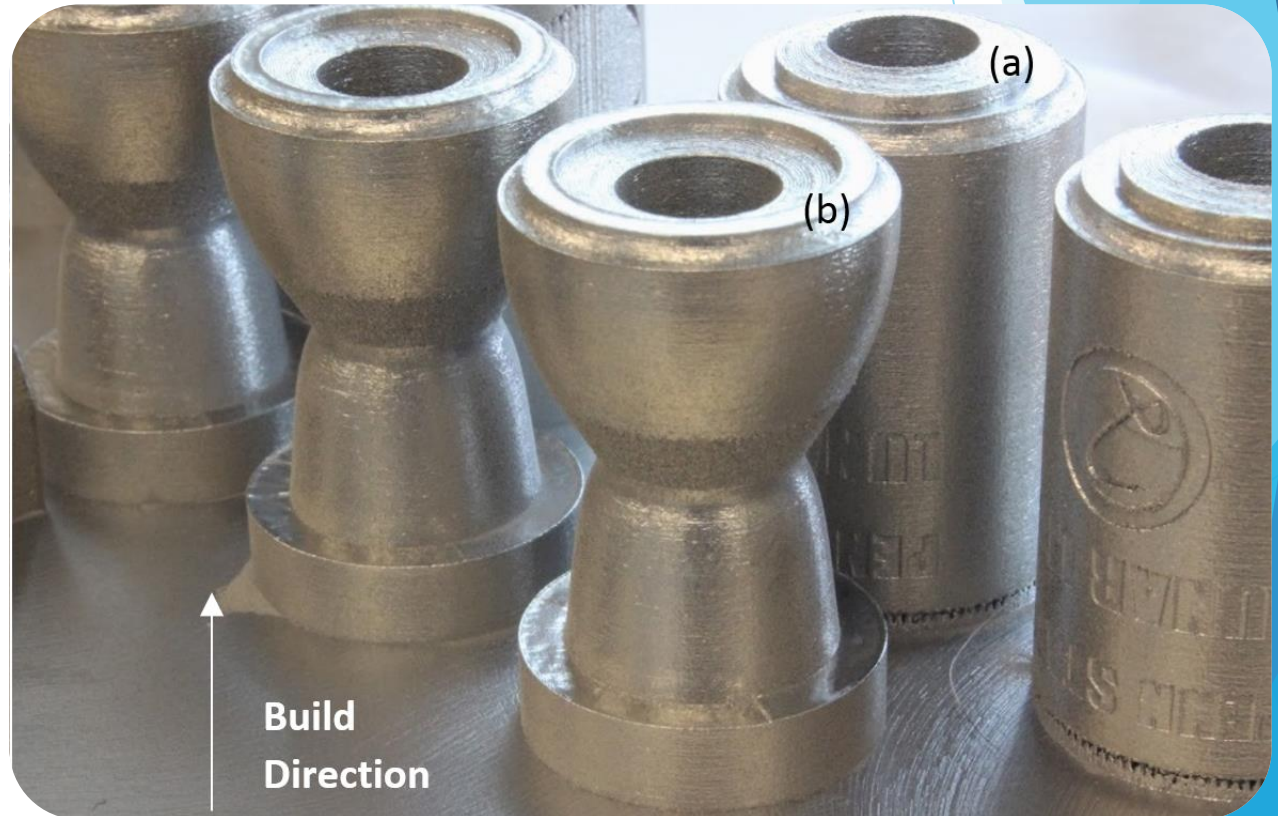
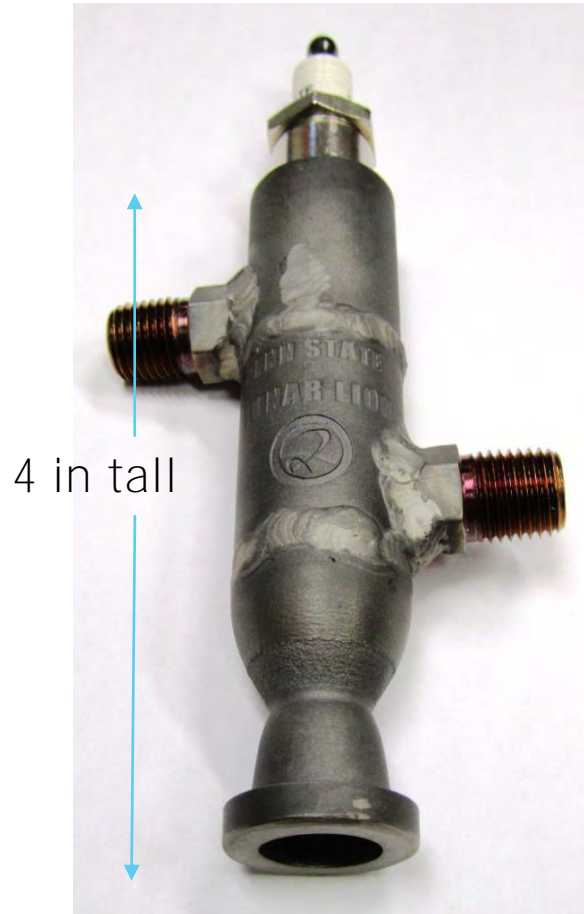


Support Material

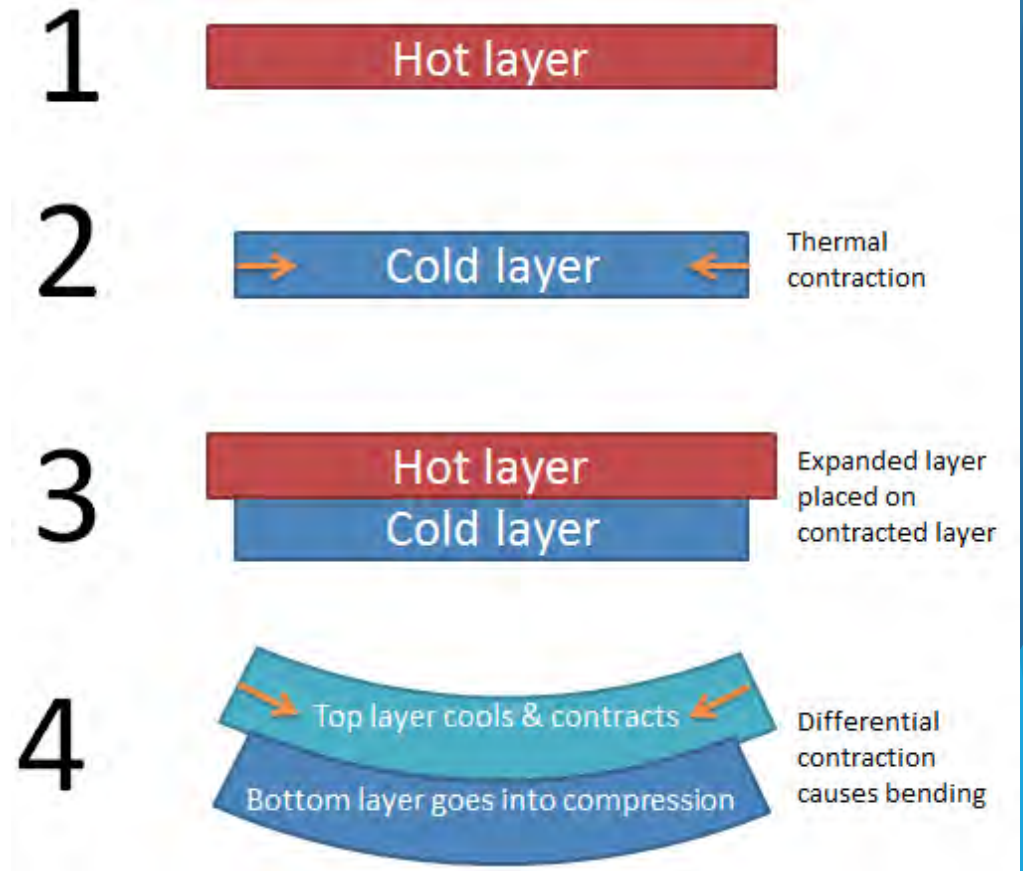
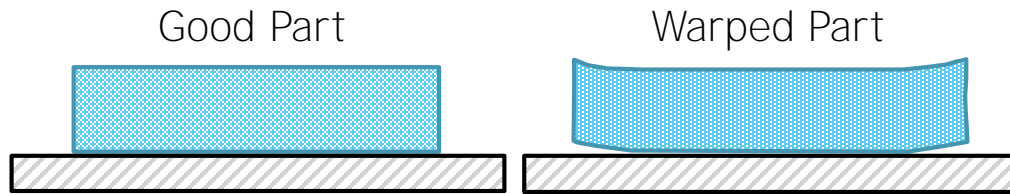


Stress Relieving

Build Height Drives Time and Cost



Thermal Deformation - Warping

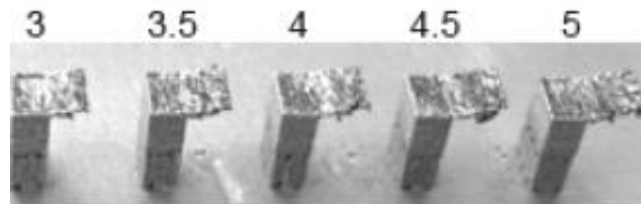


Designing For Additive Manufacturing (DfAM)

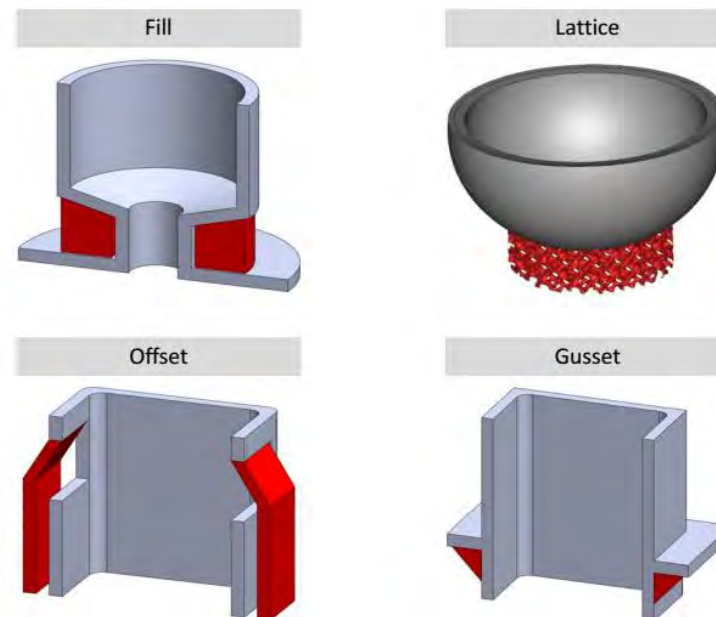
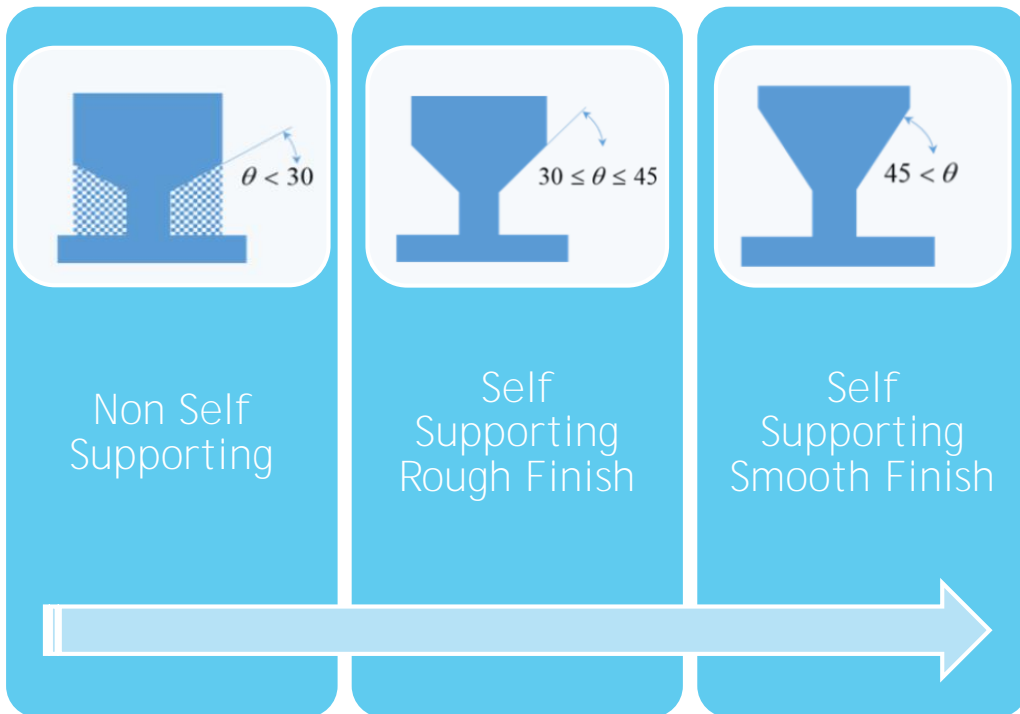
A Case Study in AM Design Considerations



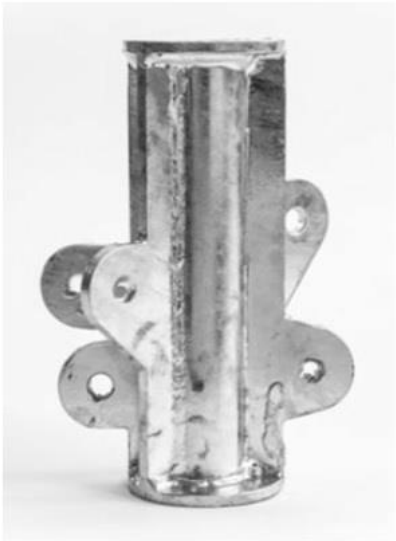
Restrictive DfAM Considerations



Curl 3



Opportunistic DfAM Considerations



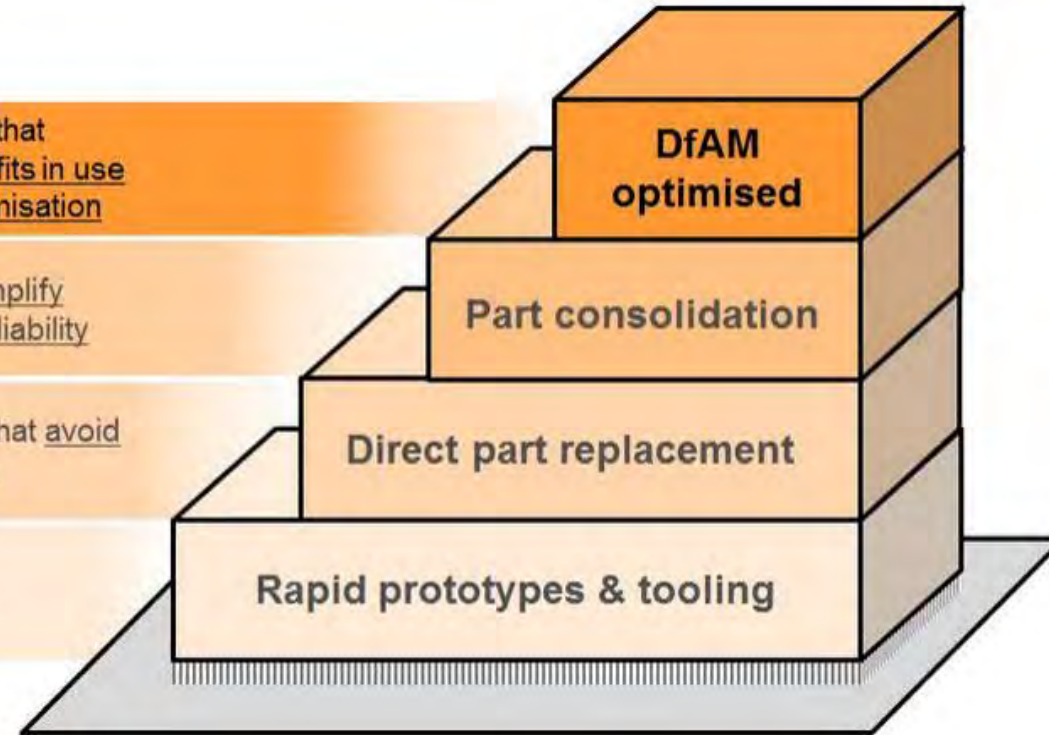
New product designs that

1. Deliver lifetime benefits in use
2. Provide mass customisation

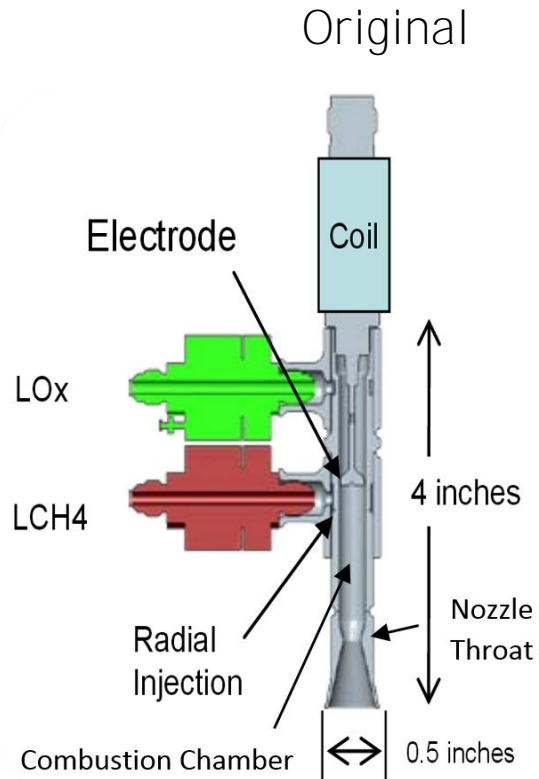
Complex parts that simplify assembly & enhance reliability

Re-production parts, that avoid complex manufacturing

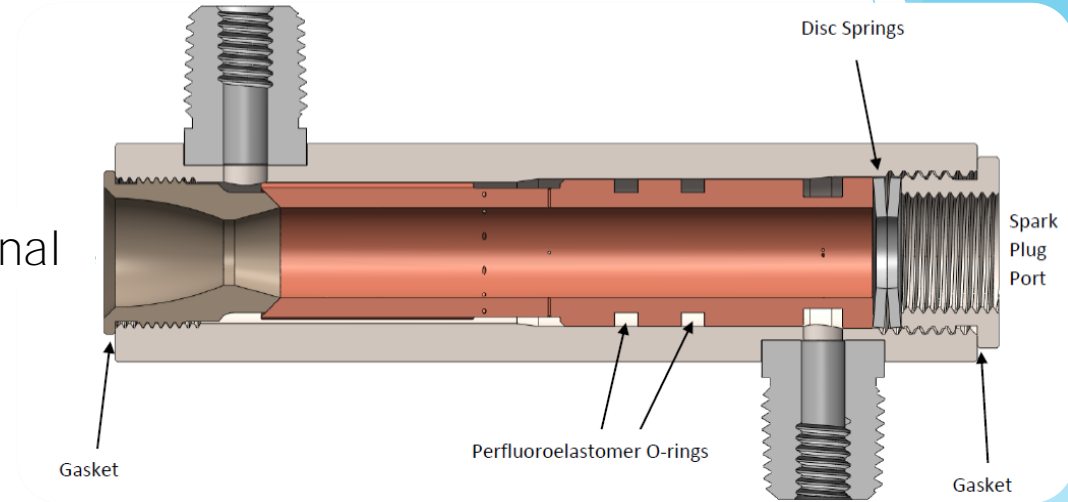
Low volume parts made direct from CAD



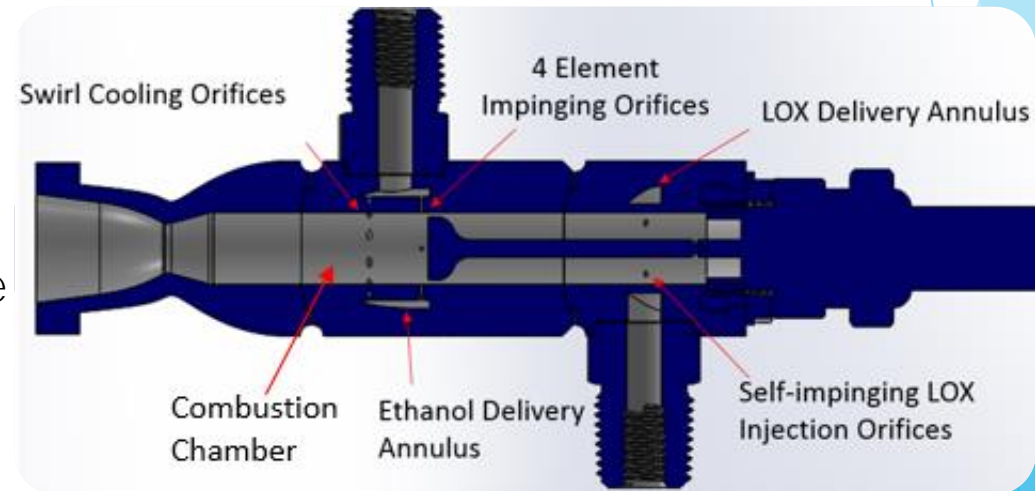
Redesigning NASA's RCS Thruster for AM



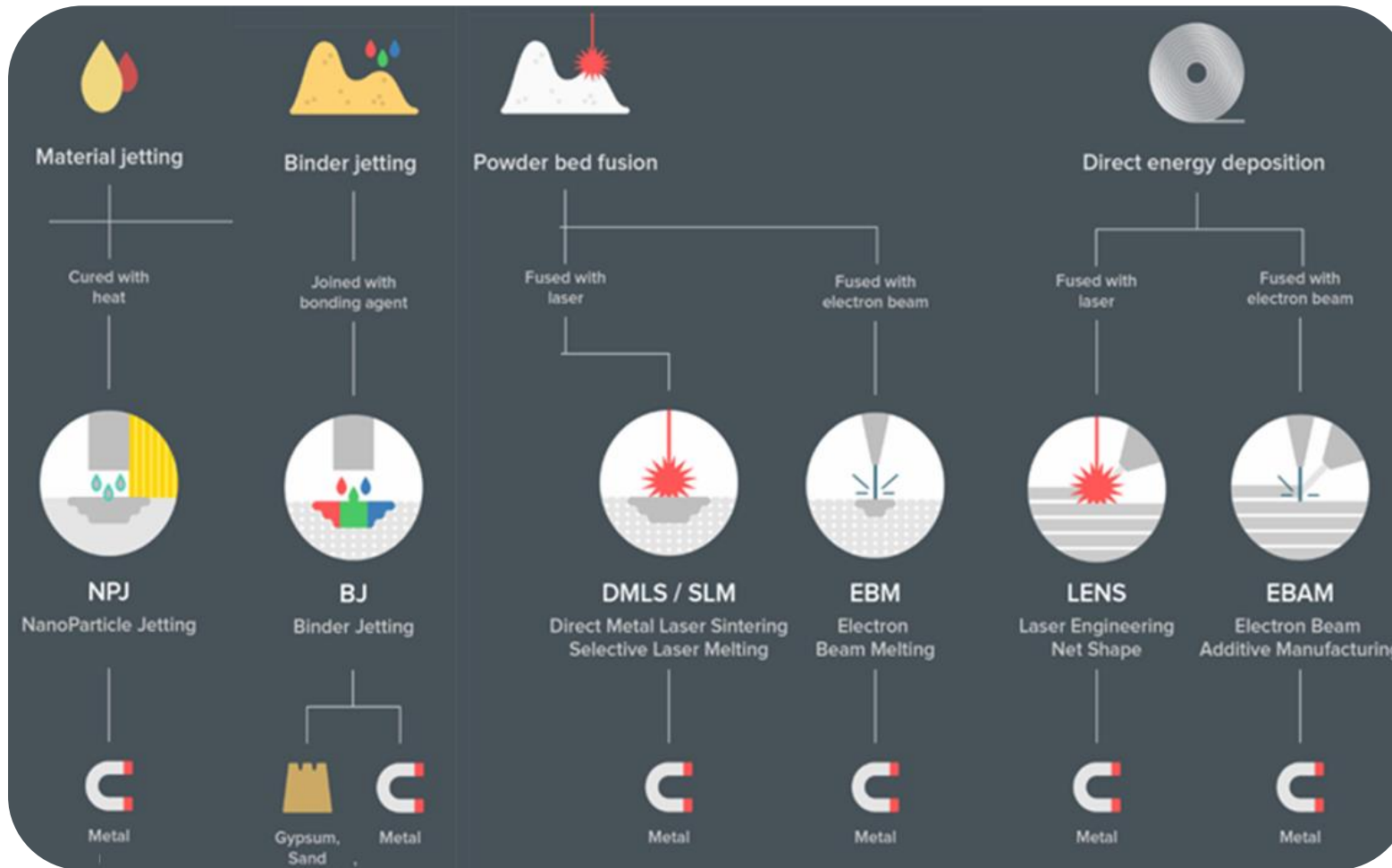
Traditional



Additive



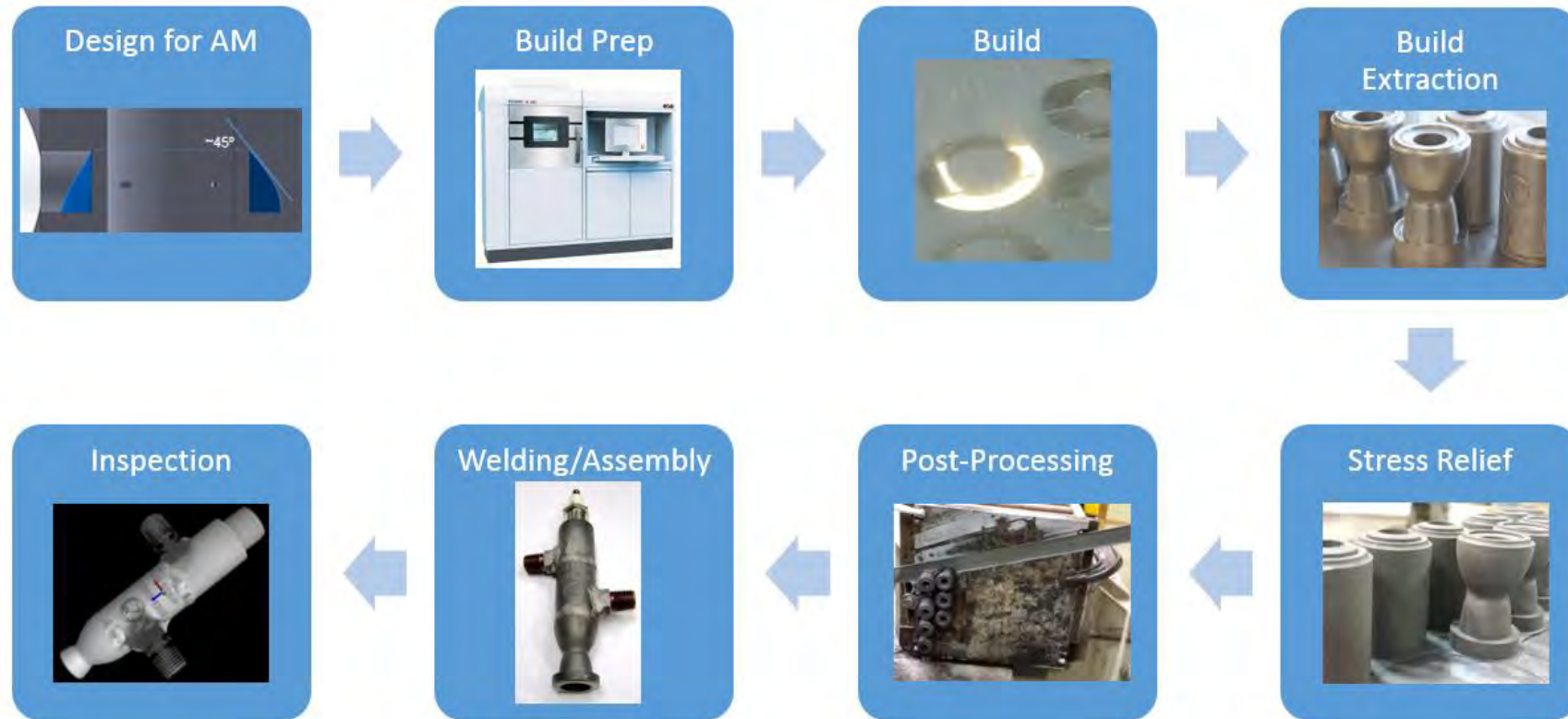
Choosing The Right AM Process



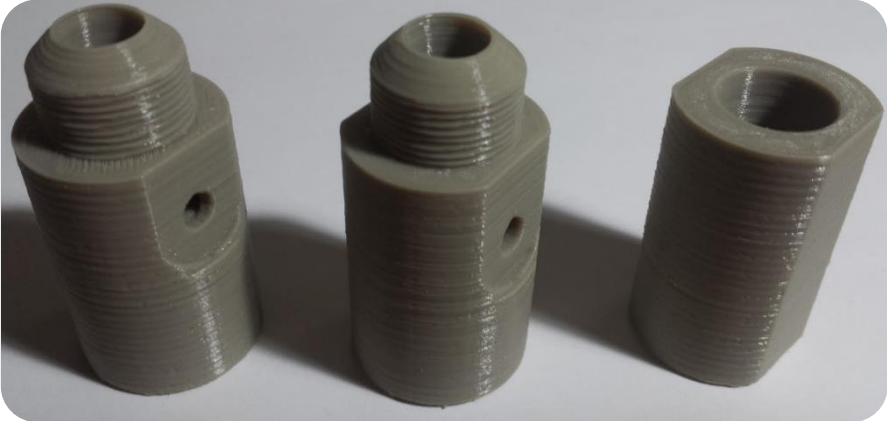
EOS M280 DMLS System



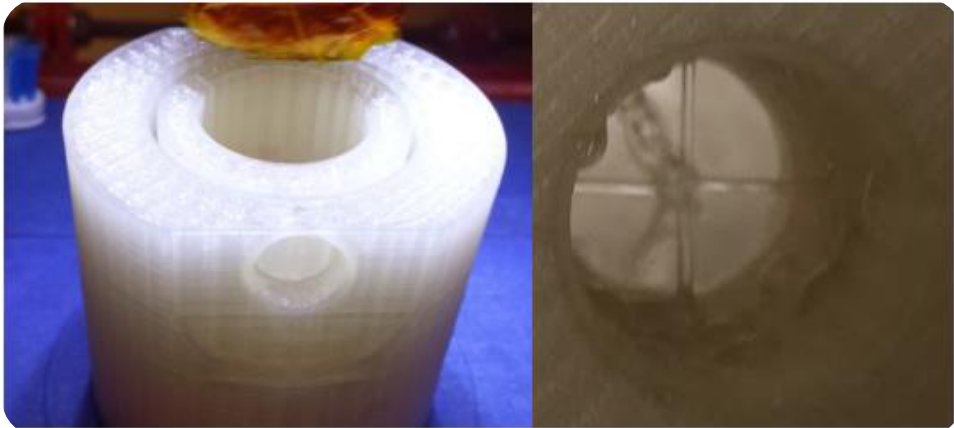
Designing For The AM Work Flow



Rapid Prototyping

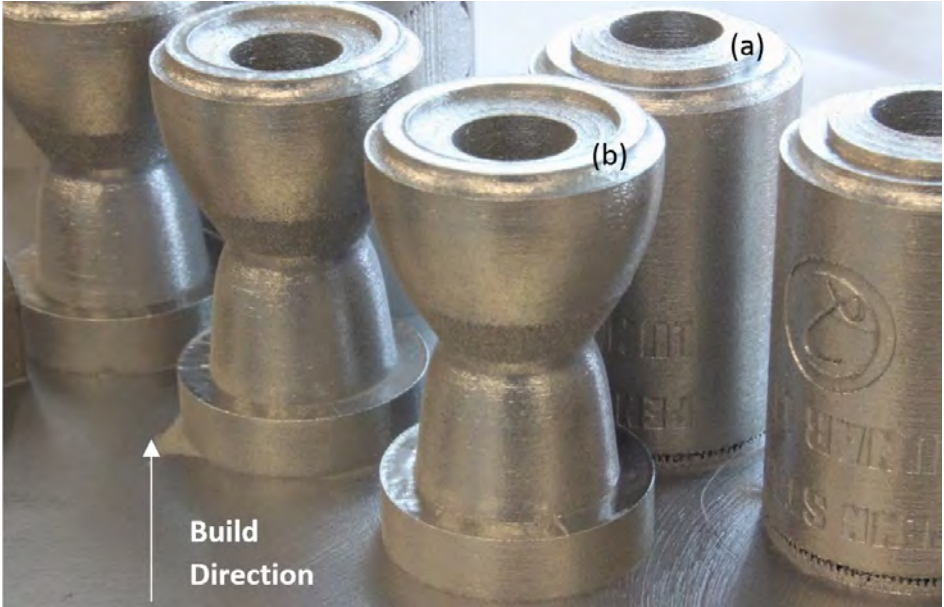


Mock Section Assembly



Water Testing

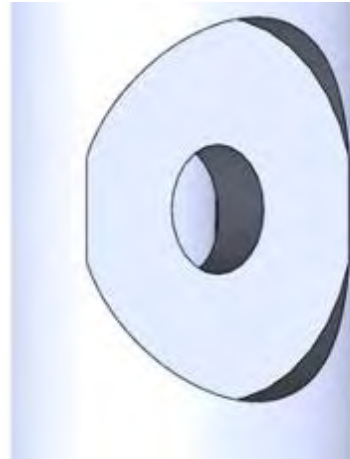
DMLS Build Process



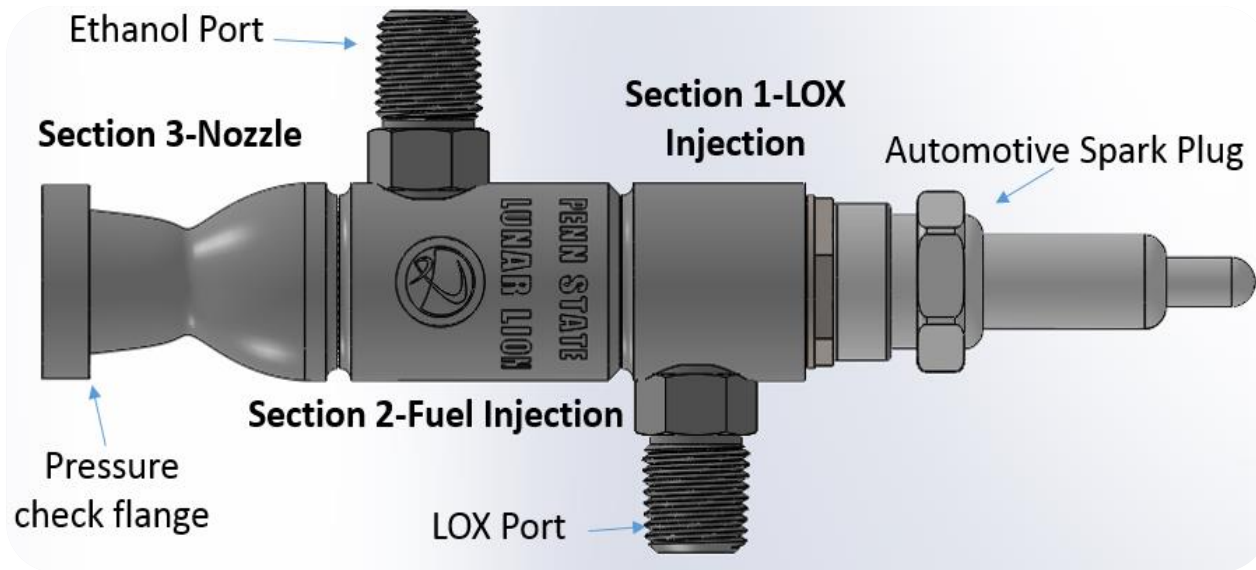
Post-Processing



Support Material Removal



Assembly

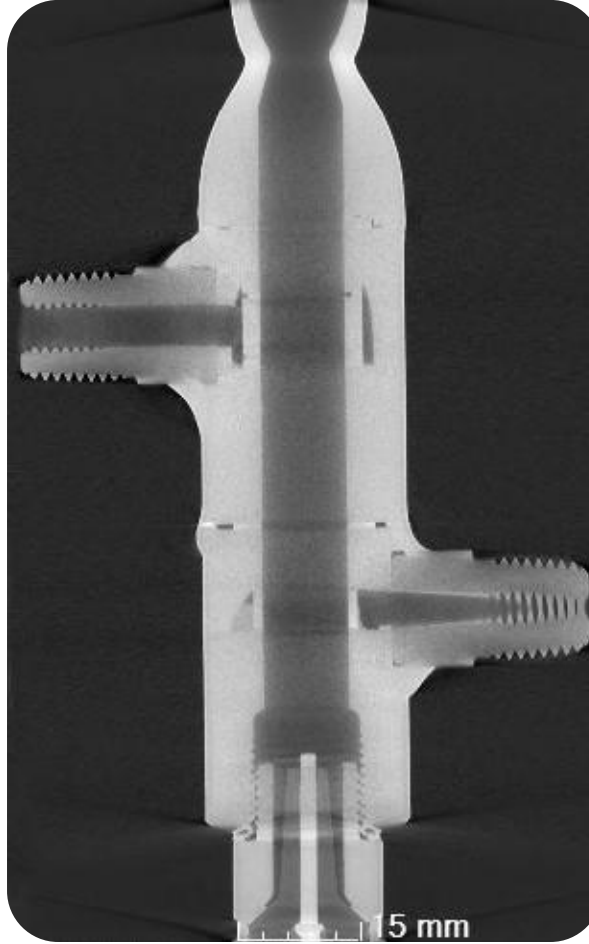
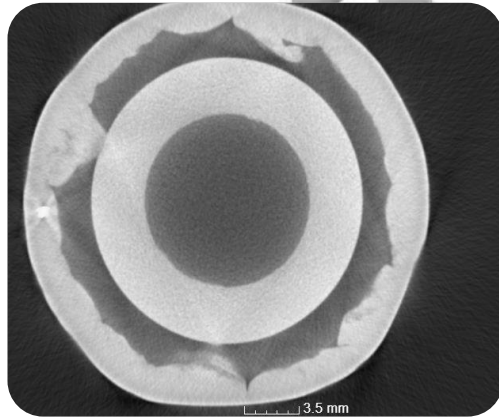
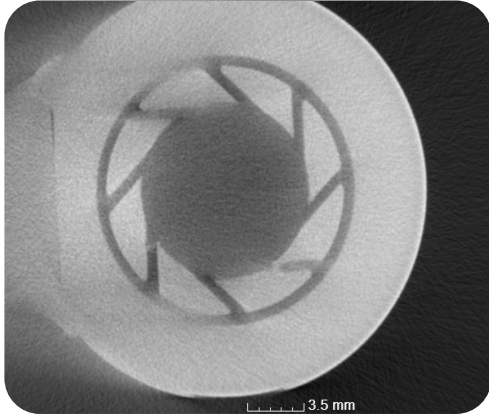


Inconel 718

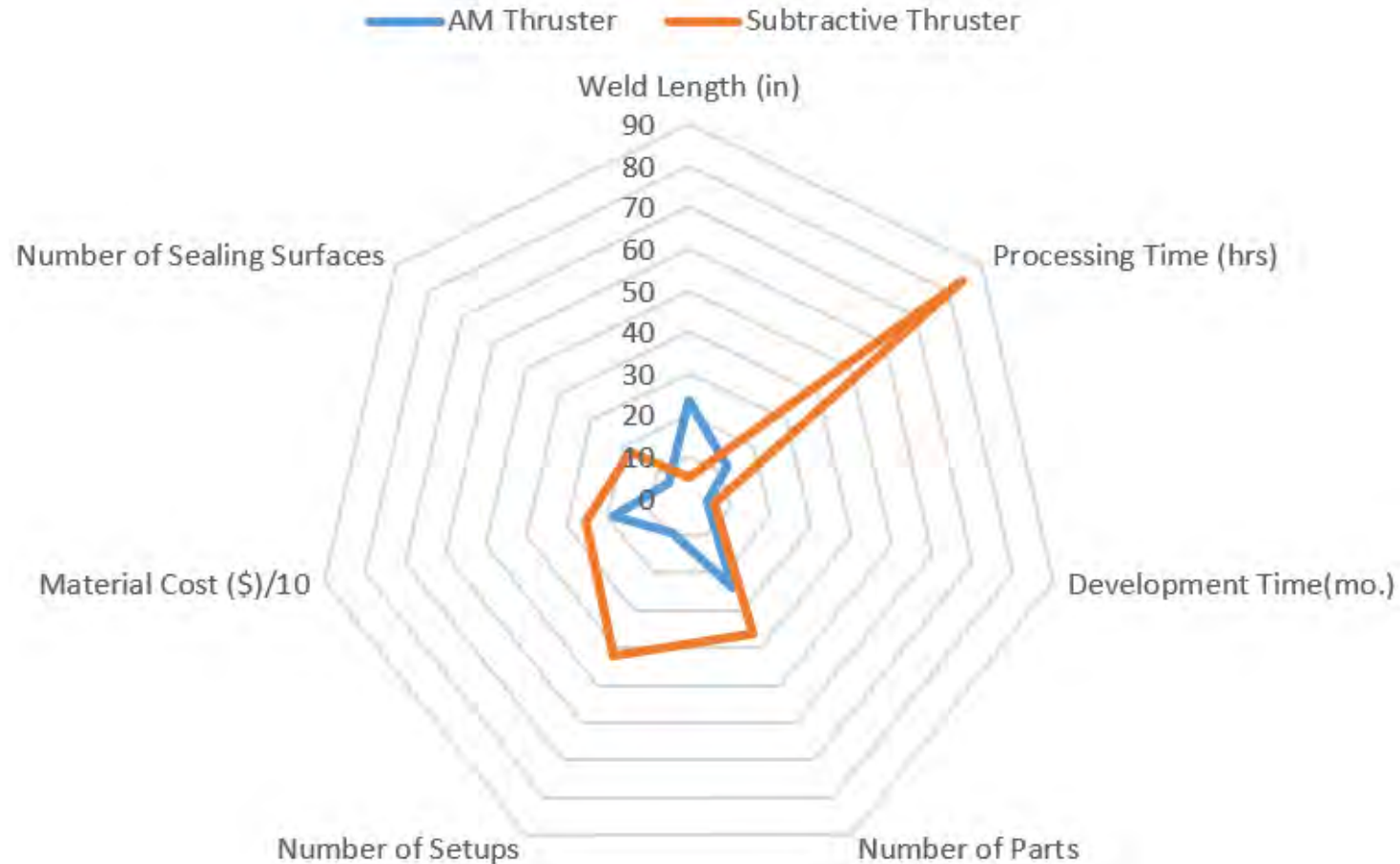
316L Stainless Steel



XRCT Inspection

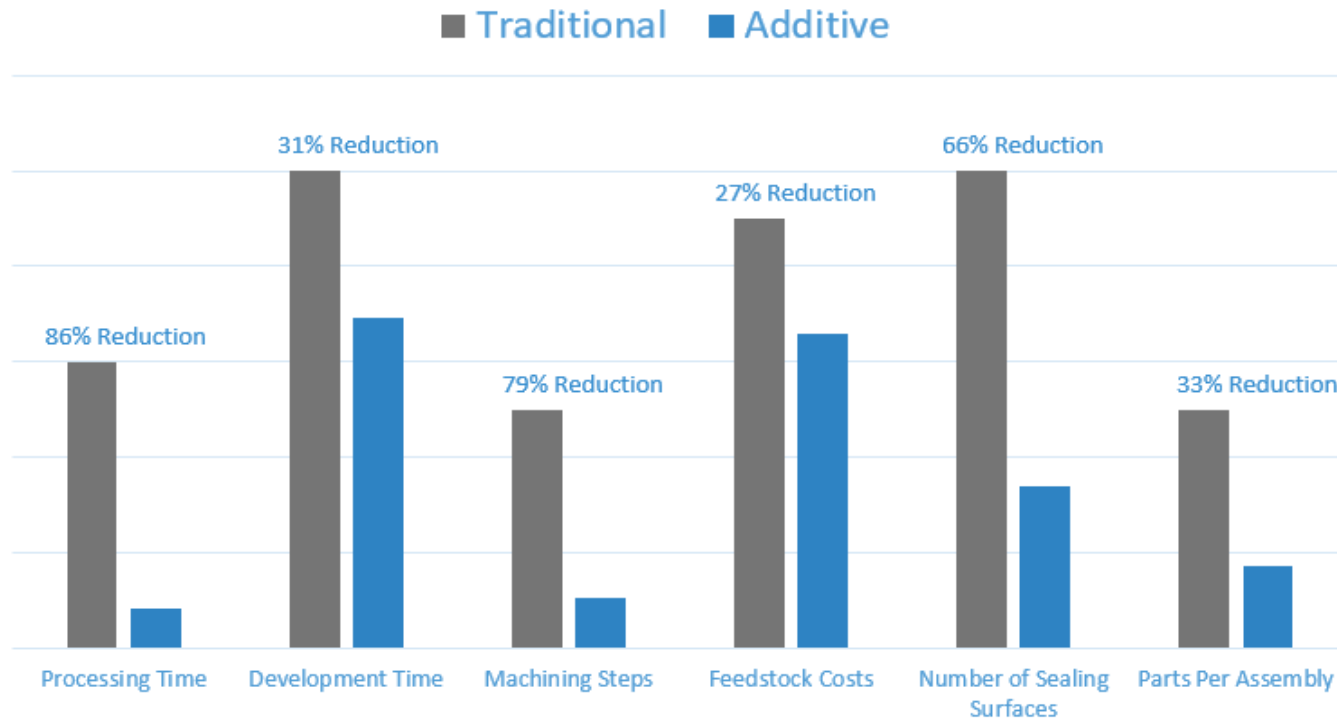


Manufacturing Metrics Comparison For 3 Units



Conclusions

- ▶ Balancing Restrictive and Opportunistic DfAM considerations allowed us to save on time and manufacturing costs
- ▶ Overall AM proved to be the better manufacturing choice for this type of project



ADDITIVE MANUFACTURING TECHNOLOGIES



Thank You

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