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A Manufacturing Technology Series Event

sme AMT

Additive Manufacturing of Industrial Scale Generative Designed Structures

Slade Gardner, PhD
President
Big Metal Additive

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Introduction: Big Metal Additive
Industrial Metal Additive Manufacturing

- Large Industrial Build Volume
  - 6ft x 12ft x 4ft
- Industrial CNC controller
  - NC operator runs machine
- Fast Metal Deposition
  - Up to 5 lbs/hr
- NC Machining Spindle
  - 10 Position Tool Changer
- Unique Hybrid Process
  - Assures Dimensional Control
  - Provides Higher Quality

Background (Prior to BMA):
Founder Pioneered Large Metal Additive Manufacturing

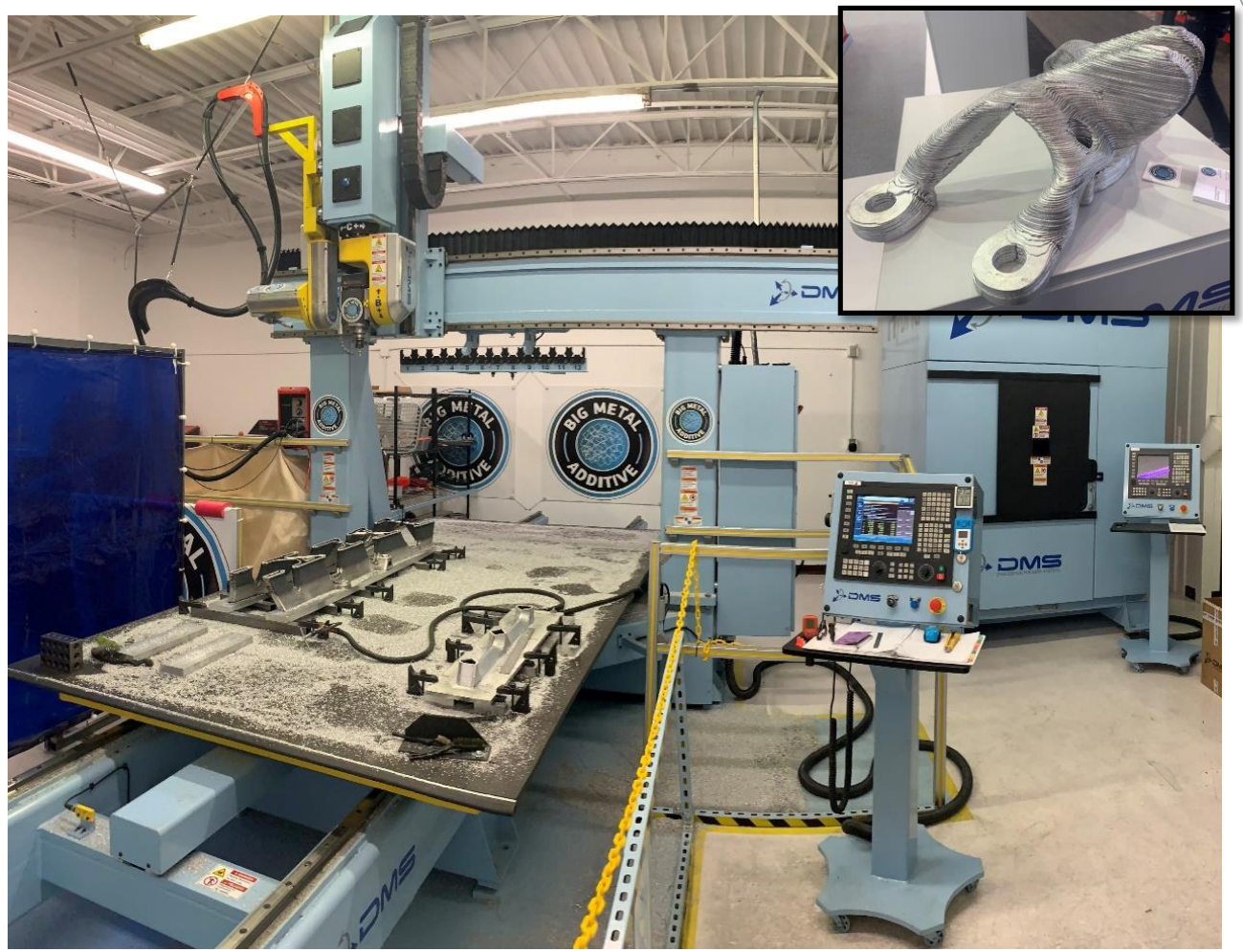
- First Large Metal Spacecraft Structure (2011)
- Titanium Propellant Tanks
  - High value product critical to satellite design
  - Stores propellant for on board propulsion system
  - 16 to 46 inch diameter
- Additive Manufacturing Impact
  - **Lead time reduced to 2 months from 20 months**
  - Cost reduced 50% from forging
  - Design flexibility
  - Machine capable of 59 inch diameter
  - 50 test cycles at max expected pressure
  - Failure above 200% design pressure

http://www.additivemanufacturing.media/articles/possibilities-of-electron-beam-additive-manufactur

http://spacenews.com/lockheed-leaning-on-3-d-printing-to-bring-tank-work-in-house/
http://www.additivemanufacturing.media/articles/lockheed-martin-importance-of-closed-loop-control-in-am
https://3dprint.com/62099/lockheed-3d-print-fuel-tanks/
http://www.lockheedmartin.com/us/news/features/2015/by-the-numbers-3dprintingatlockheedmartin.html

Big Metal Additive
Industrial Metal Additive Manufacturing

- Customer Prototypes
- Design Demonstrations
  - Architectures
  - Configurations
- Engineering Services
  - Design for Big Additive
  - Material selection
  - Data generation
- Machine Sales
  - 2Cube
  - Onsite Support
- Training



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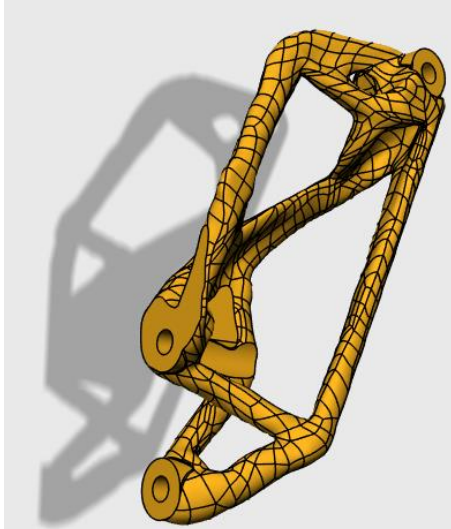
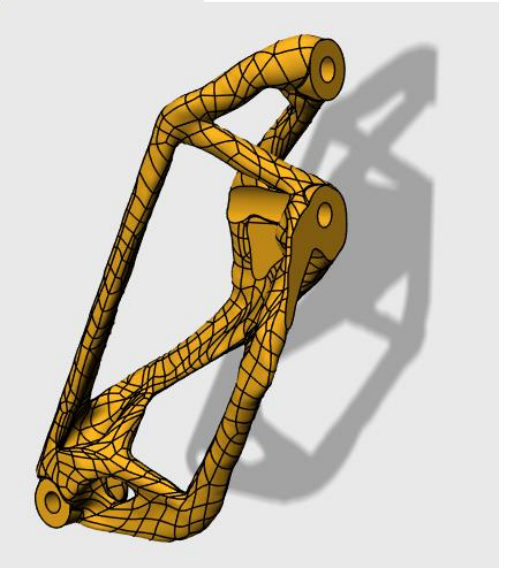
Process Advantages

Hybrid Process Allows Increased Design Complexity

- Large Scale
  - Wire feedstock for large deposition size
  - Solid structure or tubular structure
- 5 Axis Hybrid Additive
  - Additive deposition and subtractive machining in same work volume
  - Dimensional control
  - Complex geometries
  - Trimming and surfacing
  - Rework and design iterations
- Advanced designs become producible
  - Generative design at industrial scale
  - New architectures and integrations





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Process Guidelines
Tooling and Fixtures

- Build plate design and selection is important
  - Build plate can be incorporated into part design
  - Partitioned build plates can provide advantages
- Thermal Management
  - Part size and geometry are important
  - Deposition adds heat
  - Machining can remove heat
- Machining Loads and Vibrations
  - Tall parts require more attention
  - Feeds and speeds can be adjusted

Process Guidelines
Design

- Wall thickness considerations
  - Quanta or pseudo-quanta are nice
  - Drives speed of build directly and indirectly
  - Drives thermal management strategy
- Overhangs and unsupported structure
  - 3 axis parts are different than 5 axis parts
  - Large scale parts have producibility advantages
- Simulation for producibility
  - Collisions can be predicted (models required)
  - Estimate duration
  - Preview to mitigate issues

Process Guidelines

Architecture and configuration

- Larger integrated architectures are better
  - Incorporates more benefits of AM
  - Evolves design toward structural efficiencies
- Configurations with variety of features are possible
  - Wall thicknesses
  - Machined surfaces
- Enclosures, ducting and routing does not need to be parasitic structure
- Structural efficiencies improve with each iteration of build/evaluate
- 3rd Gen design will be much better than 1st Gen design but you must begin at 1st

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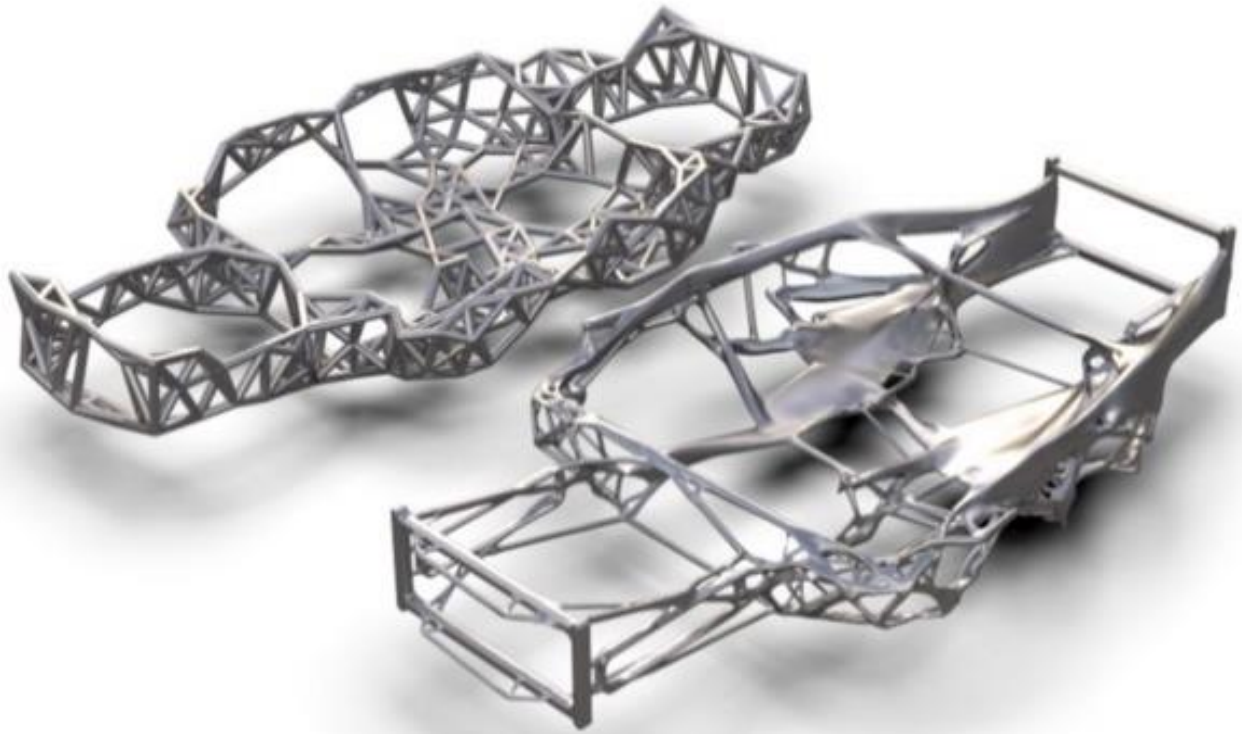
How about a 3D Printed Car?

The chassis is a good place to begin

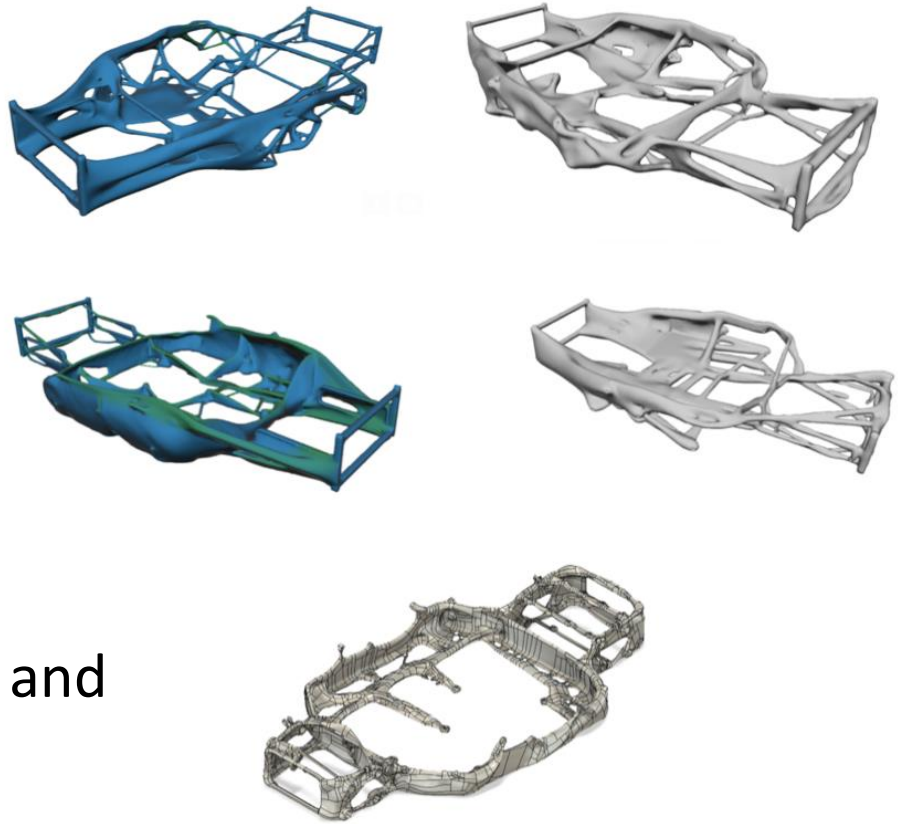
- Generative Design
  - Structural optimization method
  - Computes approximate optimized structure
  - Solid Isotropic Material with Penalization
  - Level-Set method
- Generative design chassis
  - Complex industrial scale architecture
  - Maximizes structural efficiencies
  - Enables creative system integration options
- Re-optimized chassis
  - Target is wire arc additive manufacturing
  - Use points from gen design
  - Connect points efficiently for producibility



https://medium.com/pixmoving/pix-3d-printed-car-chassis-56b4501e85ab

Why might you want to 3D print a chassis?
or any other new structural architecture

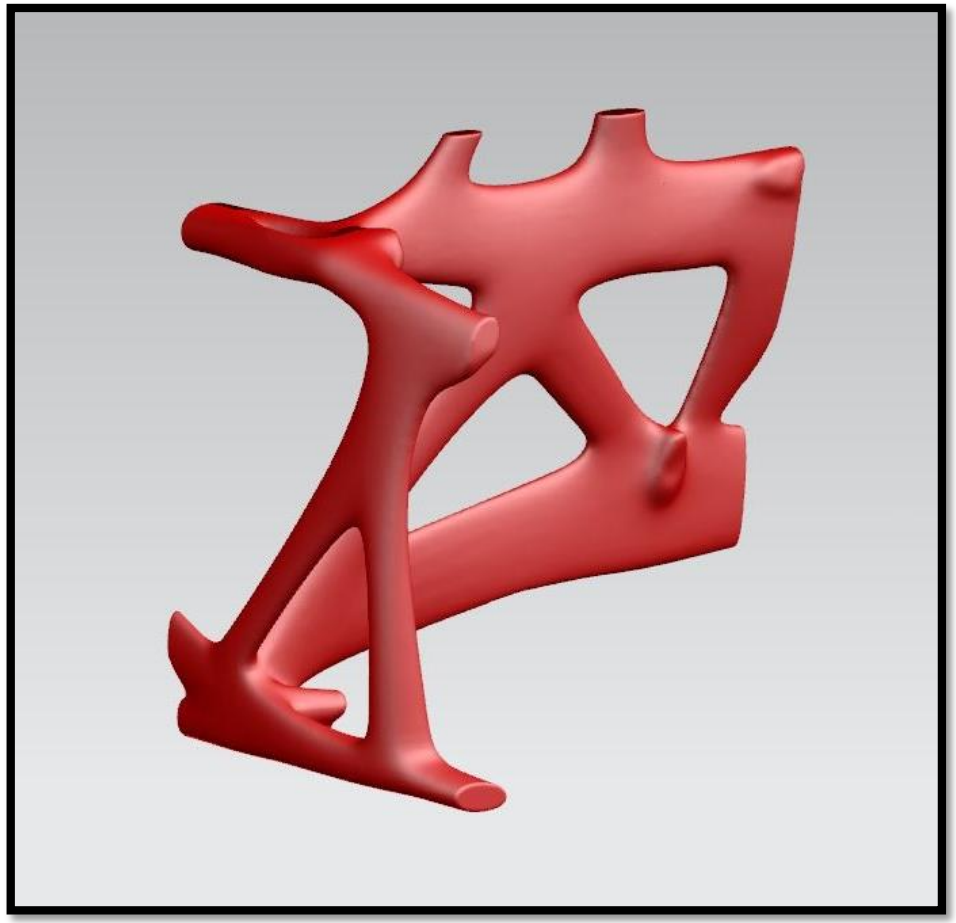
- Automobile architecture is largely unchanged for decades
- New technologies present new integration opportunities
  - Electrification – drive train, energy storage, power generation
  - Autonomy – driver and passenger requirements
  - Electronics, sensors, compute power and mechanisms
  - Safety equipment – crash avoidance and protection
- Full scale functional prototype chassis can be 3DP in weeks – design loop is accelerated
- Allows exploration of new configurations and architectures
- Competitive advantage for manufacturers, designers and entrepreneurs

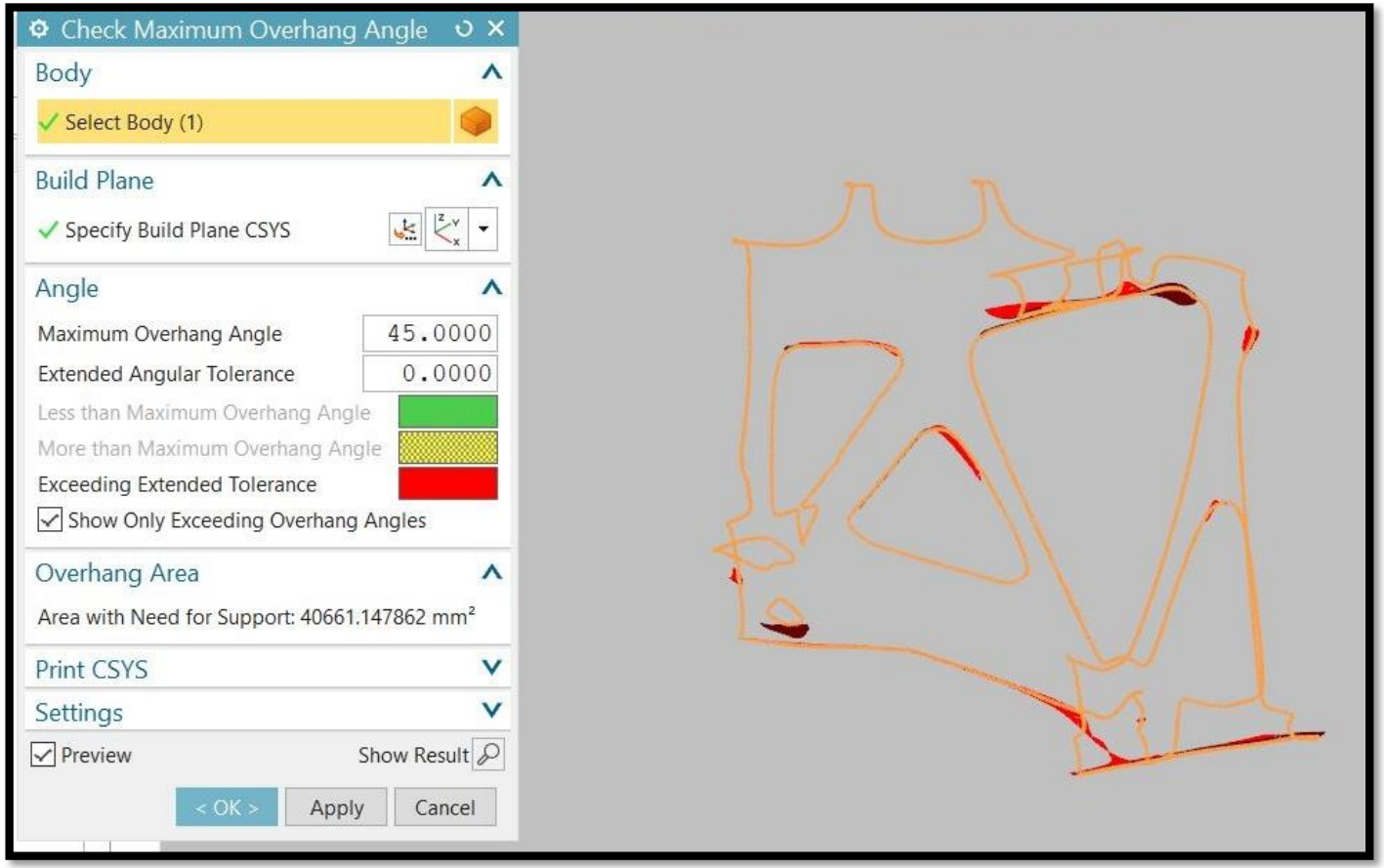


https://medium.com/pixmoving/pix-3d-printed-car-chassis-56b4501e85ab

Generative Design Part Isolation

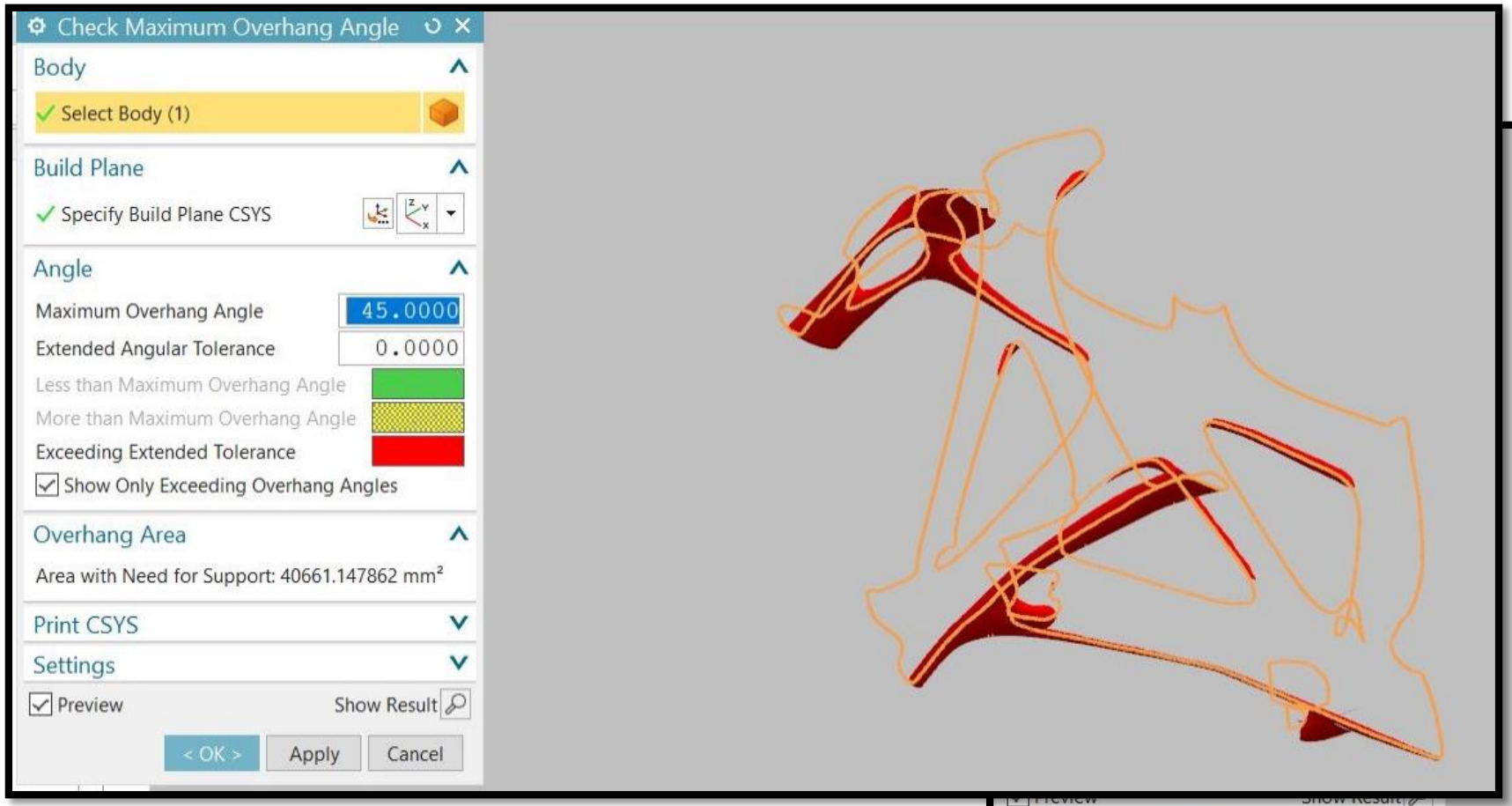
Baseline Part – Producibility Analysis





Generative Design Part Isolation

Baseline Part – Producibility Analysis



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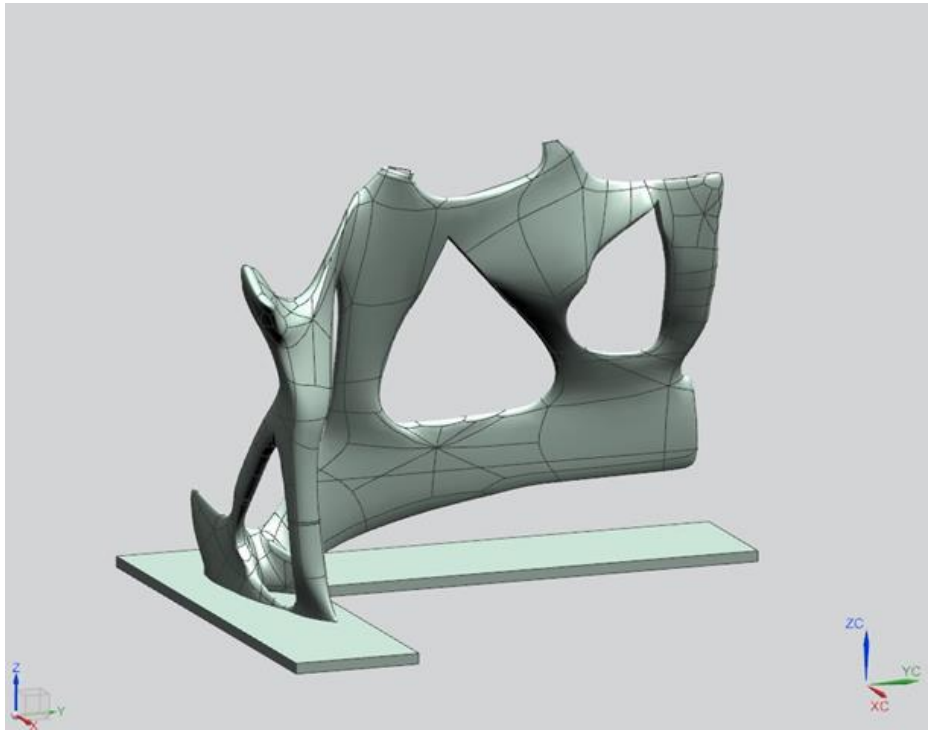
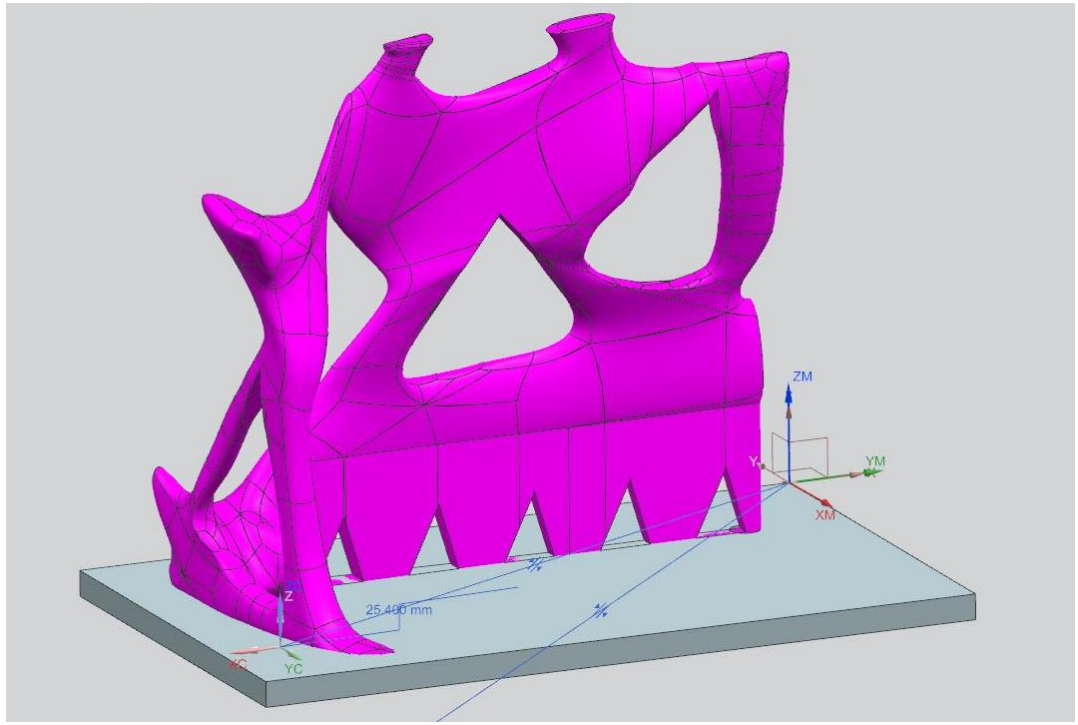
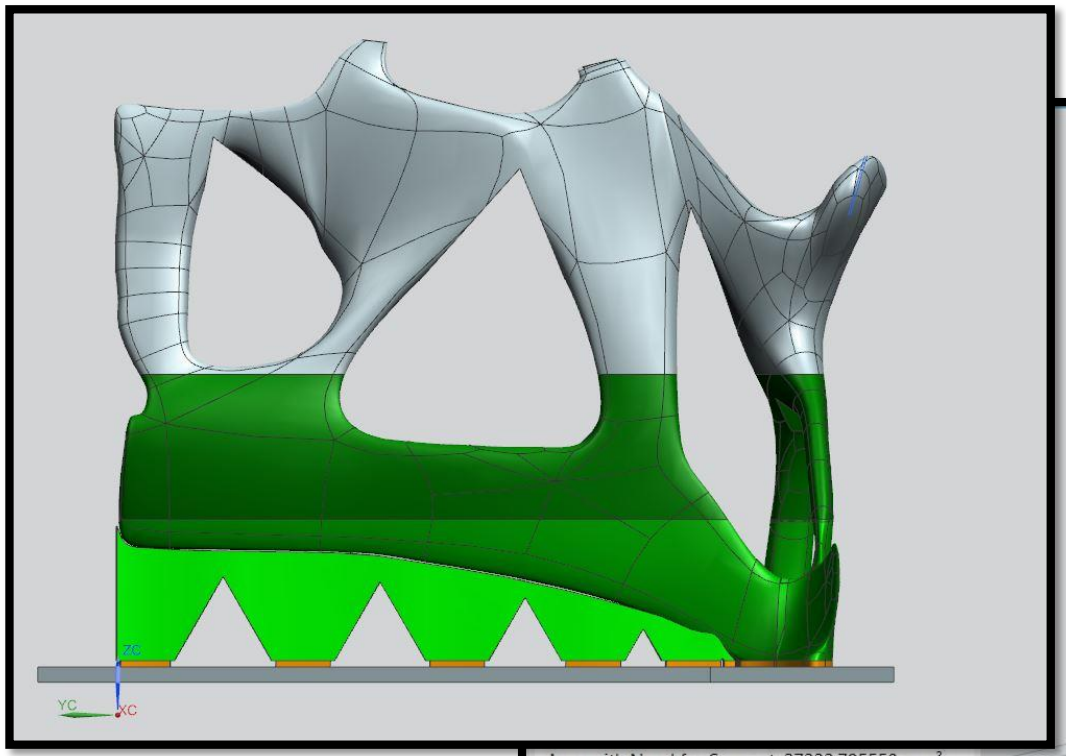
Generative Design Part Isolation
Re-Design for Producibility

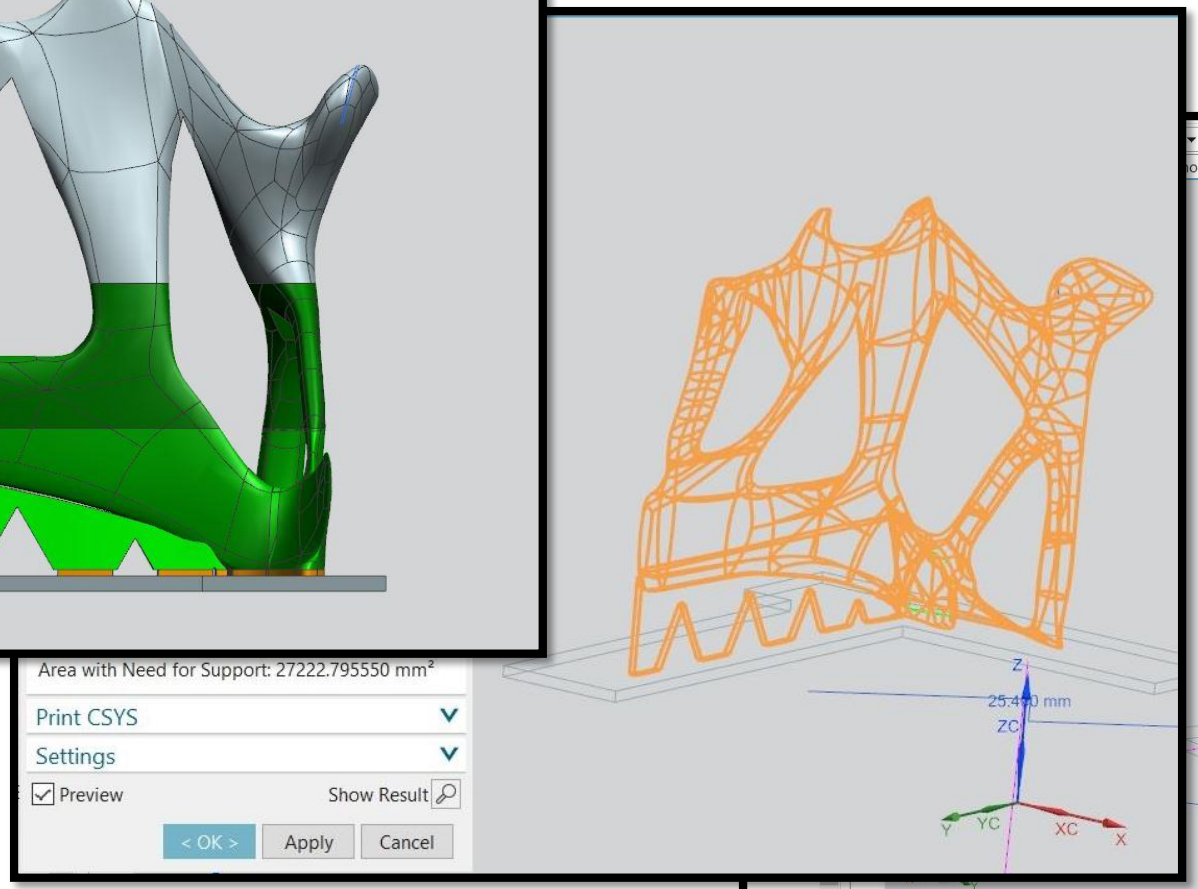


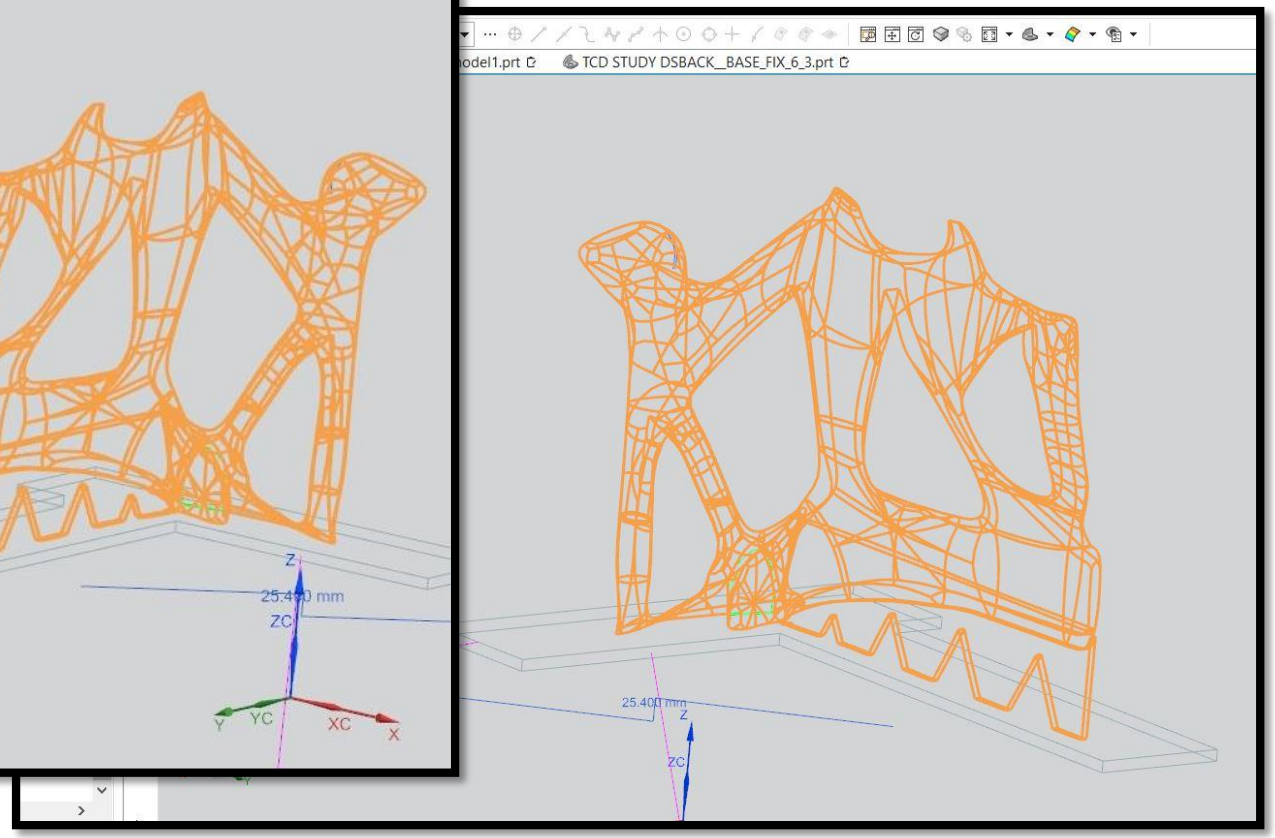


Generative Design Part Isolation

Re-Design for Producibility + Analysis







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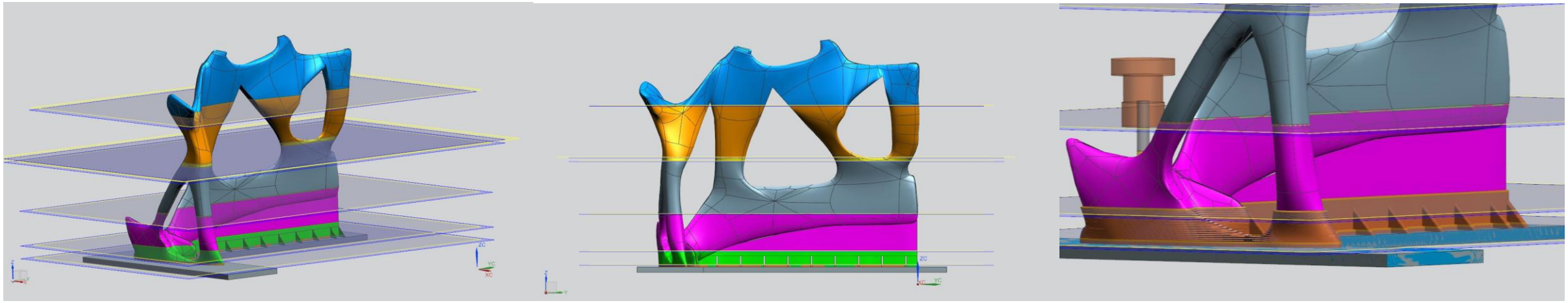
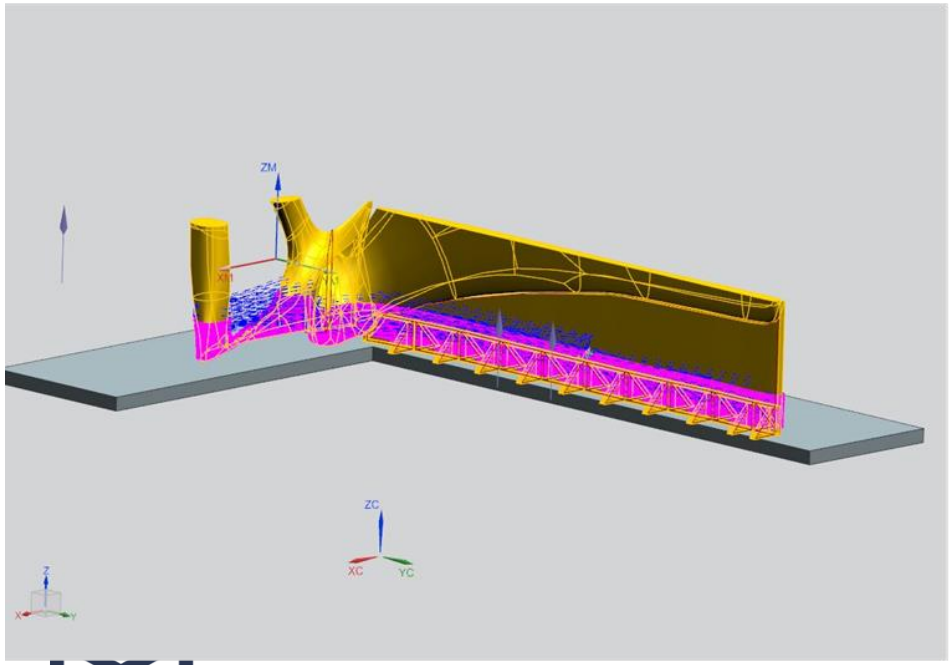
Path Programming

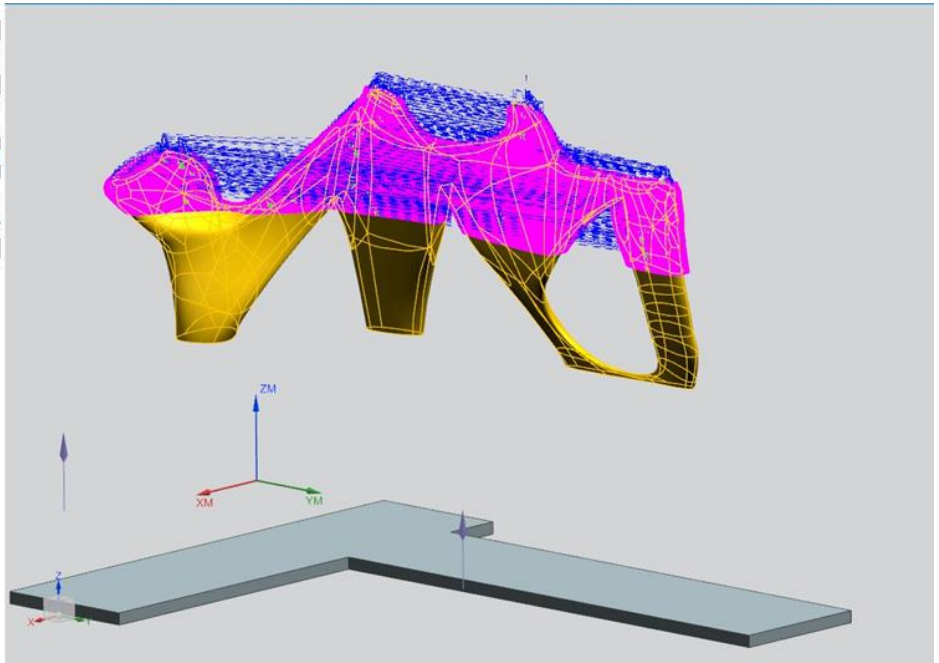
Create range levels based on geometry, run times, estimated wire changes, etc.



Path Programming

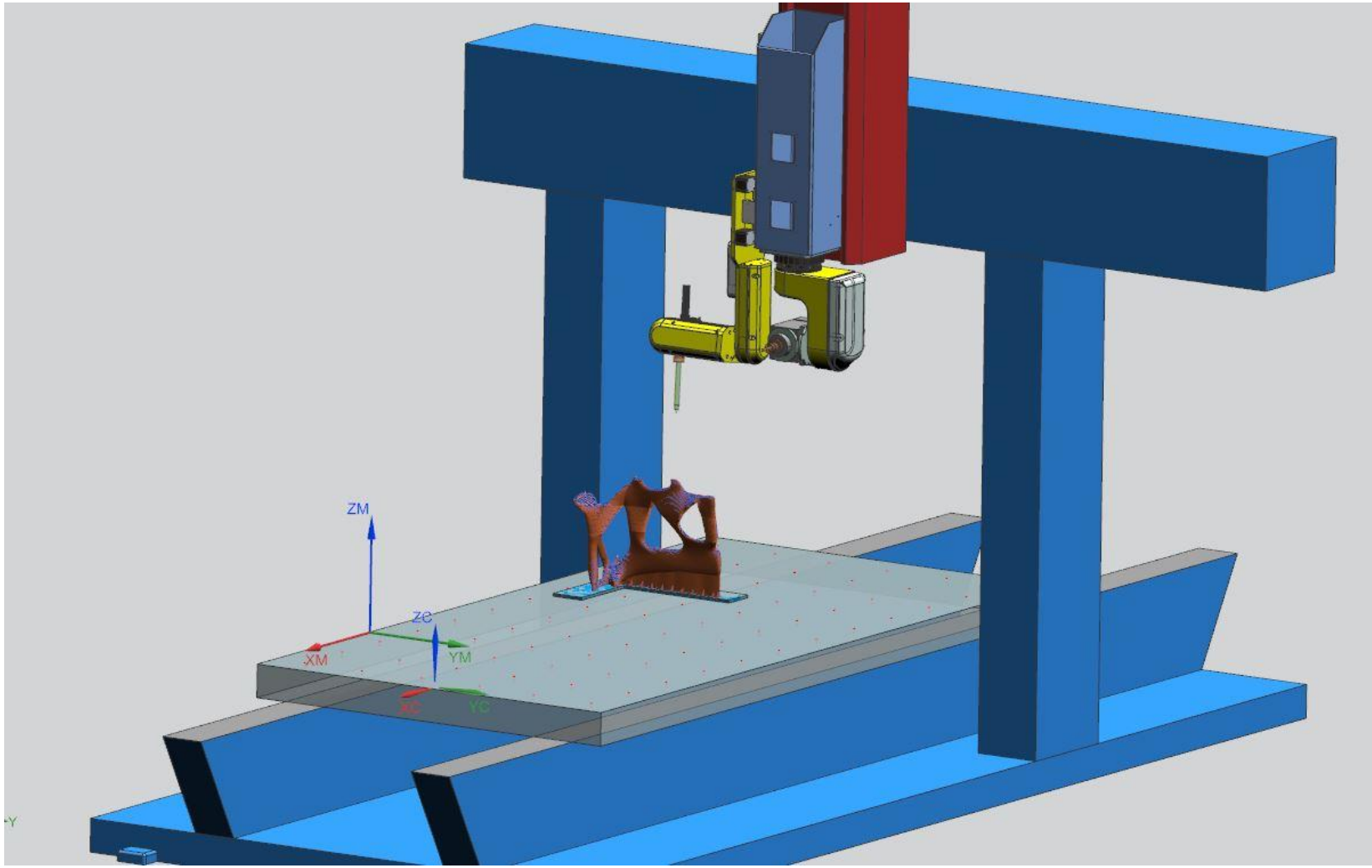
5-axis CAM programming: deposition and decking operations merged layer by layer



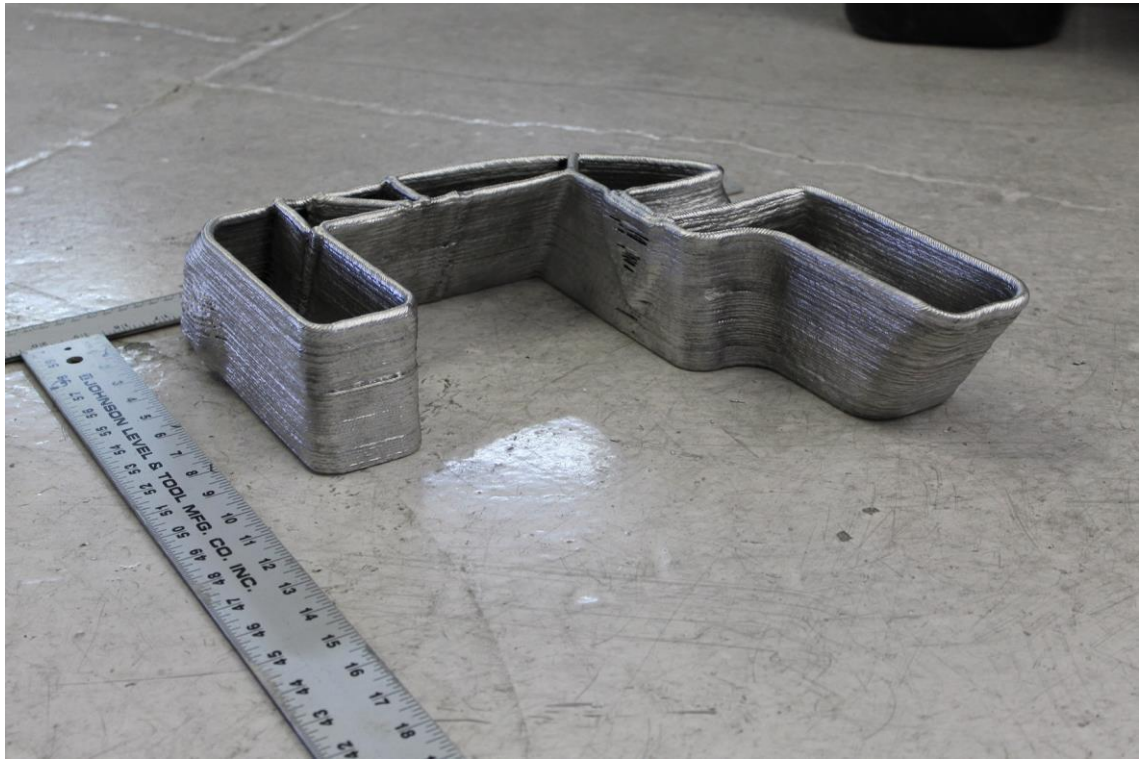


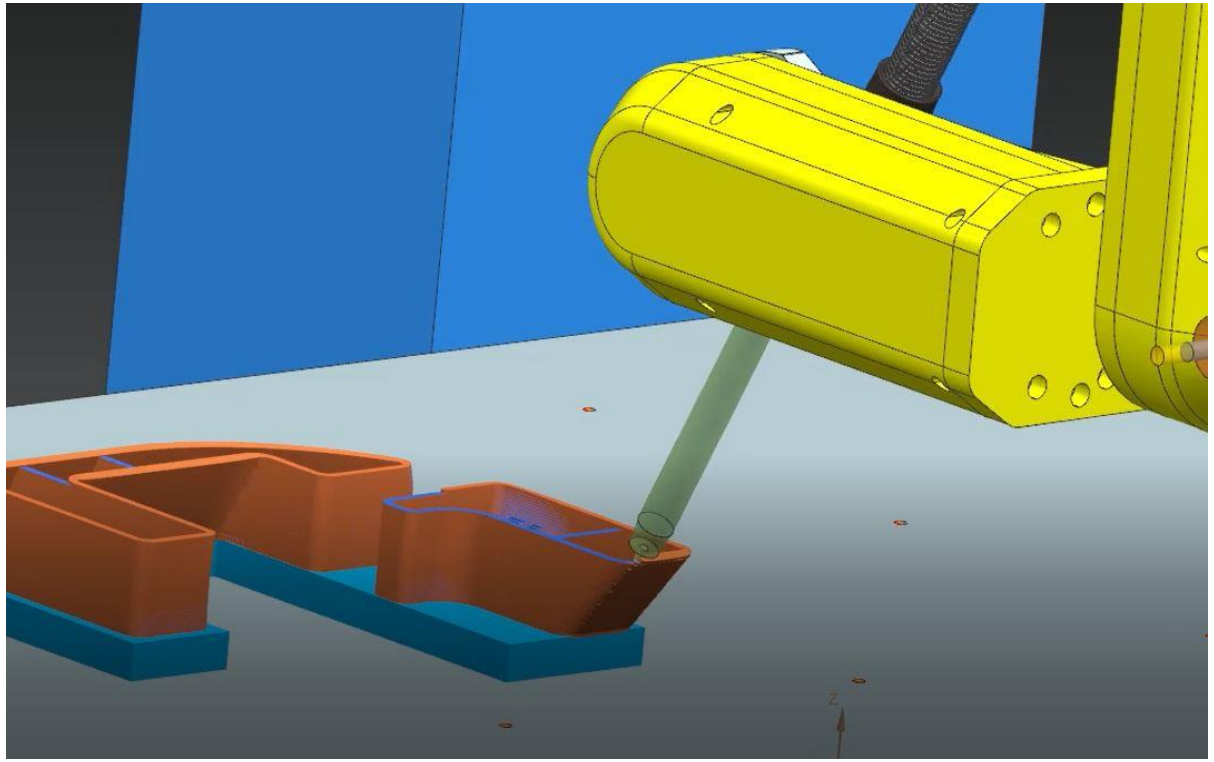
Path Programming and Validation

Machine simulation

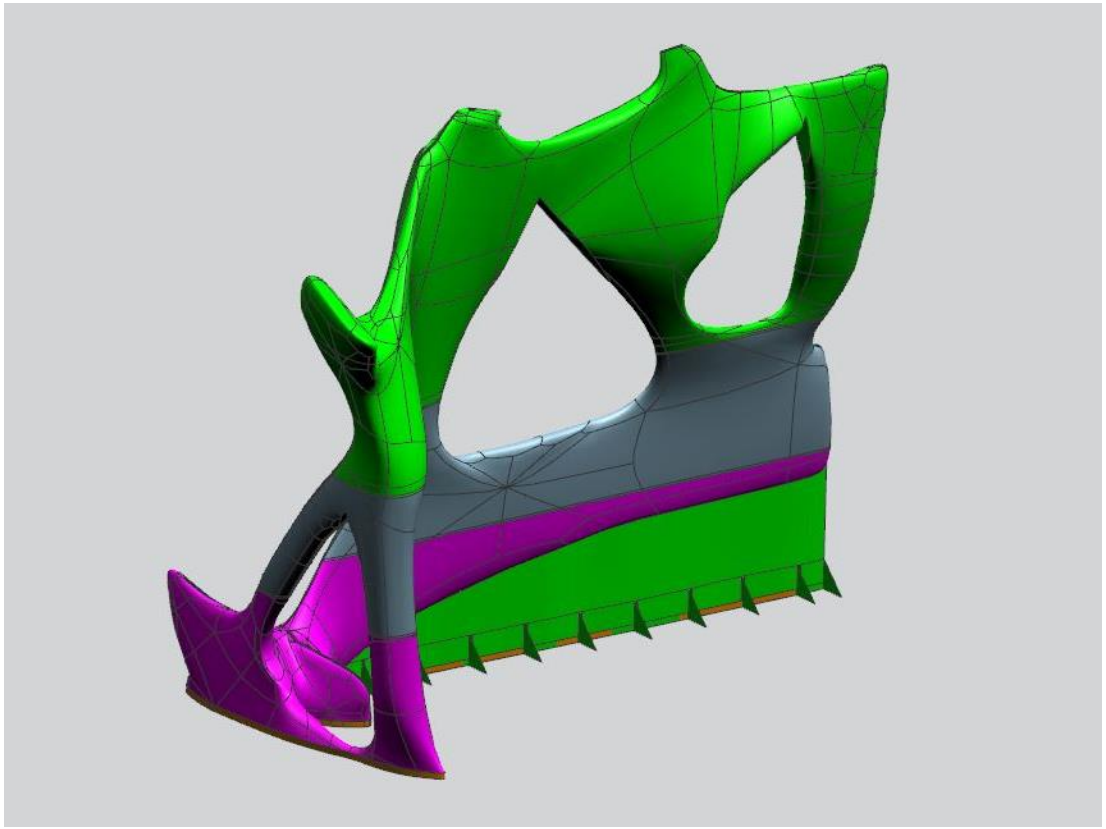


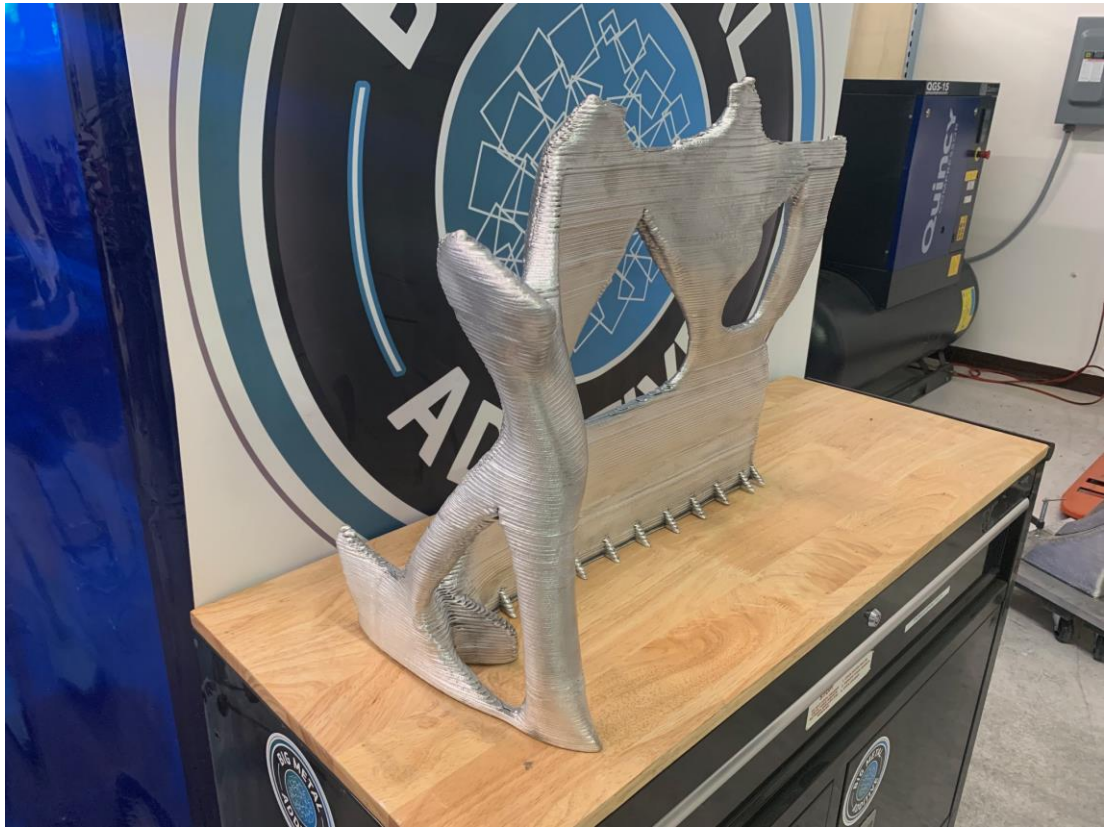
Simulation to validate toolpaths

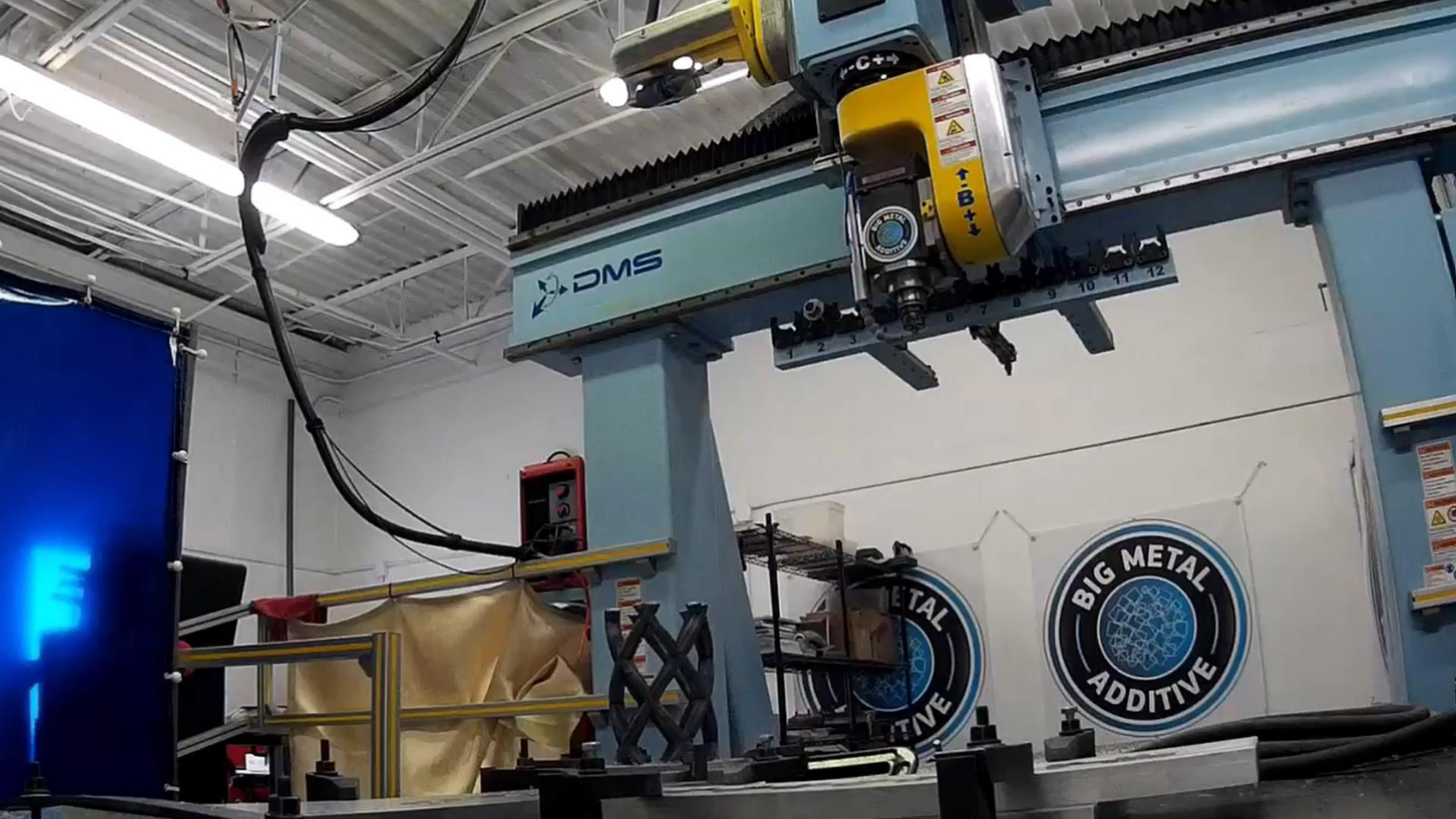




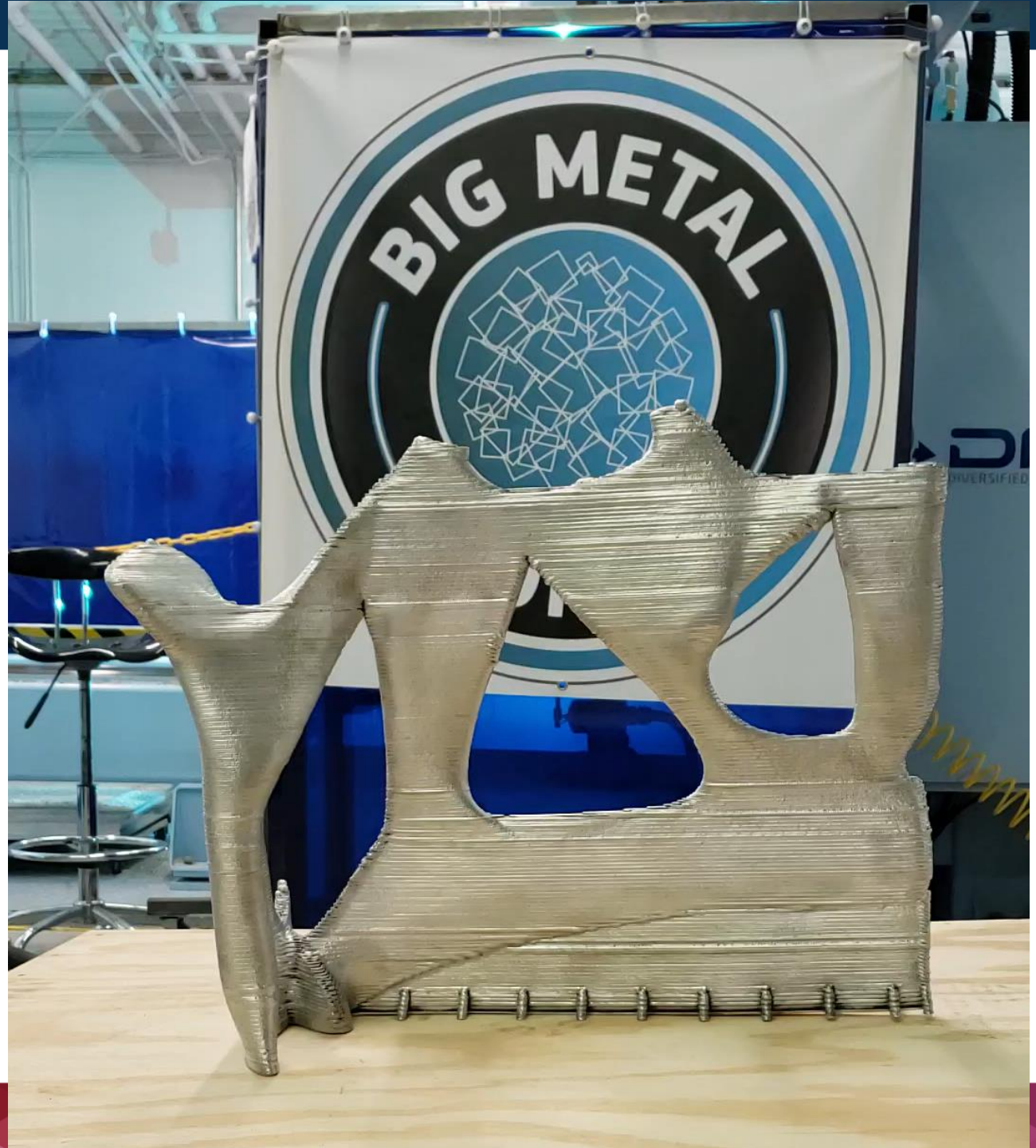
Model to Part






DMS
BIG METAL ADDITIVE

Finished Article



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