Israel 2019

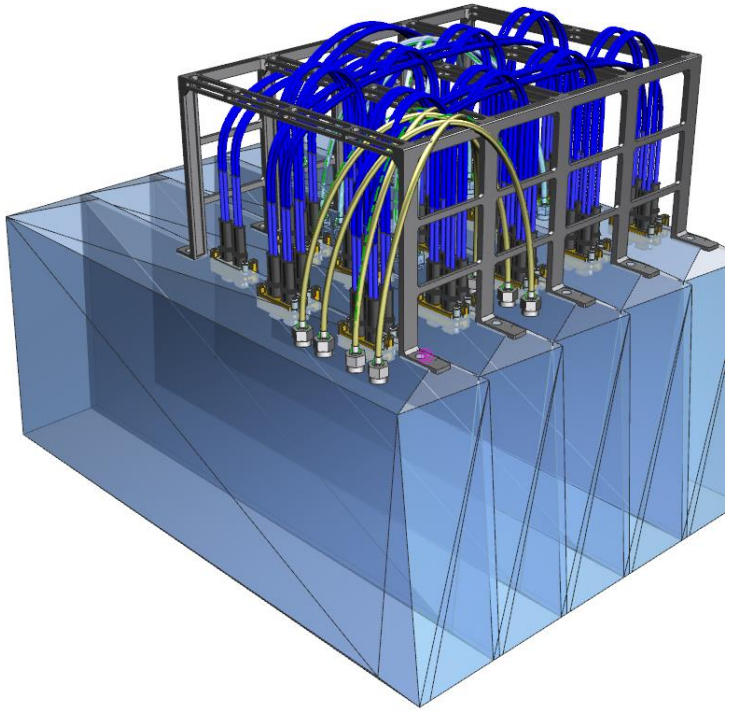
Design for Additive Manufacturing with Topology Optimization

Avishai Warszawski - IAI - October 30th, 2019

Altair

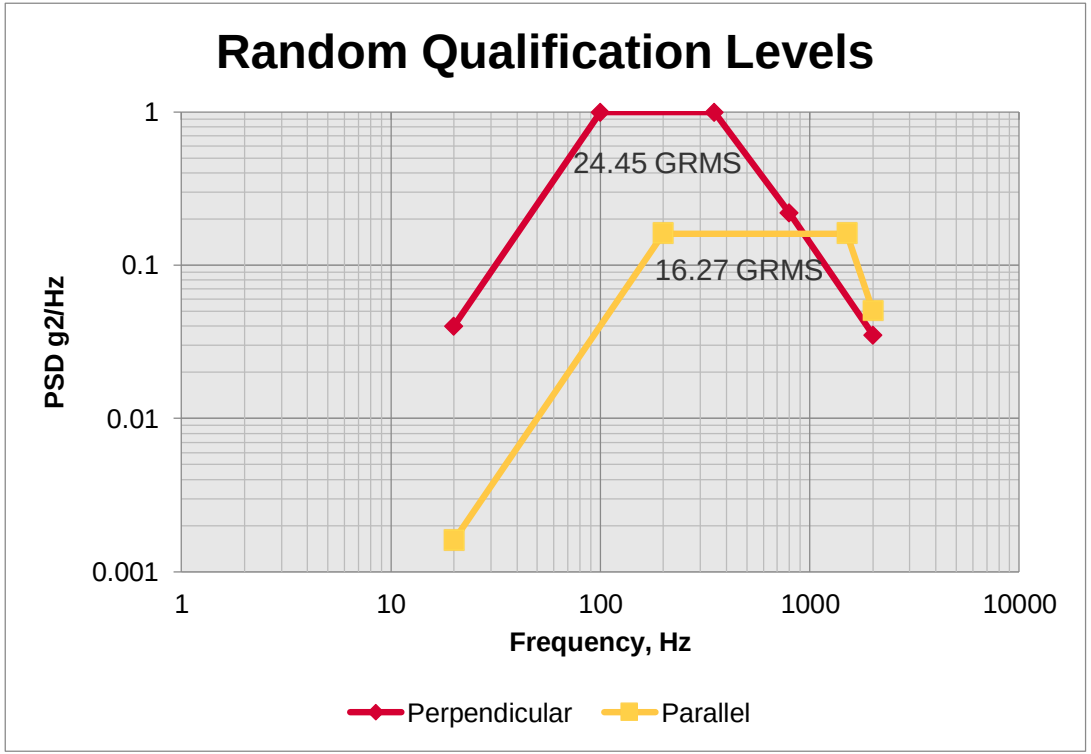
The Candidate

- Electrical unit with several modules
- Each module is connected to the other by means of delicate coaxes
- Coaxes must be supported for space launch environmental conditions



Environmental Conditions

- First natural frequency above 450Hz
- Positive margin of safety for load stress (0.3 for yield stresses)
- Dynamic Vibrations
- 3 separate g Load Cases
  - X=100g Y=100g Z=100g



Original Machining Design

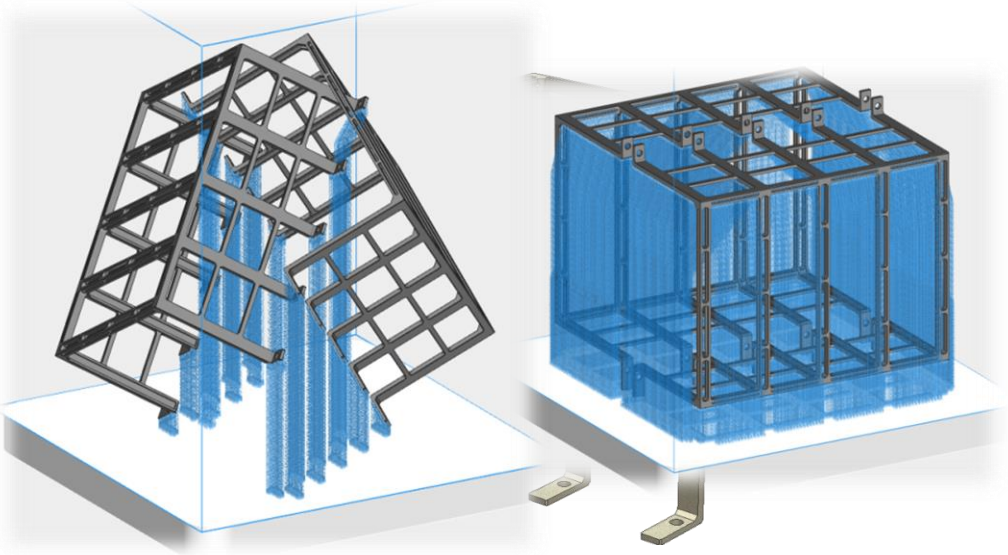
Mass: 101gr

First Natural Frequency: 197Hz

This solution does not provide the required stiffness.

Design for 3D printing was advised for stiffer design.

6 Parts were required to be printed

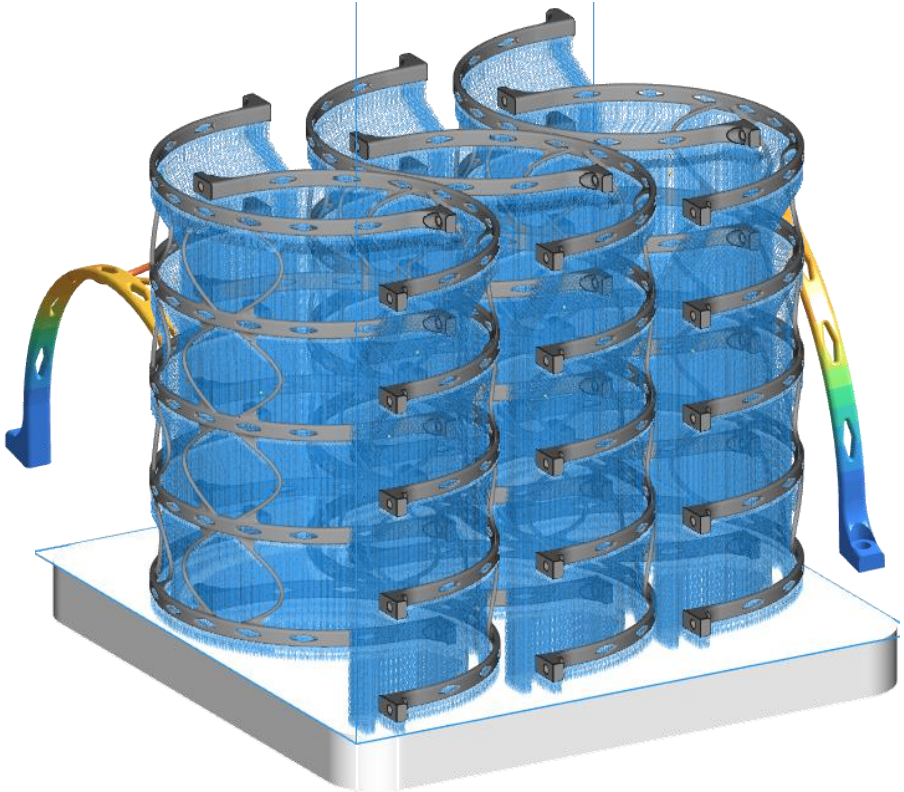


My Own Design in NX without Topology Optimization

Mass: 92gr

First Natural Freq: 417Hz

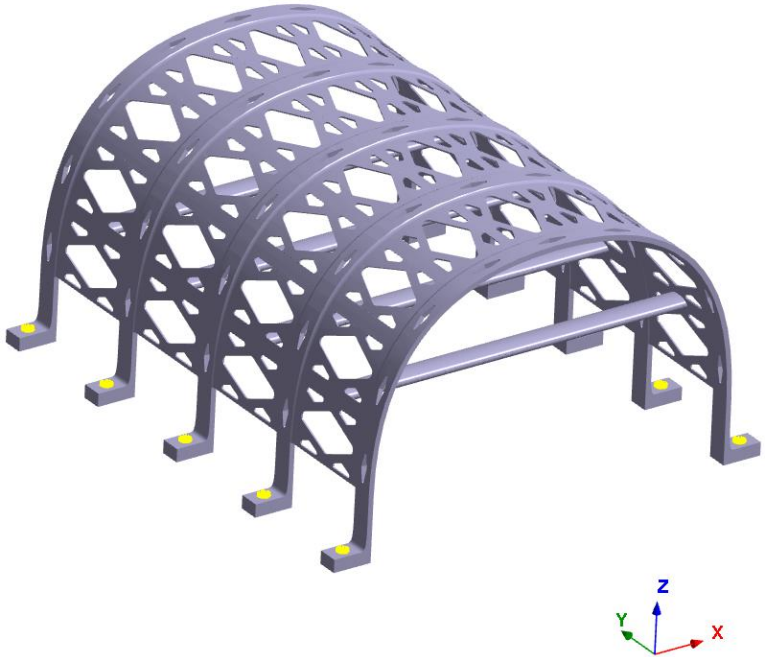
Design requires a lot of supports for printing



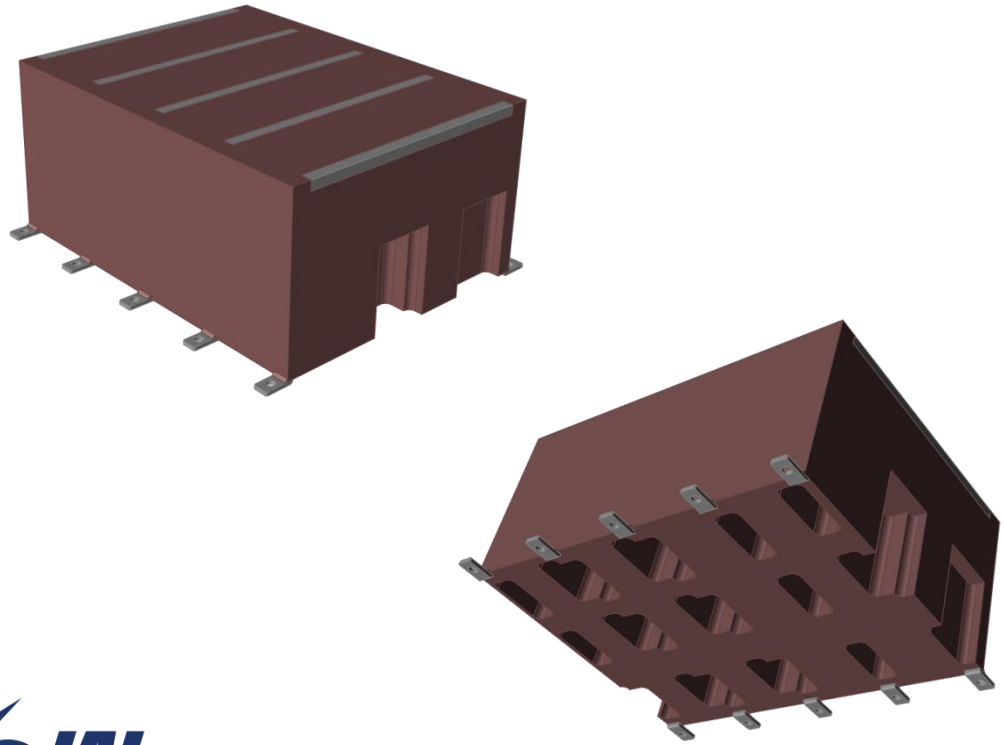
Design for AM without Topology Optimization

- Mass: 168gr
- First Natural Freq: 167Hz

- Self supporting – but does not meet requirements



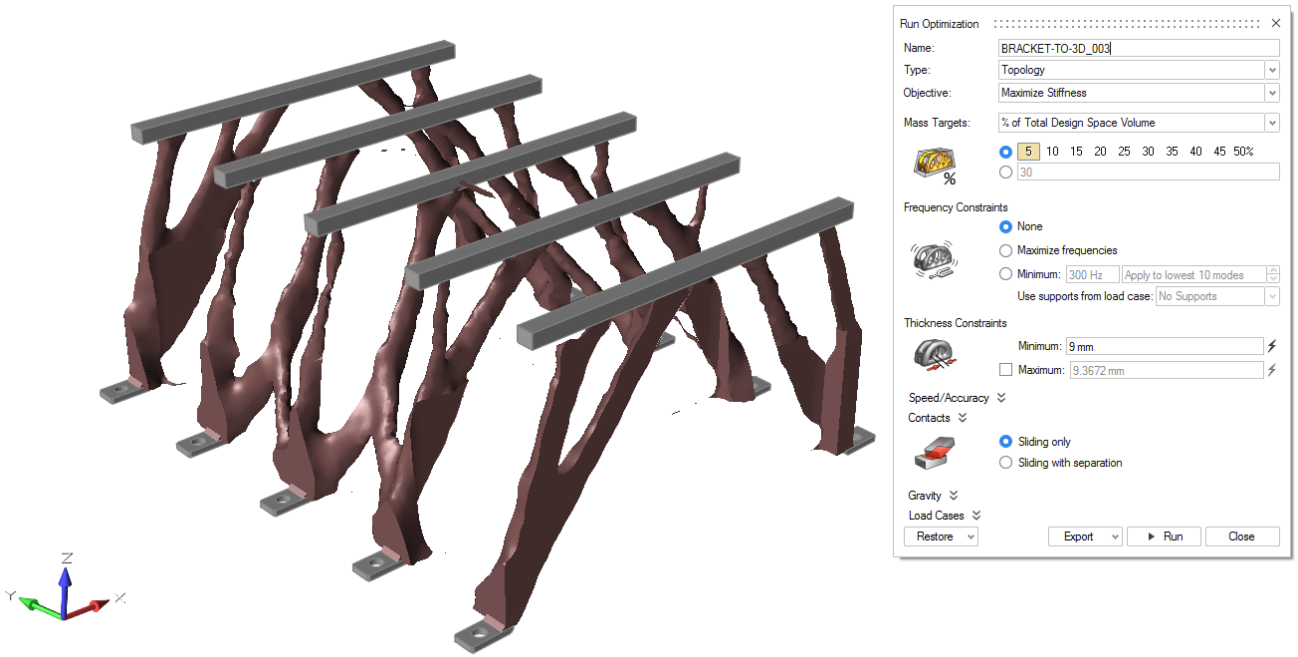
Topology Optimization



Red – Design Space
Gray – Non-Design Space

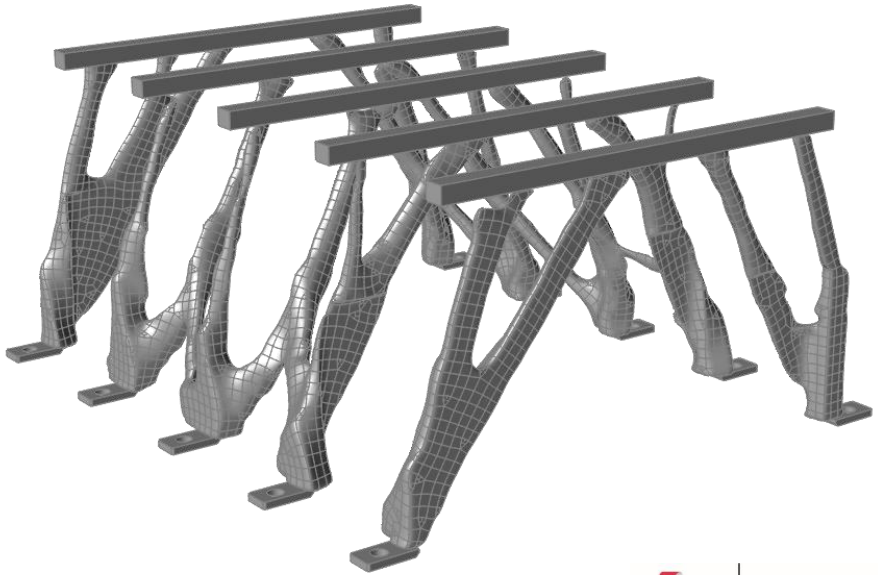
Material: AlSi10Mg
- ULTIMATE STRENGTH - 350MPa MIN
- YIELD STRENGTH - 210MPa MIN
- MODULUS OF ELASTICITY 60GPa
- DENSITY: 2720 KG/M^3

Inspire Solution

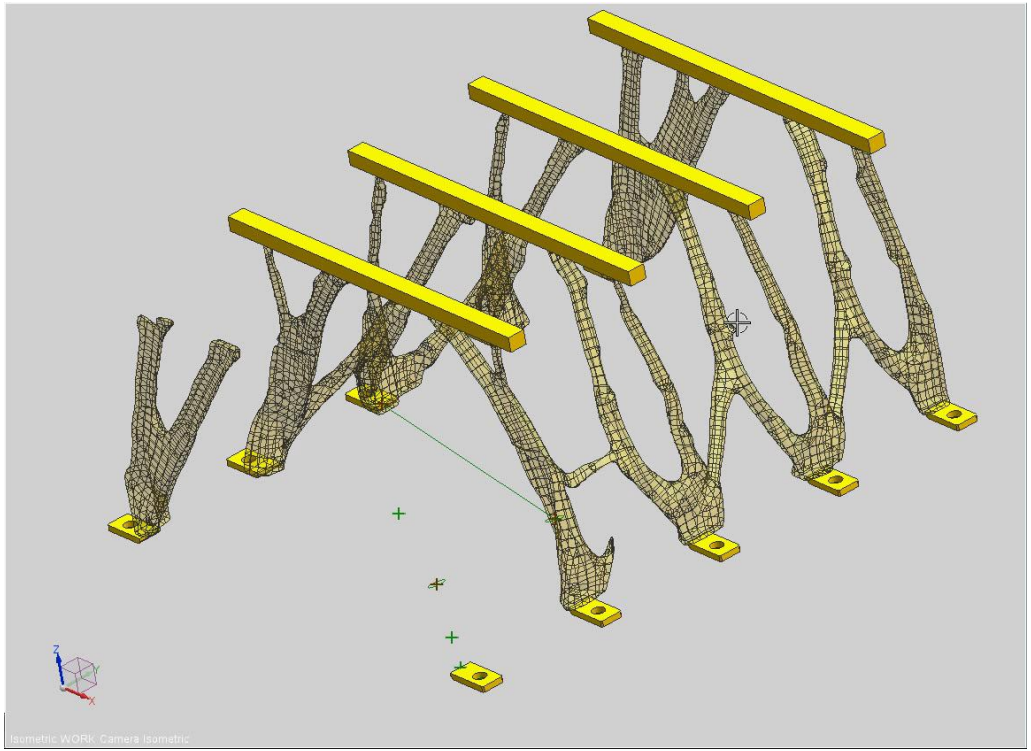


Inspire PolyNurb Fit Solution

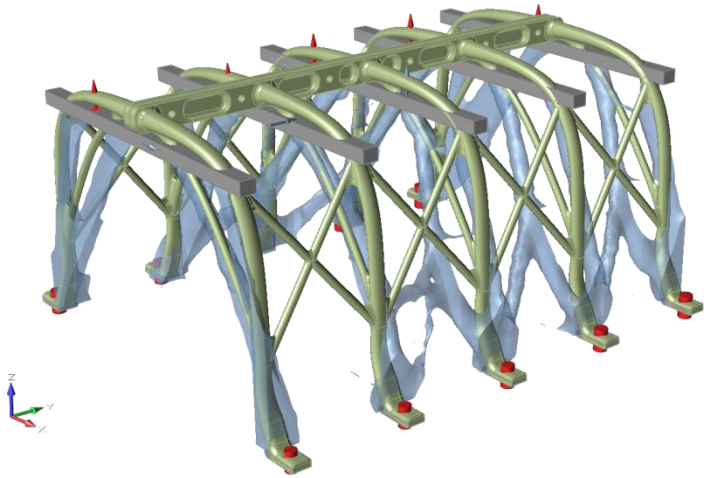
Finer detail analysis detail required
Additional work in Evolve

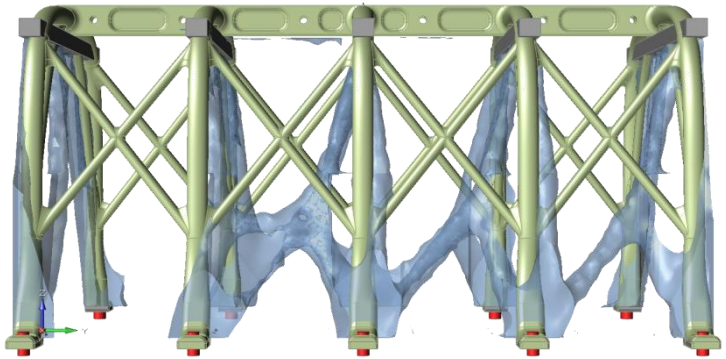


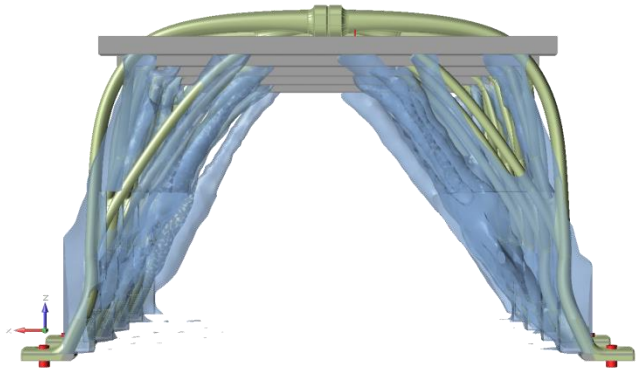
Inspire Optimization Result as an NX Template



Inspire Optimization Result as an NX Template

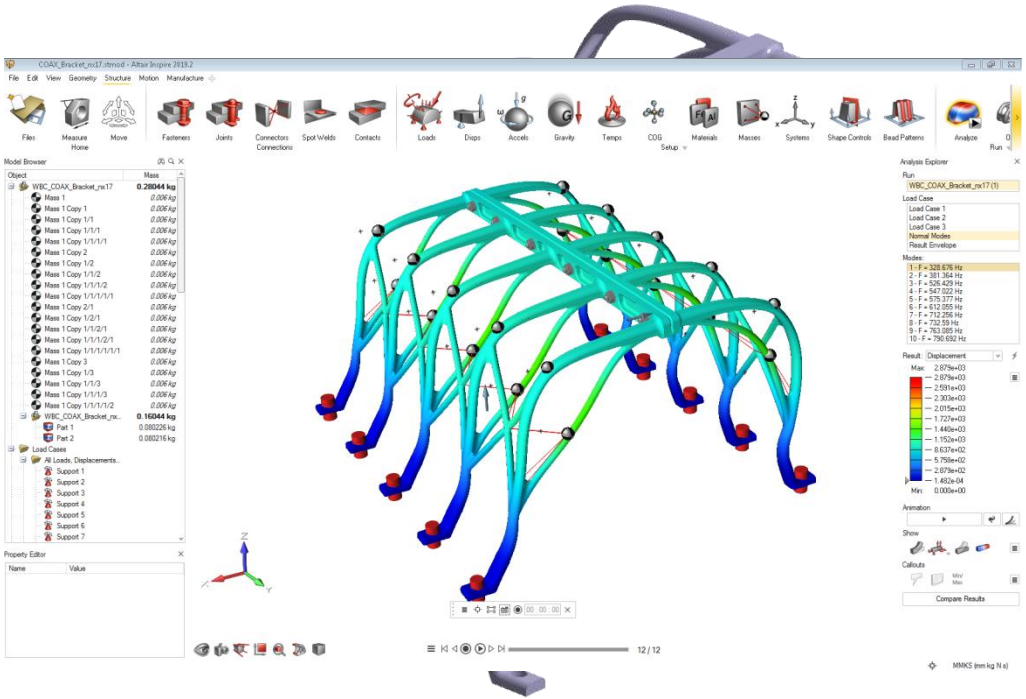






NX-Inspire Solution Validation

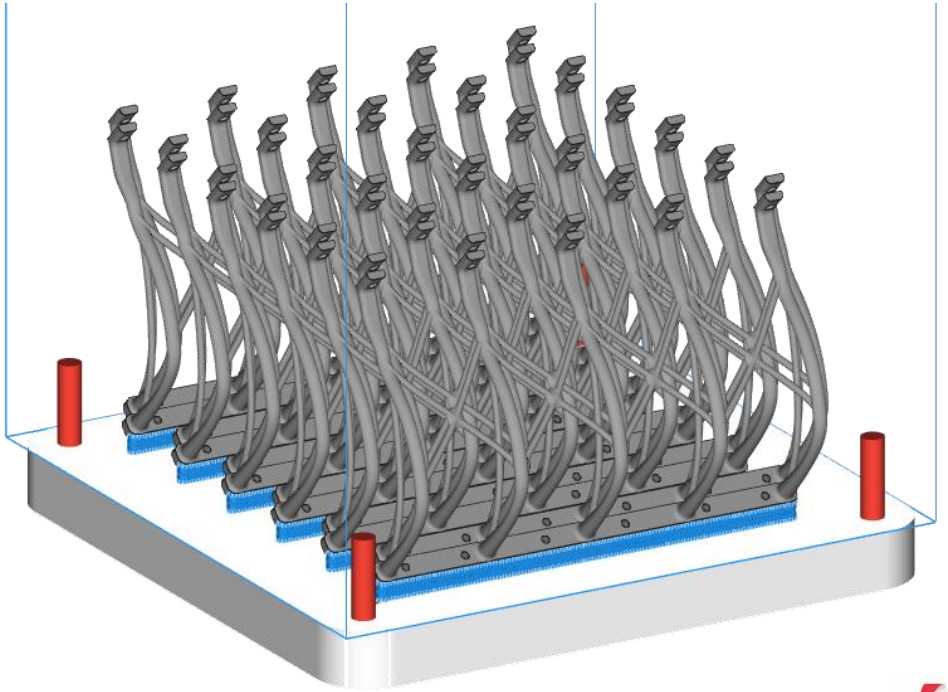
Mass: 160gr
First Natural Freq: 513Hz
First Natural Freq with mass: 328Hz



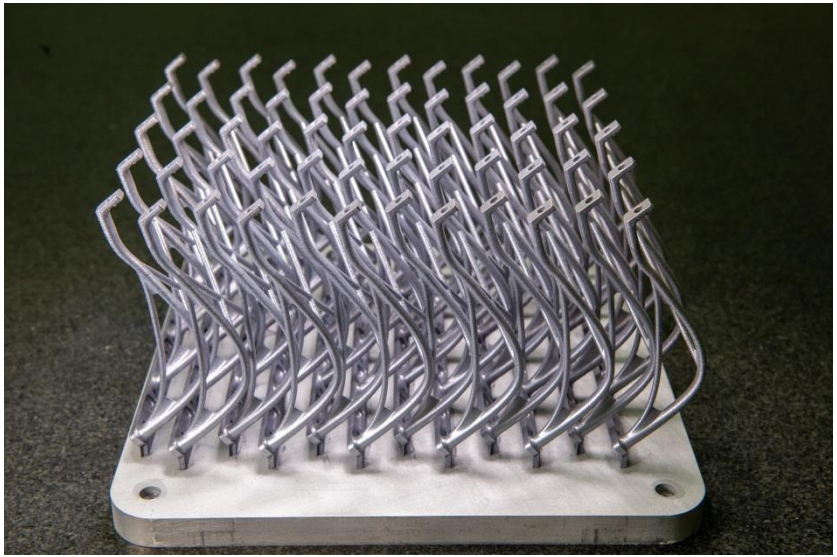
Separated part into two for assembly accessibility
Provides sufficient stiffness
Minimal required supports
Very good part nesting during print job

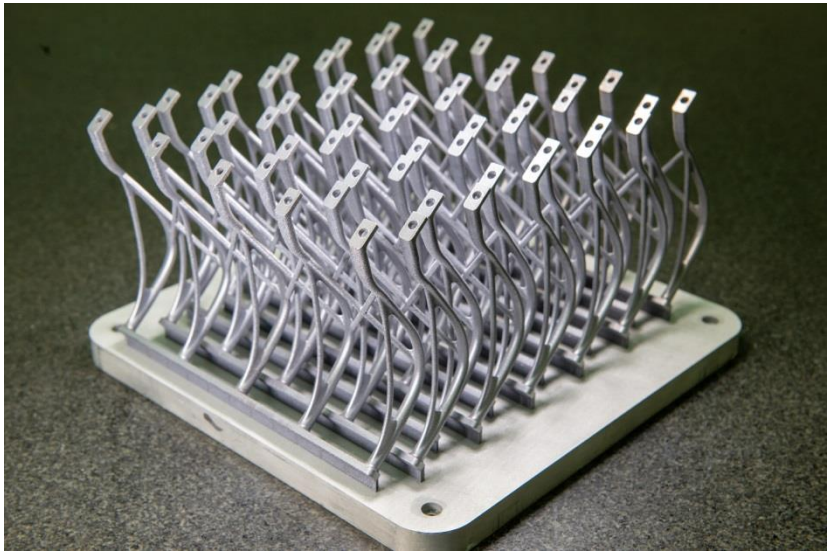
Print Job Nesting

A total of 12 parts can be printed in one job.
Assembly of 6 complete brackets



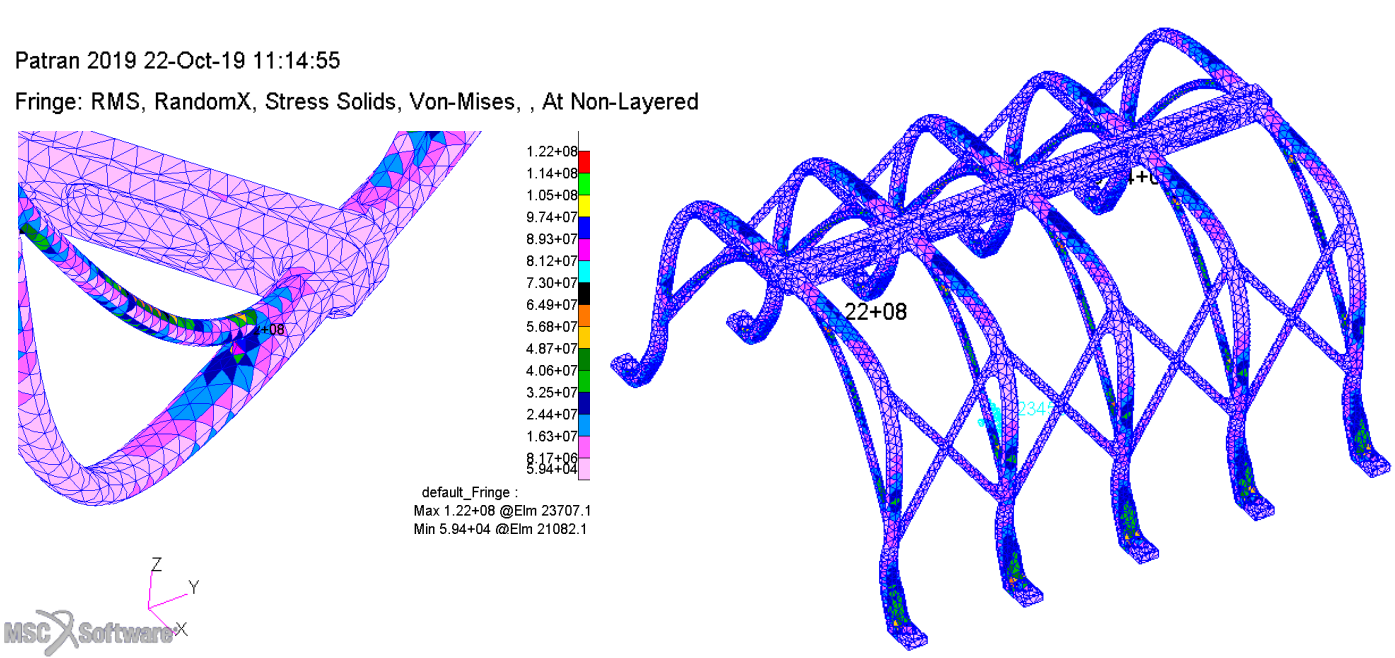
Here you go!





Printed Parts Detached from Supports

Dynamic Response Analysis Vallidation



1.22+08
1.14+08
1.05+08
9.74+07
8.93+07
8.12+07
7.30+07
6.49+07
5.68+07
4.87+07
4.06+07
3.25+07
2.44+07
1.63+07
8.17+06
5.94+04
default_Fringe :
Max 1.22+08 @Elm 23707.1
Min 5.94+04 @Elm 21082.1

What's Next?

NDT Inspection

- Tensile Specimen Testing for Each Job
- Penetrant inspection
- µCT Scan

Dynamic Testing X, Y & Z Axis Each

- Low level sin sweep resonance search
- Sinusoidal vibration
- Low level sin sweep resonance search
- Random vibration
- Low level sin sweep resonance search
- Mechanical shock
- Low level sin sweep resonance search
- Visual inspection

Thermal Cycling

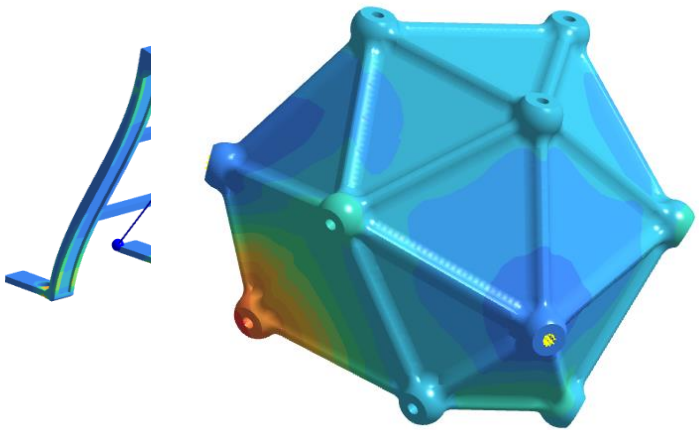
- Low level sin sweep resonance search
- Thermal Cycling
- Visual inspection
- Penetrant inspection
- µCT Scan

SIMSOLID

- Some things I have done with SIMSOLID

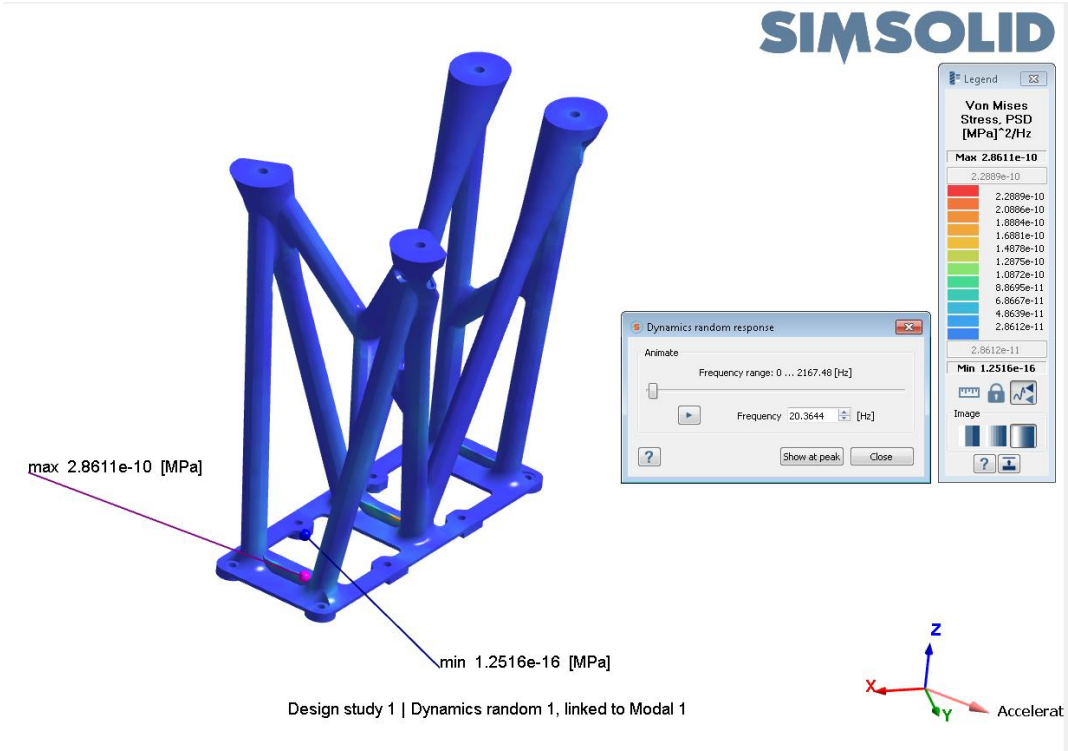
SIMSOLID Verification Examples

- Stress Analysis of machined coax bracket
- Modal analysis and verification



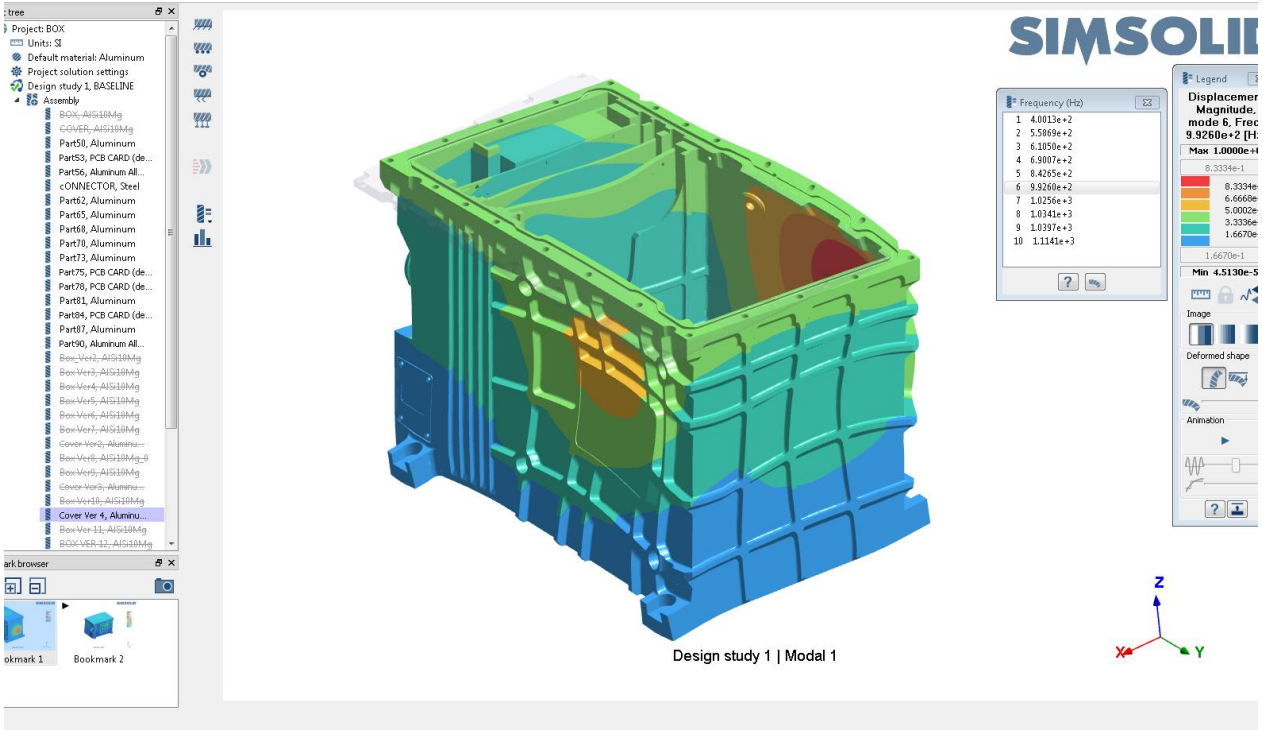
SIMSOLID Verification Examples

- Random Vibration



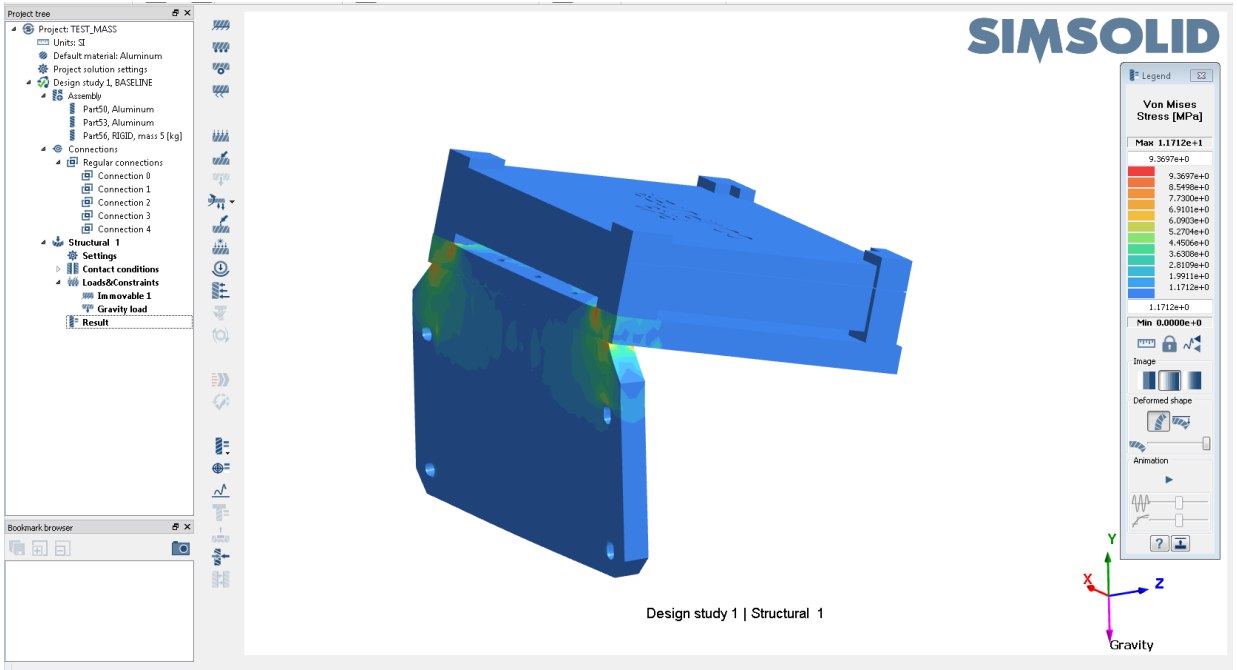
SIMSOLID Verification Examples

Modal Analysis of assembly



SIMSOLID Verification Examples

- Stress Analysis of assembly



Thank you!