Application of Metal Additive Manufacturing to Rugged Defense Electronics Systems

William VILLERS, TEN TECH LLC

iMAPS New England 45th Symposium & Expo

May 1st 2018

Today's Discussion

Introductions
- Arsenal Advanced Methods
- TEN TECH LLC Services & Solutions
- MORF3D

Rugged VPX Single Board Computer Modules
- VITA 48.2 Single Board Computer
- MIL-STD-810 Requirements

Metal Additive Manufacturing
- Geodetic & Lattice Structures

"Lattice" Core Primary Cover
- Comparative Performance Evaluation

Introductions

Arsenal Advanced Methods – MORF3D – TEN TECH LLC

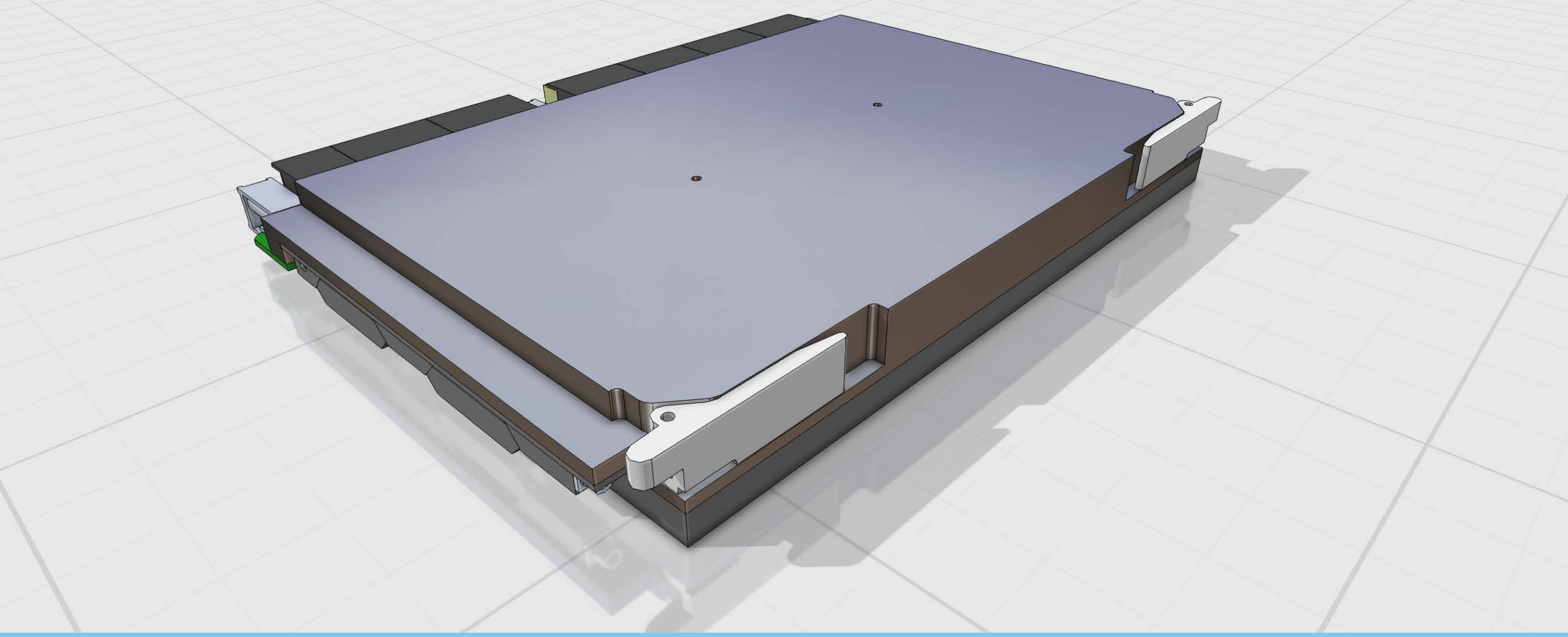
Additive Manufacturing Initiative

Redesign of Rugged Electronics Components

- Weight Reduction Initiative
- Application of Metal Additive Manufacturing
- Heavy Utilization of Predictive Engineering

Collaborative Effort Across Disciplines

- TEN TECH LLC (Los Angeles, CA): Defense Electronics Design & Simulation SME
- Arsenal Advanced Methods (Nashua, NH): Additive Manufacturing R&D
- MORF3D (El Segundo, CA): Metal Additive Manufacturing



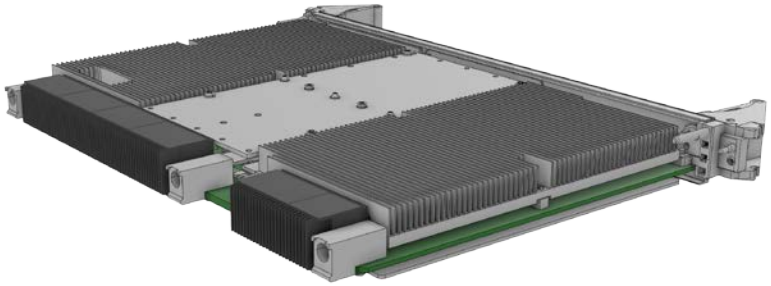
VITA 48.2 Single Board Computer

Design - Form & Function - Mechanical Requirements

Rugged VPX Single Board Computer

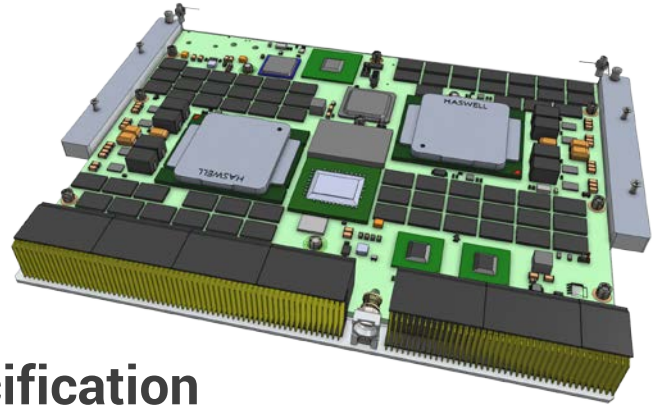
Complete Computer on Single Circuit Card

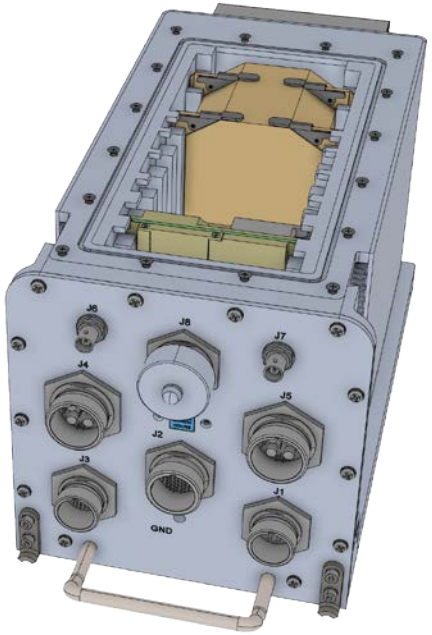
- CPU, GPU, Memory, Networking, I/O
- Rugged for Harsh Military Environments



Installed in Rugged Chassis

- Standard Form Factor (1U, ATR,…)
- Standard Mechanical/Electrical Interfaces
- Multiple SBC Installed in Chassis





ANSI/VITA 48.x Standard Mechanical Specification

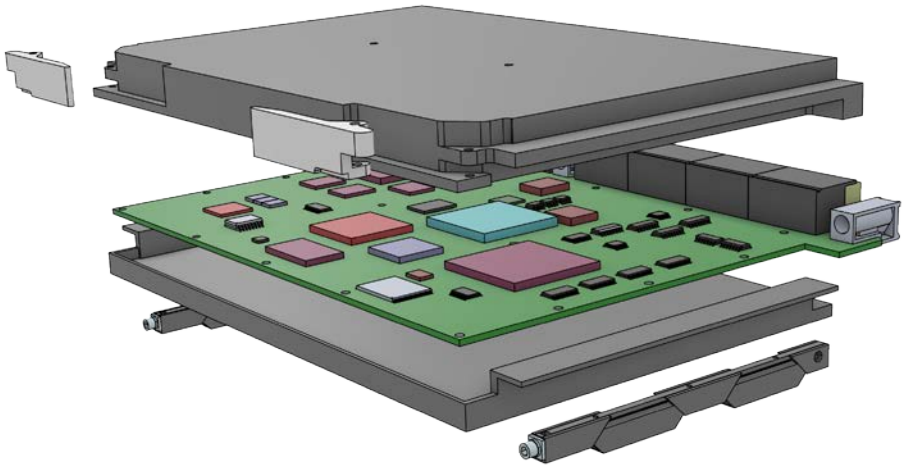
- Approved by ANSI in 2010
- VITA 48.2 Conduction-cooled SBC

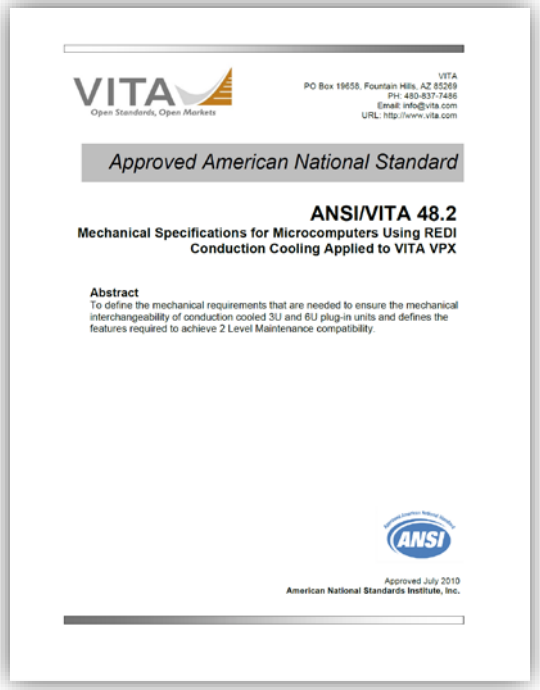
VITA
Open Standards, Open Markets

ANSI/VITA 48.2 SBC Module

Conduction-cooled Module

- Circuit Card Sandwiched Between Highly Conductive Metallic Covers
  - Typically Al 6061, but some designs use Copper
- Covers Act as Heatsink & Mechanical Support
  - Tight Fit to Provide Rigidity to the Assembly
  - Components Heat Dissipated Through and out to Chassis Sidewalls
  - Wedge-lock Interface to Hold the Modules in Chassis

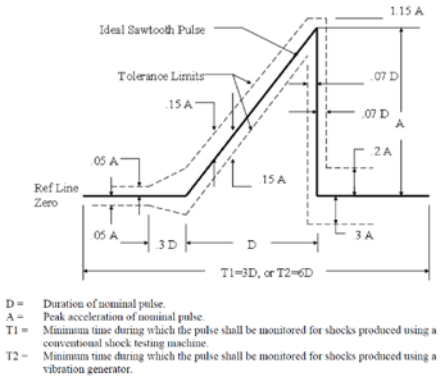




Environmental Requirements

MIL-810/NAVSEA-901/DO-160 Mechanical Specifications

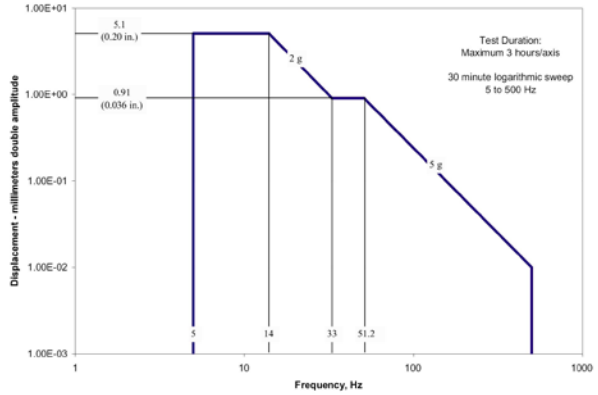
- Acceleration, Crash & Shock
- Random, Sine & Sine-on-Random
- Solder Joints High-cycle Fatigue
- Temperature Extremes

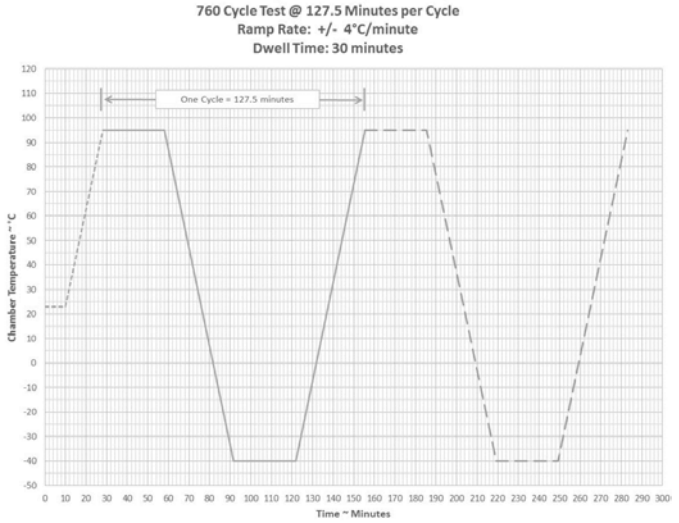


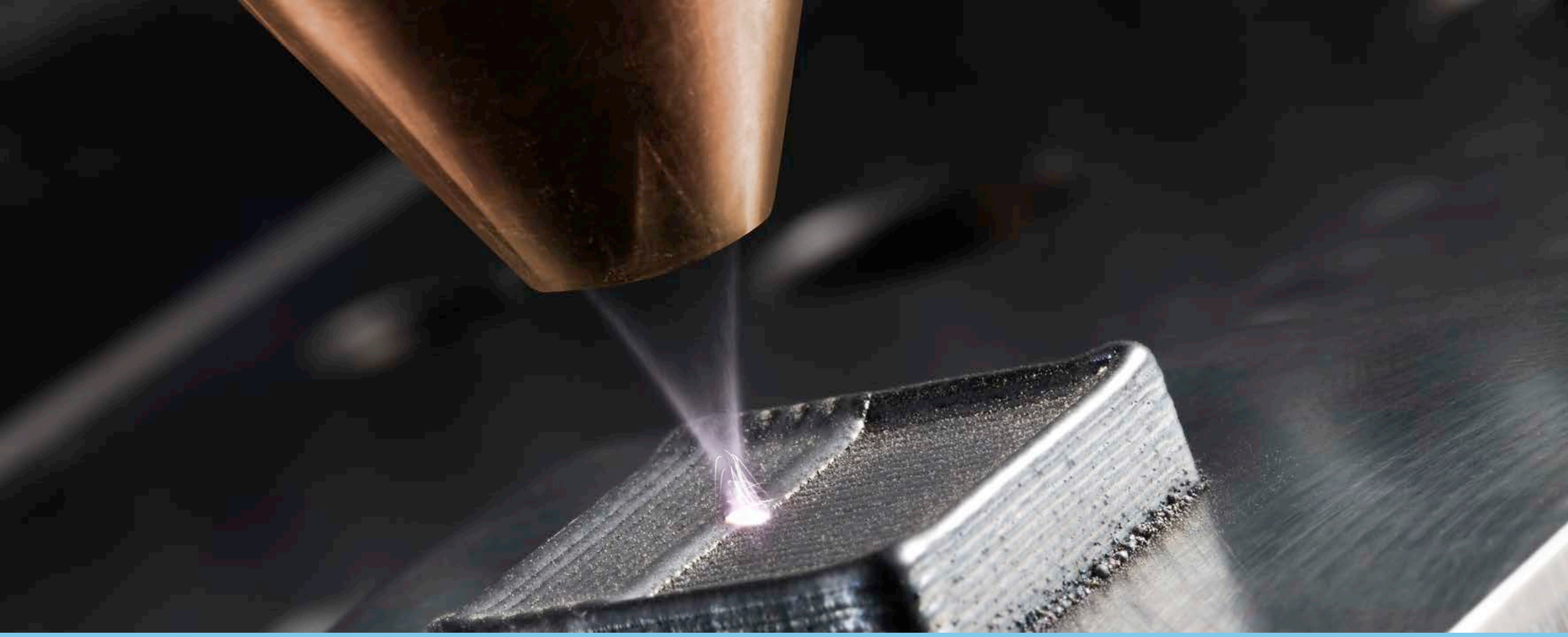
D = Duration of nominal pulse.
A = Peak acceleration of nominal pulse.
T1 = Minimum time during which the pulse shall be monitored for shocks produced using a conventional shock testing machine.
T2 = Minimum time during which the pulse shall be monitored for shocks produced using a vibration generator.

Thermal Management

- Components Operating Temperature
- Card Edge Temperature
- Conduction to Chassis Wall
- Solder Joint Low-cycle Fatigue







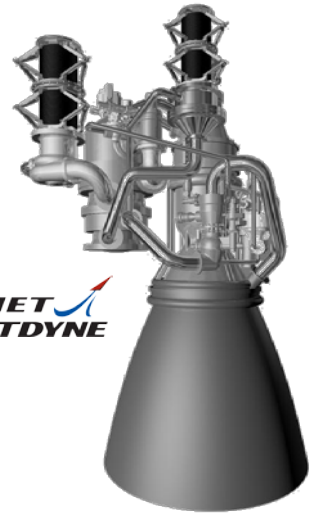
Metal Additive Manufacturing

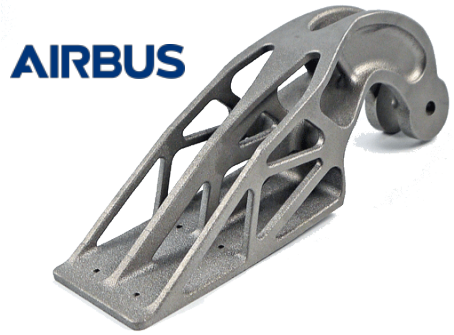
Concept & Examples – Lattice Structures

Metal AM for Tooling & Direct Use

Metal AM Technology Matured Significantly

- Industry-grade Material already in use
- Parts Being Built Directly for end-use
  - Pratt & Whitney, Rolls Royce, GE Aircraft Engines
  - Rocketdyne, GKN, SpaceX Rocket Motors





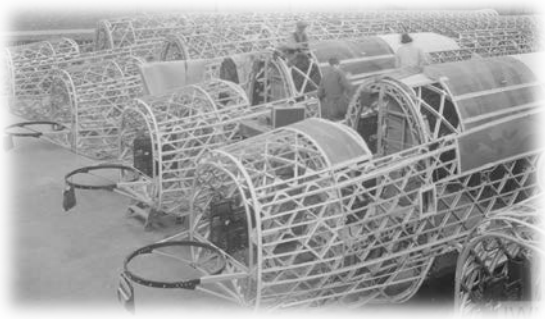
Geodetic & Lattice Structures

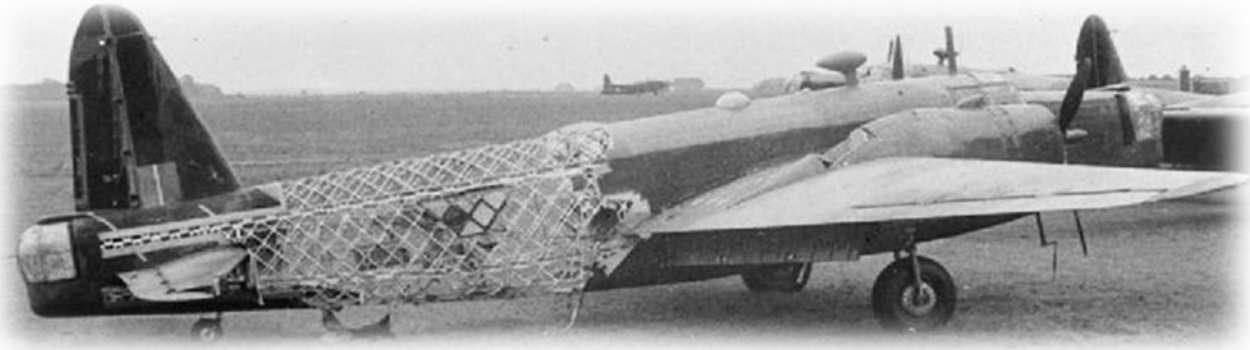
Many Closely-spaced Truss Construction

- Double-digit Weight Reduction
- Without Sacrificing Structural Integrity

WWII Vickers Wellington Bomber

- Achieved 40% Weight Reduction
- No Airworthiness Issues
- Too costly & time consuming

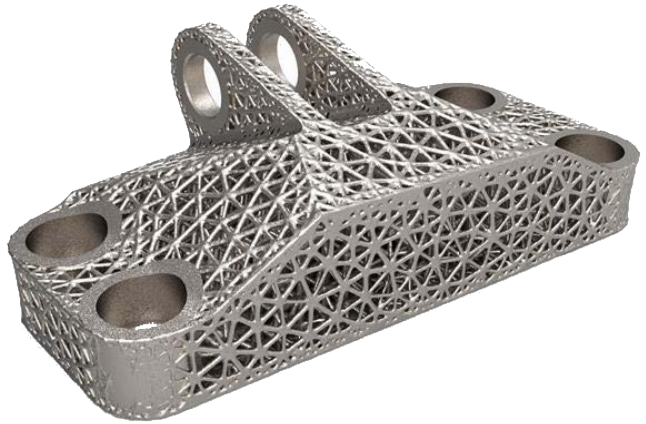


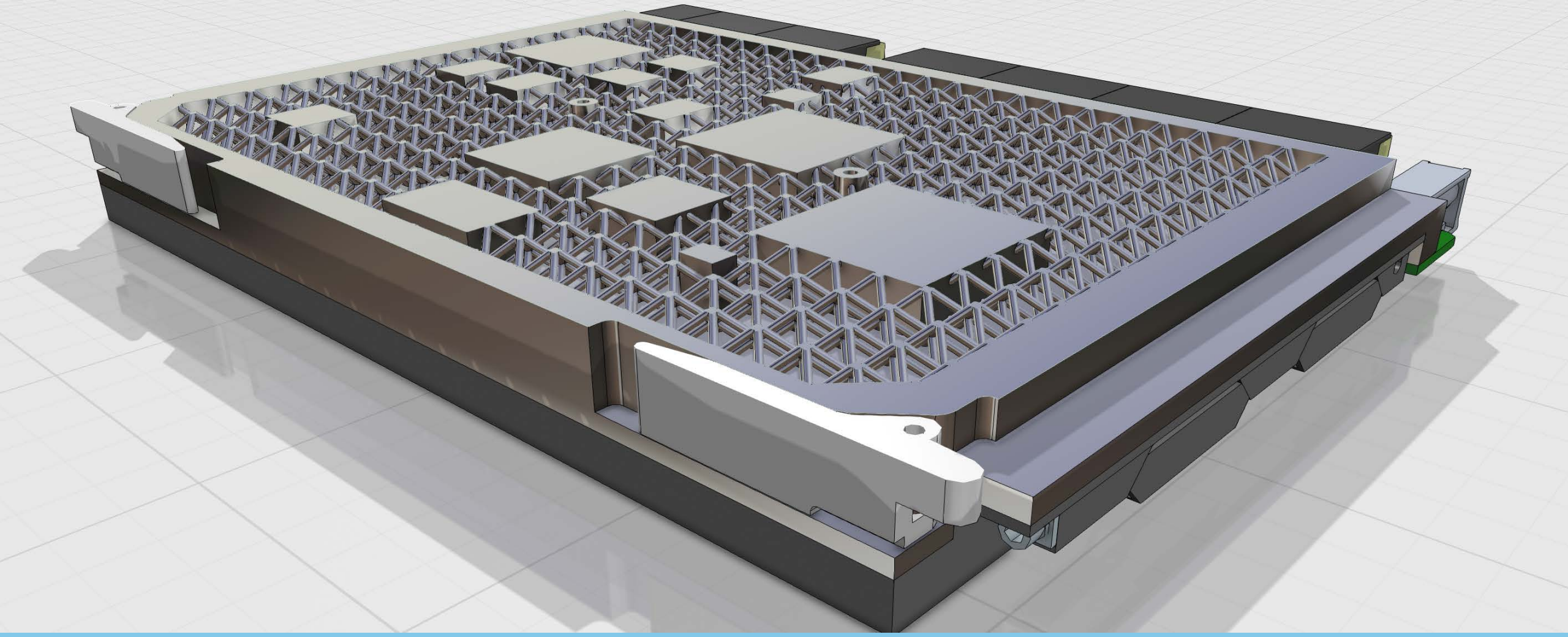


Lattice Structures with Metal AM

Very Complex Shapes Can be Generated

- With Accuracy & Repeatability
- With High Performance Materials
- With Practically No Scale Limitation





“Lattice Core” VITA 48.2 Primary Cover

Design & Performance Prediction – Preliminary Manufacturability Analysis

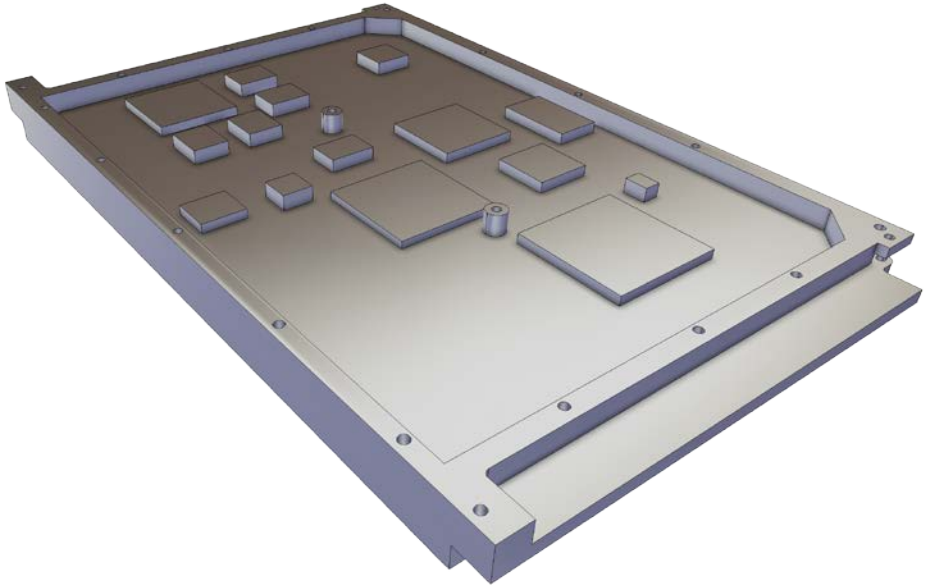
TENTECH LLC Services & Solutions

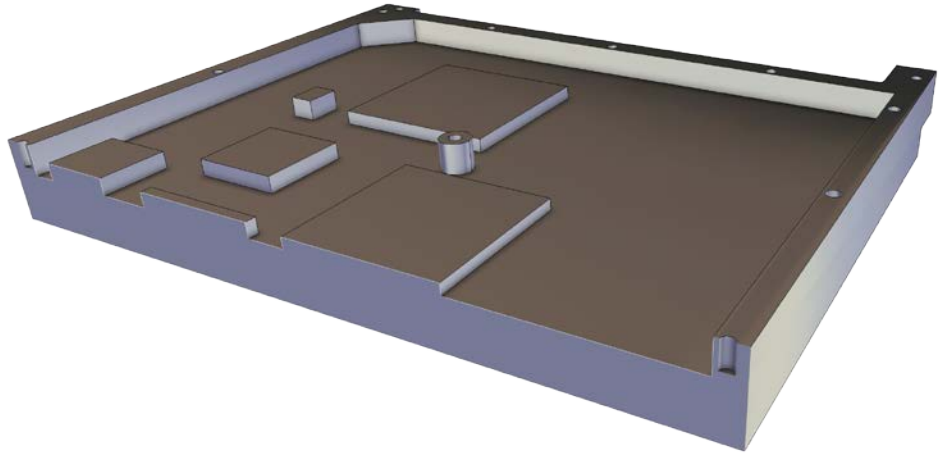
AM advanced methods

Standard VITA 48.2 Primary Cover

Monolithic Machined Aluminum

- Functions as Main Heatsink
  - Conduction “Islands” to Hottest Components
- Provides Stiffness & Interface to Chassis
  - Screwed-in Assembly





Primary Cover Redesign

Monolithic Aluminum Replaced with Lattice Core

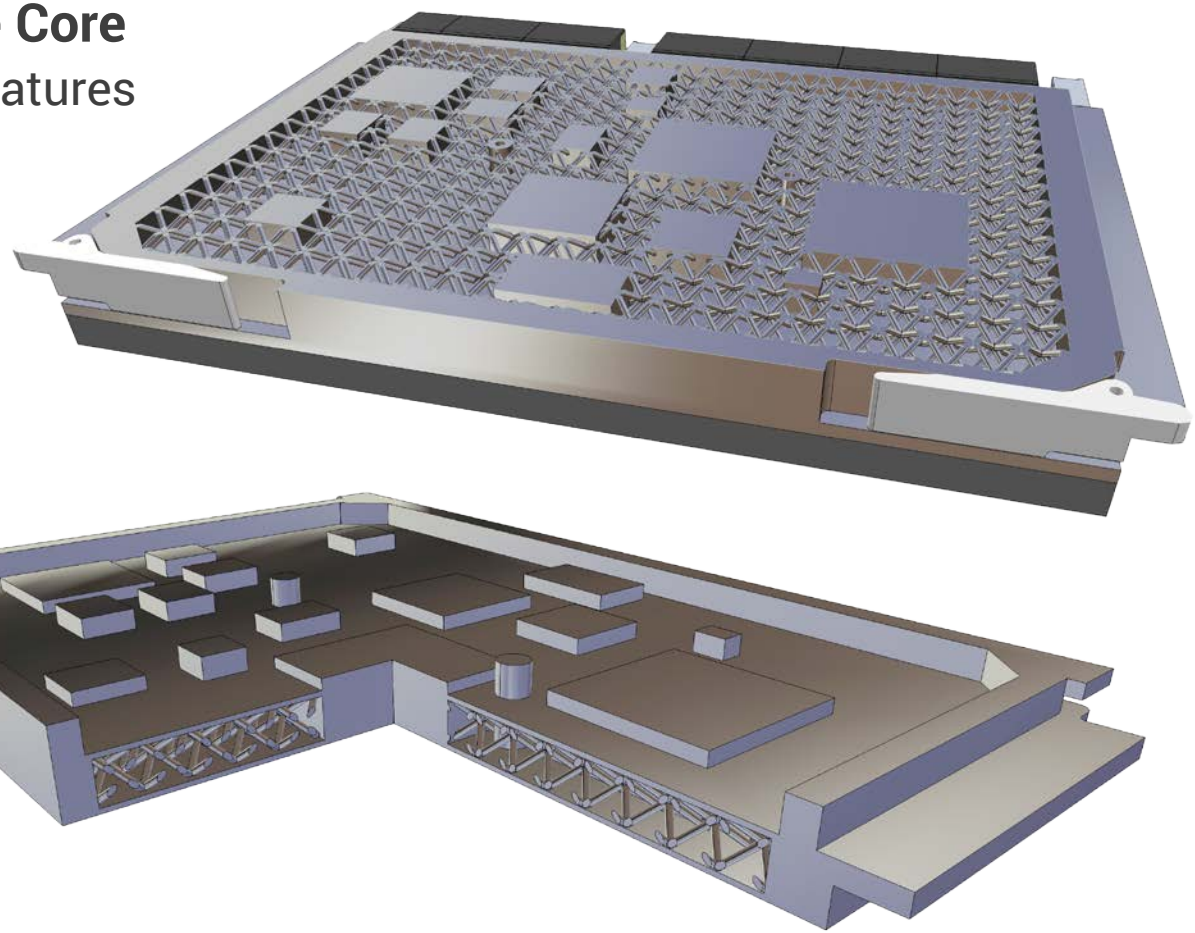
- Maintain External Flat Surface & Mounting Features
- Hollow Core with Lattice Supports
- Conduction Pass-through “Islands”

40% Mass Reduction

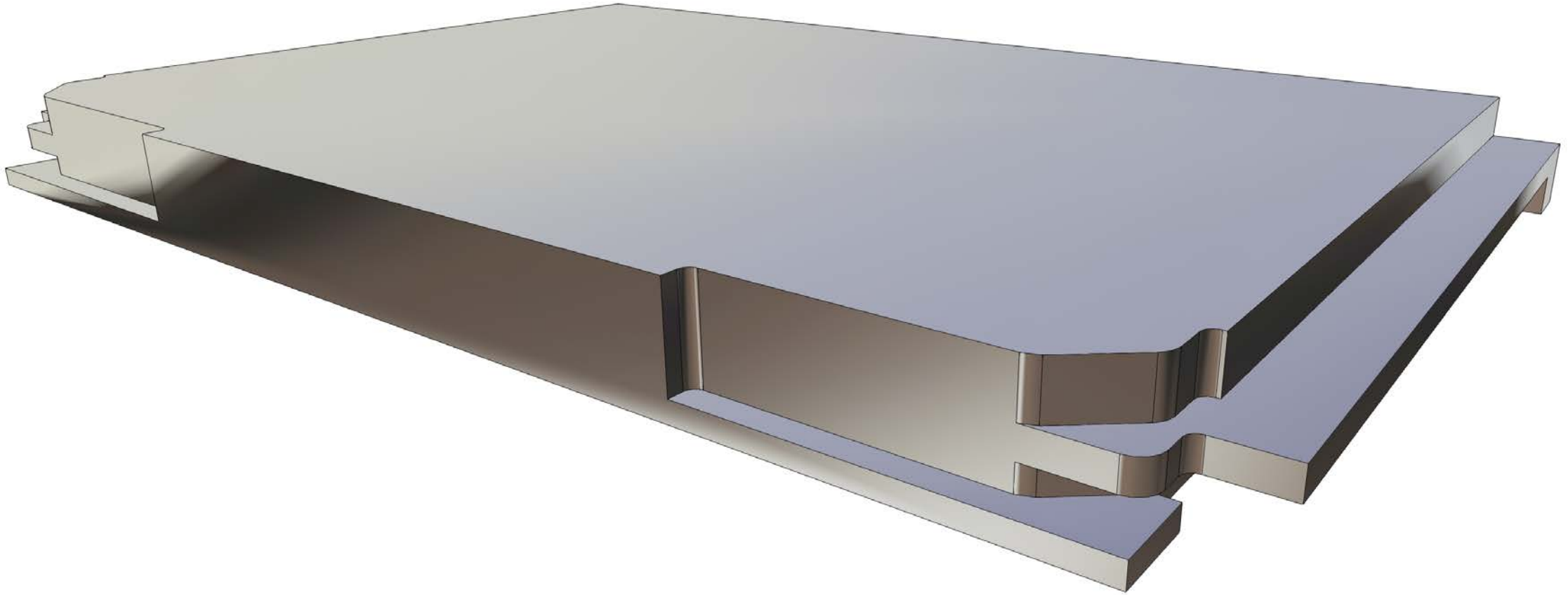
- 1.3lb vs. 2.2lb

Similar Mechanical Performance

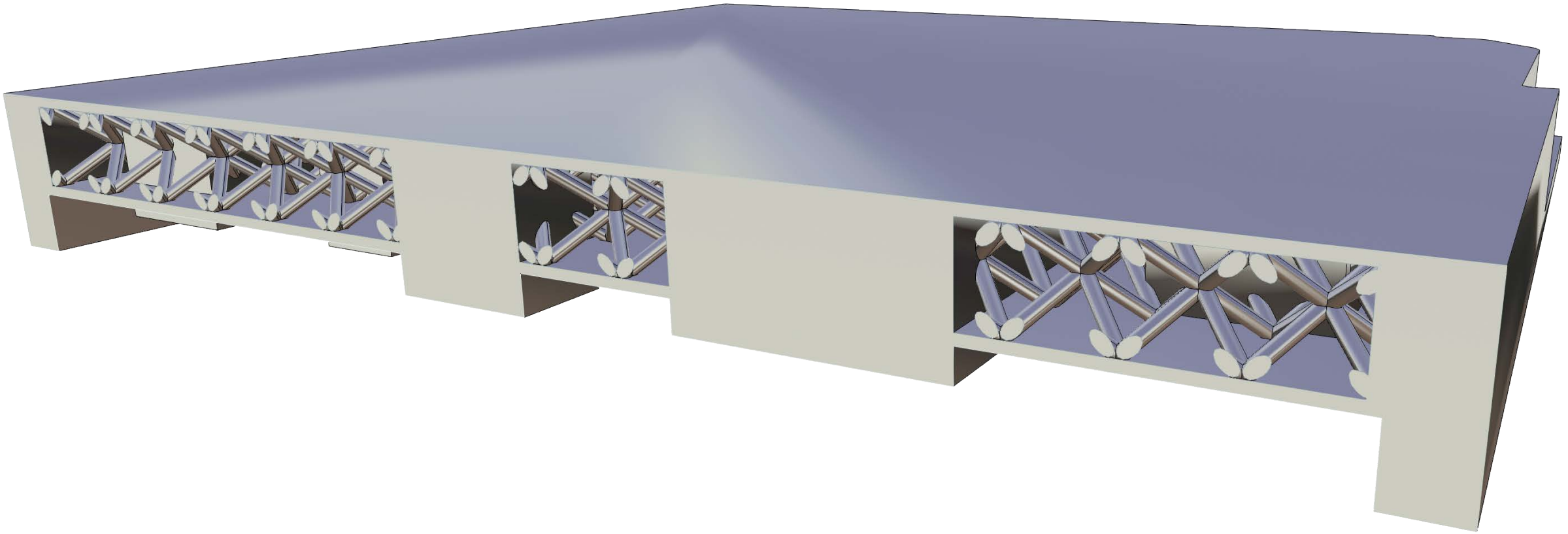
- Thermal & Vibration



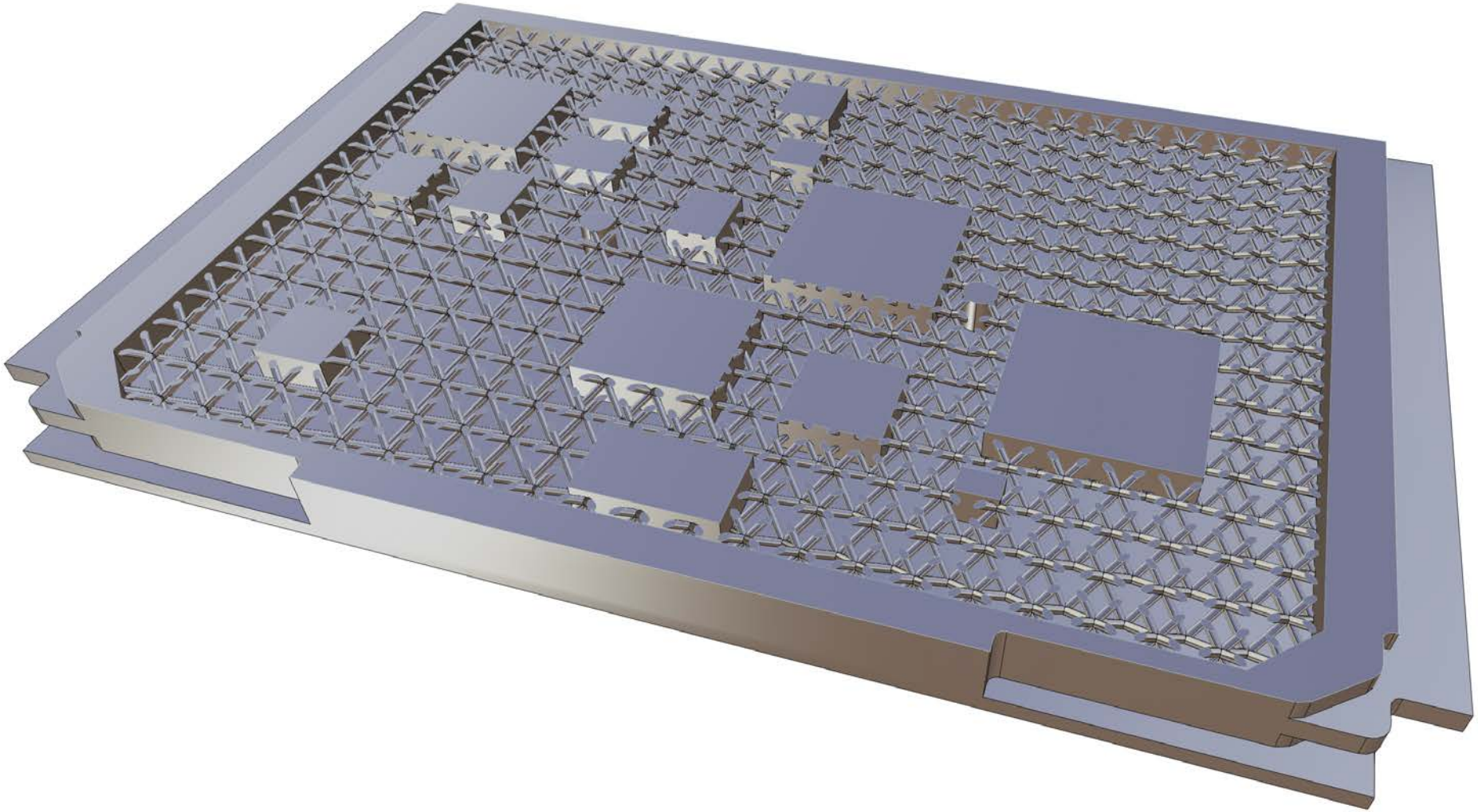
Standard External Footprint



Hollow Core with Lattice Structure



Internal Lattice & Conduction Islands



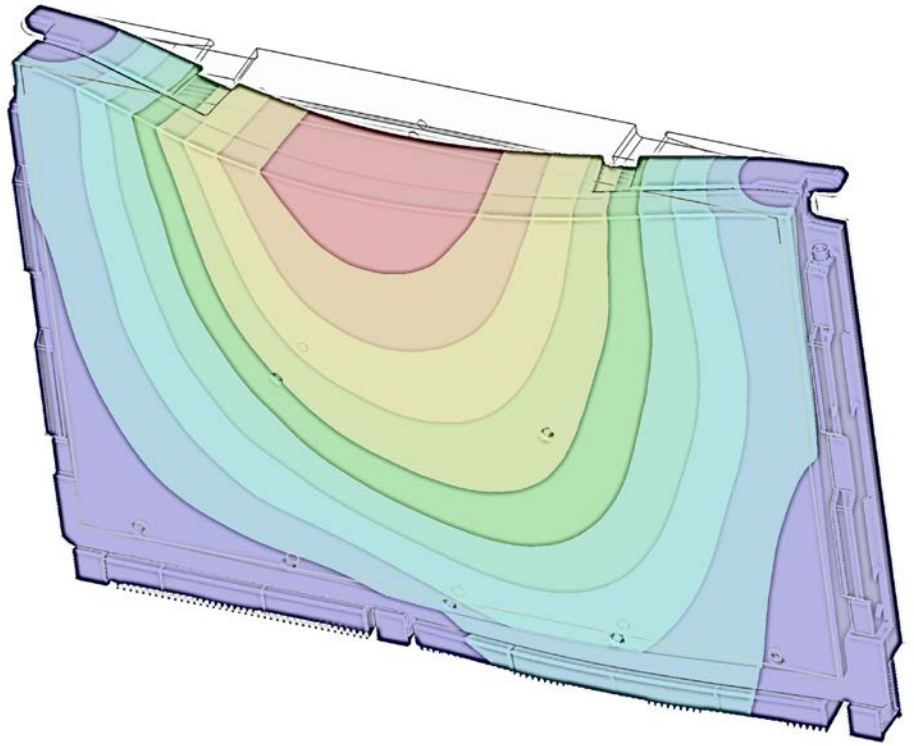
Relative Vibration Performance

Natural Frequencies & Modal Response

- Stiff Enough to Avoid Dynamic Coupling with Chassis
  - No Natural Frequencies Below 100Hz
- Analysis to 2kHz for Airborne Applications
  - Envelops Most Vehicles Sine & Random Vibrations

Similar Dynamics Between VITA 48.2 and Redesign

- 5%-10% Difference in Frequency Content
- Lattice Design Shows Higher Frequencies
- No Spurious Modes Created by Lattice Structure

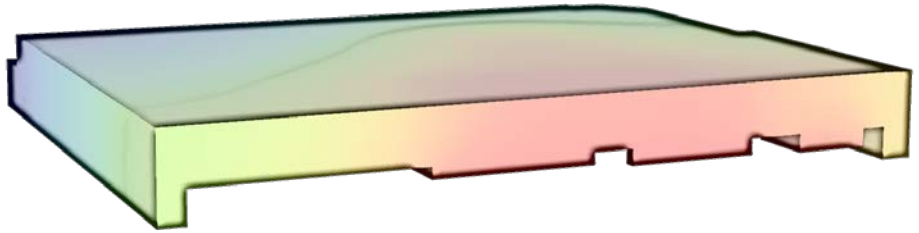


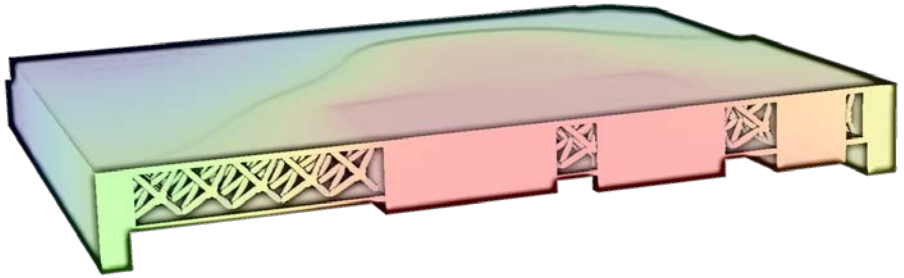
VITA 48.2: 1350Hz
Lattice Design: 1400Hz

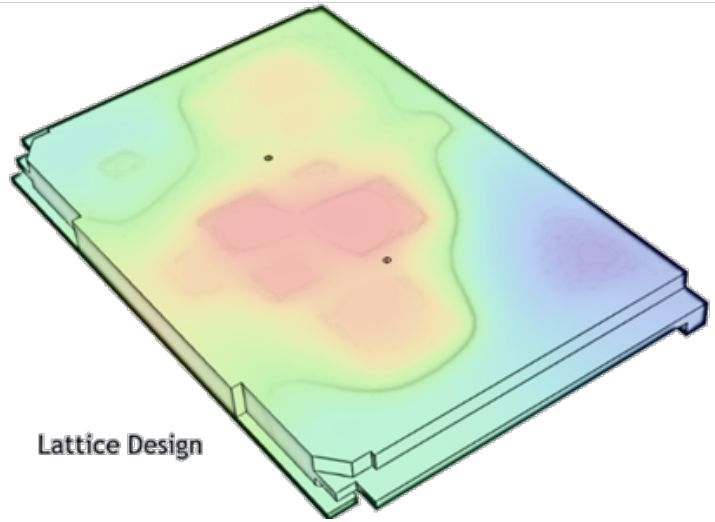
Relative Thermal Performance

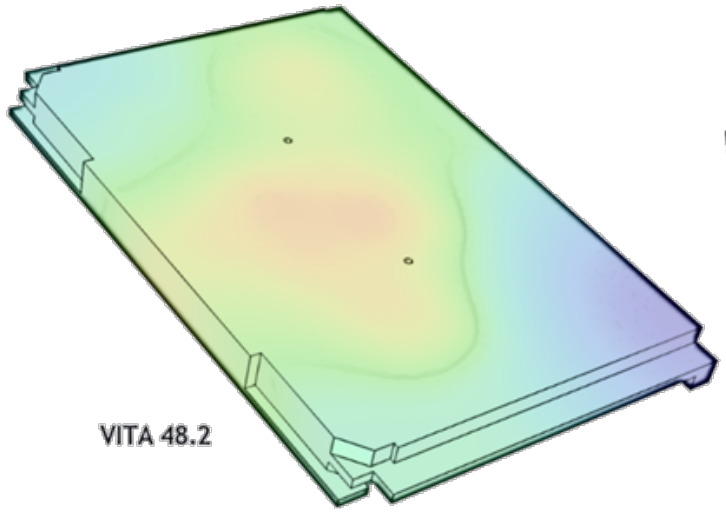
Primary Conduction Heatsink Verification

- Verification by Simulation
- Lattice Design Functions Similarly to VITA 48.2
- Maximum Temperature Slightly higher with Lattice
- Temperature Concentration, Larger Gradient









Preliminary Manufacturability Study

Direct Metal Laser Sintering Process

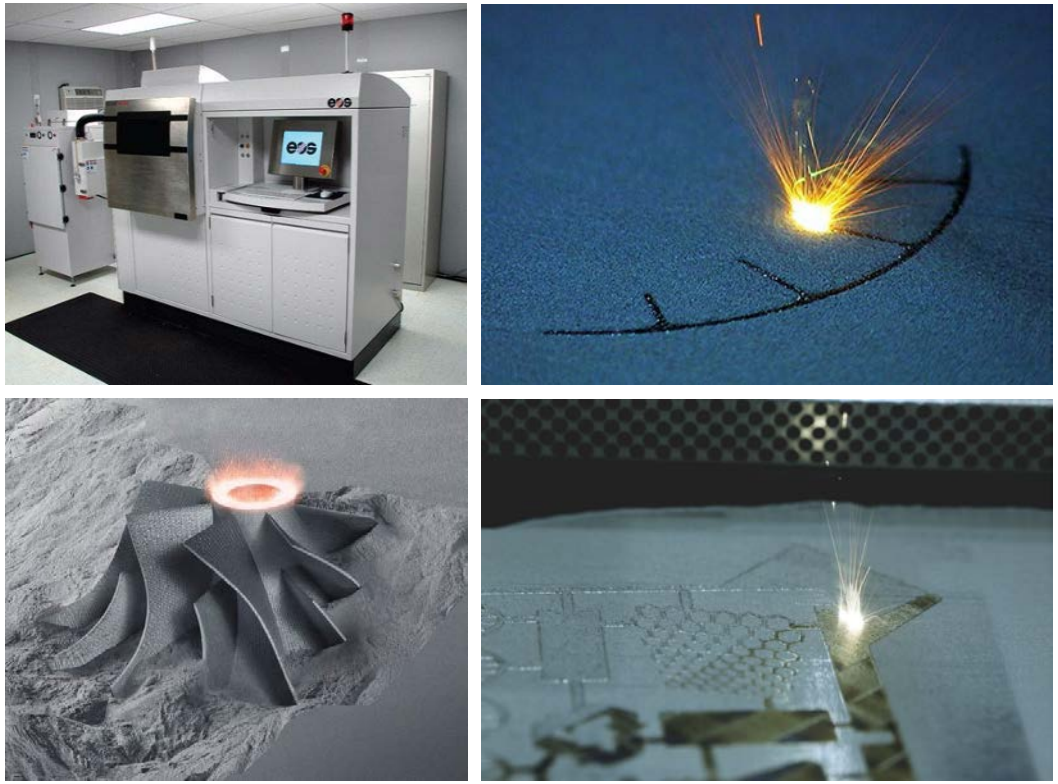
- AlSi10Mg Powder
- Estimated 24h Build Time

Subtractive Manufacturing & Heat Treatment

- Reach T4 or T6 Material Conditions
- Insures Surface Smoothing/Flatness
- Addition of Mounting Hole Features

Estimated Fabrication Cost Below $5,000

- Cost of Space Payload $10,000/lb (NASA)



Closing Remarks

Lattice Redesign Offers Improved Performance

- 40% Weight Savings over Standard VITA 48.2 Design
- Higher Tolerance to Vibration
- Comparable Thermal Performance

Simulation Crucial to Design Evaluation

- Many Design Iterations Performance Evaluation
- Temperature & Vibration Qualification by Analysis

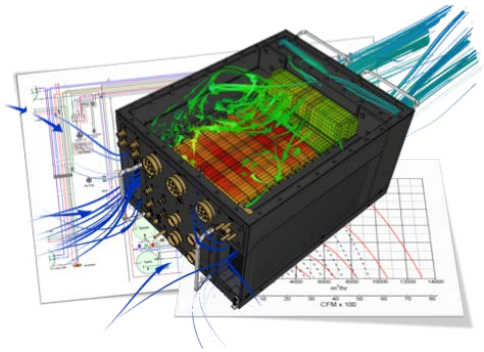
Working Prototype in Q4 2018

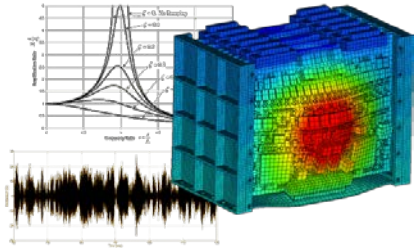
- Predictive Virtual Manufacturing Process
- Assembly & Qualification Test

Contact Information

TEN TECH LLC: www.tentechllc.com

- Design & Simulation Services
- Based in Southern California (Los Angeles)
- Booth #613 at iMAPS Expo





Arsenal Advanced Methods: www.arsenalam.com

- Aerospace & Defense R&D
- Based in New England (Nashua, NH)

MORF3D: www.morf3d.com

- Metal Additive Manufacturing
- Based in Southern California (El Segundo)