Topological Optimization Case Histories at GE Healthcare

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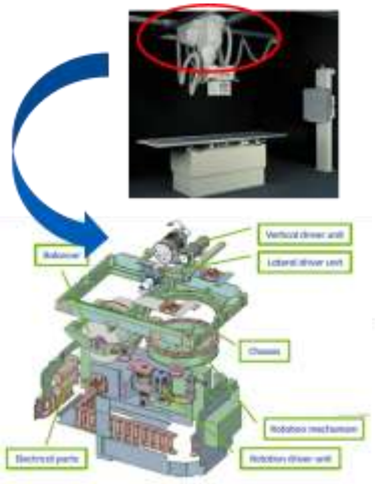
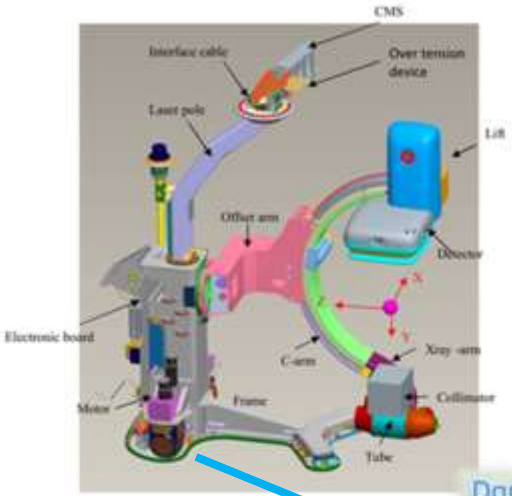
GE Healthcare Overview

- $19B revenue, 50,000 employees worldwide
- Products = Diagnostic & manufacturing equipment for the medical provider industry
  - ✓ Imaging – MRI, CT, X-Ray, Nuclear Medicine
  - ✓ Anesthesia Delivery & Ventilators
  - ✓ Ultrasound
  - ✓ Patient Monitoring
  - ✓ Infant Care
  - ✓ Life Sciences – Biomanufacturing Equipment
- Primary simulation toolset = ANSYS

Why Optimize?

- Weight = Cost
  - ✓ Material
  - ✓ Machining
  - ✓ Shipping/Handling
  - ✓ Ancillary effects - larger drive systems, etc.
- Customer Impacts
  - ✓ Room size, floor strength
  - ✓ Workflow obstacles
- Time to Market
  - ✓ Optimization = get it right the first time
  - ✓ “More inspiration, less perspiration”





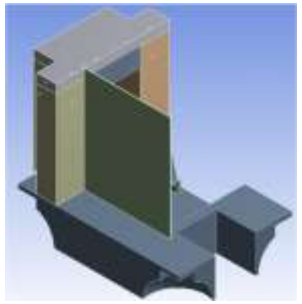
Topological Optimization at GE Healthcare (GEHC)

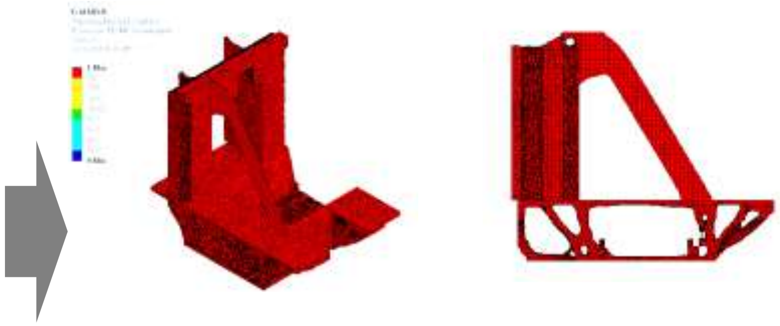
History & Current State

- March 2014 - Demonstration optimizations using GTAM performed on Portable Ultrasound base by Vanderplaats R&D (Hong Dong)
- September 2014 – Purchased (3) globally shareable GTAM licenses, have re-purchased every year
  - ✓ ANSYS Workbench plug-in = major selling point
- GTAM has been used by a few GEHC business unit engineers, more frequently is applied by corporate central team as an engineering service

Portable Ultrasound

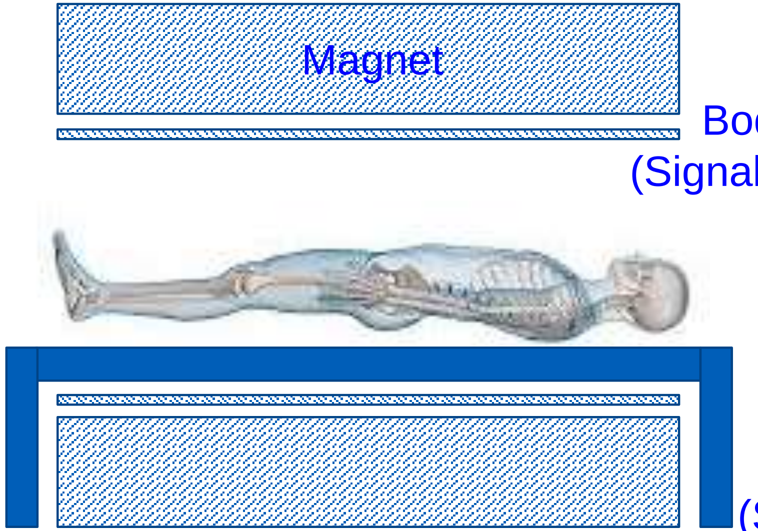

Base Structure


Design Space


Optimized Shapes

1st Optimization Success – “The Convincer”

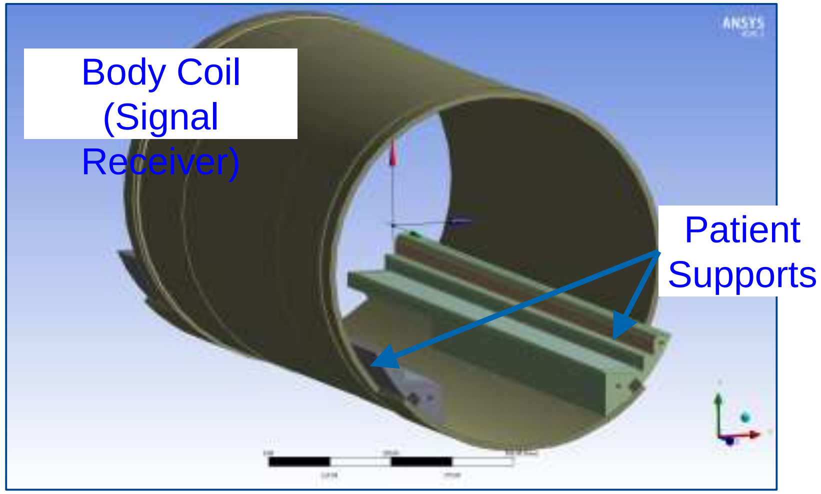
- Design Project = Integrated MR “Body Coil” and Patient Support



Body Coil
(Signal Receiver)

Patient
Support
(Standalone
Structure)

Current Design



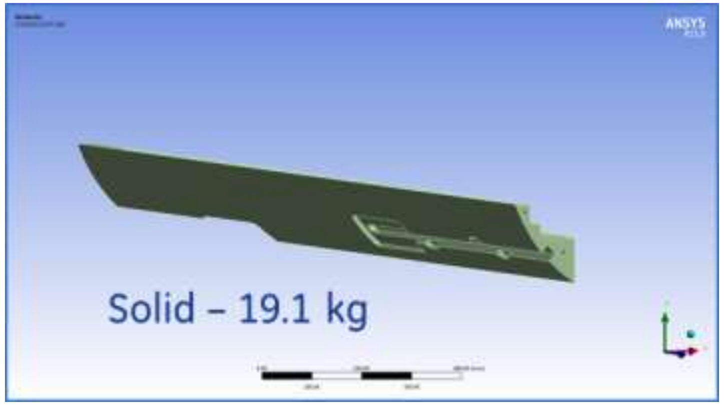
Proposed Design

➢ Design Objective = Integrated patient support with minimal material that satisfies body coil deflection criteria

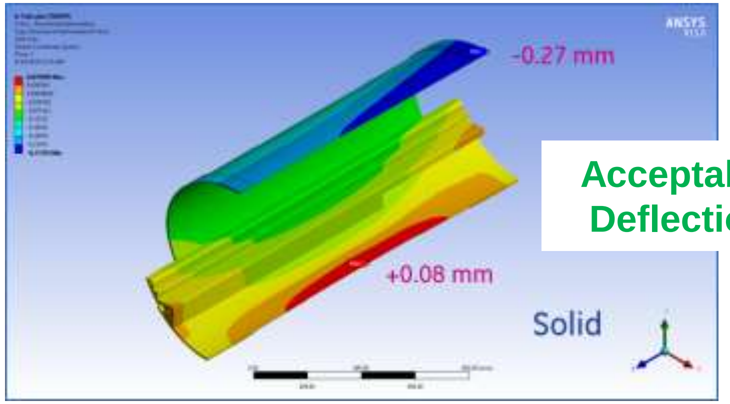
GE Healthcare

Initial Evaluations using Conventional FEA

Proposed Support Design 1

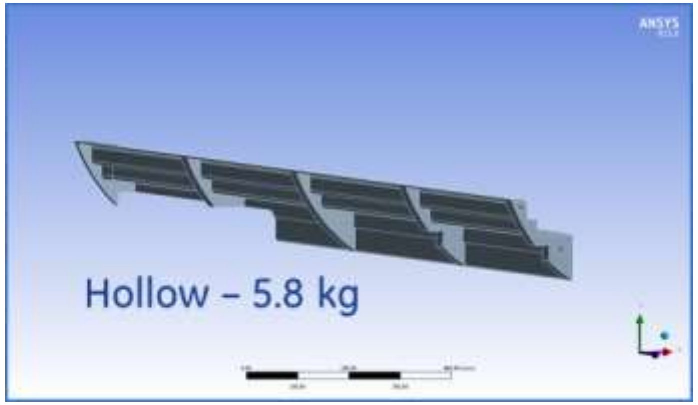


Conventional FEA

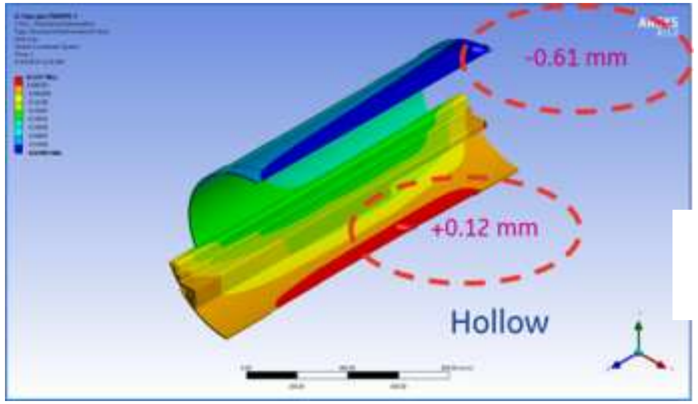


Acceptable Deflection

Proposed Support Design 2

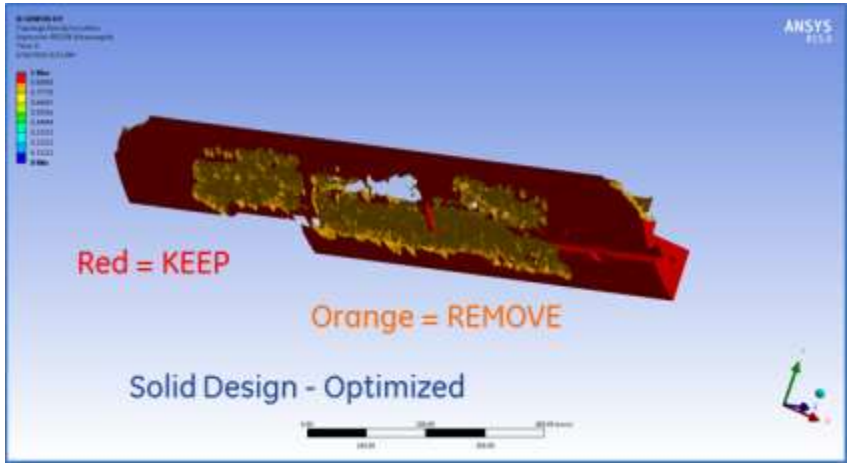


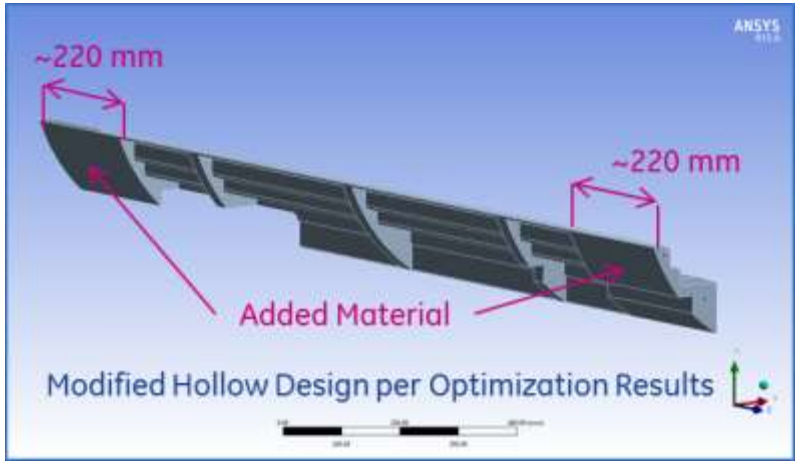
Conventional FEA



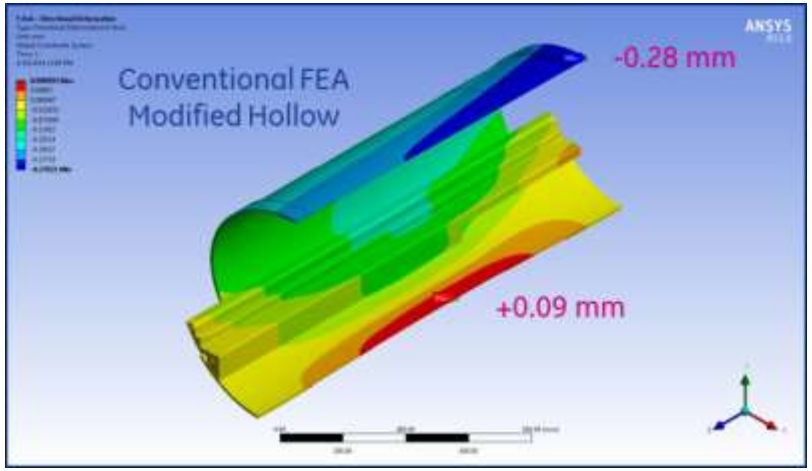
Unacceptable Deflection

Topological Optimization Solution using GTAM





Conventional FEA

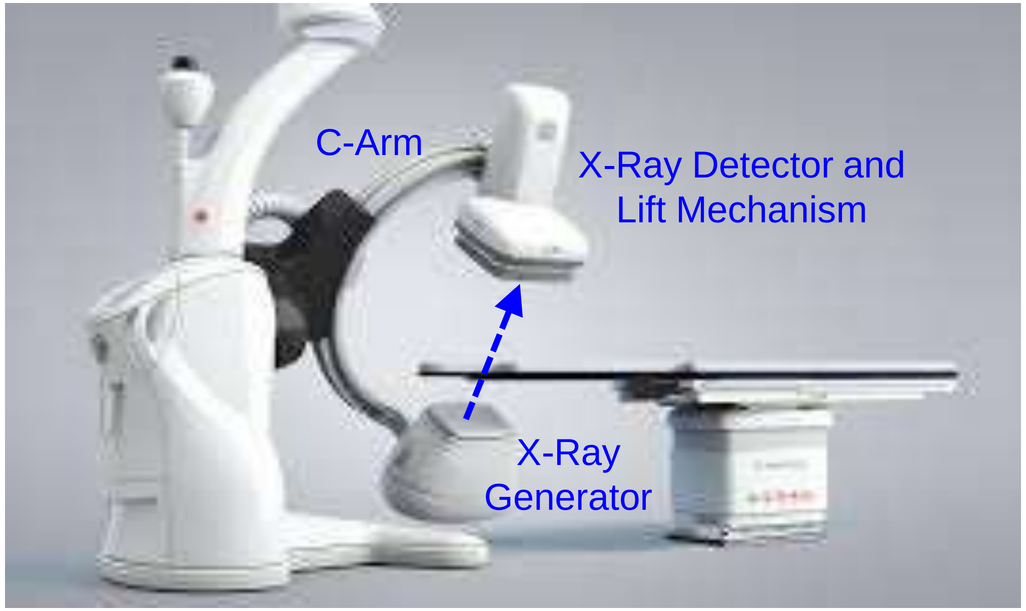


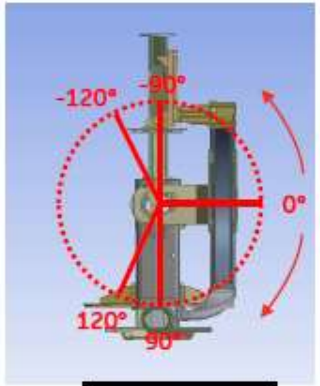
Design	d, mm	Mass, kg
Solid	-0.27	19.1
Hollow	-0.61	5.8
Modified Hollow	-0.28	9.0

- *Design based on optimization gives same performance as fully solid design with >50% mass reduction*

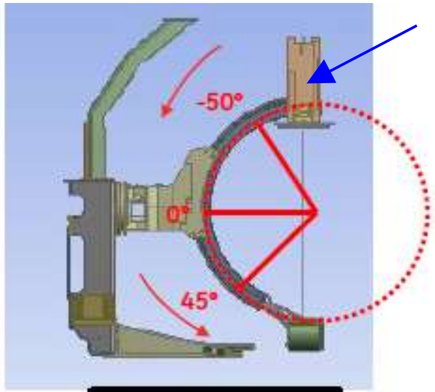
Optimization of a Multi-Configuration Structure

- Design Objective = Reduce mass of robotic C-arm X-Ray detector lift mechanism
- Primary load = self-weight
- Optimization challenge = mechanism and support structure can assume numerous positions and orientations



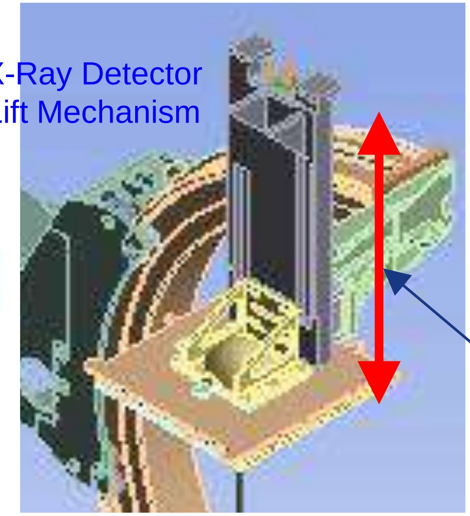


Pivot Rotation



C-arm Rotation

X-Ray Detector Lift Mechanism



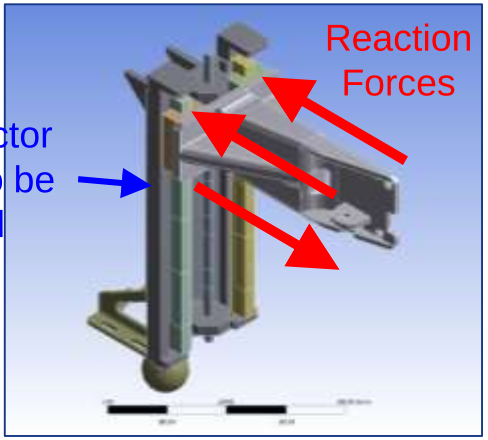
Detector can be randomly positioned vertically

Optimization of a Multi-Configuration Structure

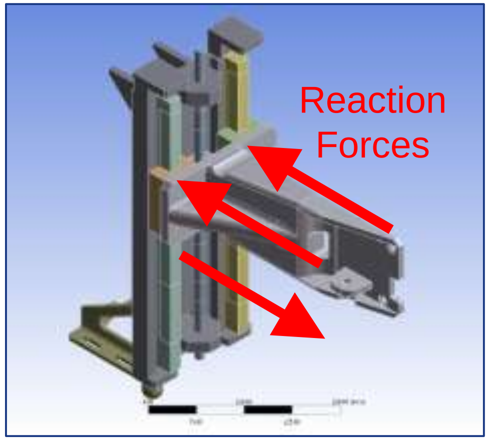
Simulation Methodology

- Use conventional FEA to determine
  - ✓ Worst case C-Arm orientation
  - ✓ Reaction forces imposed on lift mechanism for a series of detector positions
- Use reaction forces as multiple load cases in GENESIS optimization solutions

X-Ray Detector Lift Frame to be optimized

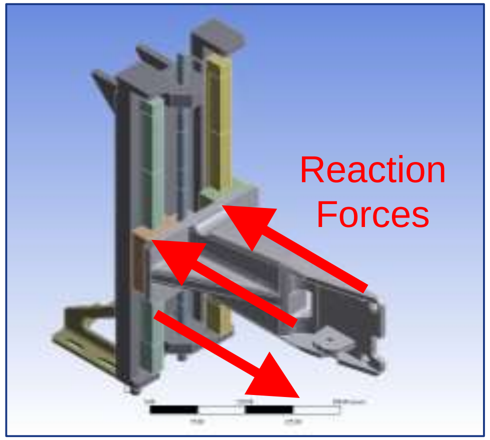


Load Case 1

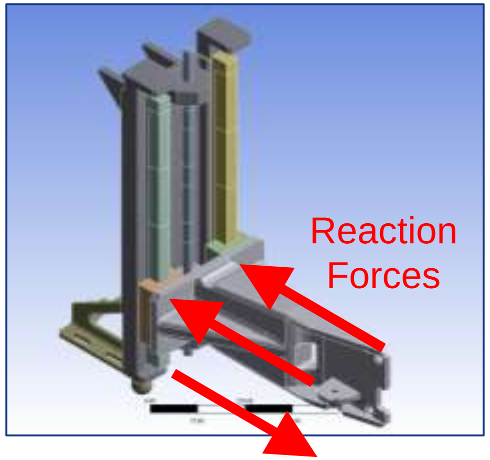


Load Case 2

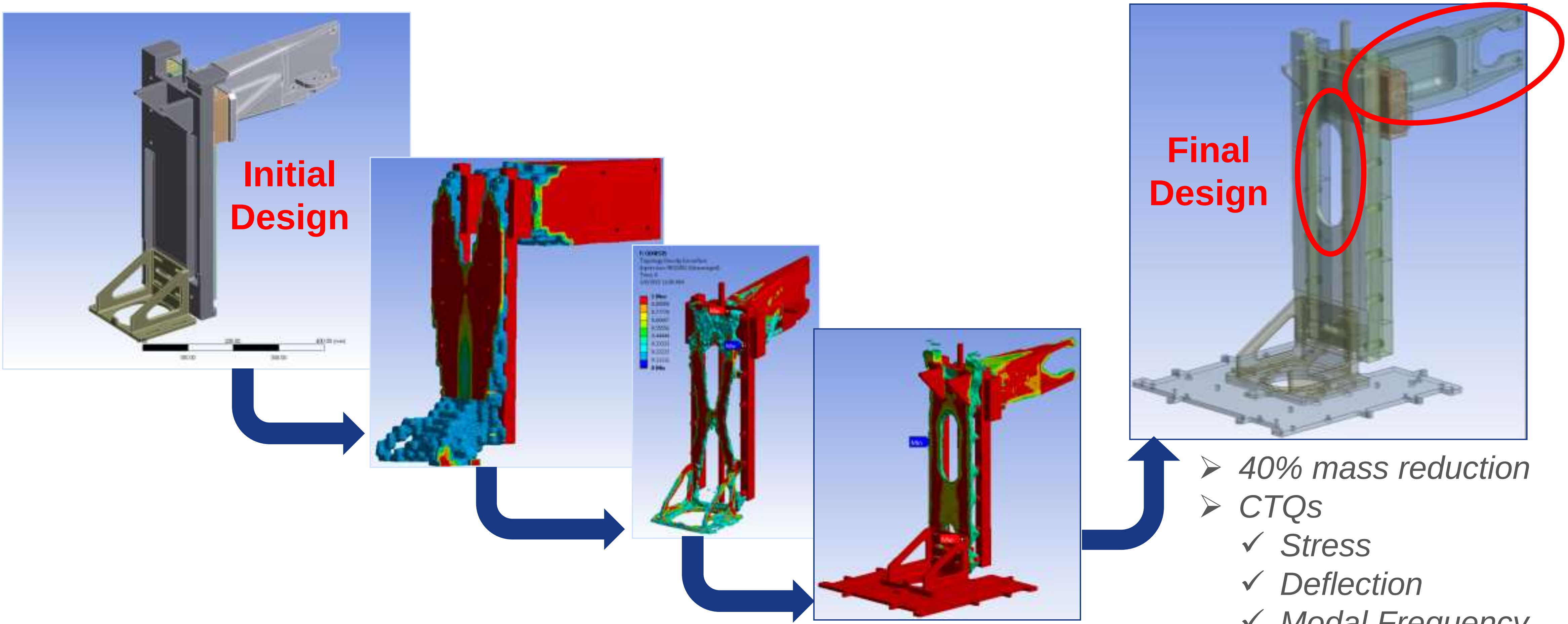
Load Case 3



Load Case 4



Optimization of a Multi-Configuration Structure

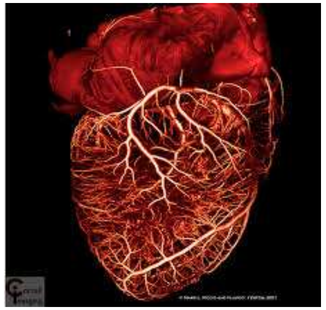


- 40% mass reduction
- CTQs
  - Stress
  - Deflection
  - Modal Frequency

CT Upgrade Structural Design via Topological Optimization

- Design Challenge = Increase 1st natural frequency of stationary CT support structure by 2x to prevent vibration-induced image distortion

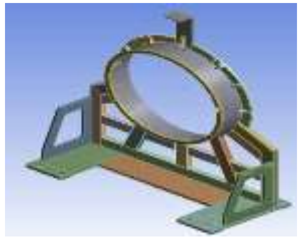
"Supervalue" CT

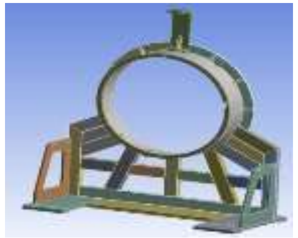


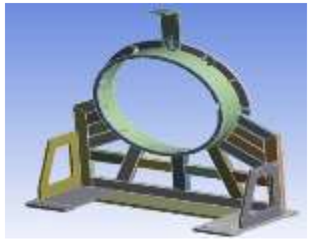
- Initial Design Approach = trial & error DOE via conventional FEA

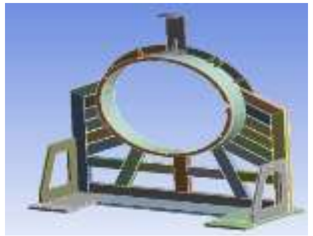
CT Upgrade Structural Design via Topological Optimization

- Design Iterations:

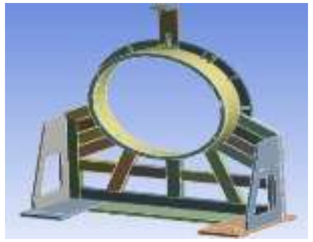

(1) 9.4 Hz

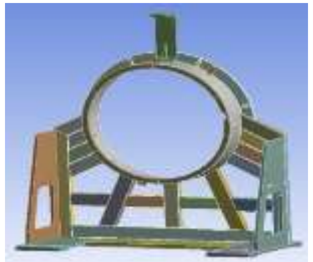

(2) 10.0 Hz

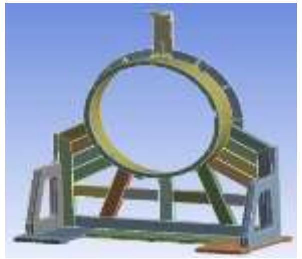

(3) 10.2 Hz


(4) 10.4 Hz

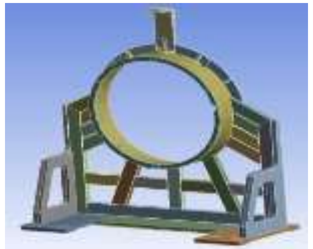

(5) 11.5 Hz


(5) 12.5 Hz

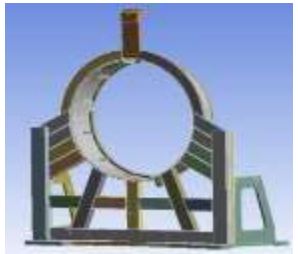

(6) 12.5 Hz


(7) 11.9 Hz

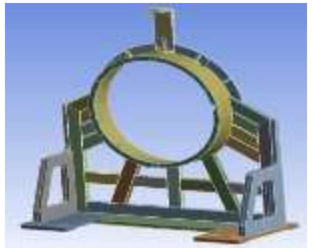

(8) 11.7 Hz


(9) 11.5 Hz


(10) 12.5 Hz

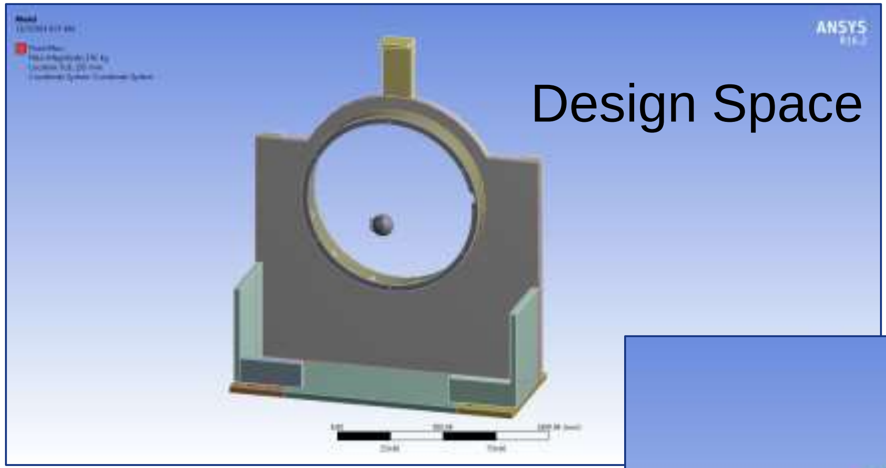

(11) 12.7 Hz

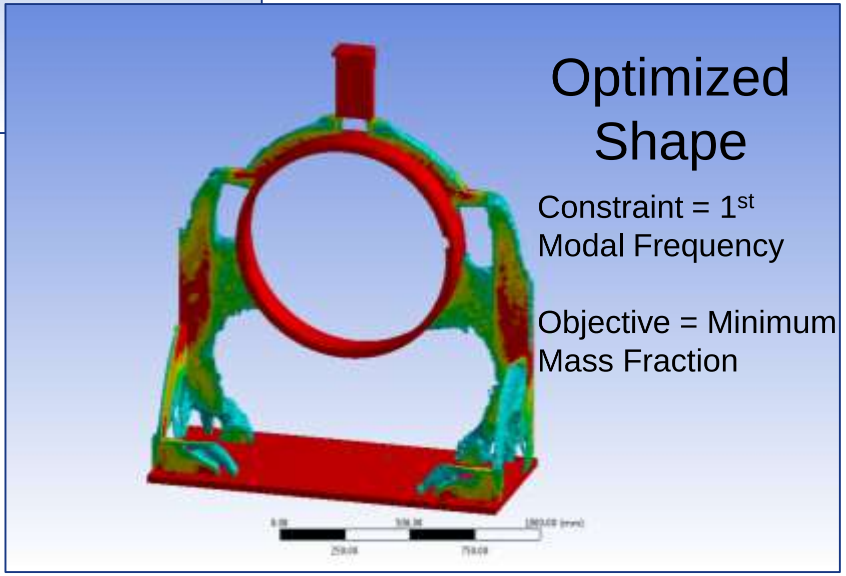

(12) 12.8 Hz

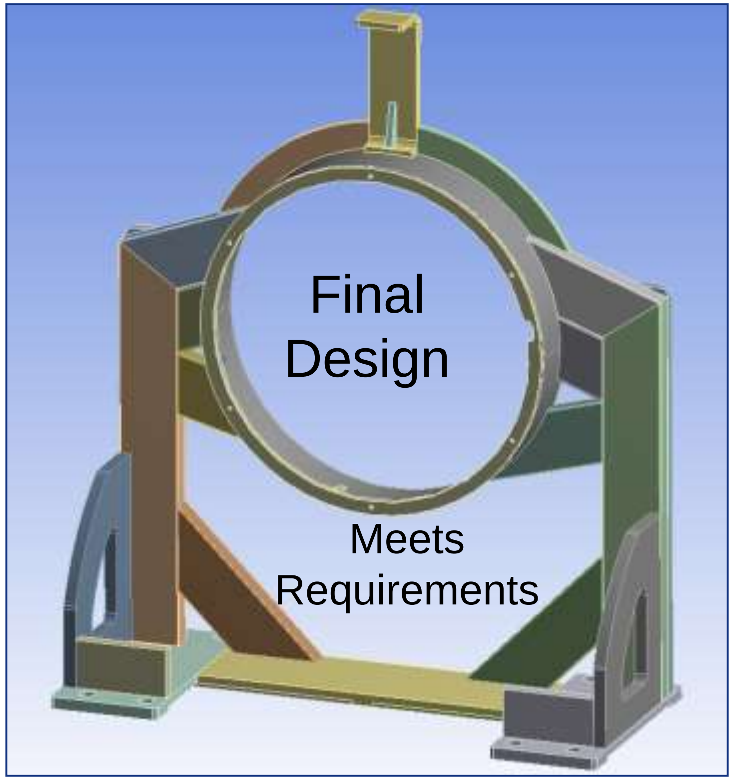

(13) 16.0 Hz

➢ *After 13 iterations (2 engineer-weeks), 18 Hz target natural frequency still not reached*

CT Upgrade Structural Design via Topological Optimization



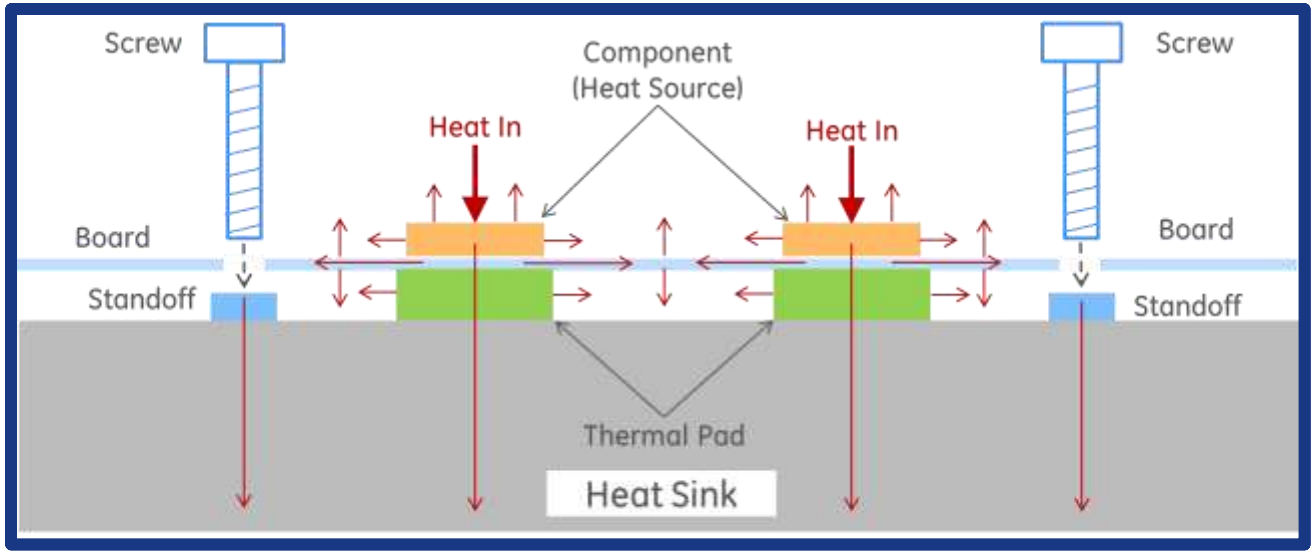




Thermal Optimization for Circuit Board Heat Sink Design

- Design Challenge = keeping circuit board components below maximum allowable temperatures via passive heat rejection (conduction and natural convection)
  - Circuit board is enclosed in airtight housing to shield from EMI emitted by Magnetic Resonance electromagnets and RF generators
  - Typical heat rejection solution = uncooled aluminum plate + thermally conductive padding mounted below circuit board

Enclosure

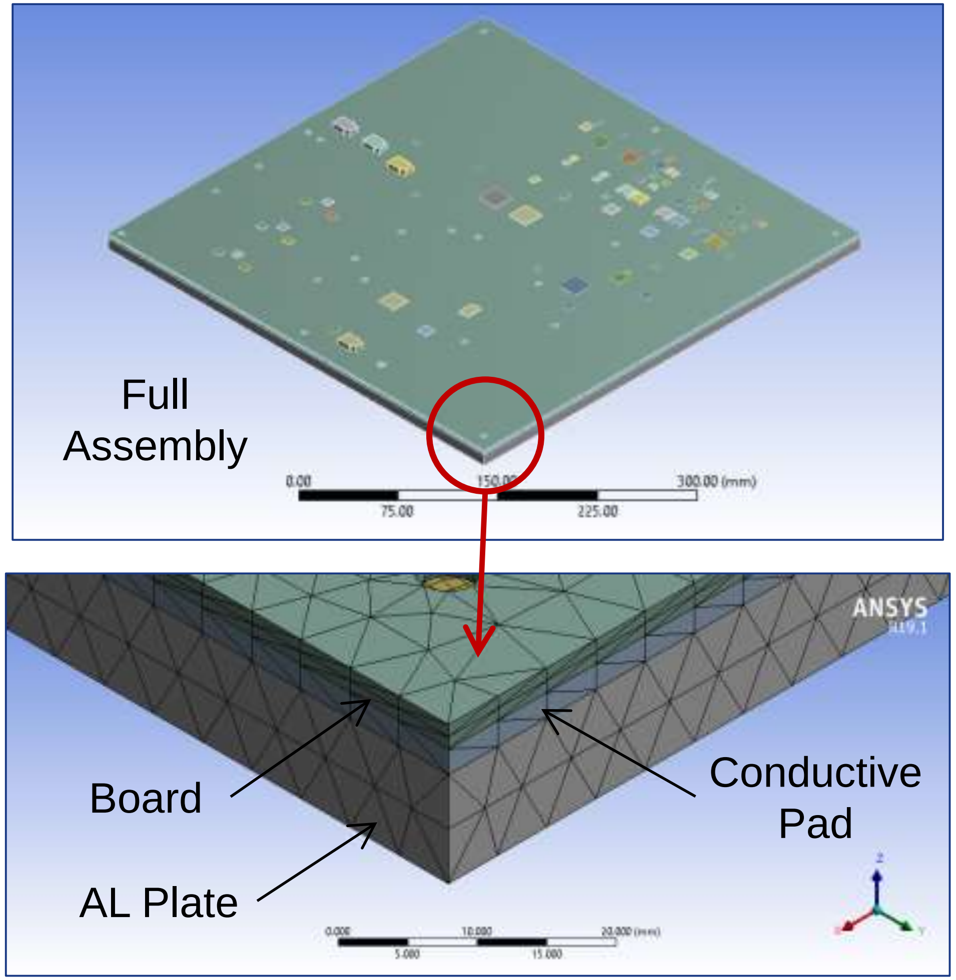


- Topology Challenge = determine optimal shape of heat sink plate that enables all electrical components to operate below their maximum allowable temperatures
  - Full coverage plate = heavy, expensive, potentially not feasible due to interferences with cables, connectors, etc.

Thermal Optimization for Circuit Board Heat Sink Design

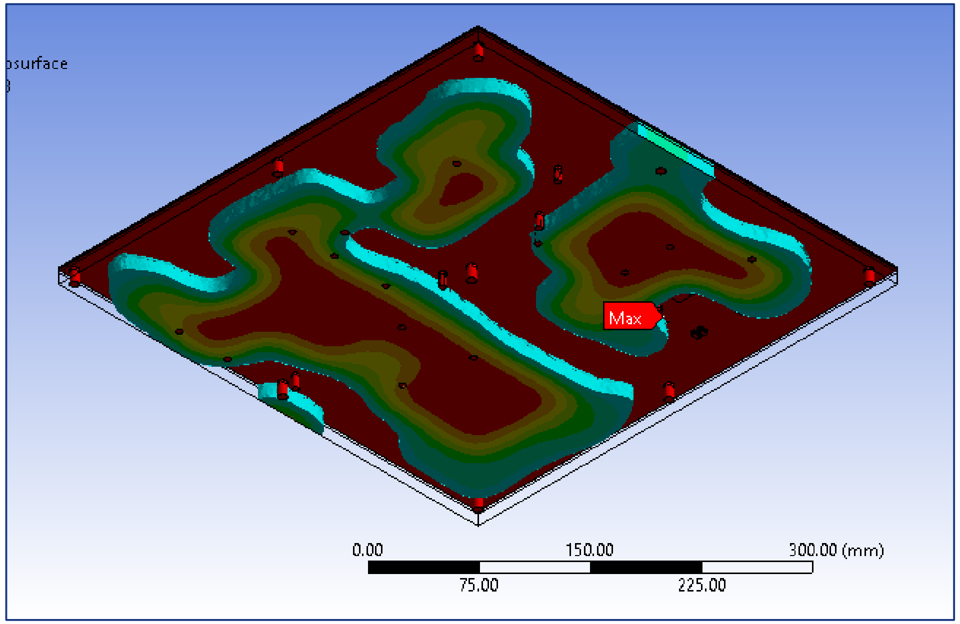
Methodology and GTAM Setup

- Design Space (Topology Region) = full coverage aluminum plate and thermal pad (size = 400mm x 400 mm)
  - Plate and Pad modeled with 5 mm linear tetrahedral elements
- Manufacturing Constraint = “Z” (through thickness) extrusion
- Minimum Member Size = 100mm
- Objective = Minimum Mass Fraction
- Constraints = Maximum Allowable Temperature for each electrical component (66 total)
  - Geometry = corners of components’ top surface to reduce design cycle solve time

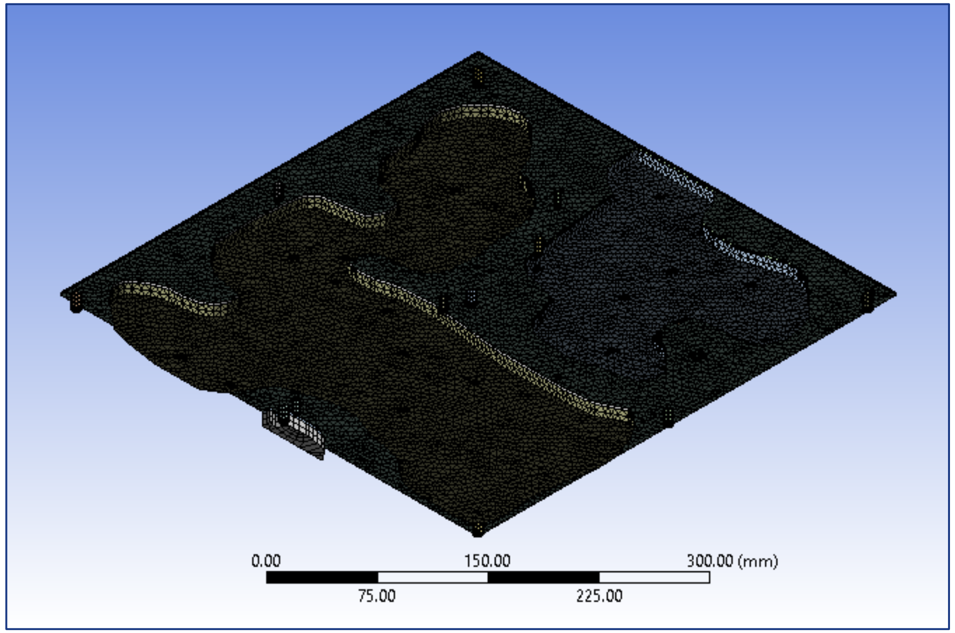


Thermal Optimization for Circuit Board Heat Sink Design

- Results – 1st Optimization



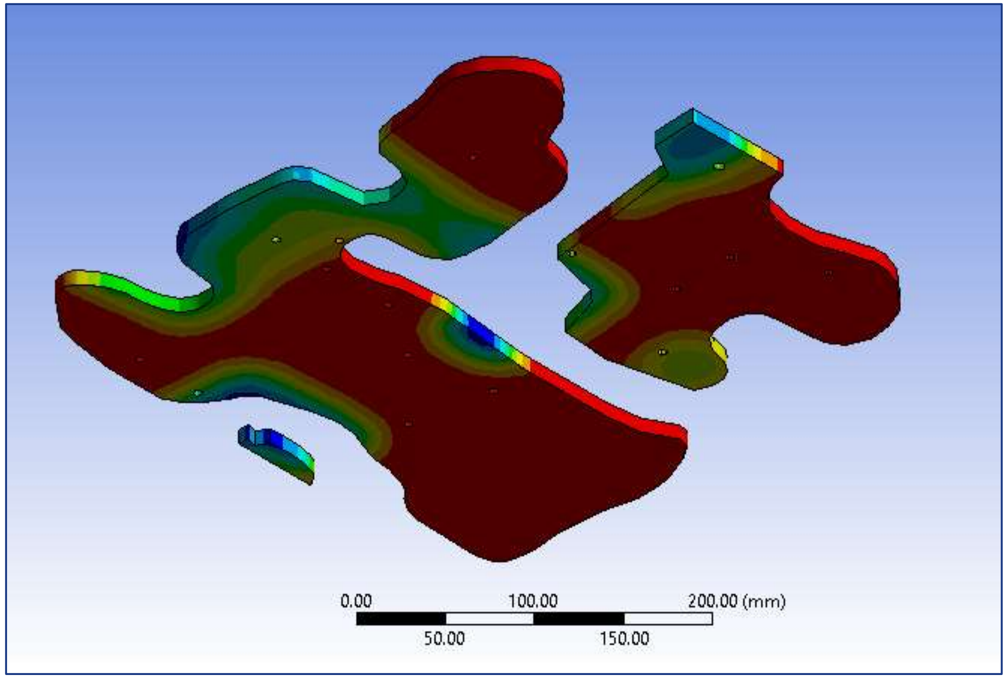
Topology Isosurfaces #1
Visualization Slider = 0.30



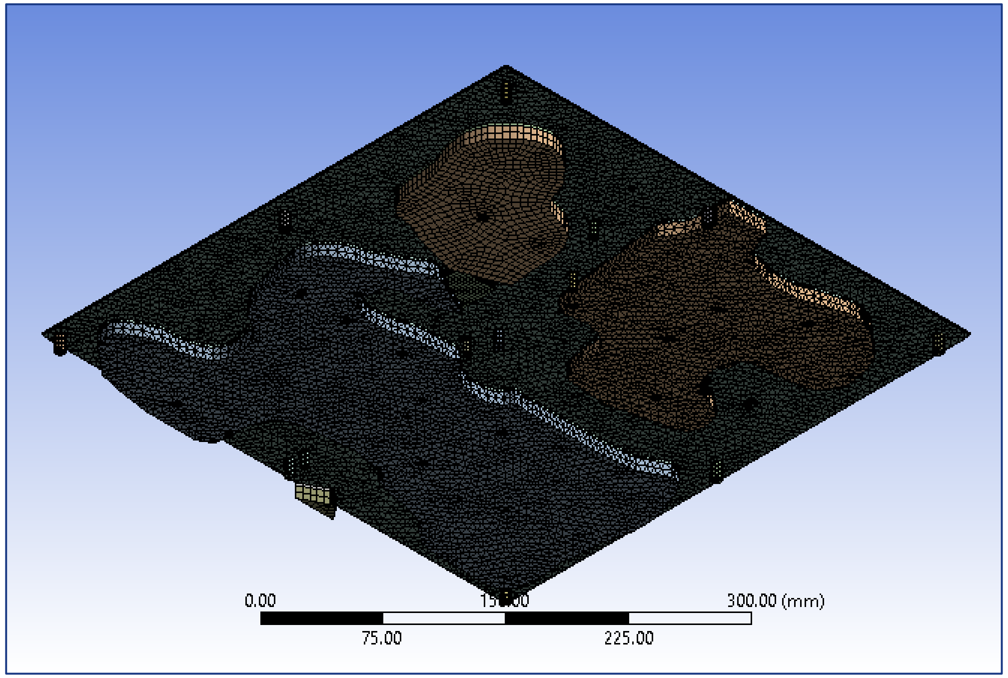
Verification Model #1
(Used for Optimization Run #2)

Thermal Optimization for Circuit Board Heat Sink Design

- Results – 2nd Optimization

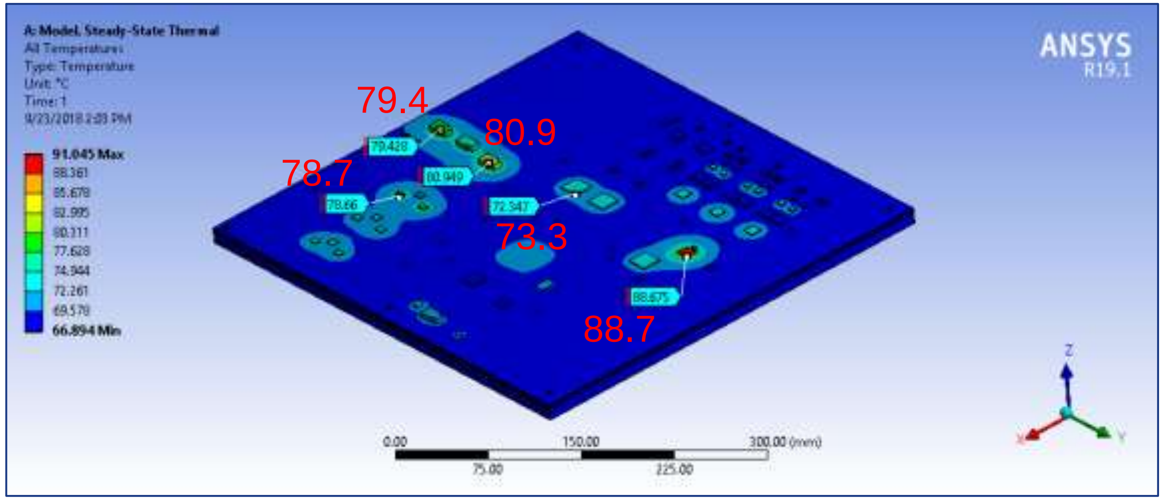


Topology Isosurfaces #2
Additional Material Can Be Removed (Shown in Blue)

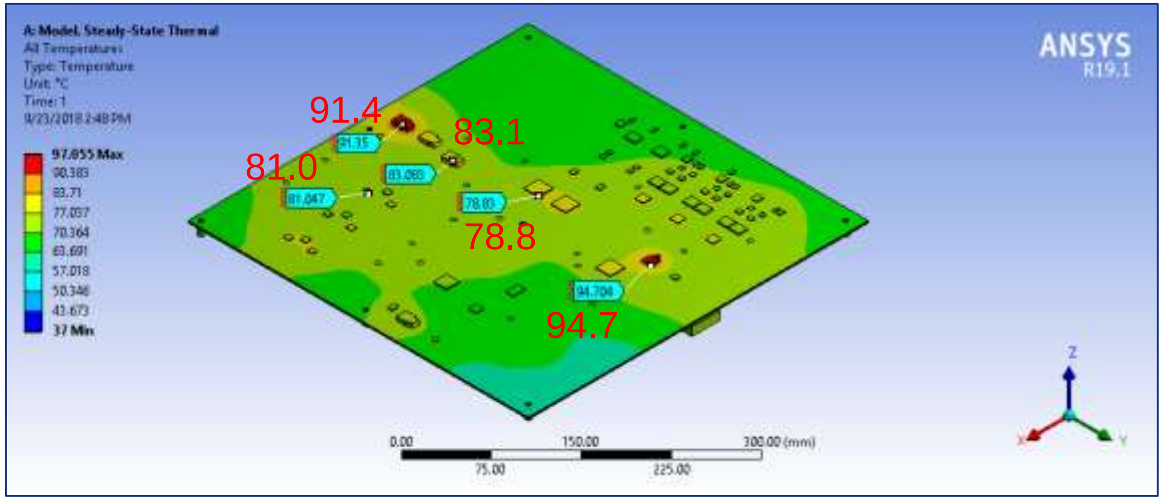


Verification Model #2

Thermal Optimization for Heat Sink Design



Component Temperatures – Full Coverage Heat Sink



Component Temperatures – Optimized Heat sink #2

- Temperatures in optimized design have increased, but are still below their allowable levels

Thermal Optimization for Circuit Board Heat Sink Design

Conclusions

- Optimal heat sink shapes can successfully be developed via thermal topological optimization
- Verification shapes based on 30% retained material appear to match optimization results well
- Topology results are significantly affected by minimum member size, should perform parametric studies to select optimum value
- Definition of temperature constraints drives tradeoffs between fidelity and solve time
- Next step = design and verify practical heat sink shapes