Sandia National Laboratories

AFRL THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

ADVANCED FUZING TECHNOLOGY

Effects of Orientation & Boundary Condition on Encapsulated Electronics

Presented By:

Caleb White, Shane Curtis

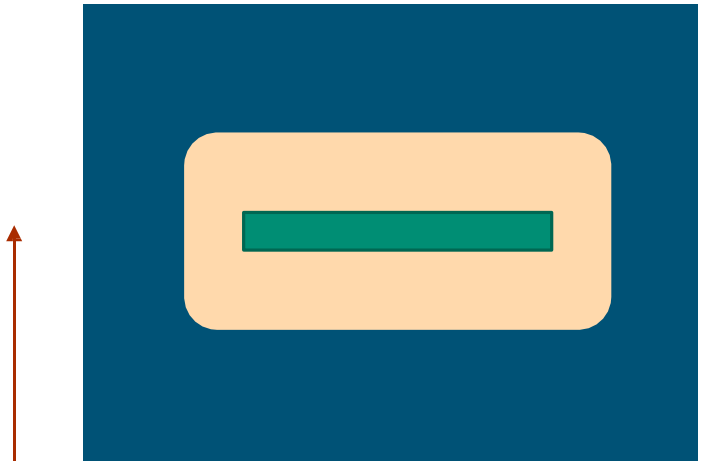
(505) 228-1425,
cwhite3@sandia.gov

Distribution A/ Unclassified

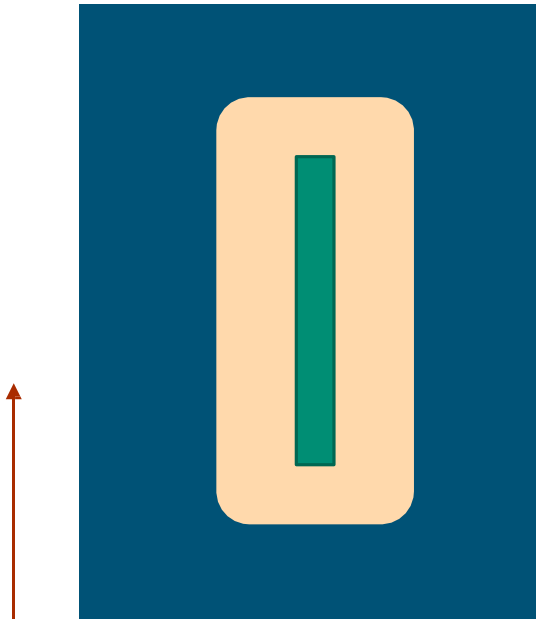
SAND2021-5442 C

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Introduction



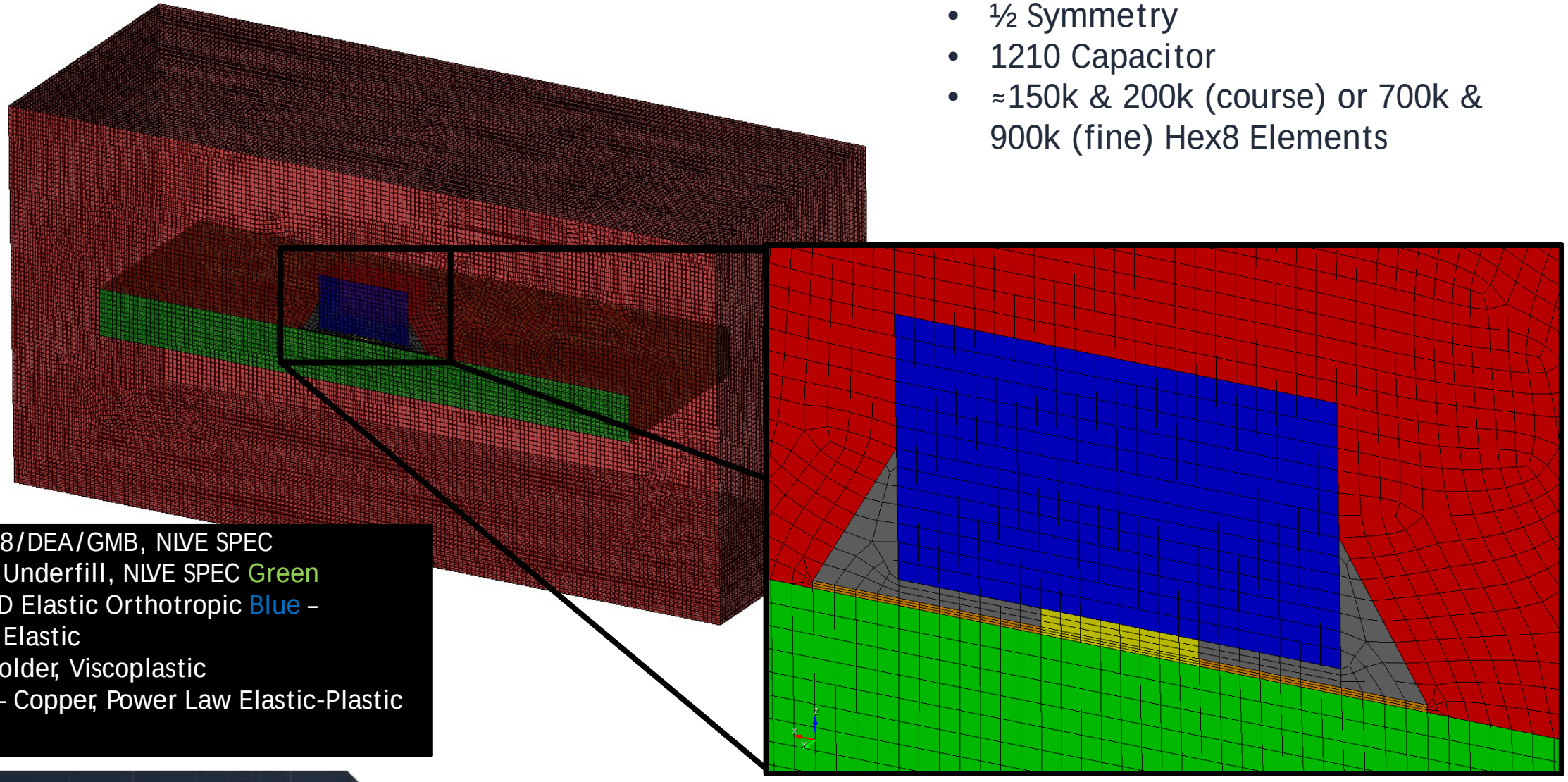
Horizontal / Perpendicular



Vertical / Parallel

Generic Mesh

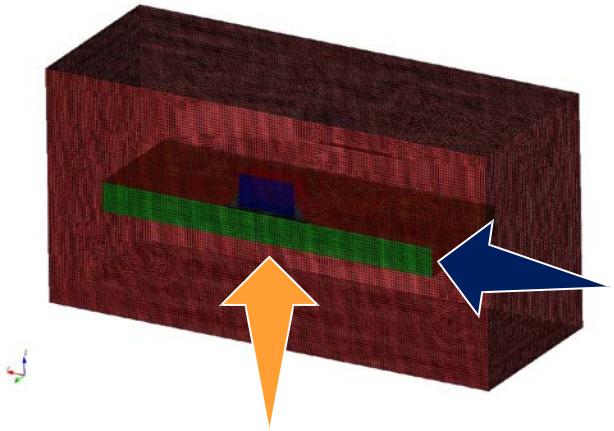
- ½ Symmetry
- 1210 Capacitor
- ≈150k & 200k (course) or 700k & 900k (fine) Hex8 Elements

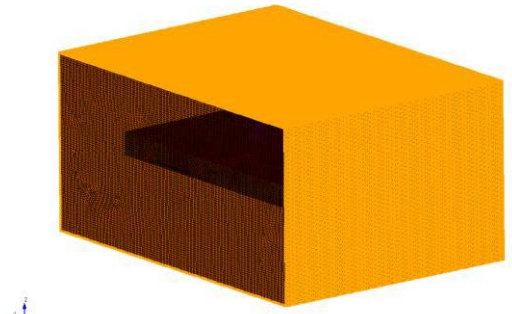


Red – 828/DEA/GMB, NLVE SPEC
Yellow – Underfill, NLVE SPEC Green – FR4, 3D Elastic Orthotropic Blue – Ferrite, Elastic
Grey – Solder, Viscoplastic
Orange – Copper, Power Law Elastic-Plastic

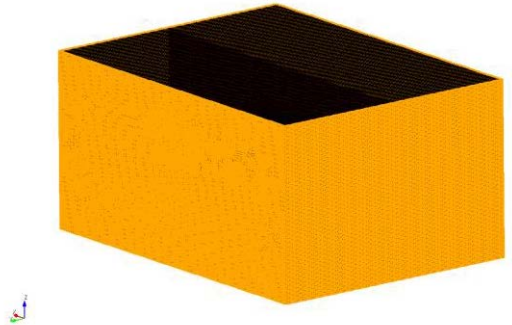
FEA Procedure & Parameters

1. Instantiate parametric study with Dakota
2. Create generic mesh geometry using Cubit
3. Implicitly cure (Sierra/SM Adagio) from 70ºC → 25ºC
4. Explicitly accelerate (Sierra/SM Presto) fixed exterior with representative haversine pulse*
5. Post-process with Python & Paraview

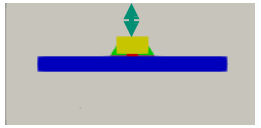




Side Relief

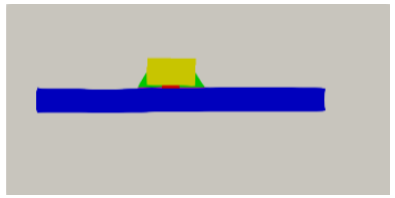
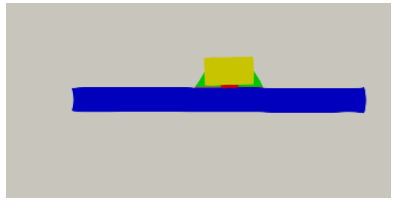
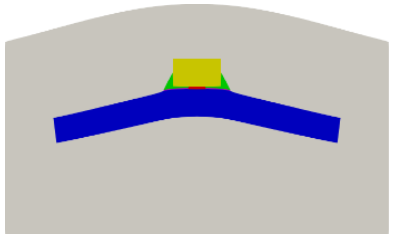
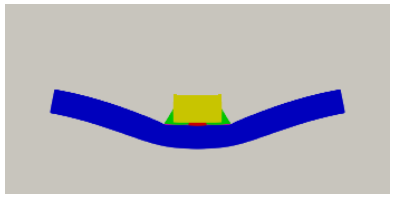
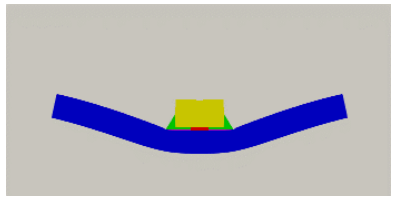
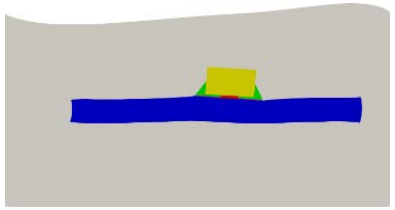


Top Relief

Parameter	Value
Boundary Condition	No Relief Side Relief Top Relief Bottom Relief Top/Bottom Relief
Loading Direction	Normal-to-PCB Parallel-to-PCB
PCB Length	.75”x.5”x.062” .50”x.5”x.062”
Boundary Proximity 	.041” .075” .108” .141”
Mesh Size	Course: .010” Fine: .006”
Pulse Width (µs)	1.95, 2.93, 3.91, 5.87, 7.81, 11.72, 15.6, 23.4, 31.3, 46.95, 62.5, 93.75, 125, 250, 500

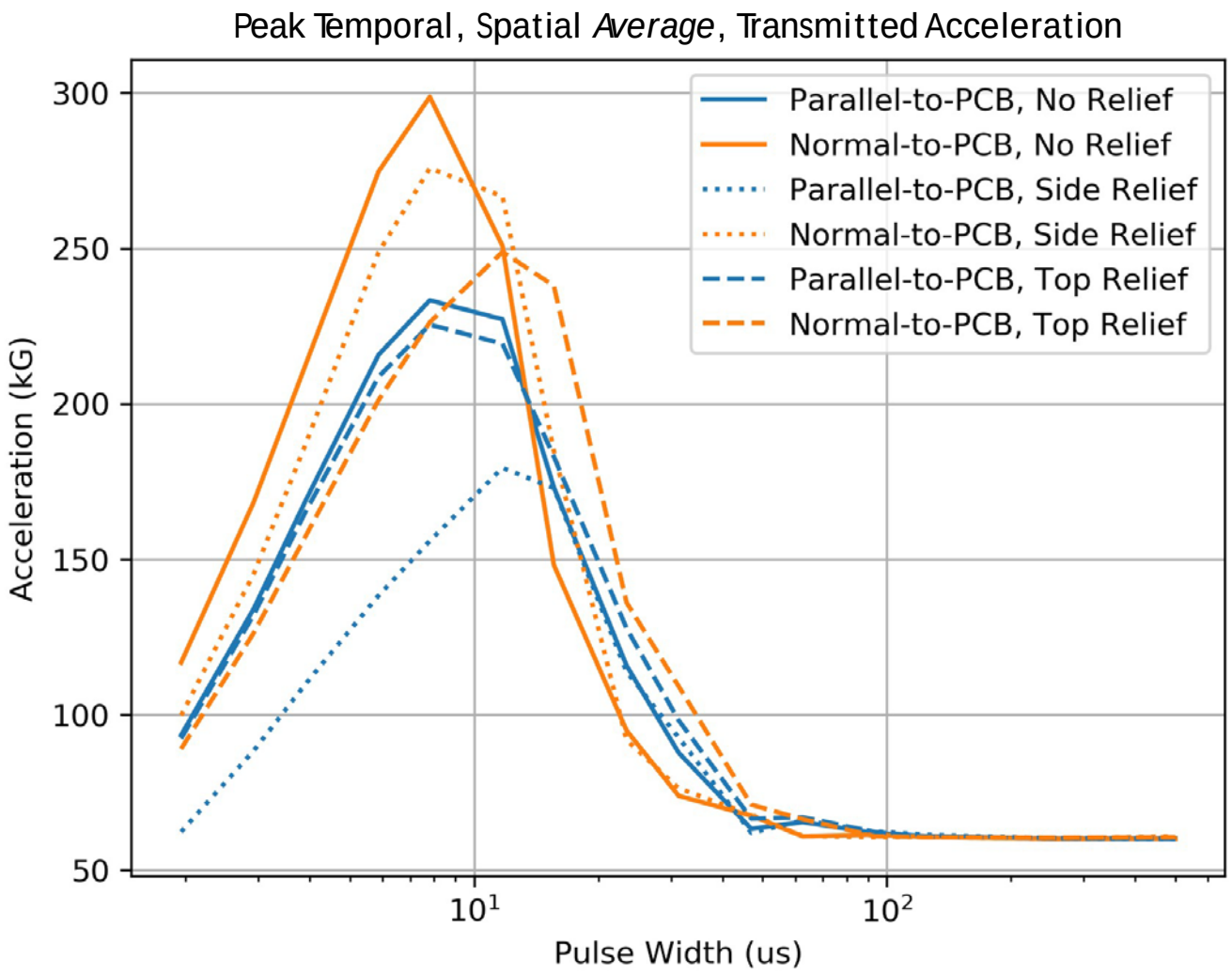
*Simulation extended for 1 ms after pulse to allow assembly to freely resonate.

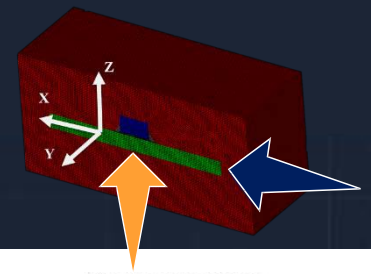
Fundamental Mode Shapes

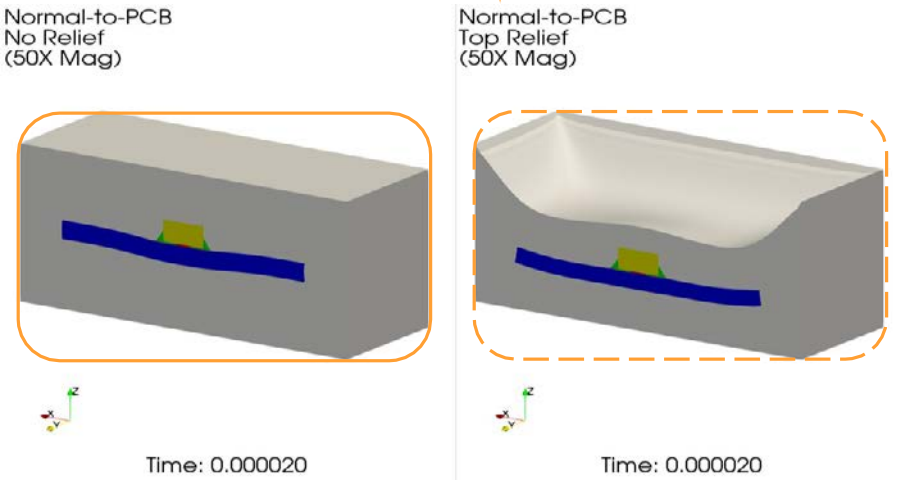
	No Relief	Side Relief	Top Relief
Mode 1	 67 kHz	 61 kHz	 54 kHz
Mode 2	 82 kHz	 77 kHz	 57 kHz

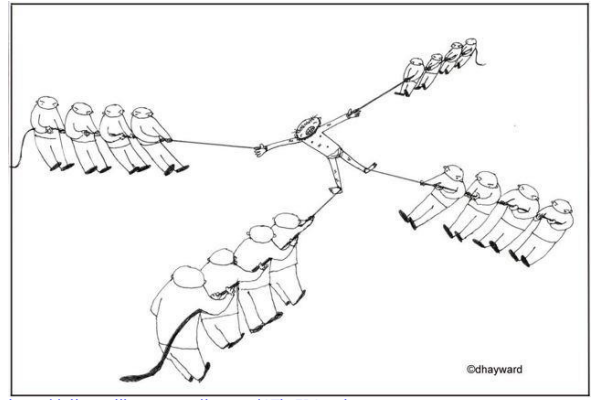
During mechanical insult, the shape of the PCB deflection is determined by the loading direction, *regardless of boundary condition* (i.e., different loading directions excite different modes).

Capacitor Acceleration Transmissibility





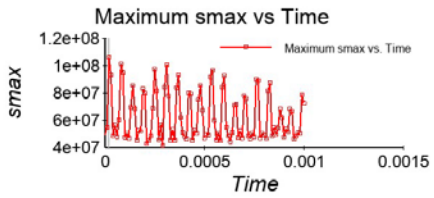


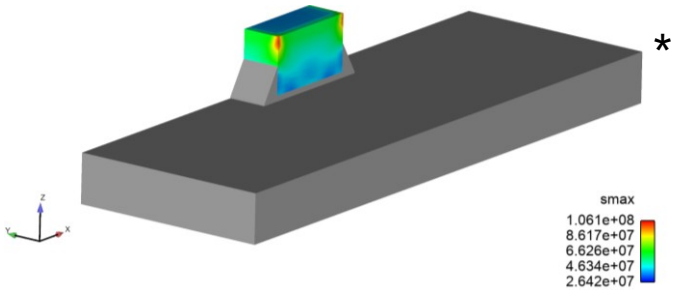


http://clipart-library.com/images/ATbr5BAyc.jpg

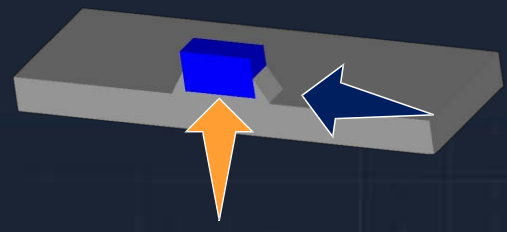
Relief mechanisms drastically affect deflection behavior.

Resultant Capacitor Stress

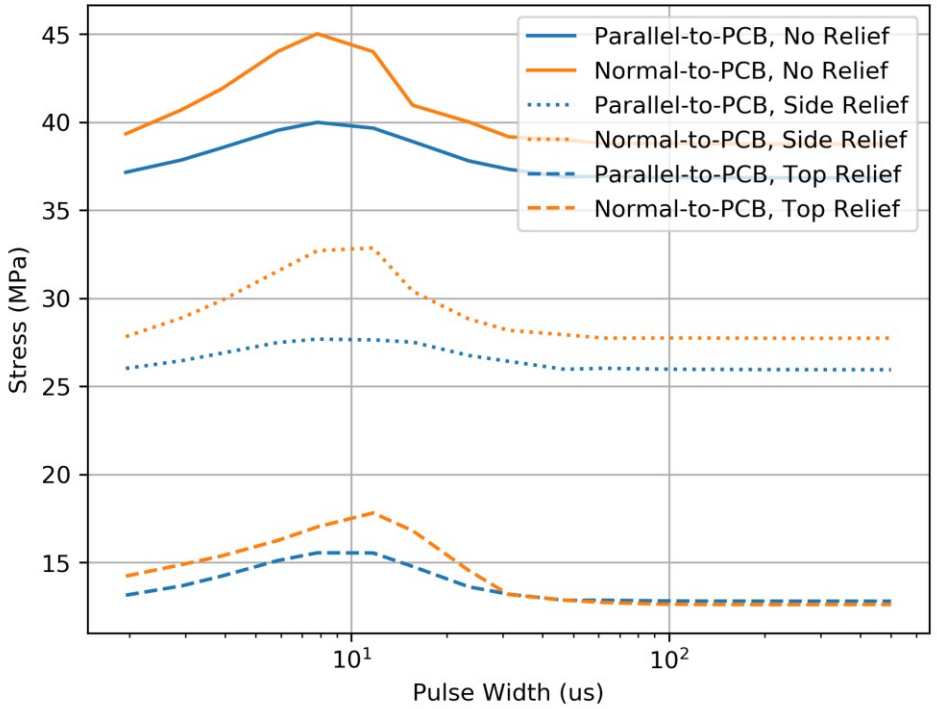




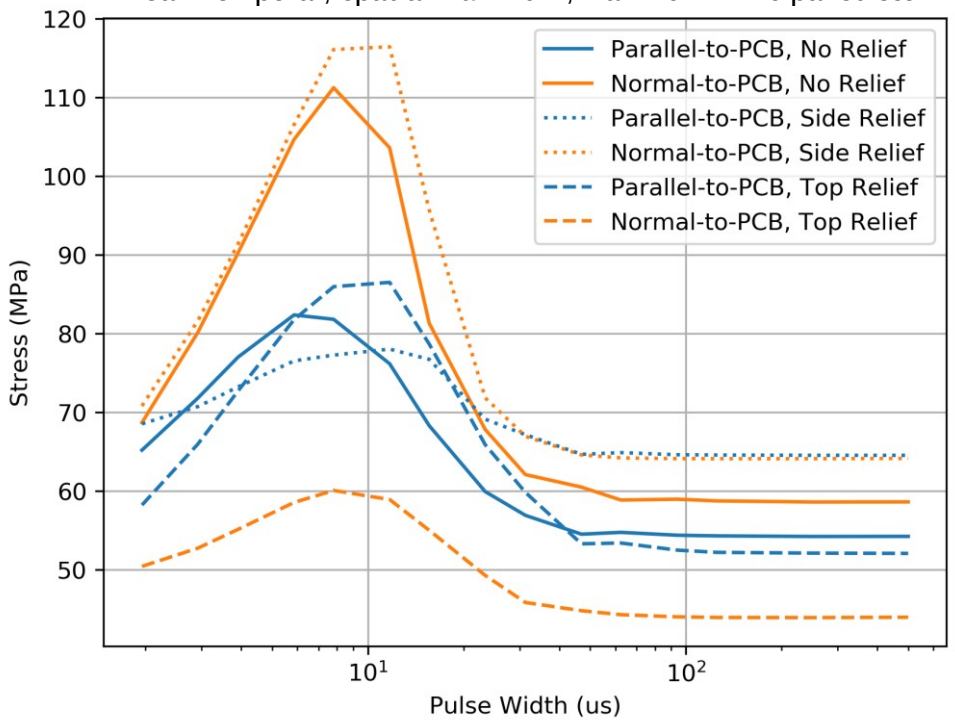
*



Peak Temporal, Spatial *Average*, Maximum Principal Stress



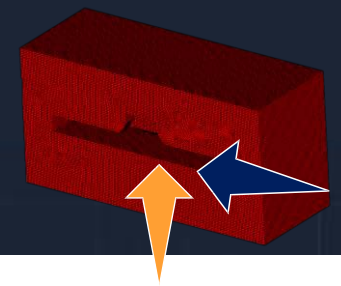
Peak Temporal, Spatial *Maximum*, Maximum Principal Stress

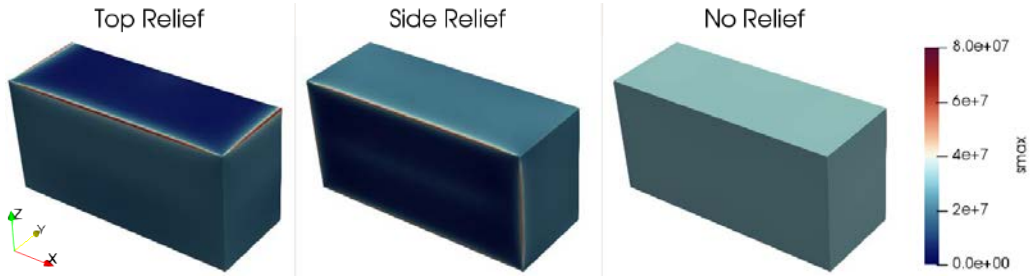


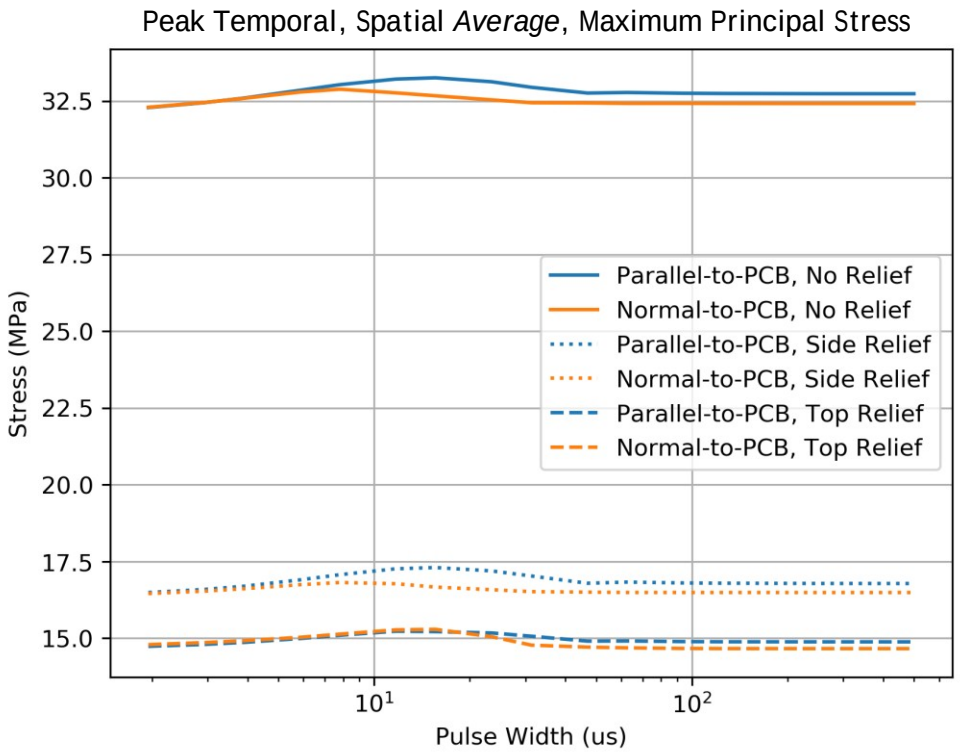
Tensile load on capacitor exacerbates dynamic stress.

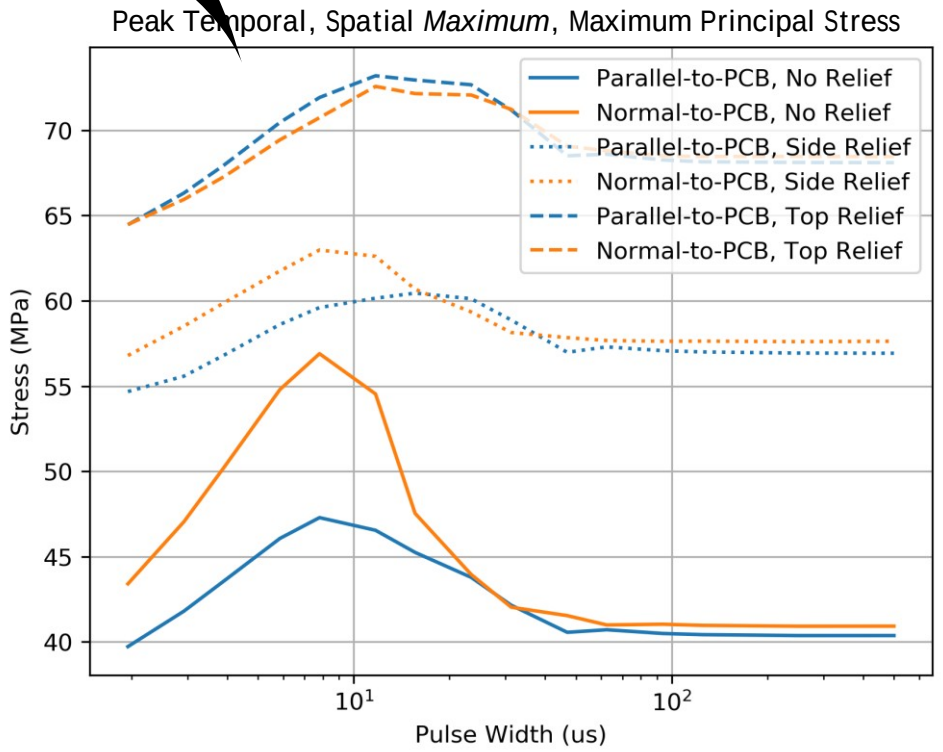
*No Relief, Normal-to-PCB, Pulse Width: 7.81 µs

Resultant Potting Stress



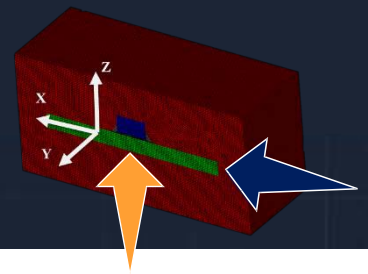




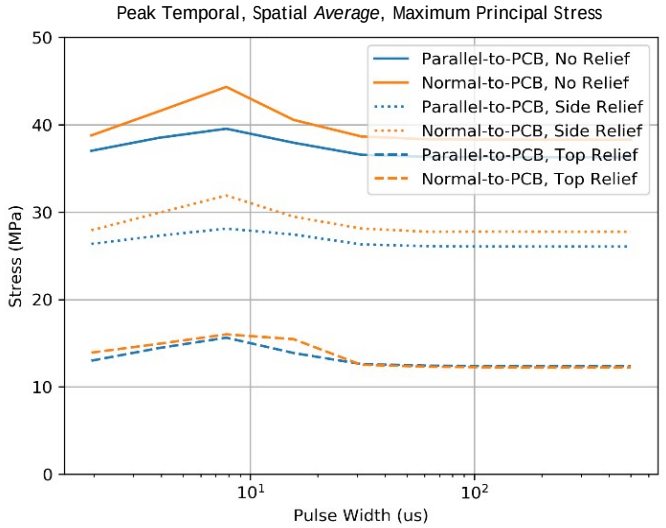


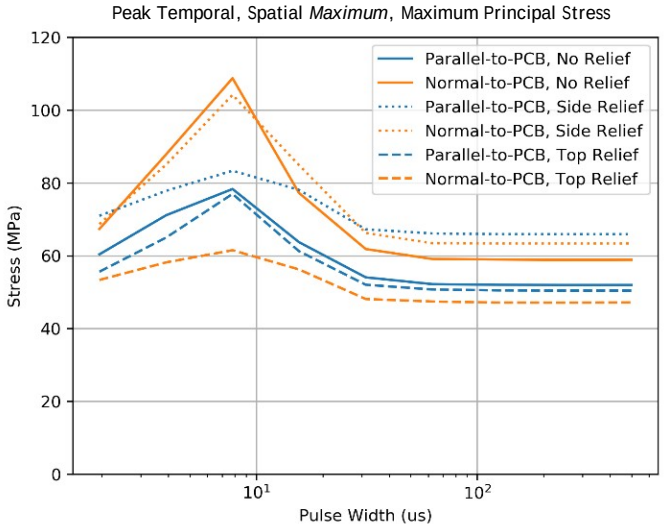
Delamination likely to occur along housing interface.

PCB Length Comparison: Capacitor Stress

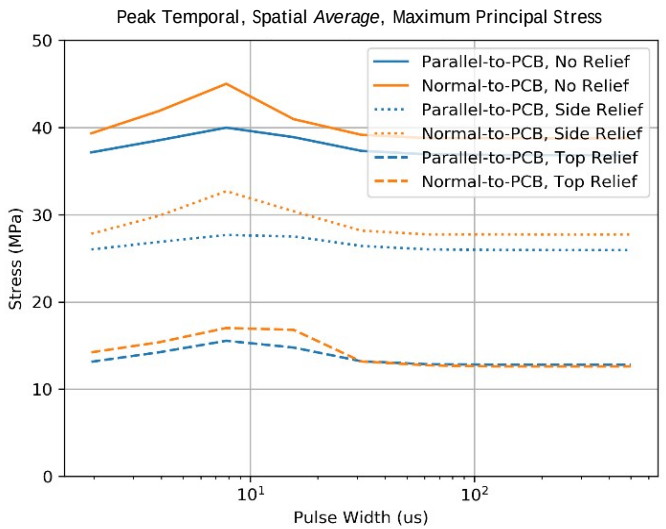


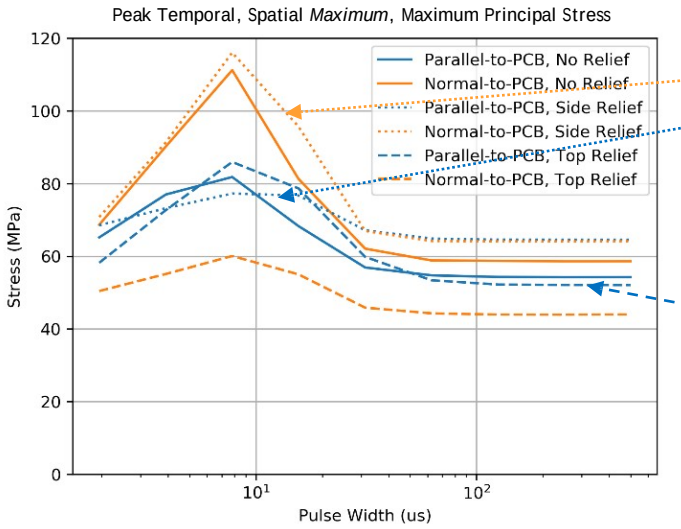
.5”L PCB



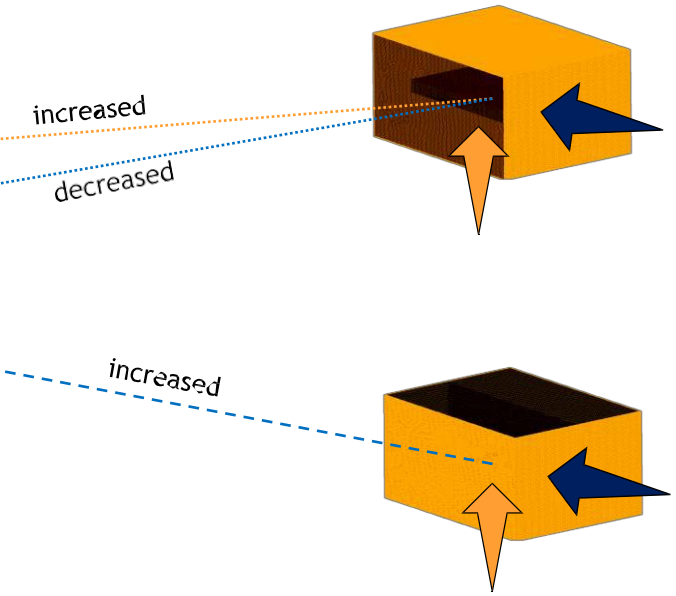


.75”L PCB



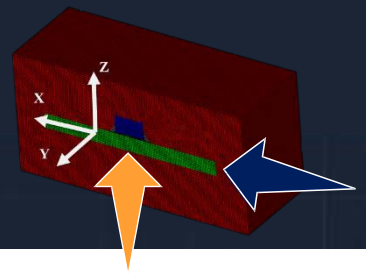


- Negligible effect on spatial averaged stress
- Stress increased for Normal-to-PCB/Side Relief and Parallel-to-PCB/Top Relief
- Stress decreased for Parallel-to-PCB/Side Relief



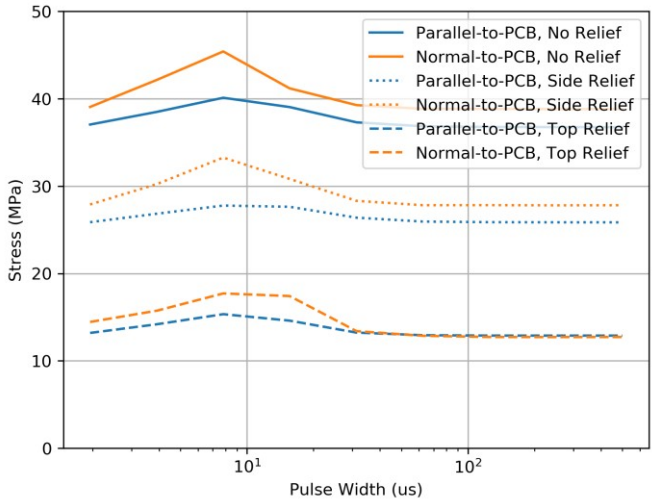
Increasing PCB length reduces bending stiffness and resonant frequency.

Mesh Comparison: Capacitor Stress



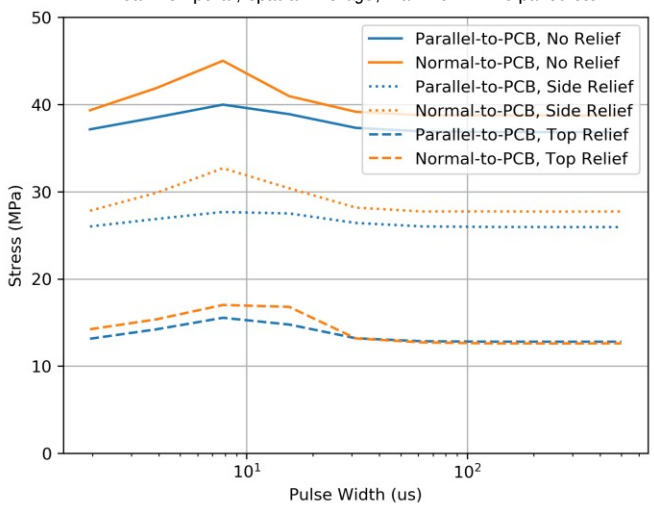
Course: .010”

Peak Temporal, Spatial *Average*, Maximum Principal Stress

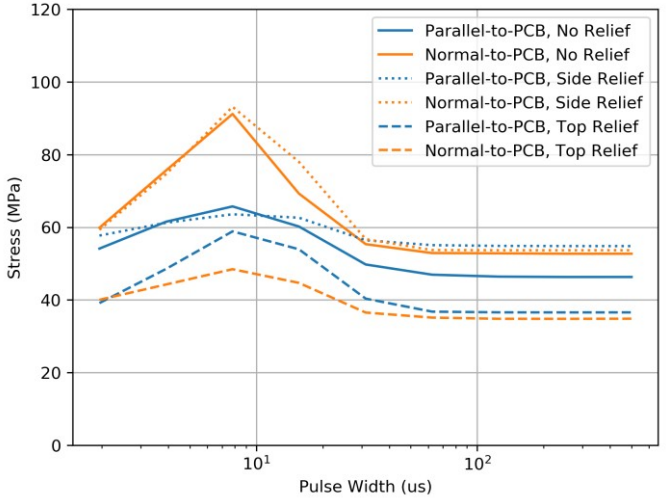


Fine: .006”

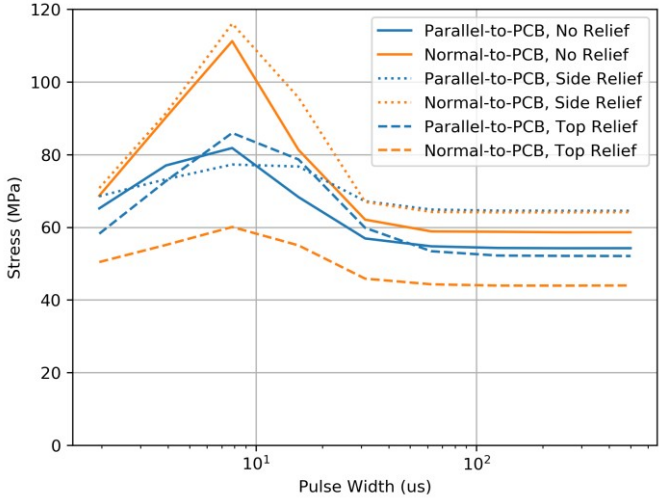
Peak Temporal, Spatial *Average*, Maximum Principal Stress



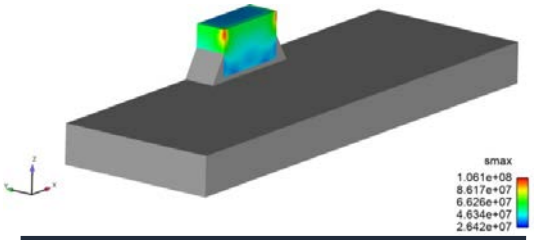
Peak Temporal, Spatial *Maximum*, Maximum Principal Stress



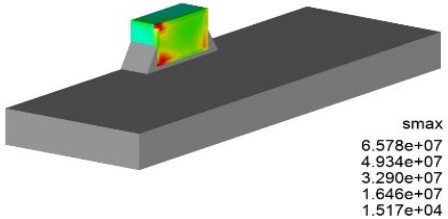
Peak Temporal, Spatial *Maximum*, Maximum Principal Stress



- Spatial averages stresses have converged
- Mesh contains stress risers which fail to converge



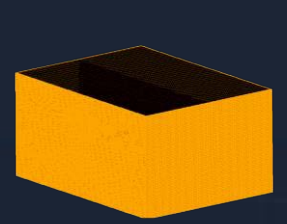
Normal-to-PCB/No Relief

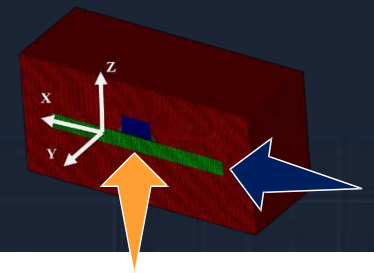


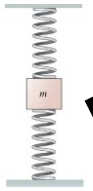
Parallel-to-PCB/Side Relief

Geometry is mesh-dependent due to existence of stress concentrators.

Bottom/Top Comparison: Capacitor Stress

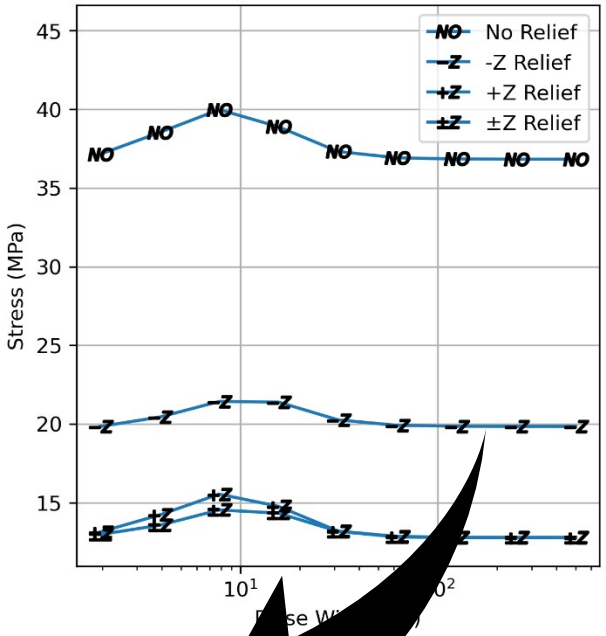




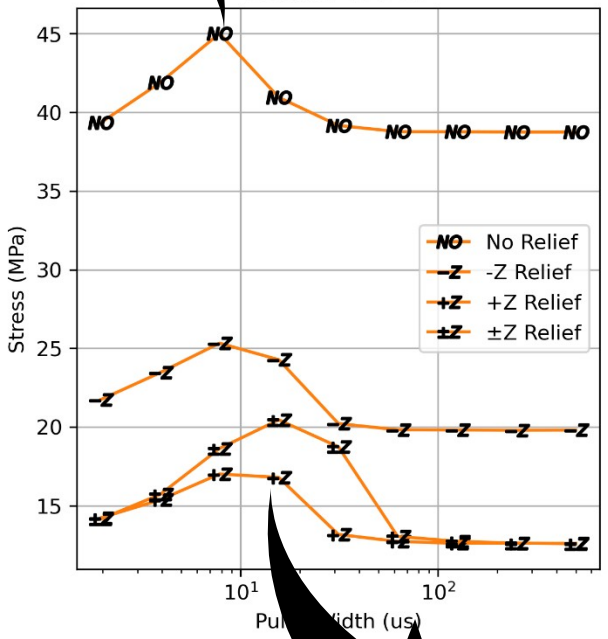


Peak Temporal, Spatial *Average*, Maximum Principal Stress

Parallel-to-PCB

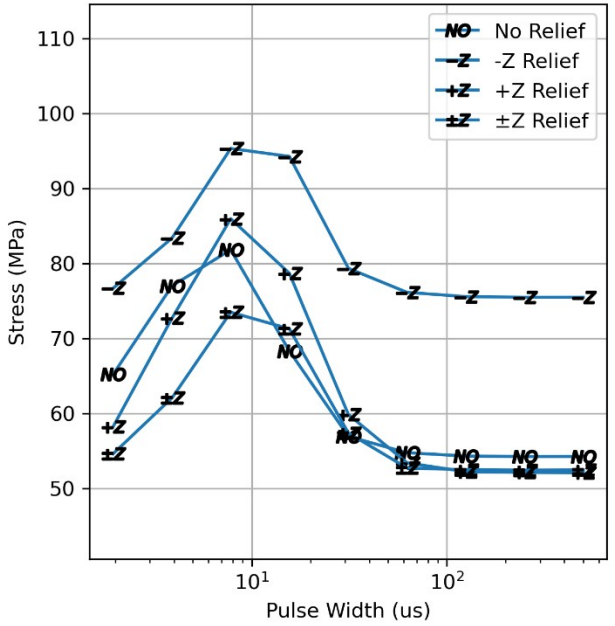


Normal-to-PCB

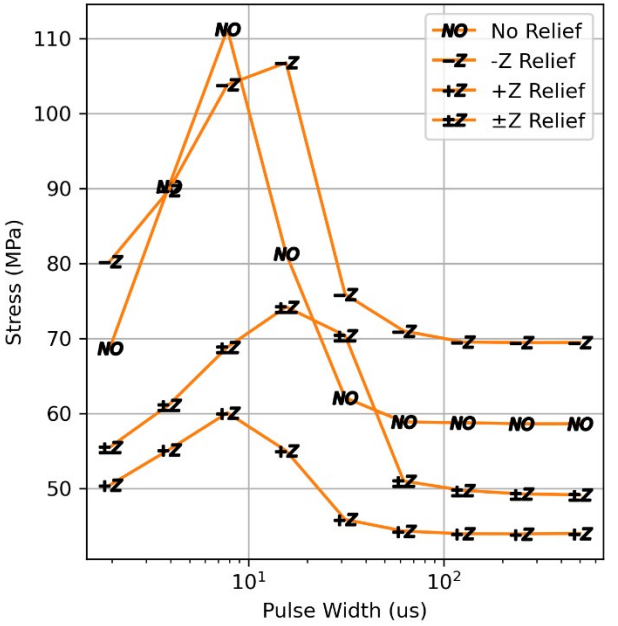


Peak Temporal, Spatial *Maximum*, Maximum Principal Stress

Parallel-to-PCB

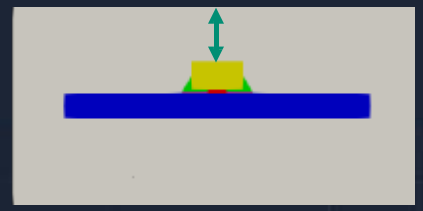


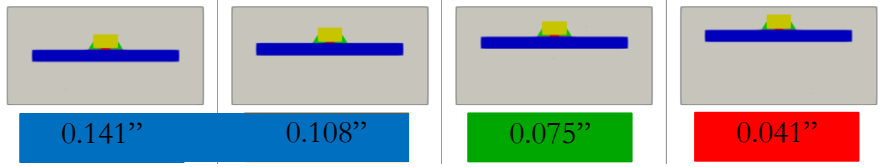
Normal-to-PCB

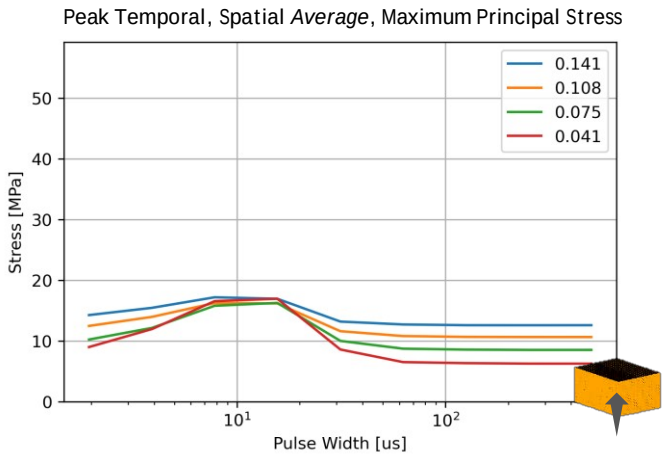


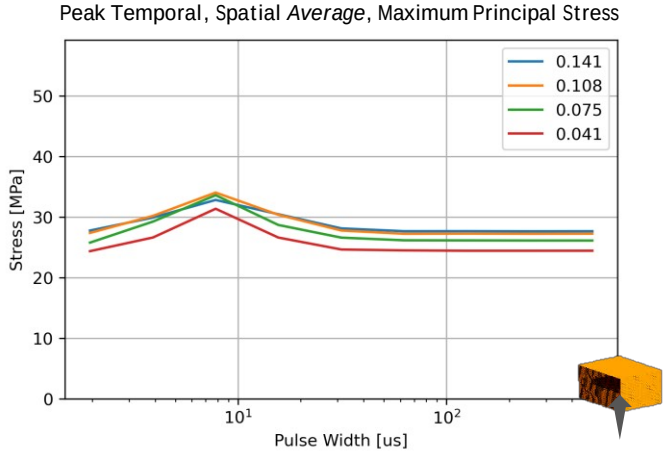
Tensile loads can resist PCB deflection; reliefs can exacerbate stress.

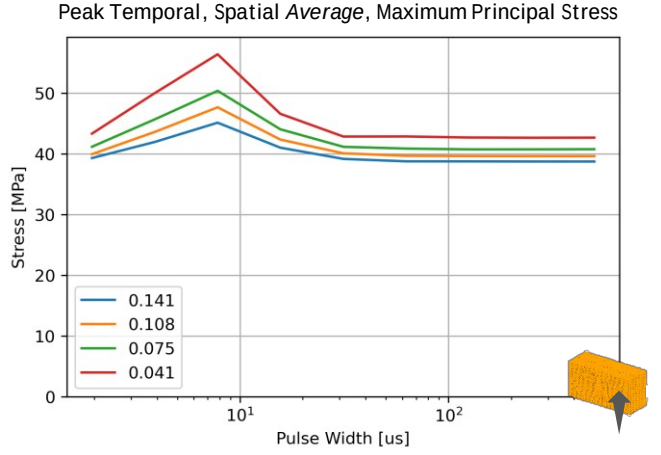
Boundary Proximity: Average Capacitor Stress

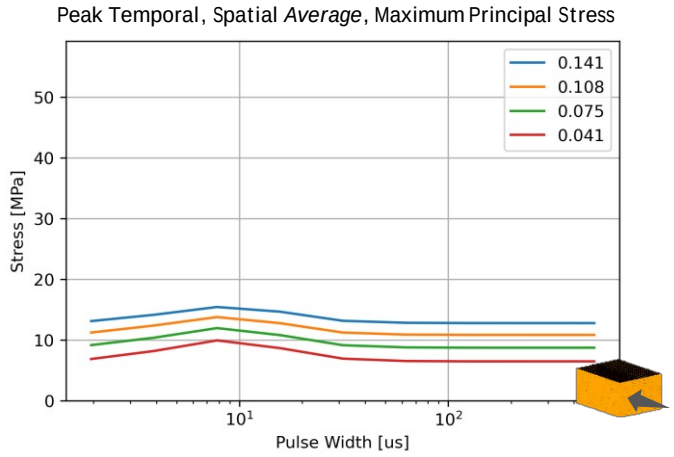


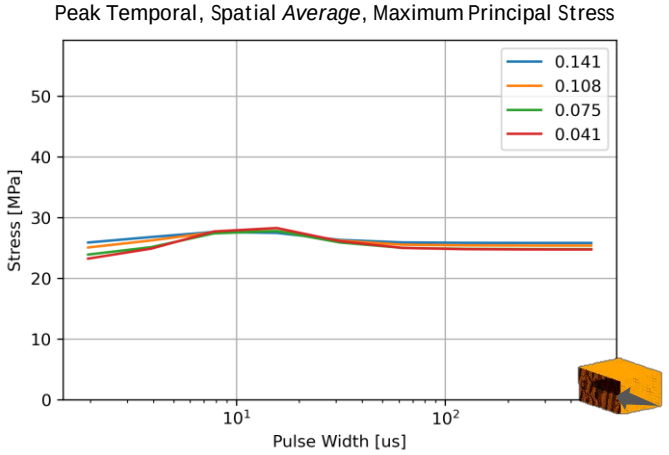


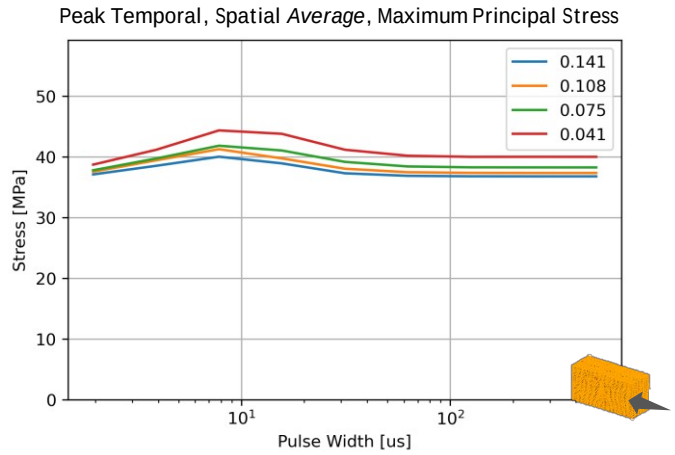






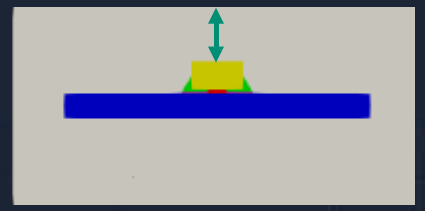


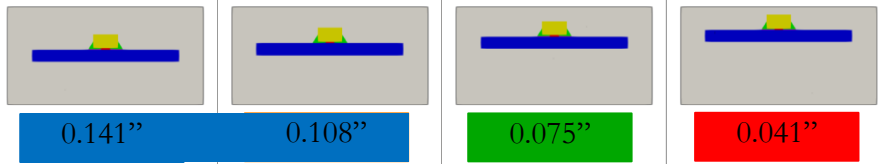


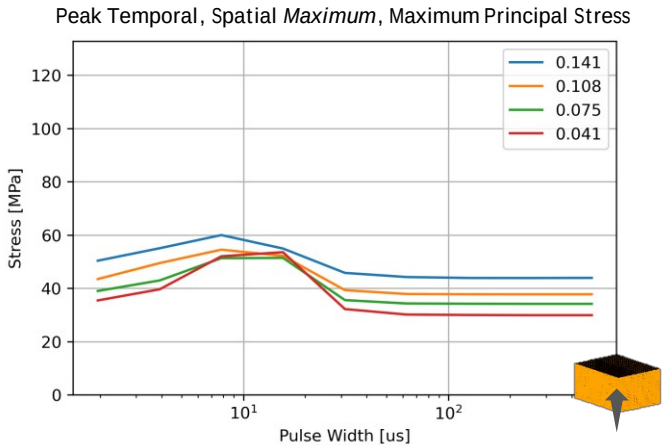


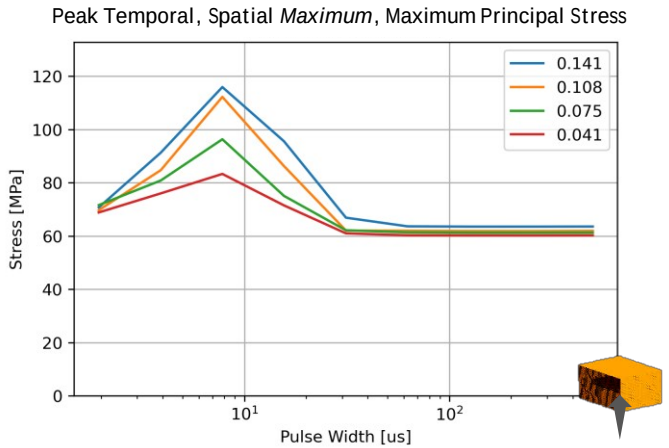
Proximity negligibly affects stress for Side Relief boundary condition.

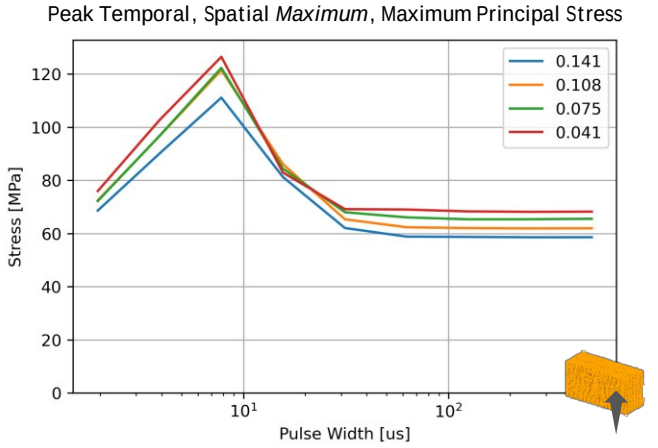
Boundary Proximity: Maximum Capacitor Stress

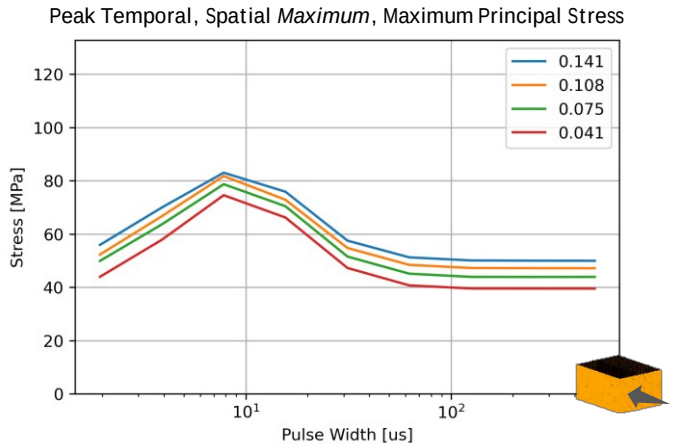


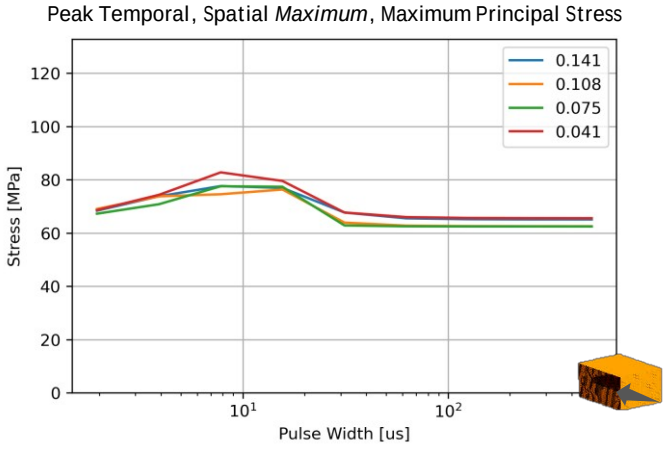


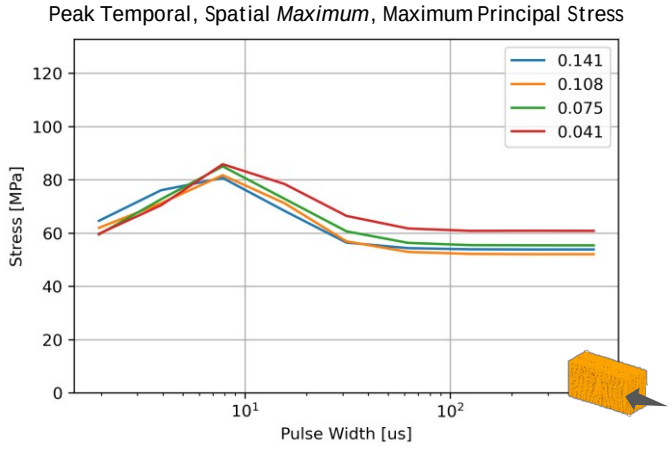






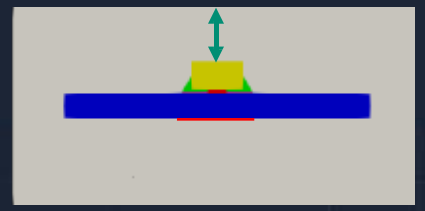


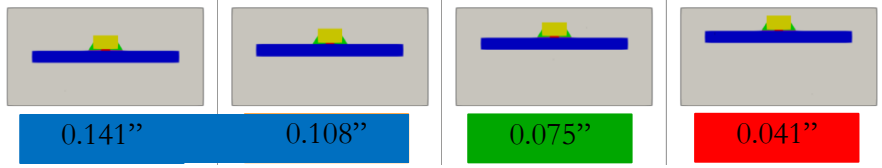


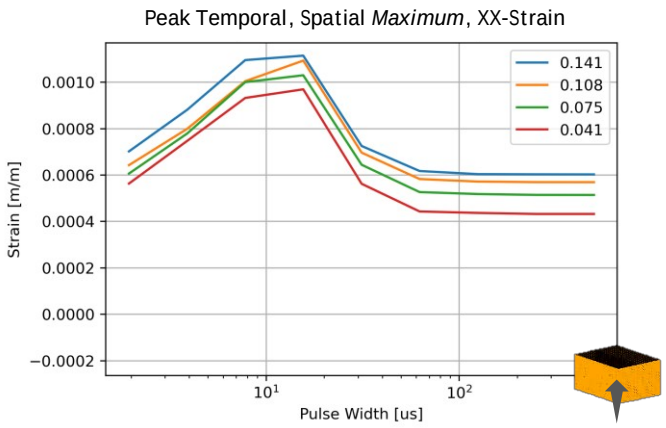


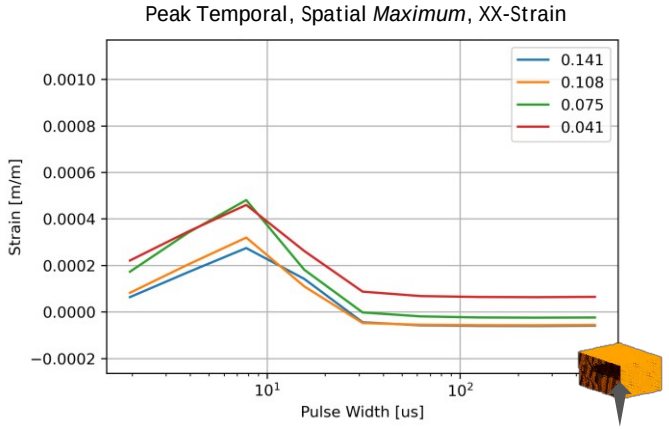
Relation of proximity to stress inverts in absence of reliefs.

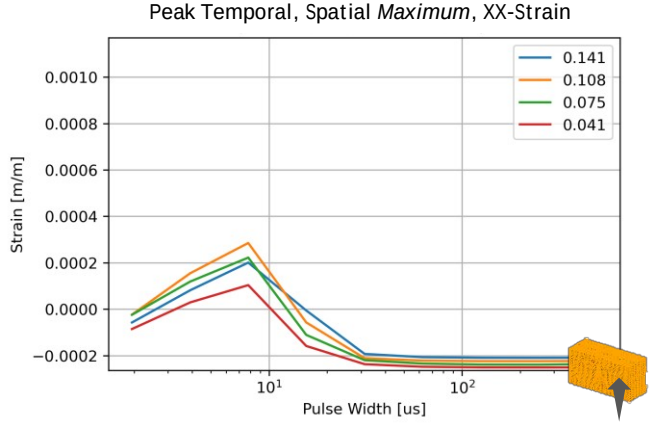
Boundary Proximity: Maximum PCB XX-Strain

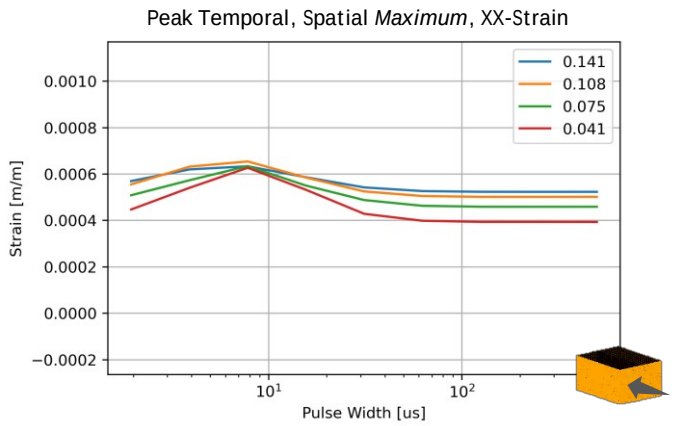


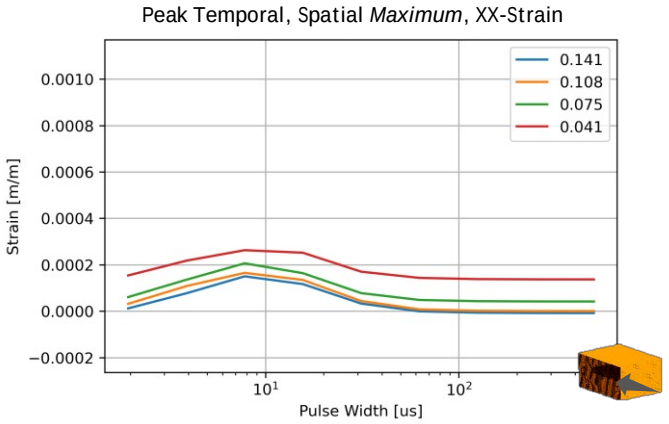


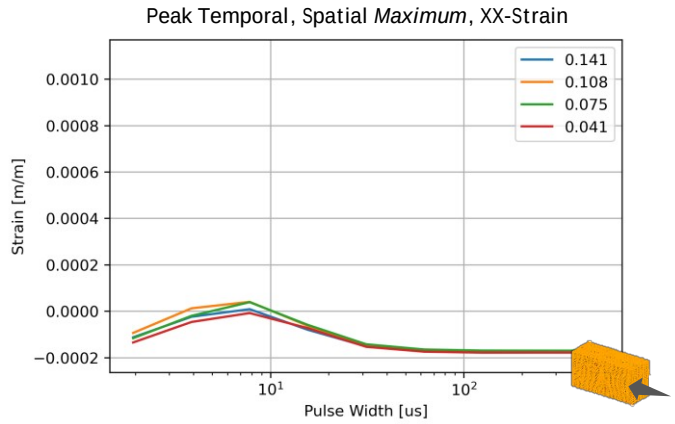






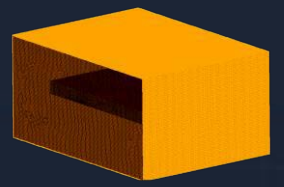


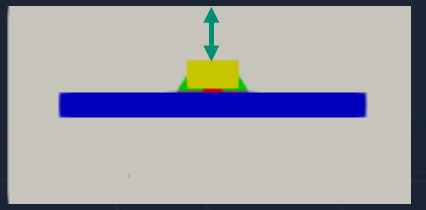




PCB flexure behavior is complicated/dependent on variety of parameters.

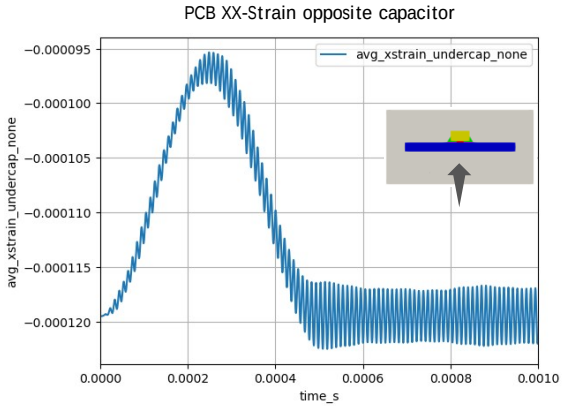
Boundary Proximity: Nuances



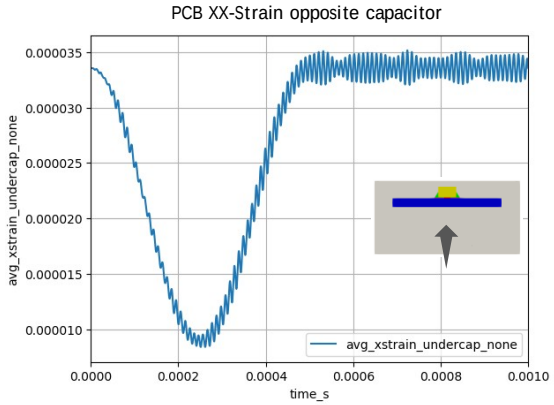


Normal-to-PCB / Side Relief

.141”

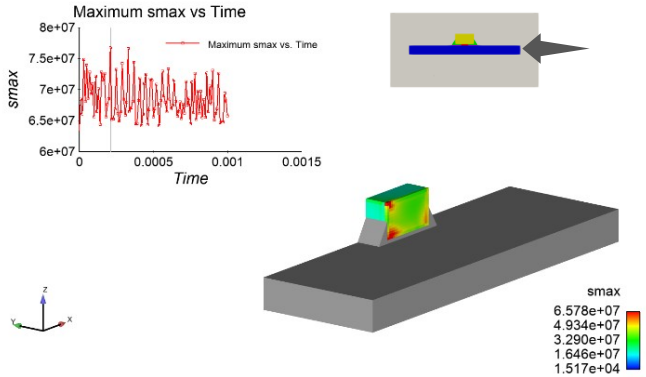


.041”

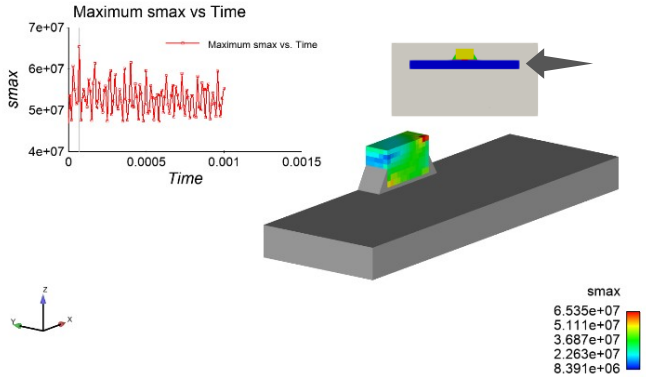


Parallel-to-PCB / Side Relief

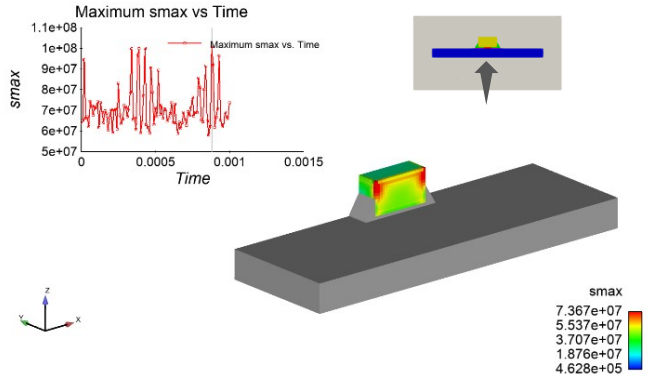
.141”

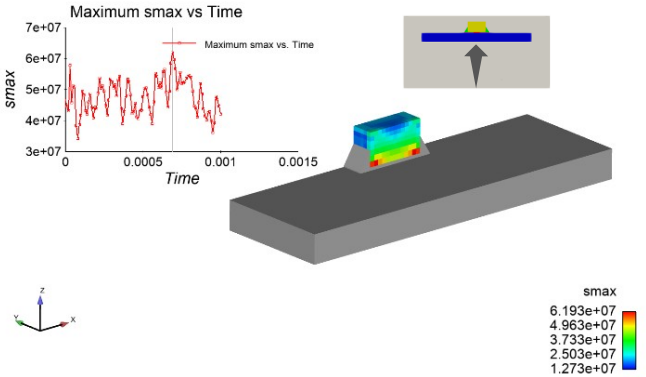


.041”



Normal-to-PCB / Side Relief





Inconsistent, complex damage mechanisms confound intuition.

Conclusions

- Strategic inclusion of relief mechanisms are critical for electronic survivability.
- The PCB *orientation* dictates fundamental displacement mode, the *relaxation condition* of the boundary in the direction of the displacement mode affects the resultant component stress state.
- Analyses of systems are vital, as complex, non-linear damage mechanisms can defy engineering intuition.
- Length of PCB has little effect in this study, longer PCBs could induce greater PCB deflection in other applications.
- Boundary proximity is directly related to the stress state in the absence of reliefs, but inversely related otherwise.
- Best performer[1]: Top Relief boundary condition & Normal-to-PCB loading direction.
- 2nd performer[2]: Side Relief boundary condition & Parallel-to-PCB loading direction.

[1]Does not account for components on opposite side of PCB.
[2]Possibly best case for real applications.

Exceptional Service in the National Interest

Sandia National Laboratories