SAND2017-3286PE

Function-driven Design with Topology Optimization

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Simulation Modeling Sciences, Sandia National Labs

SAND2015-10065 PE

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Inversion of Design

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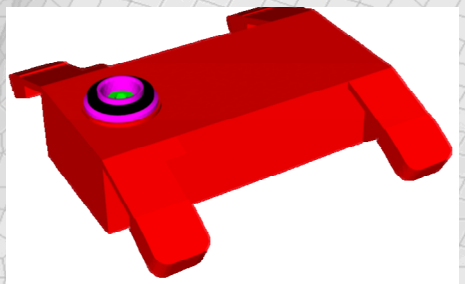
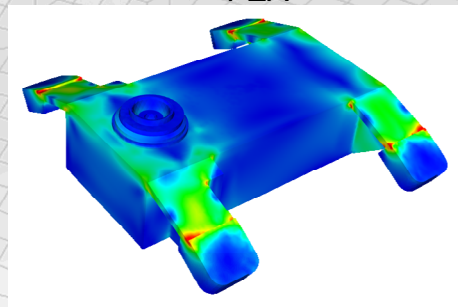
CURRENT

Specify Form

Design



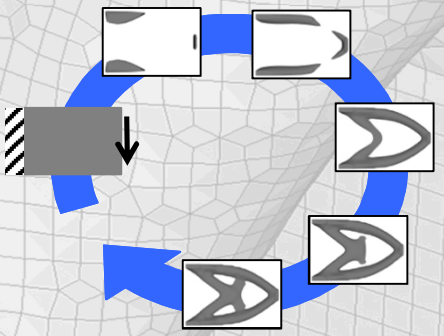
Verify Function Using FEA



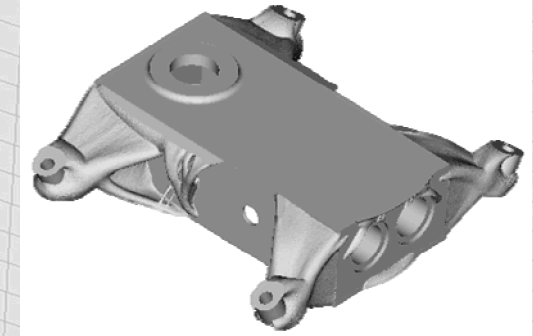
NEW

Specify Design Domain and Function

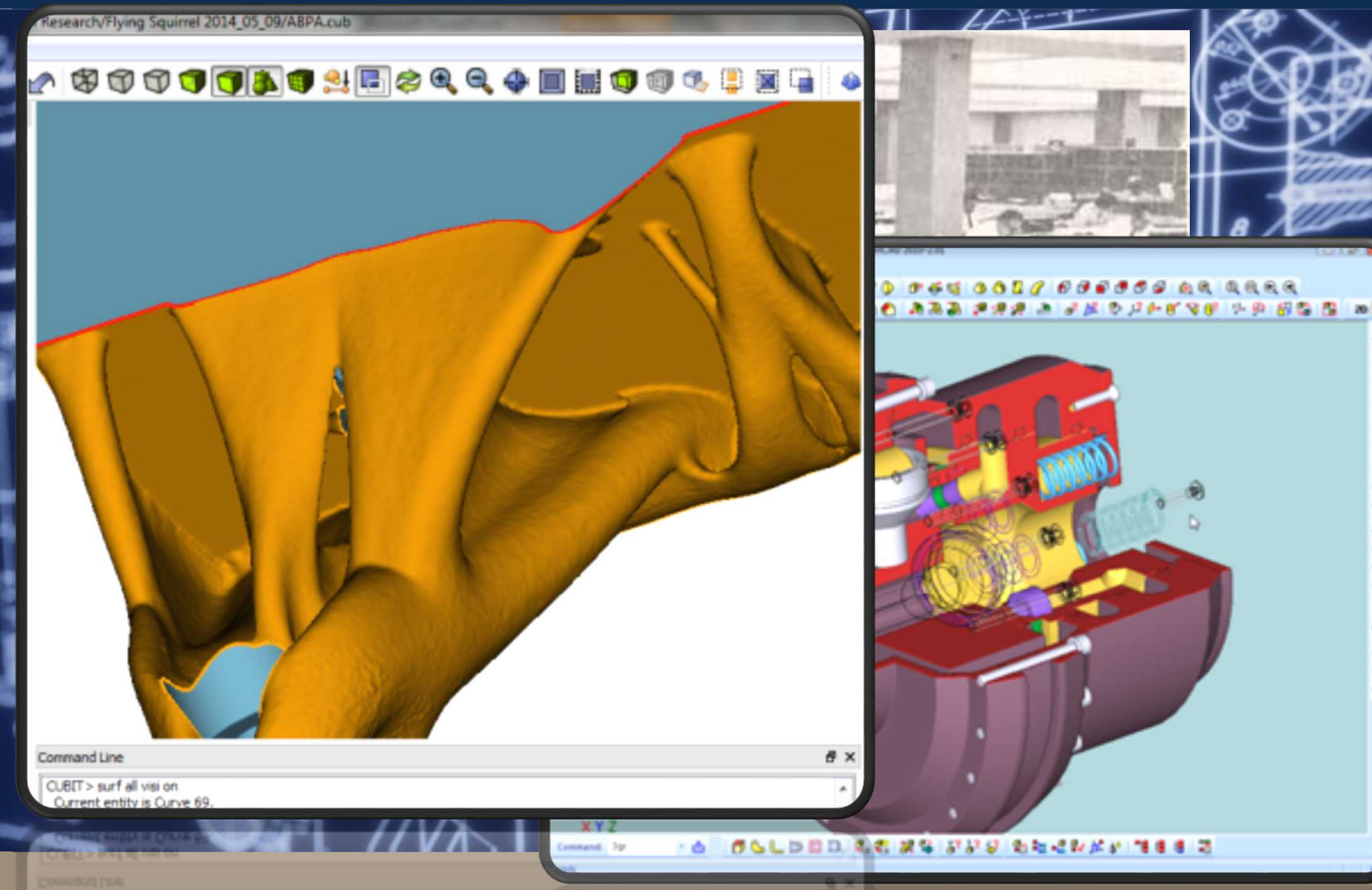
Use Topology Optimization (FEA) to Determine Form that Meets Function



Optimized Design (Form)

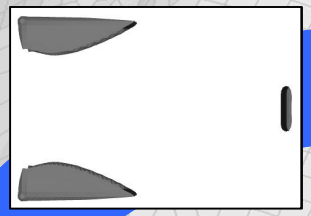


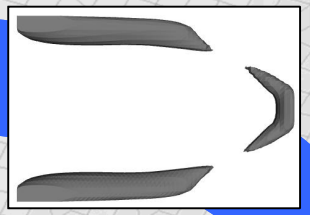
A Design Revolution



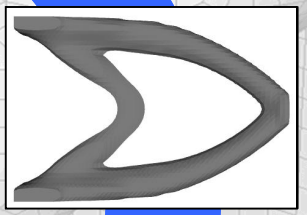
Topology Optimization

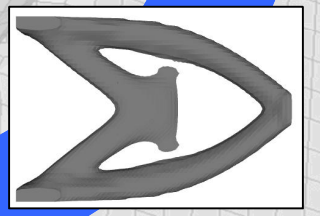
Specify design domain and functional requirements.

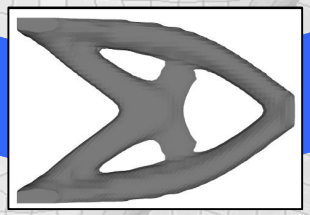




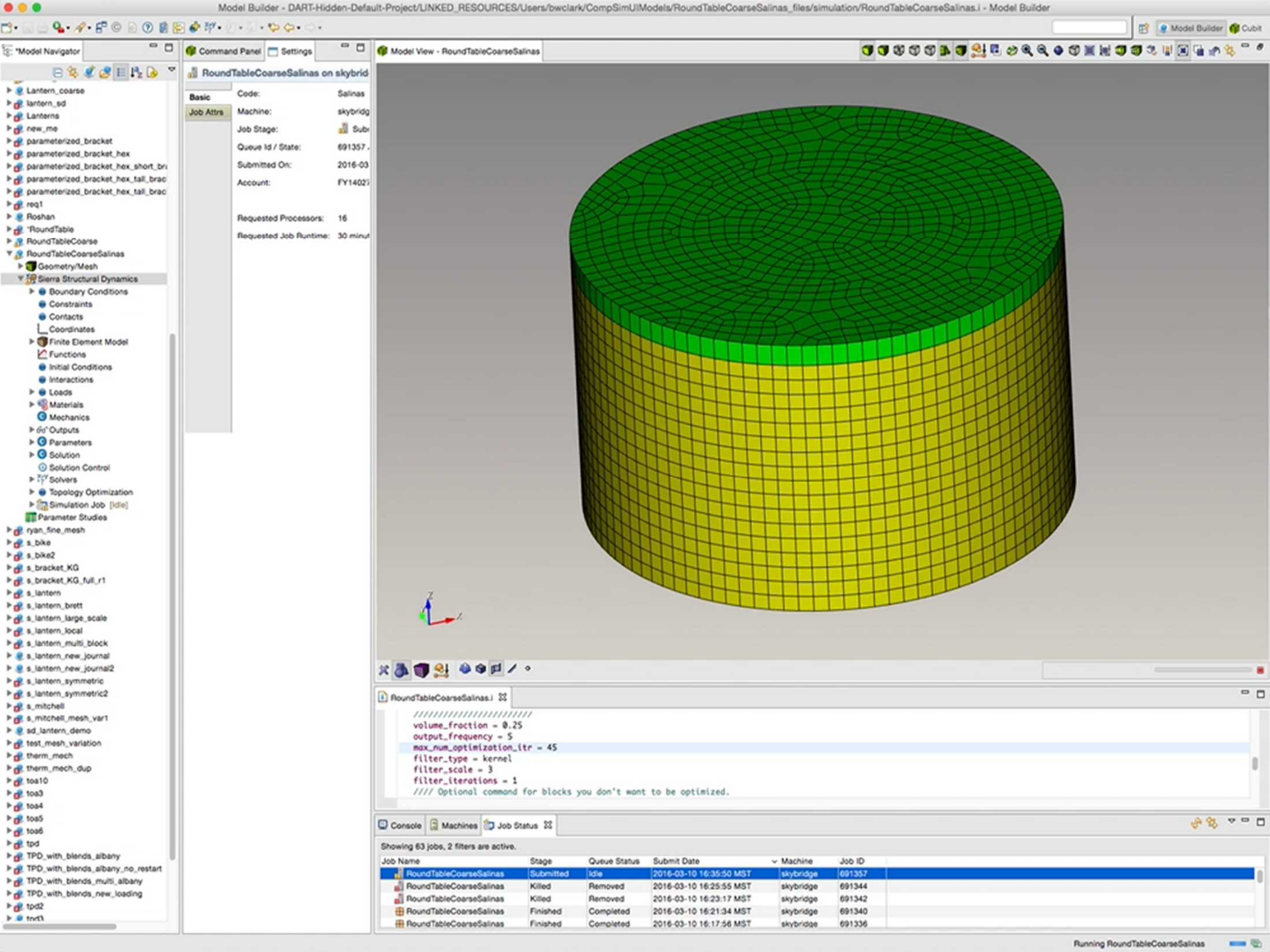
Iteratively solve physics simulations to determine optimal distribution of material.



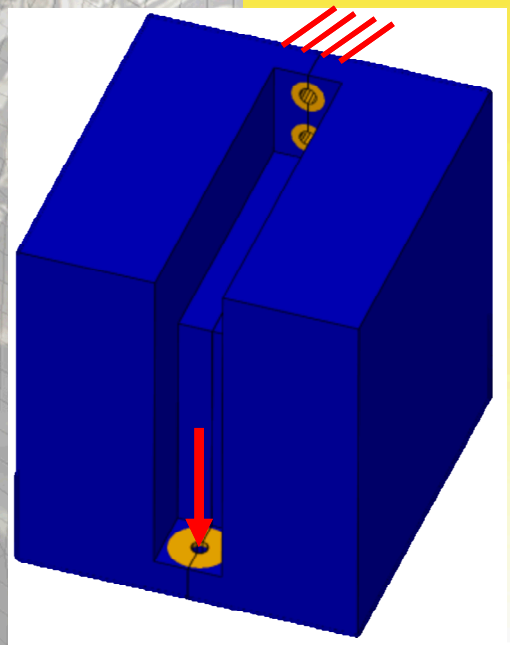




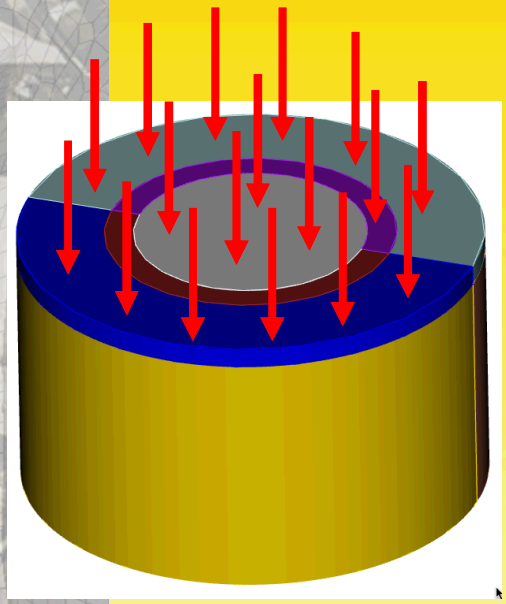
The result is a design optimized for the functional requirements

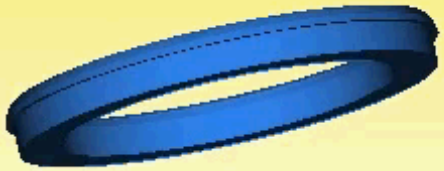

Model Builder - DART-Hidden-Default-Project/LINKED_RESOURCES/Users/bwclark/CompSimUIModels/RoundTableCoarseSalinas_files/simulation/RoundTableCoarseSalinas.i - Model Builder
*Model Navigator
Lantern_coarse
lantern_sd
Lanterns
new_me
parameterized_bracket
parameterized_bracket_hex
parameterized_bracket_hex_short_bri
parameterized_bracket_hex_tall_brac
parameterized_bracket_hex_tall_brac
req1
Roshan
*RoundTable
RoundTableCoarse
RoundTableCoarseSalinas
Geometry/Mesh
Sierra Structural Dynamics
Boundary Conditions
Constraints
Contacts
Coordinates
Finite Element Model
Functions
Initial Conditions
Interactions
Loads
Materials
Mechanics
Outputs
Parameters
Solution
Solution Control
Solvers
Topology Optimization
Simulation Job [Idle]
Parameter Studies
ryan_fine_mesh
s_bike
s_bike2
s_bracket_KG
s_bracket_KG_full_r1
s_lantern
s_lantern_brett
s_lantern_large_scale
s_lantern_local
s_lantern_multi_block
s_lantern_new_journal
s_lantern_new_journal2
s_lantern_symmetric
s_lantern_symmetric2
s_mitchell
s_mitchell_mesh_var1
sd_lantern_demo
test_mesh_variation
therm_mech
therm_mech_dup
toa10
toa3
toa4
toa5
toa6
tpd
TPD_with_blends_albany
TPD_with_blends_albany_no_restart
TPD_with_blends_multi_albany
TPD_with_blends_new_loading
tpd2
Command Panel
Settings
RoundTableCoarseSalinas on skybrid
Basic
Job Attrs
Code: Salinas
Machine: skybridg
Job Stage: Subr
Queue Id / State: 691357
Submitted On: 2016-03
Account: FY1402
Requested Processors: 16
Requested Job Runtime: 30 minut
Model View - RoundTableCoarseSalinas
Z
Y
RoundTableCoarseSalinas.i
//////////////////////
volume_fraction = 0.25
output_frequency = 5
max_num_optimization_itr = 45
filter_type = kernel
filter_scale = 3
filter_iterations = 1
//// Optional command for blocks you don't want to be optimized.
Console
Machines
Job Status
Showing 63 jobs, 2 filters are active.
Job Name Stage Queue Status Submit Date Machine Job ID
RoundTableCoarseSalinas Submitted Idle 2016-03-10 16:35:50 MST skybridge 691357
RoundTableCoarseSalinas Killed Removed 2016-03-10 16:25:55 MST skybridge 691344
RoundTableCoarseSalinas Killed Removed 2016-03-10 16:23:17 MST skybridge 691342
RoundTableCoarseSalinas Finished Completed 2016-03-10 16:21:34 MST skybridge 691340
RoundTableCoarseSalinas Finished Completed 2016-03-10 16:17:56 MST skybridge 691336
Running RoundTableCoarseSalinas

Examples



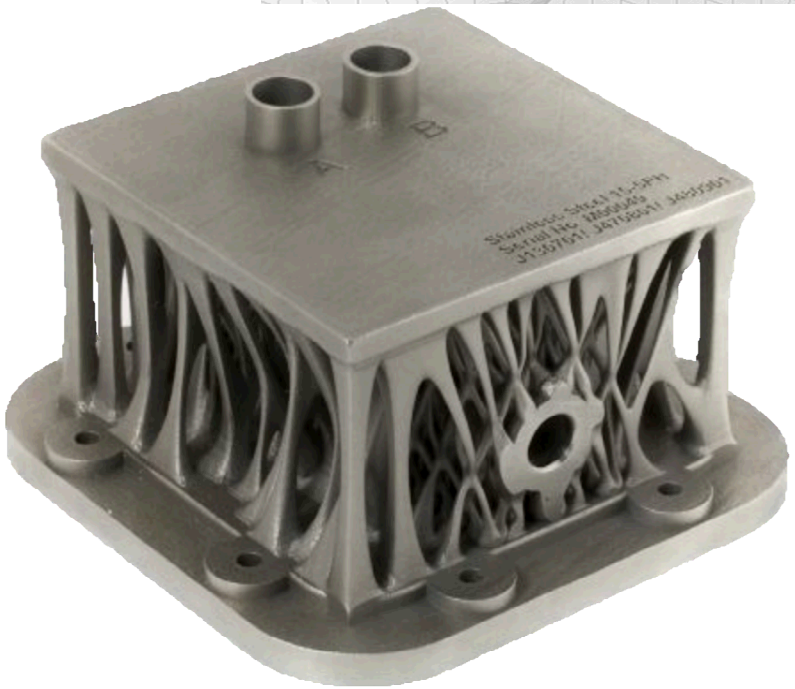
Examples



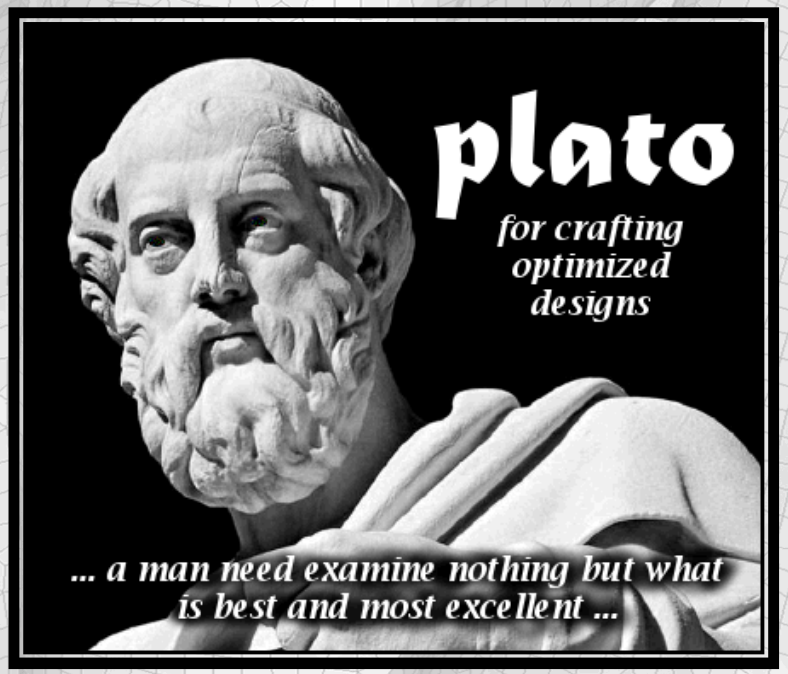


Why now?

- Topology Optimization is not new
- Advancements in Additive Manufacturing technologies are making it possible to manufacture topologically optimized designs (in metals).

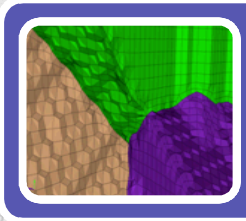


Plato



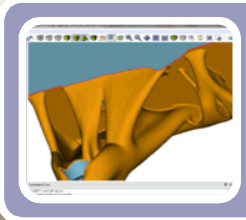
Topology Optimization
- PLATO

Physics Solvers
- SIERRA / ALBANY / ...



Meshing and Geometry
- CUBIT / ACIS / KCM

Optimization and UQ
- DAKOTA / ROL



Design Environment
- SAW

What are the challenges?

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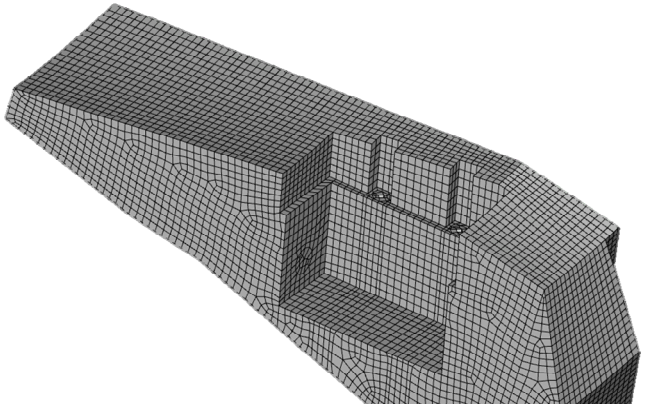
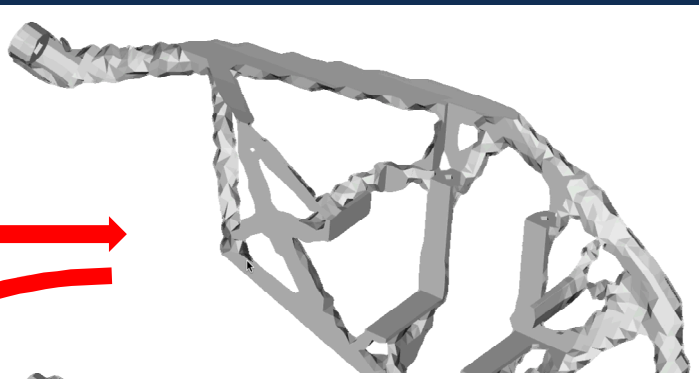
Challenges	What we are doing…
1. Incorporating more challenging physics	1. Stress minimization, modal analysis, CG constraint
2. Interfacing with multiple physics codes	2. Plato “engine” architecture, multi-physics problems
3. Designing with lattices	3. Homogenization and conformal lattice insertion
4. Designing to avoid support material	4. <Future>
5. Delivering topology optimization in a usable tool	5. HPC-enabled interactive design environment, prune/refine work
6. Getting topologically optimized designs back into a traditional workflow	6. STL->CAD conversion
7. Robust vs. optimized designs—taking into account uncertainty in loads and materials	7. Forays into load uncertainty-enabled topology optimization
8. Model representations in CAD, analysis, and synthesis	8. Volumetric-based geometry representations using level-sets

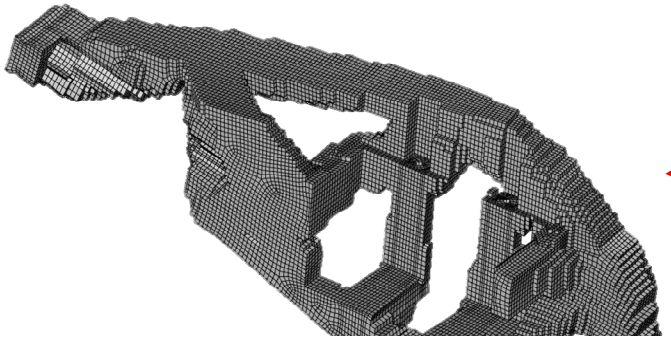
Mesh pruning/refining



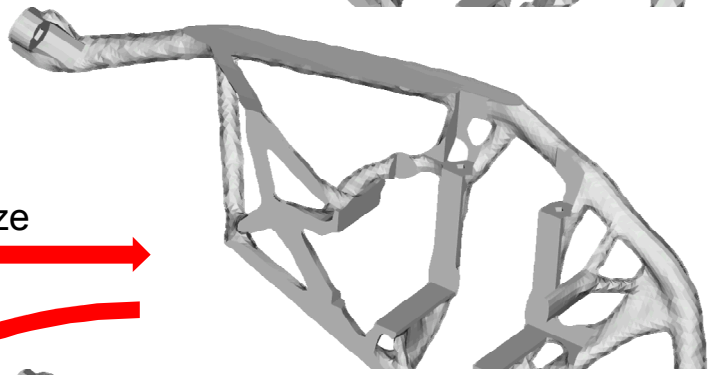
1. Optimize



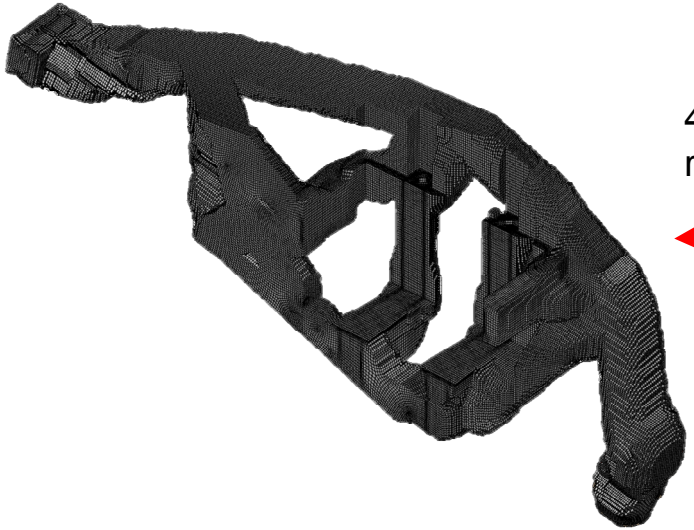
2. Prune and refine mesh



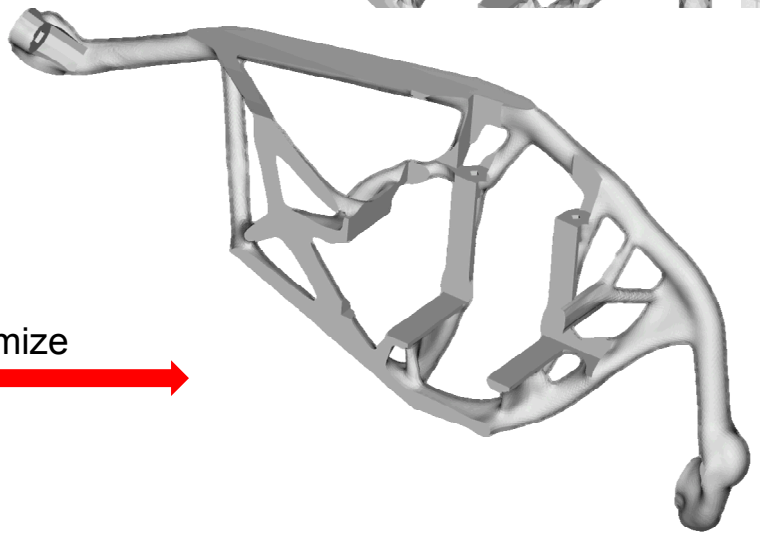
3. Optimize



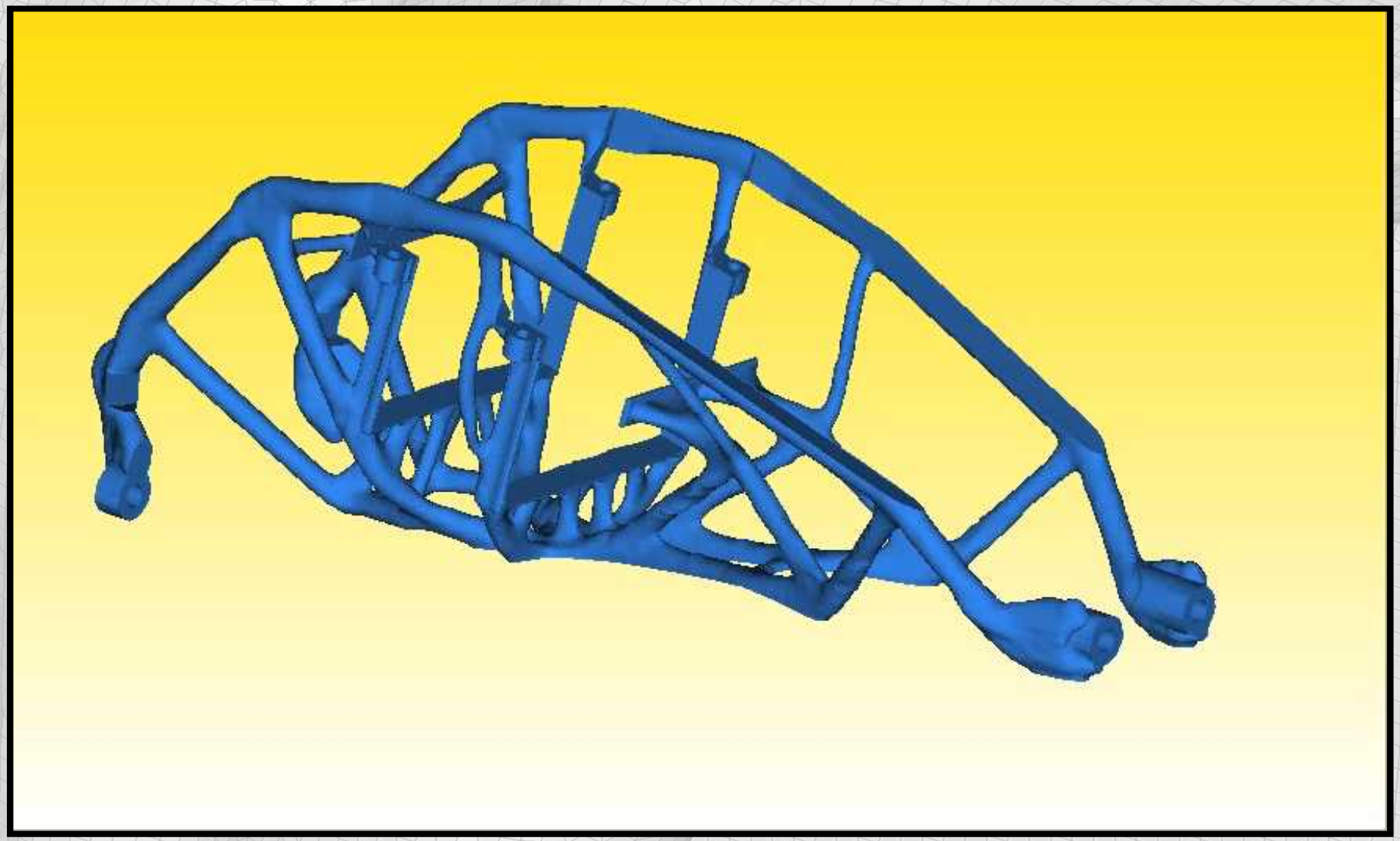
4. Prune and refine mesh



5. Optimize



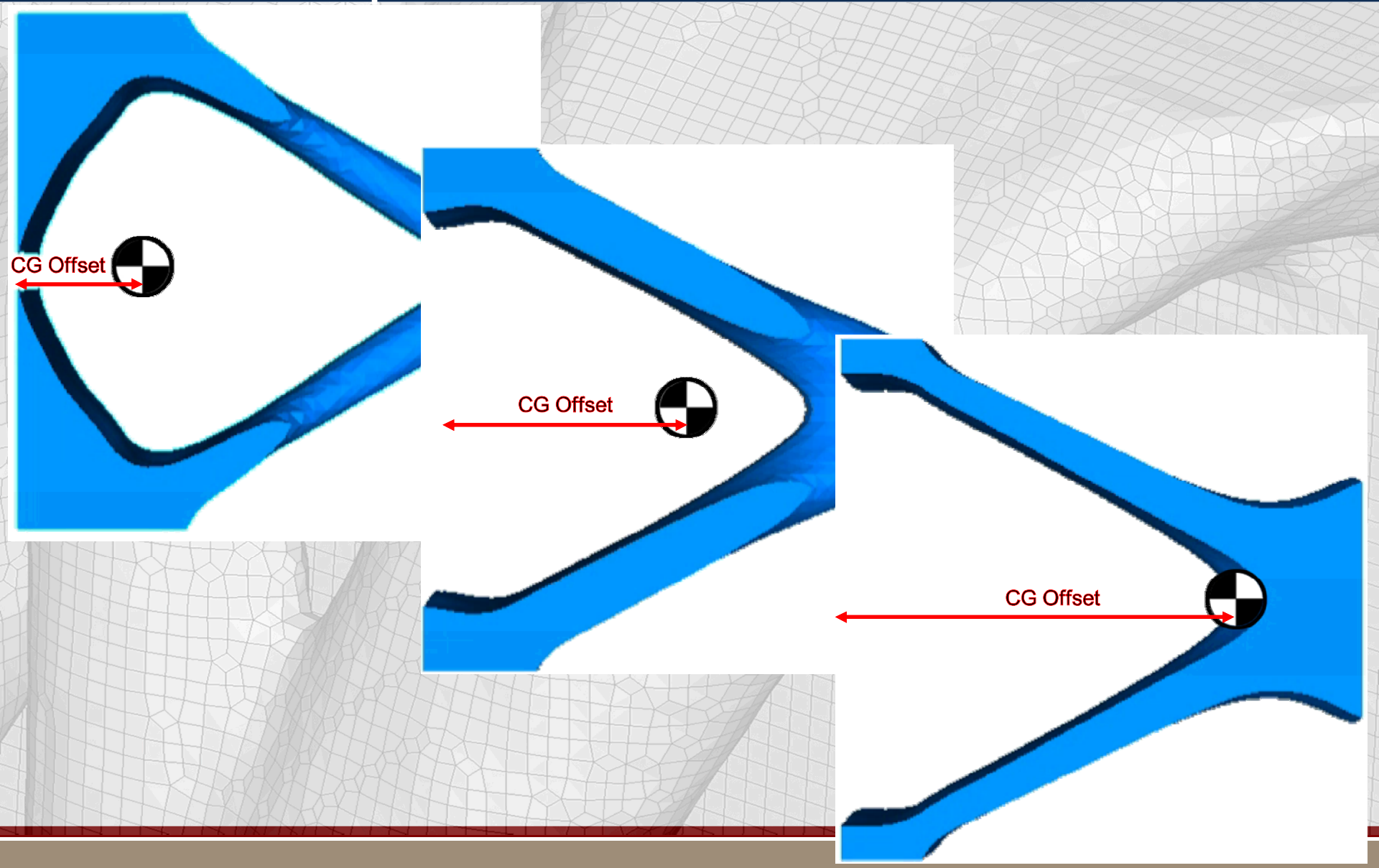
Full Bracket



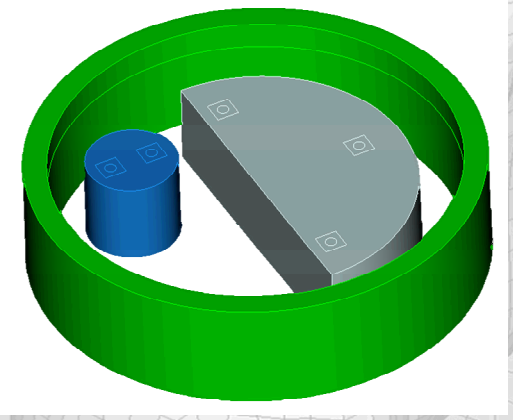
Conversion to Geometric CAD

Conversion to Geometric CAD

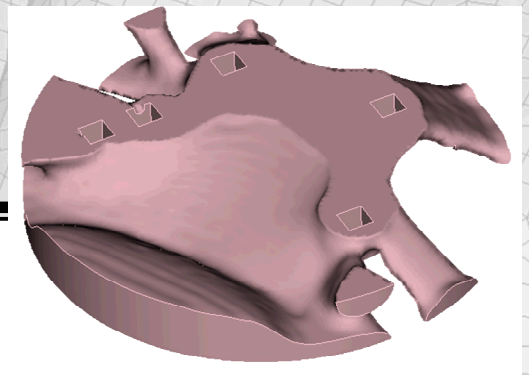
CG Constraint:
Min Compliance with fixed CG Location

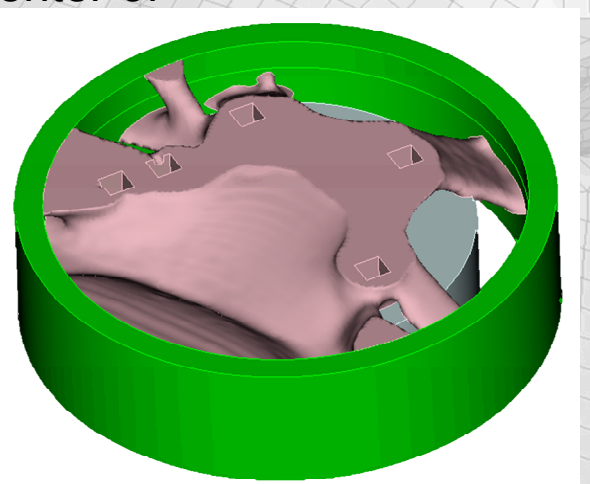


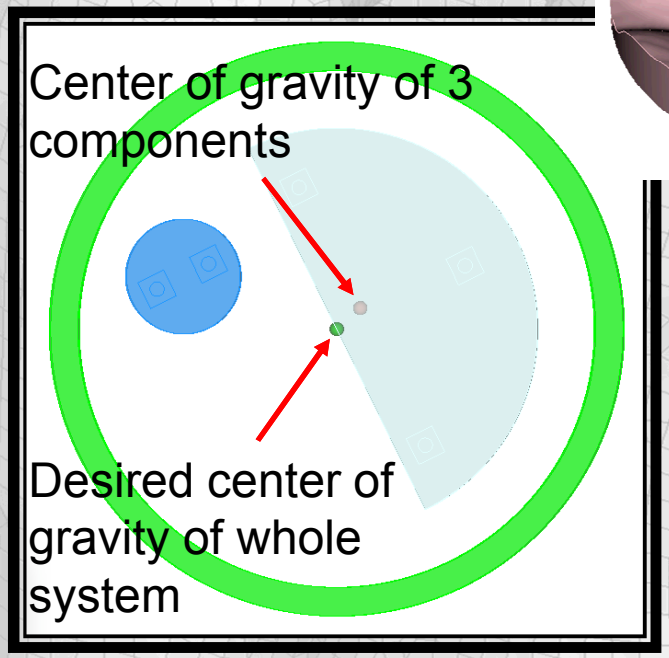
Center of Gravity Constraint

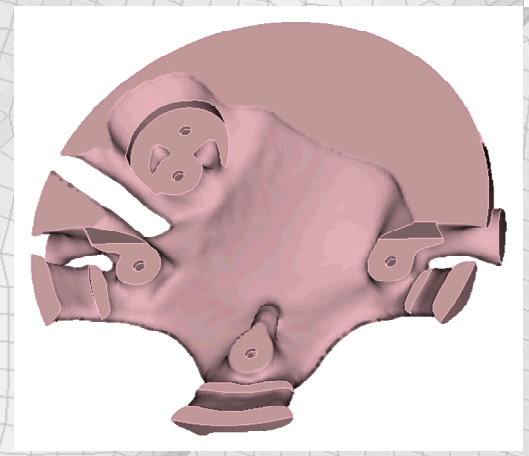


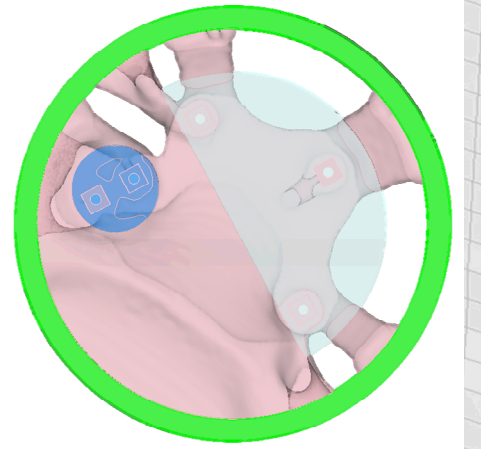
Goal: Design a bracket to secure the components and also move the center of gravity to the desired location



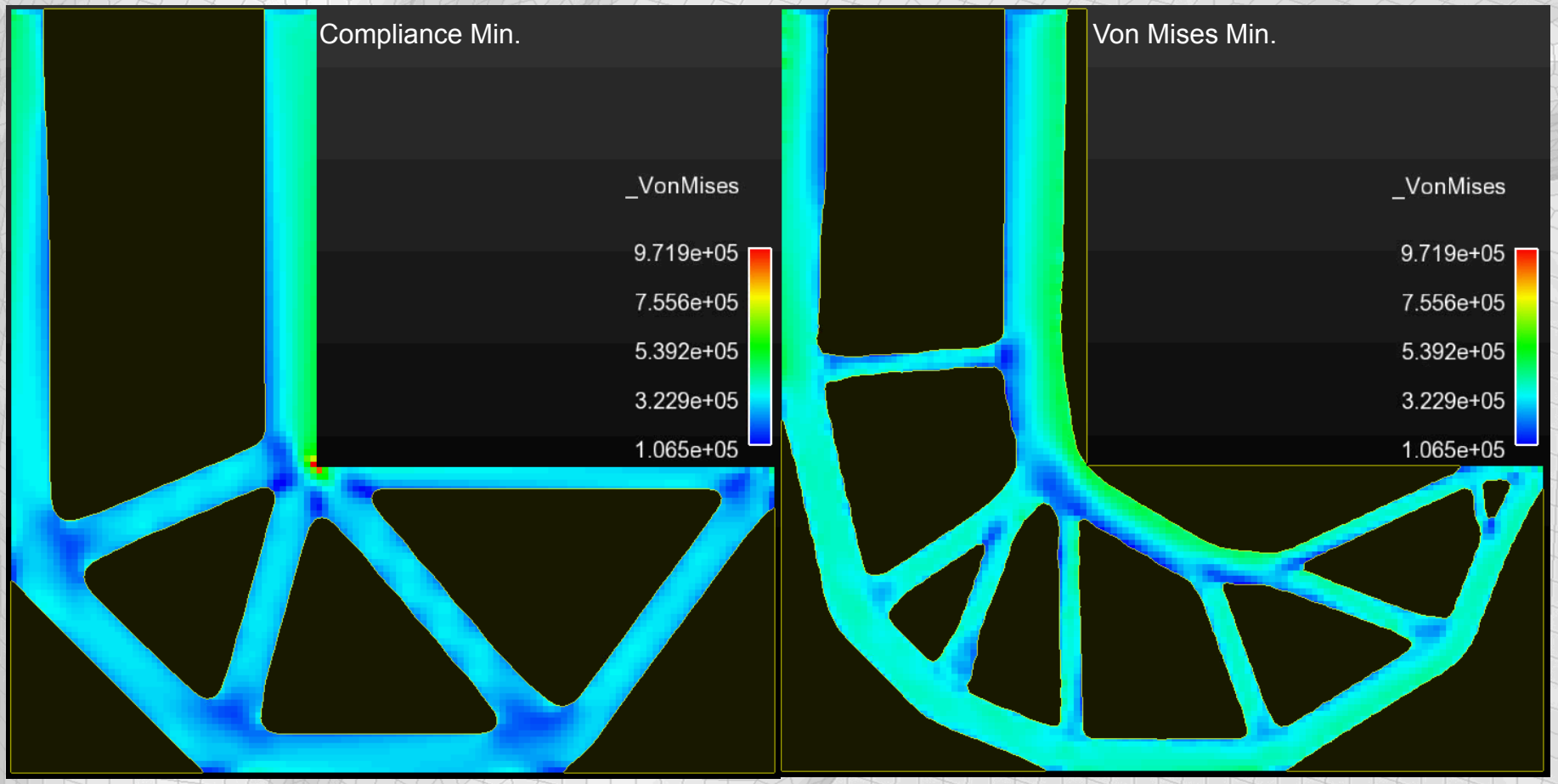




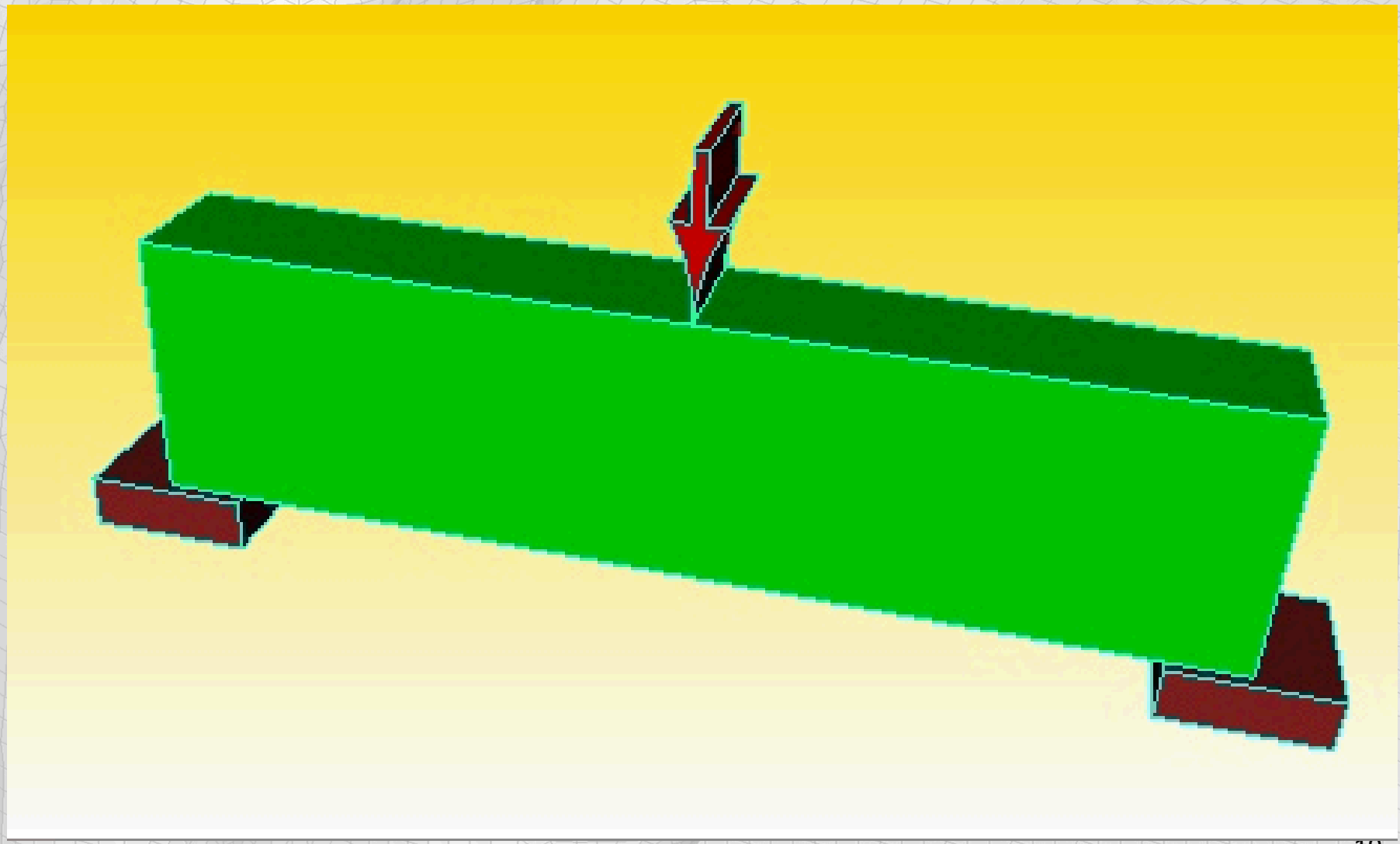




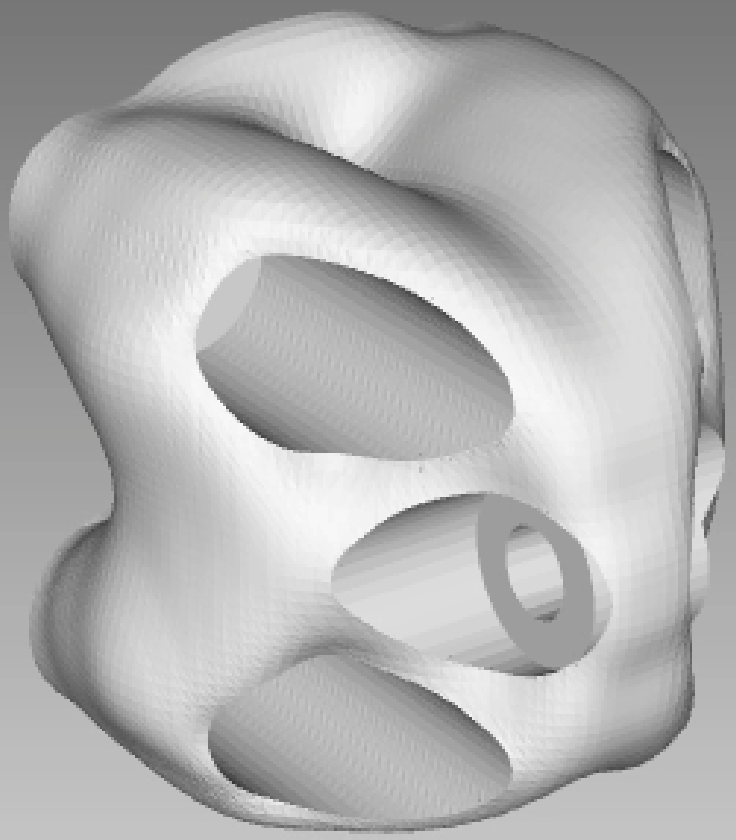
Stress Minimization



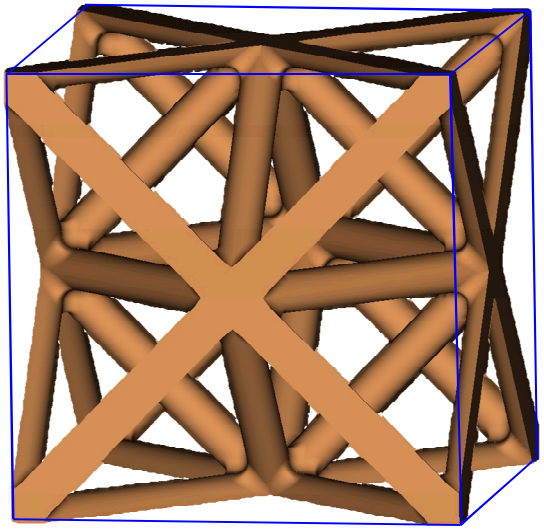
N-Material Optimizations

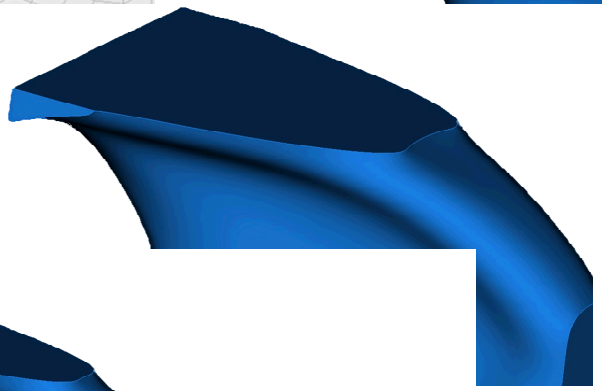


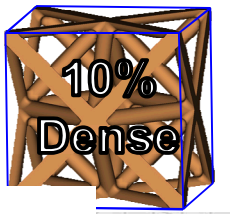
XFEM Configuration Exploration

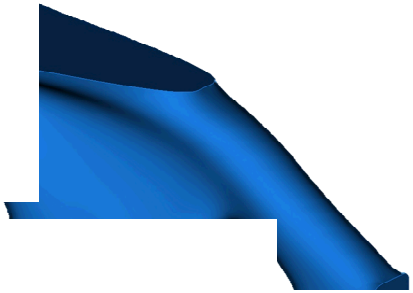


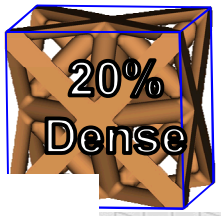
Meso Scale Lattice Homogen

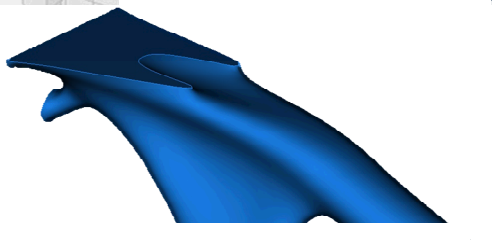


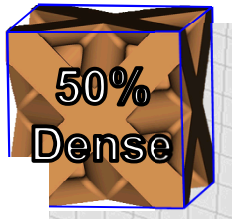


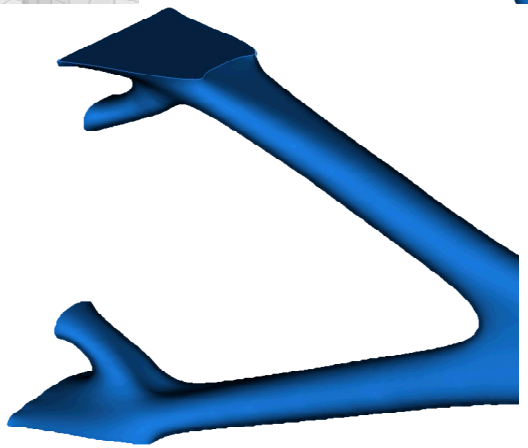


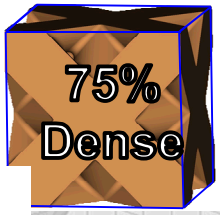


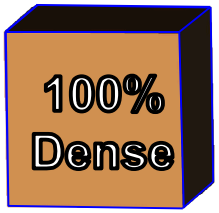


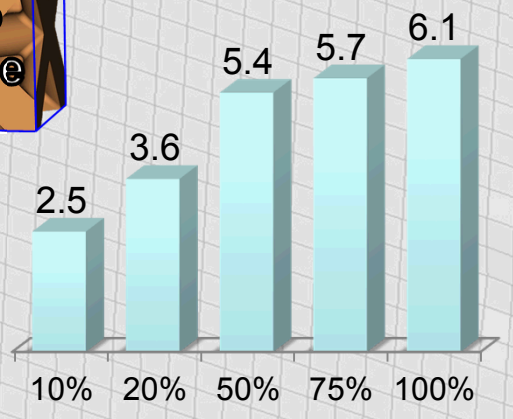




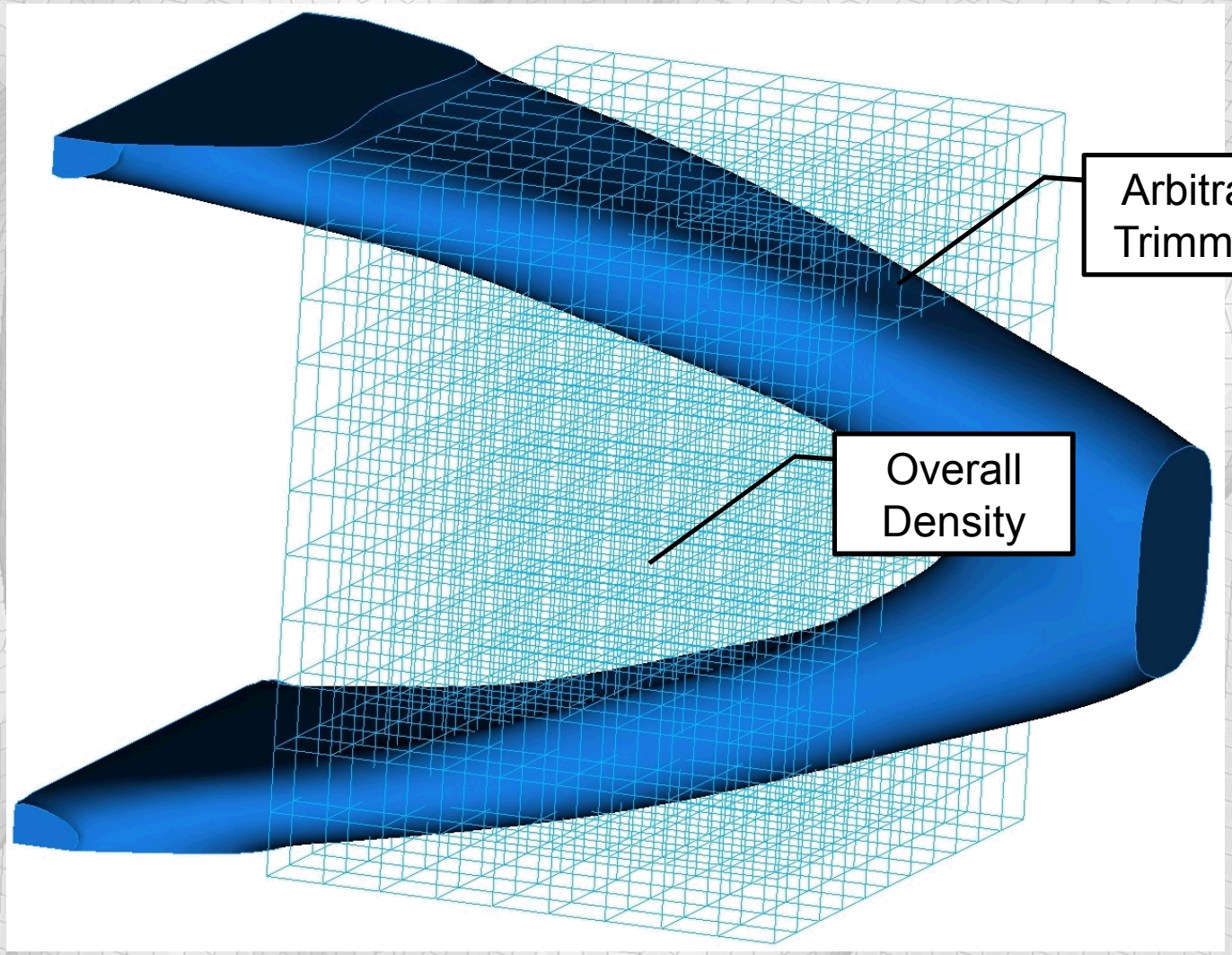




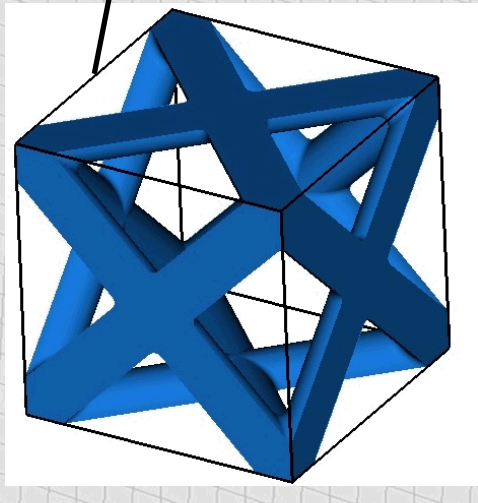




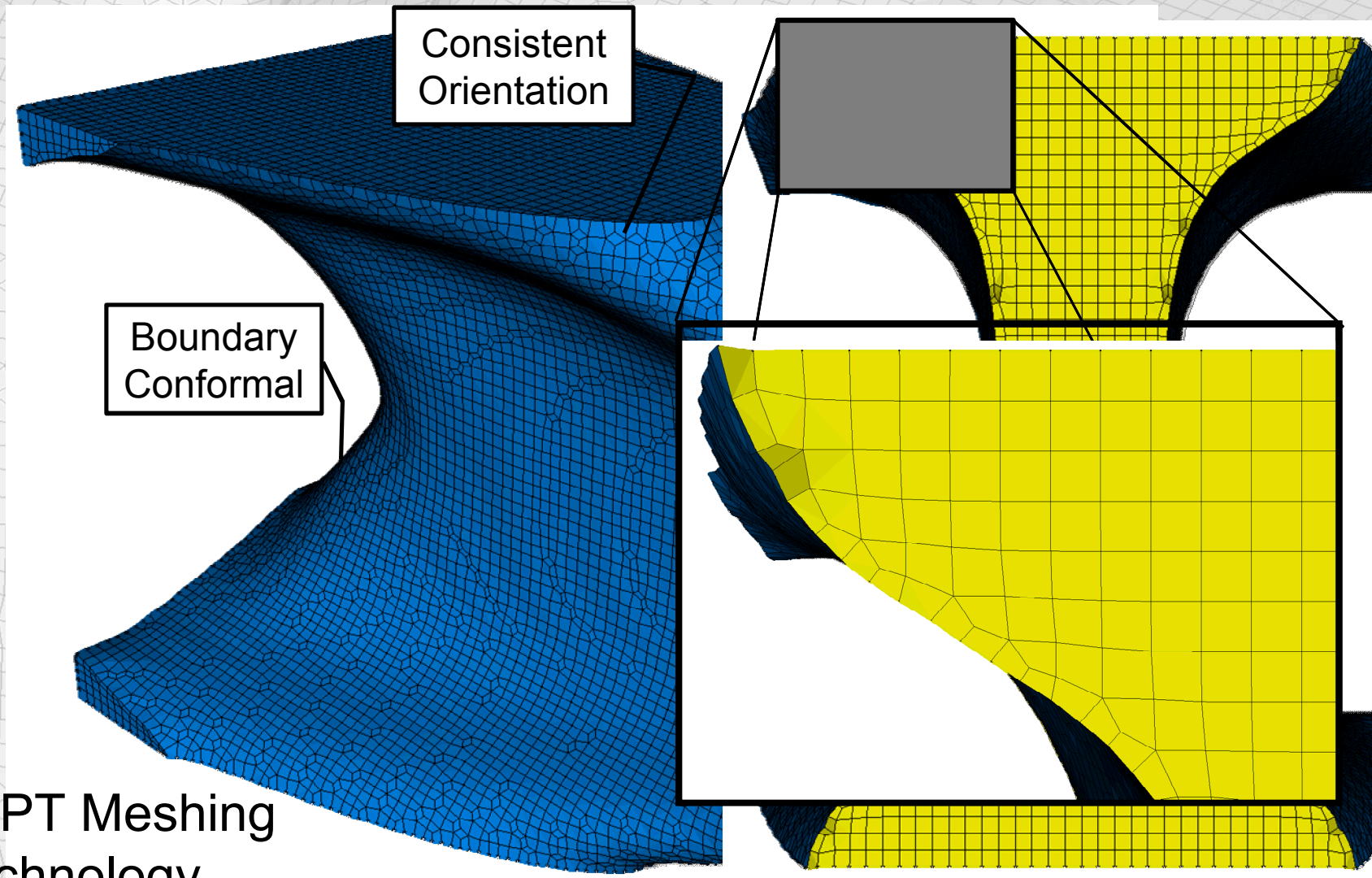
Careful Crafting: Feasible Lattice Printing



Complex Internal Structure



Careful Crafting: Feasible Lattice Printing



SCULPT Meshing Technology

Careful Crafting: Feasible Lattice Printing

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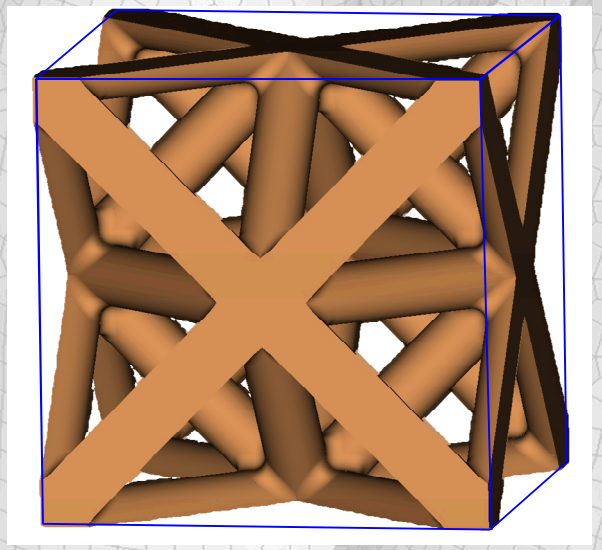
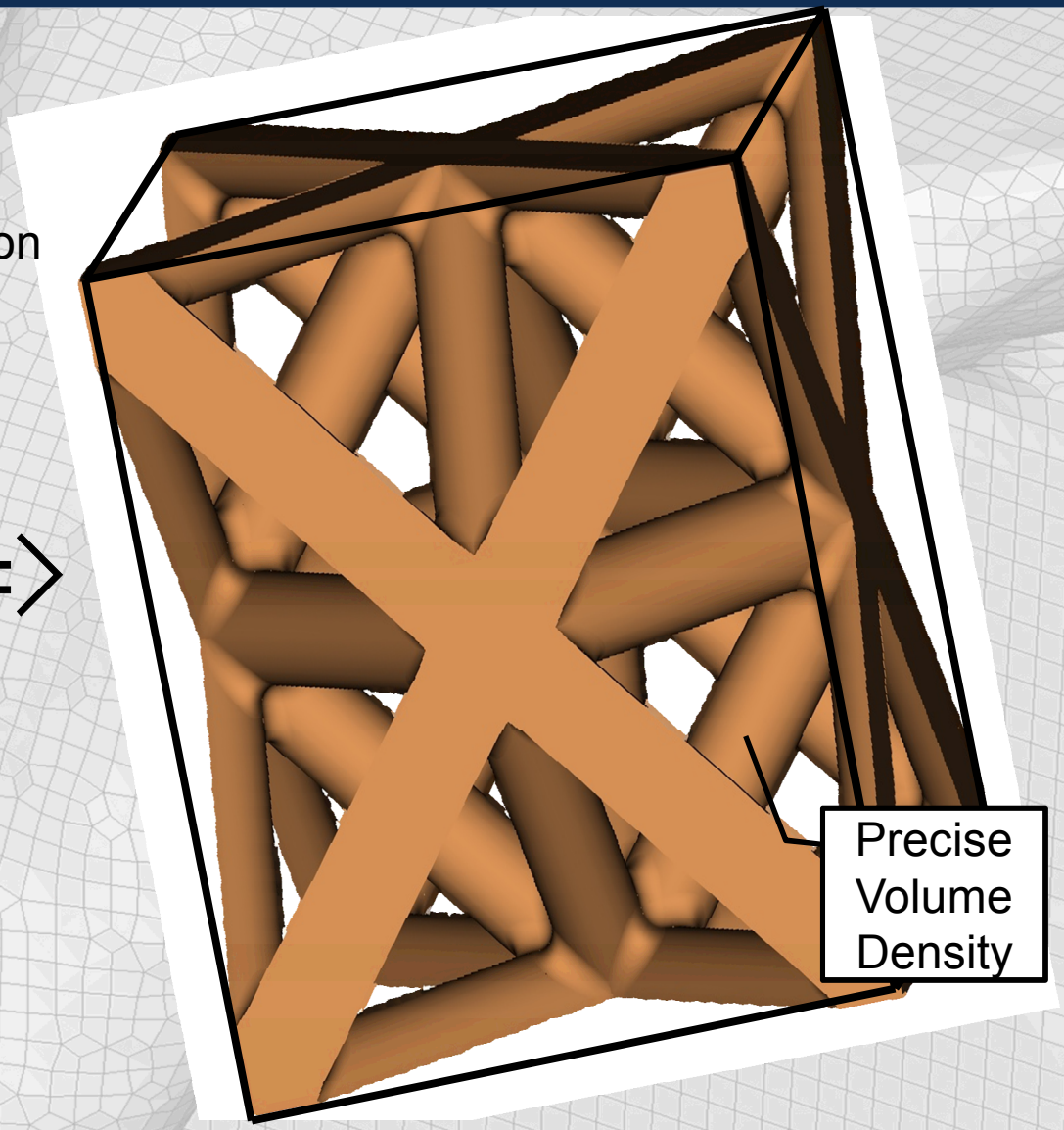
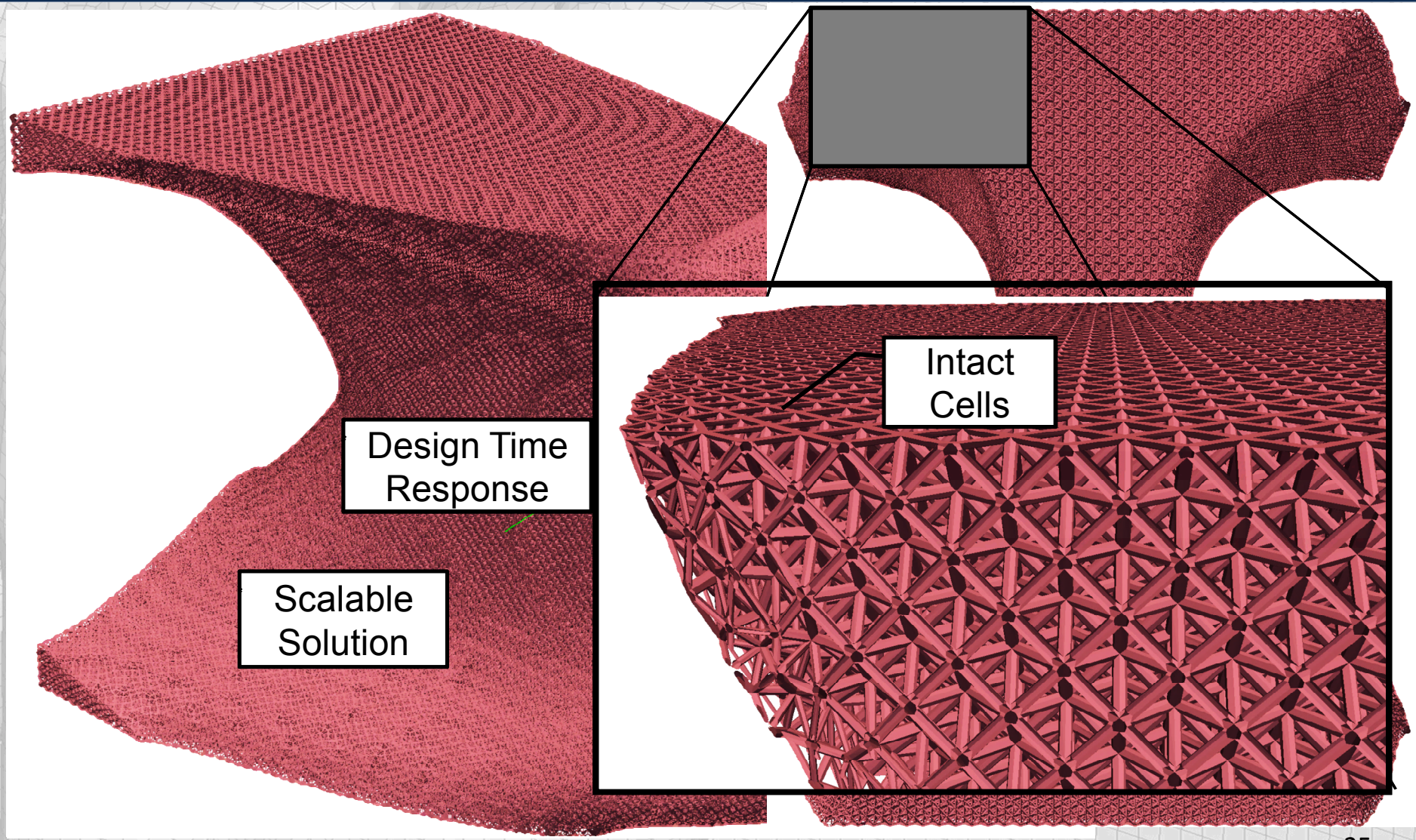
Linear Transformation

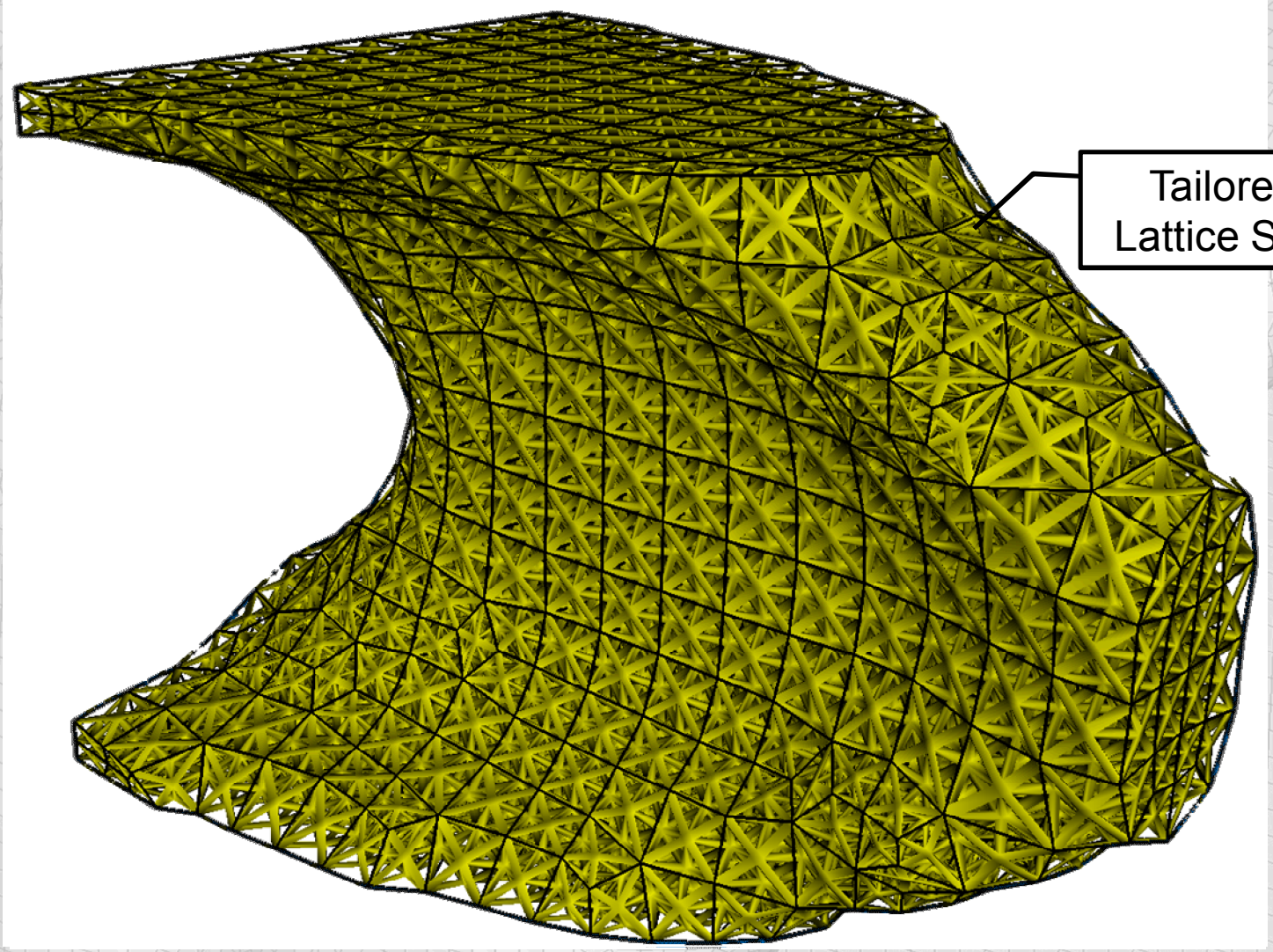




Careful Crafting: Feasible Lattice Printing



Feasible Lattice Printing



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GOD WE
TRUST
LIBERTY
P
QUARTER DOLLAR

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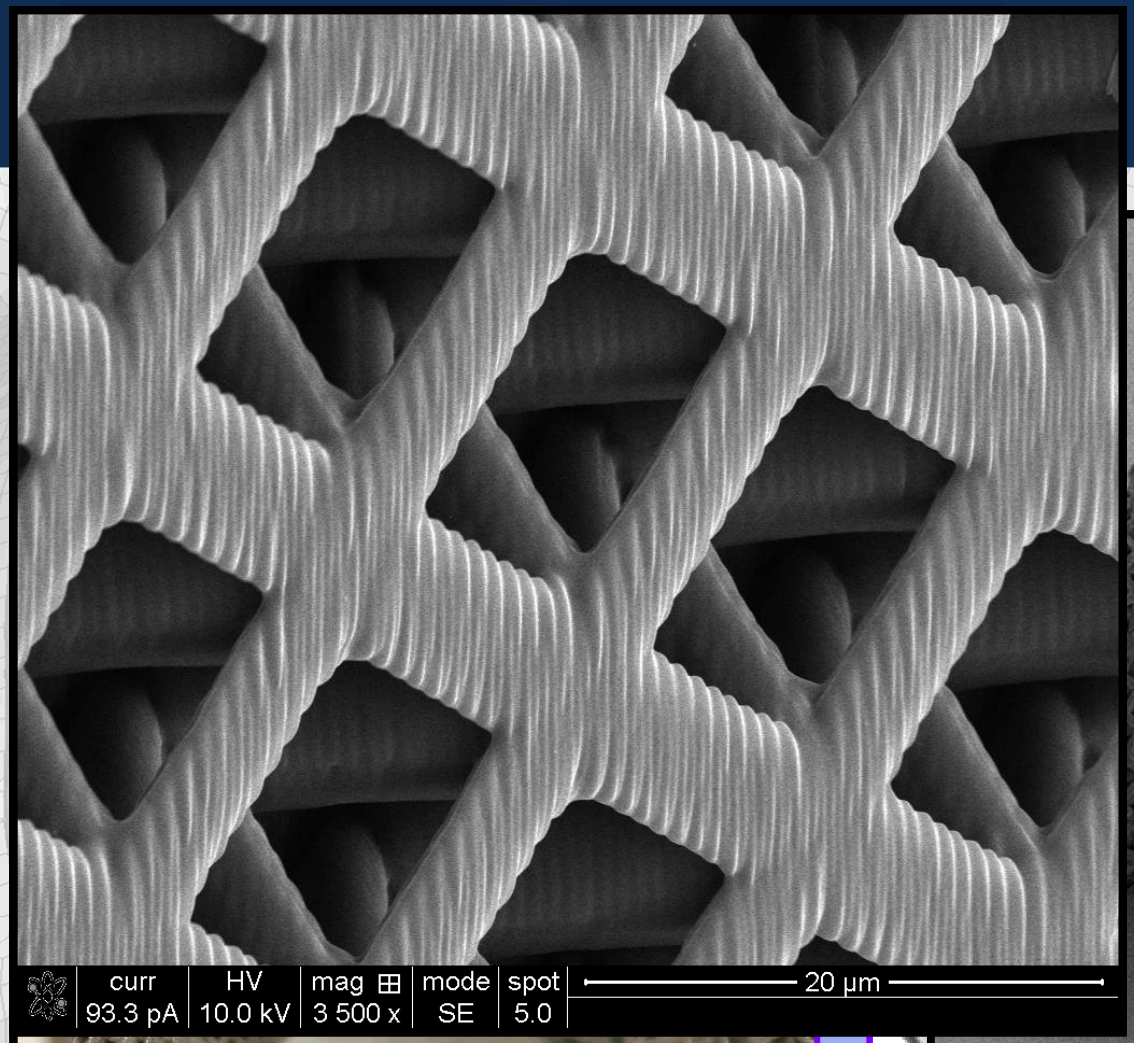
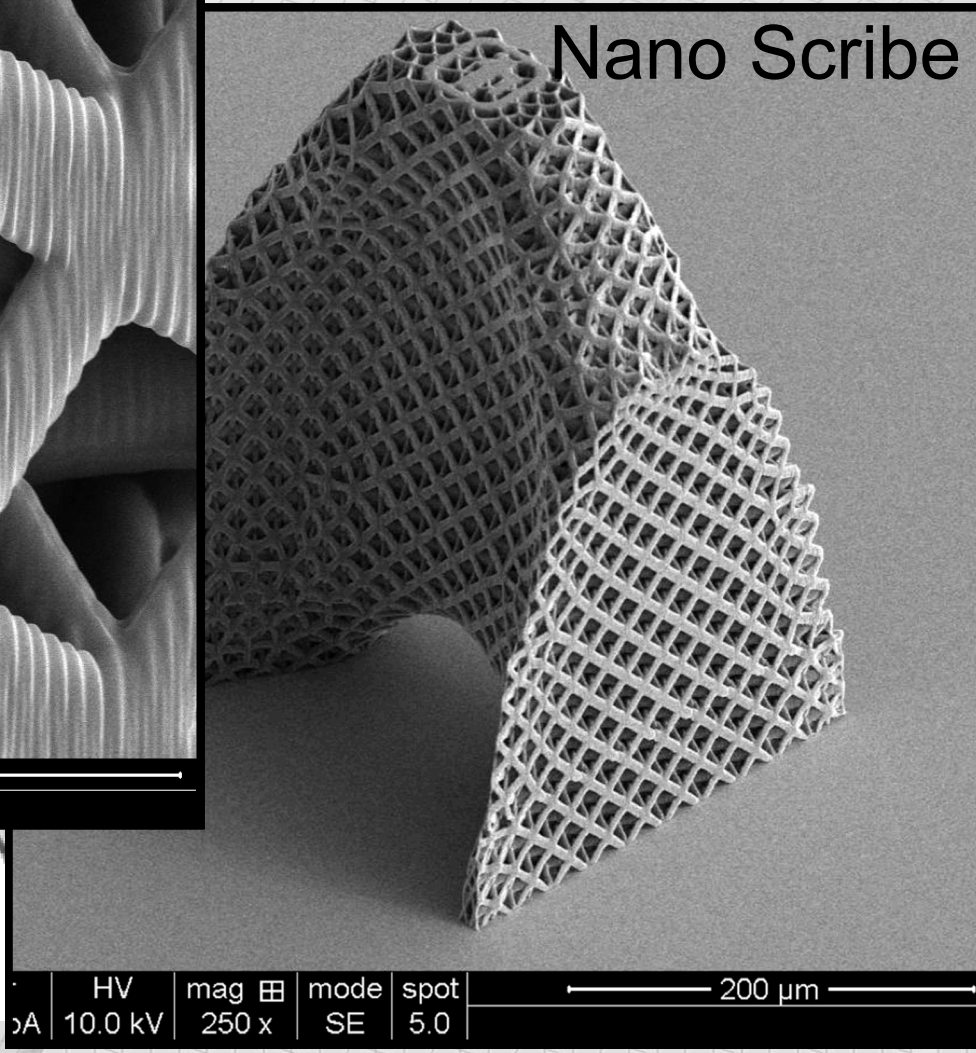
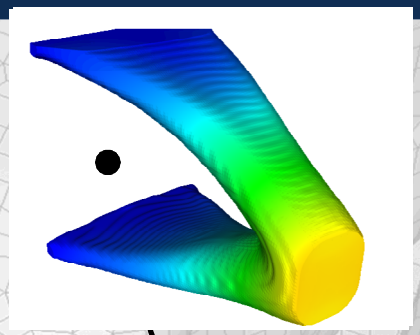
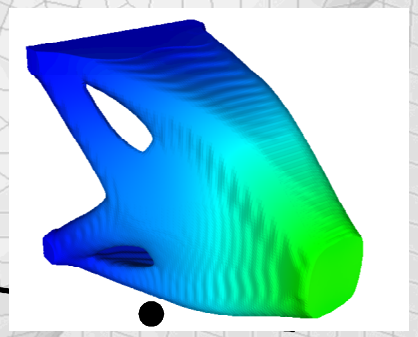


Nano Scribe

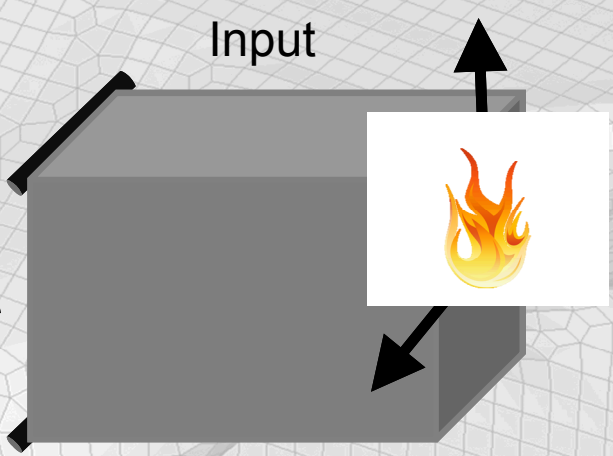


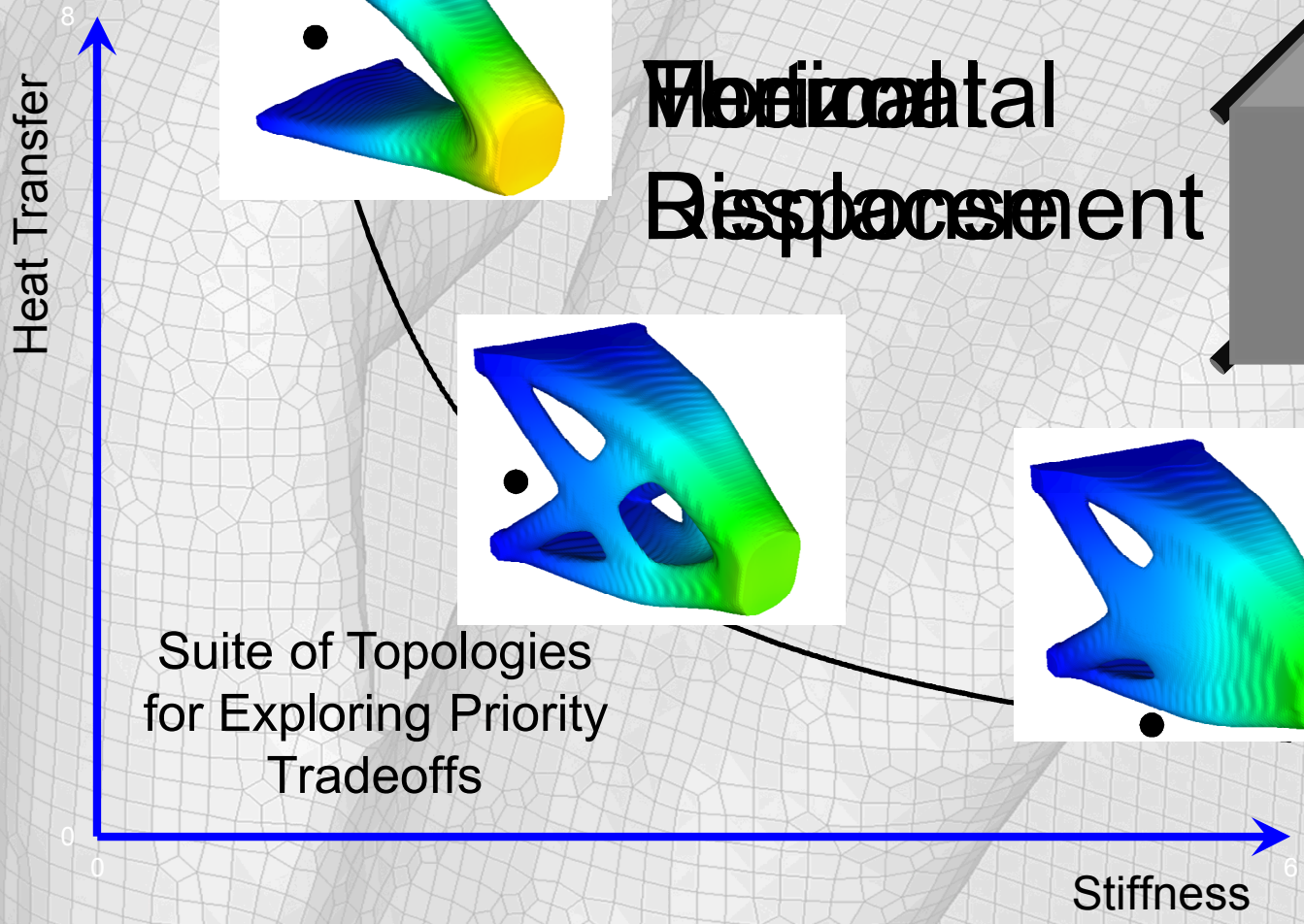
Multi-objective/physics





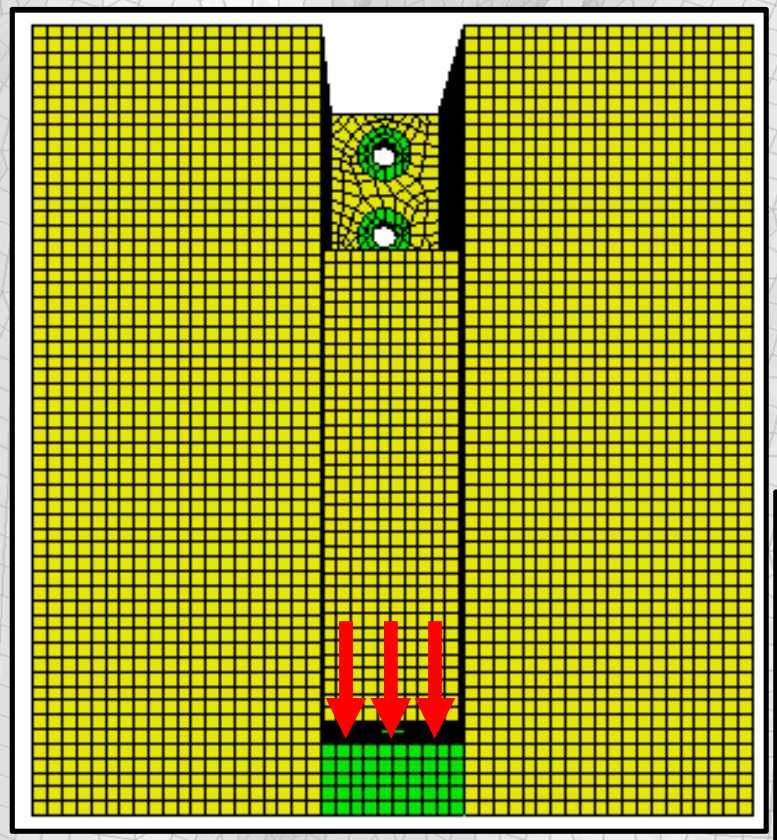
Suite of Topologies
for Exploring Priority
Tradeoffs





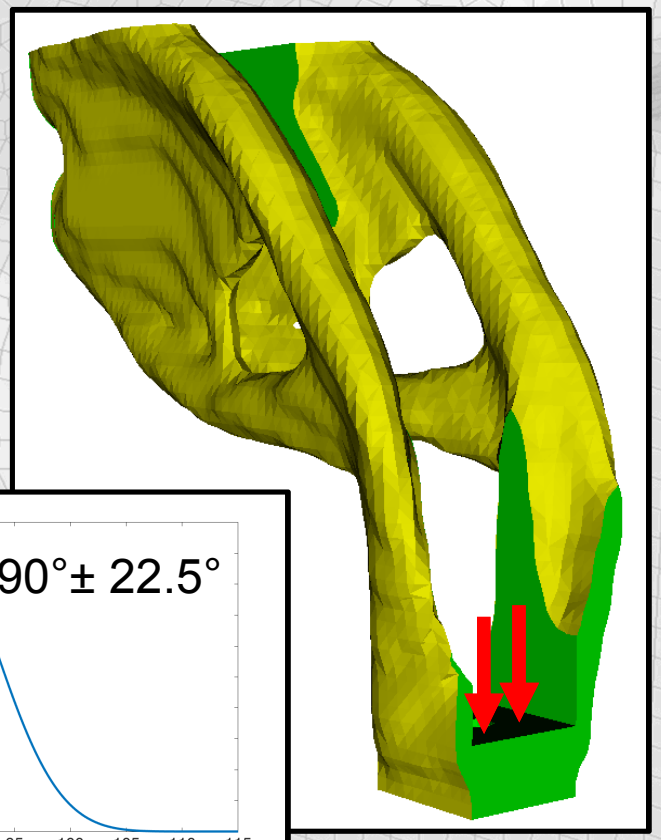
Stochastic Reduced Order Model (SROM) Structural Topology Optimization

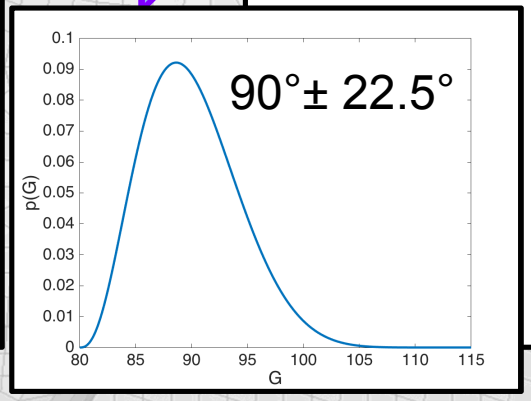
Target: 7% of Initial Volume
Mesh: 139,540 HEX8
Material: Moduli=1e8
Poisson Ratio=0.3



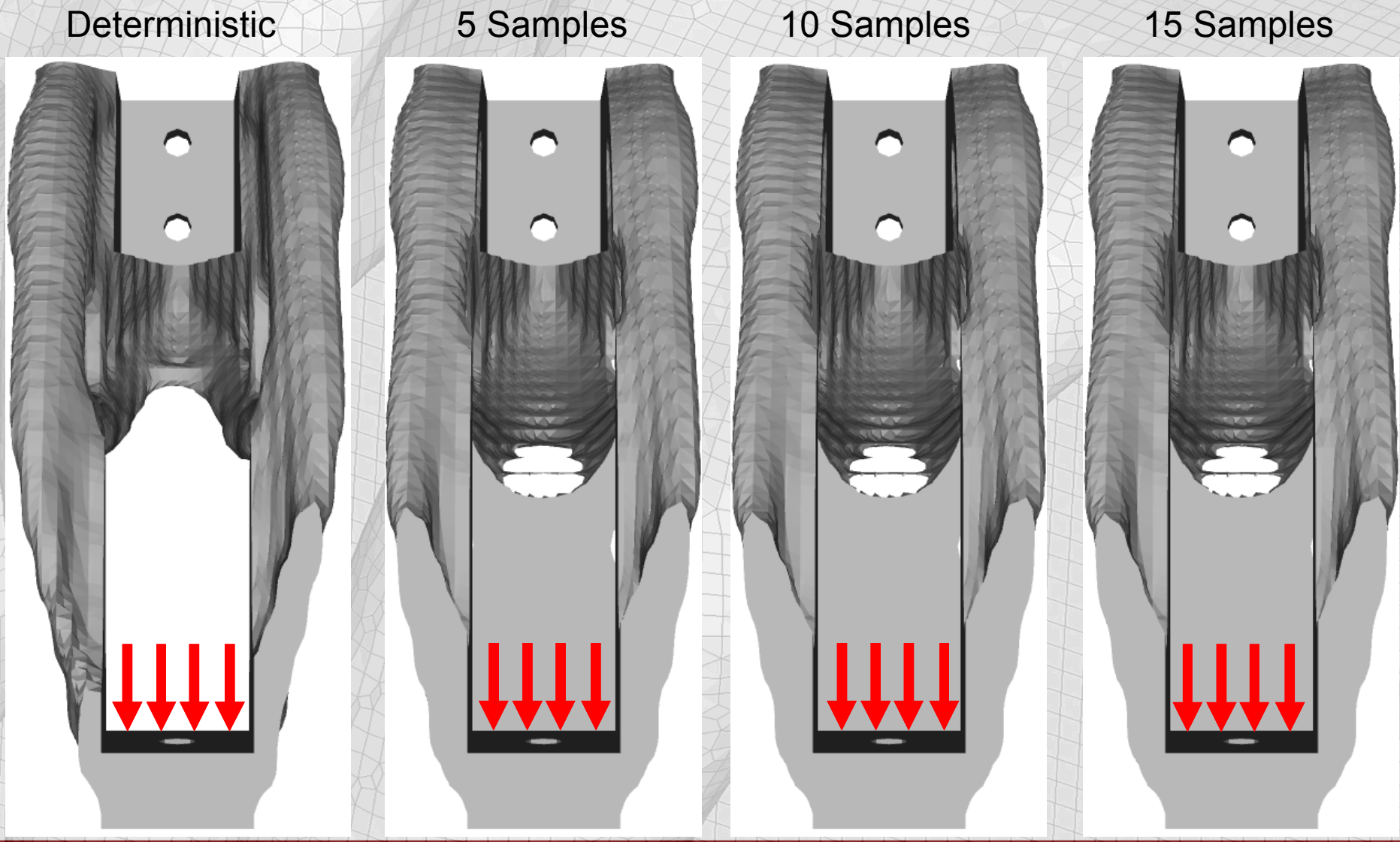
Load:1e5

Deterministic Solution



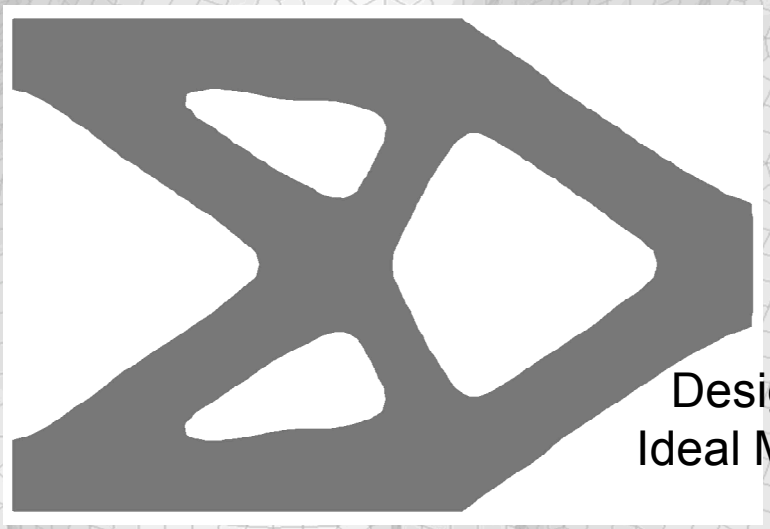


Results: Uncertainty Aware Structural Topology Optimization

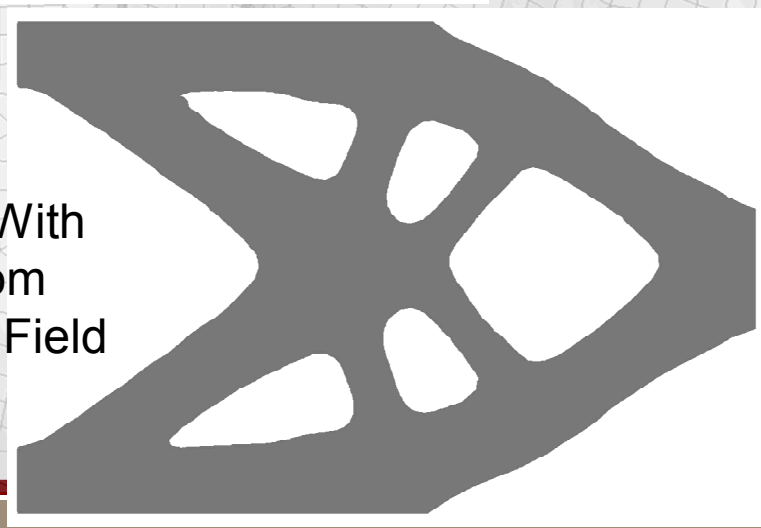


Robust Designs to Random Residual Stress

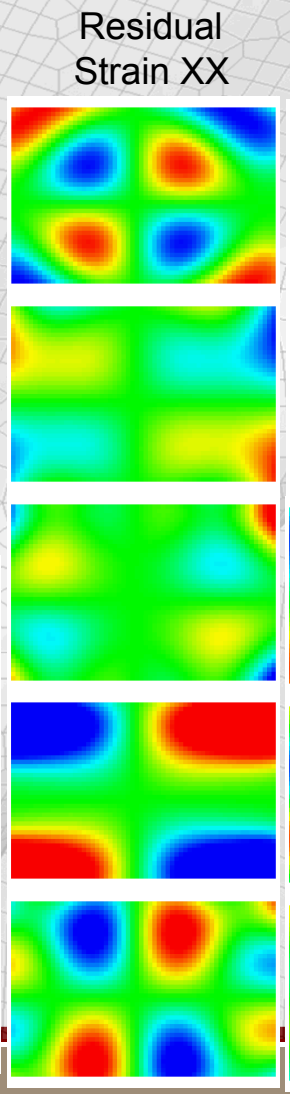
min: (α)*(Strain Energy) + (1-α)*(Random Strains)



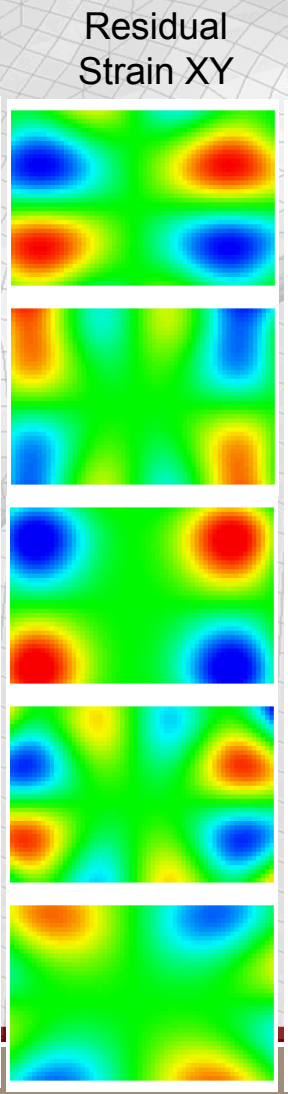
Design for
Ideal Material



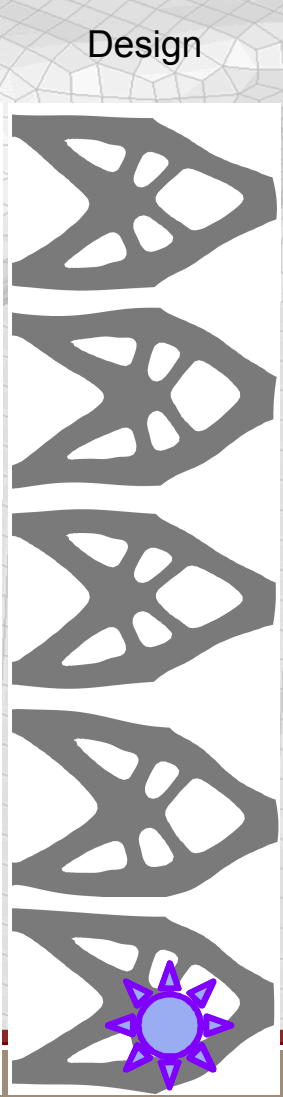
Design With
Random
Residual Field



Residual
Strain XX



Residual
Strain XY



Design

Backup Slides

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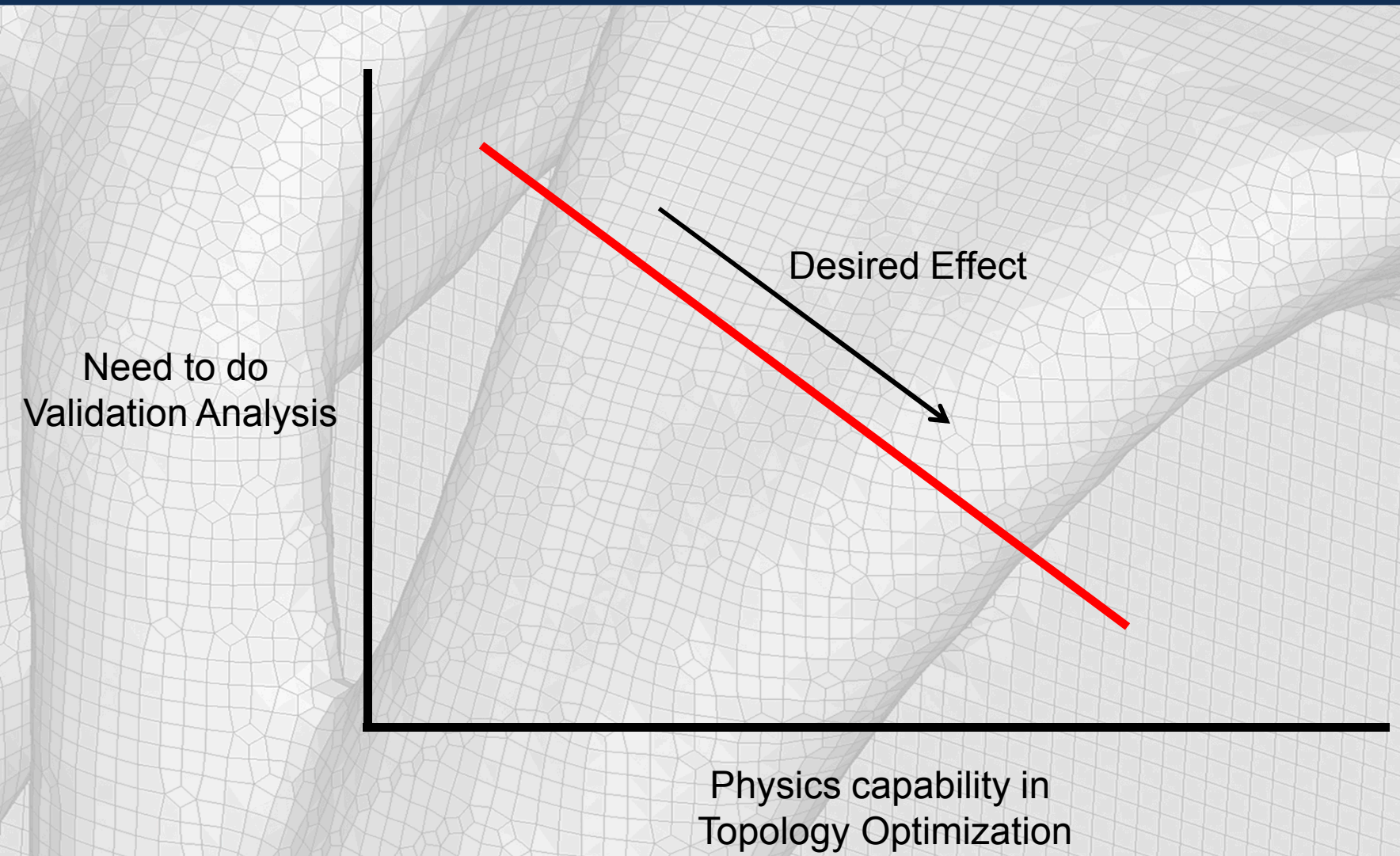
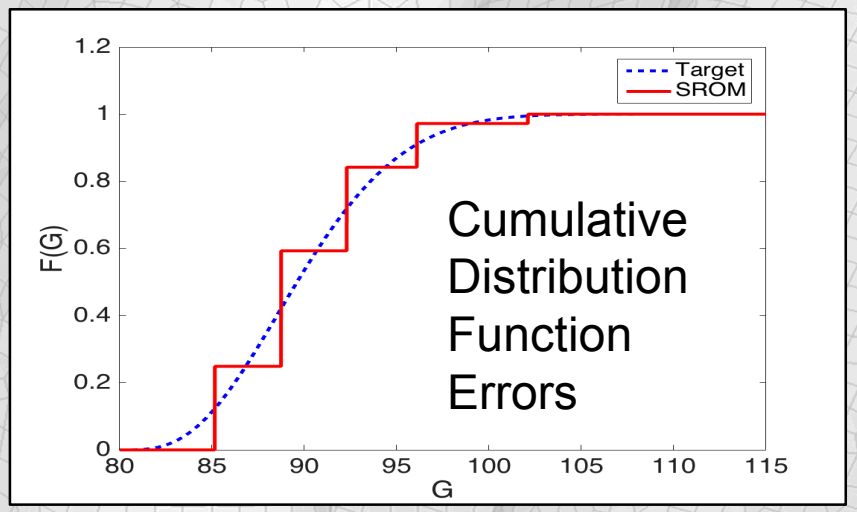
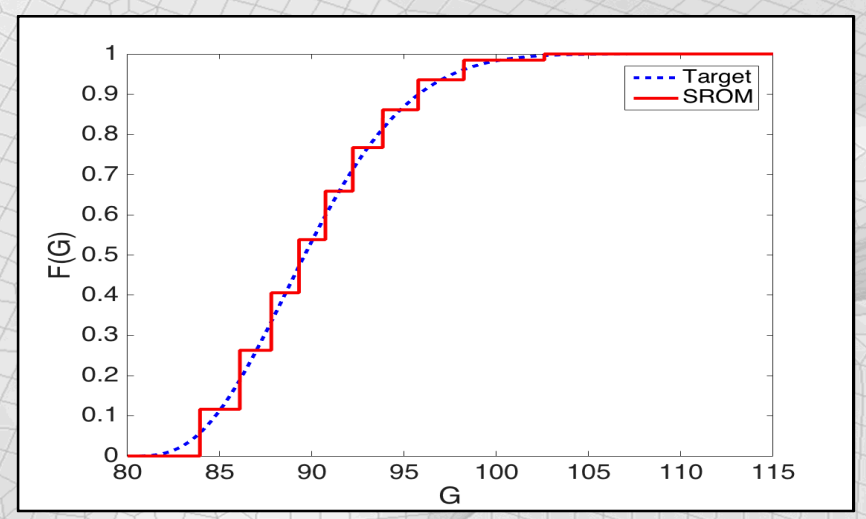
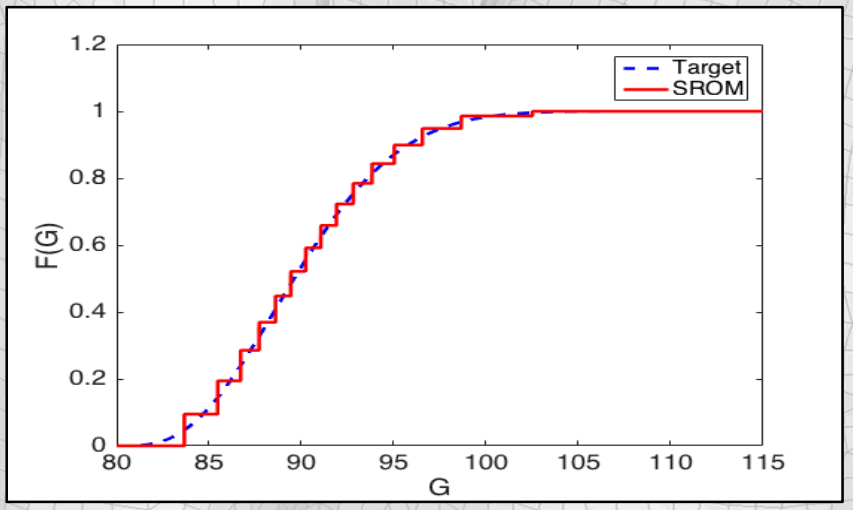
Pushing Analysis Upstream

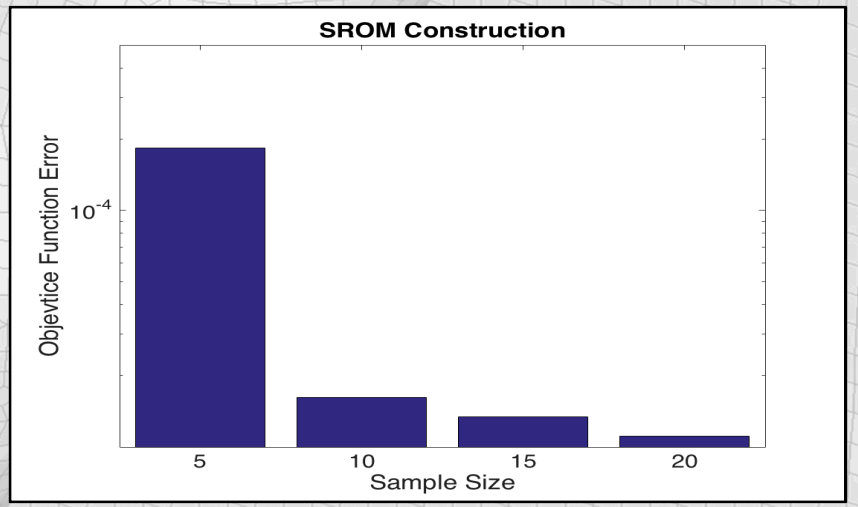


Results: Uncertainty Aware Compliance Minimization



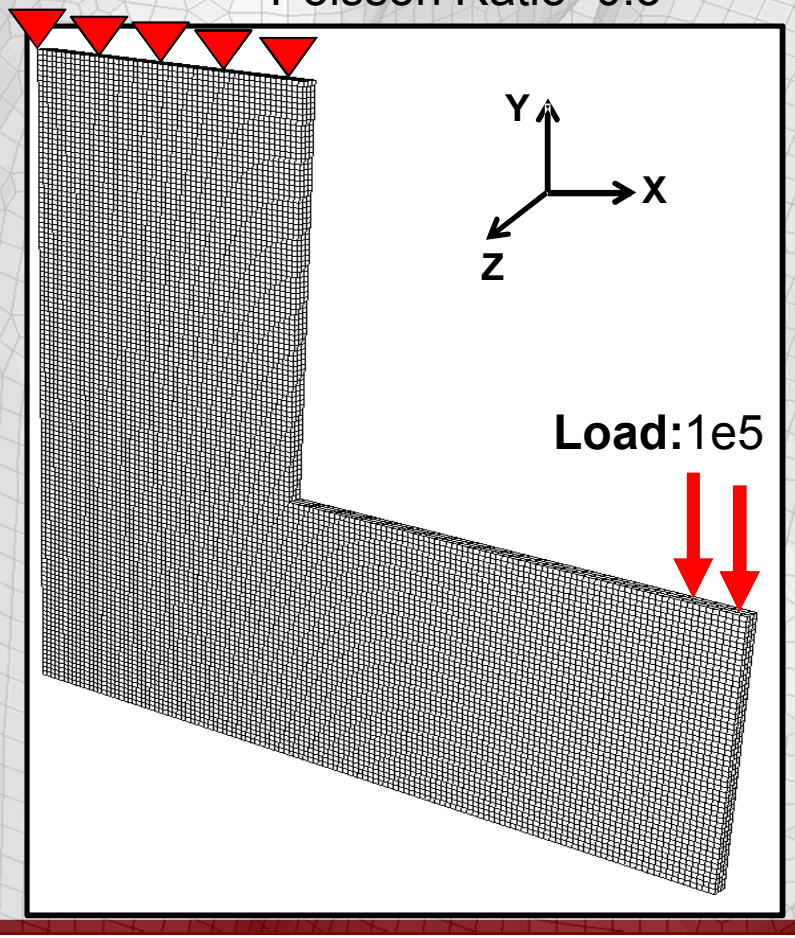




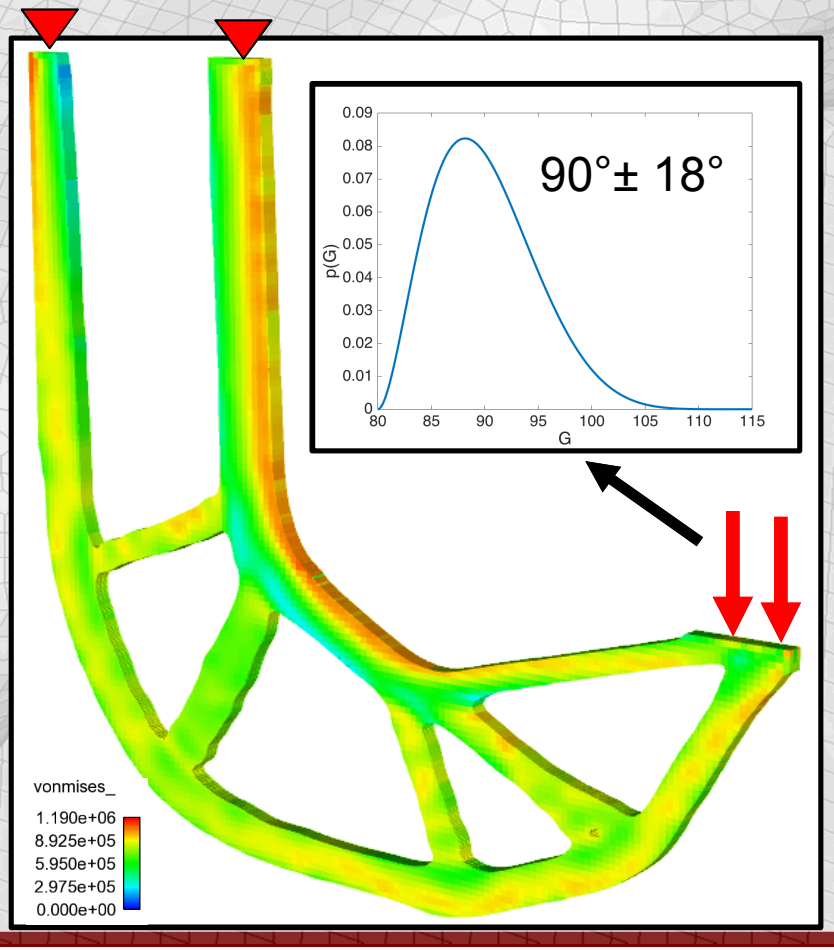


Stochastic Reduced Order Model (SROM) Stress Minimization Topology Optimization

Target: 30% of Initial Volume
Mesh: 33,867 HEX8
Material: Moduli=1e8
Poisson Ratio=0.3

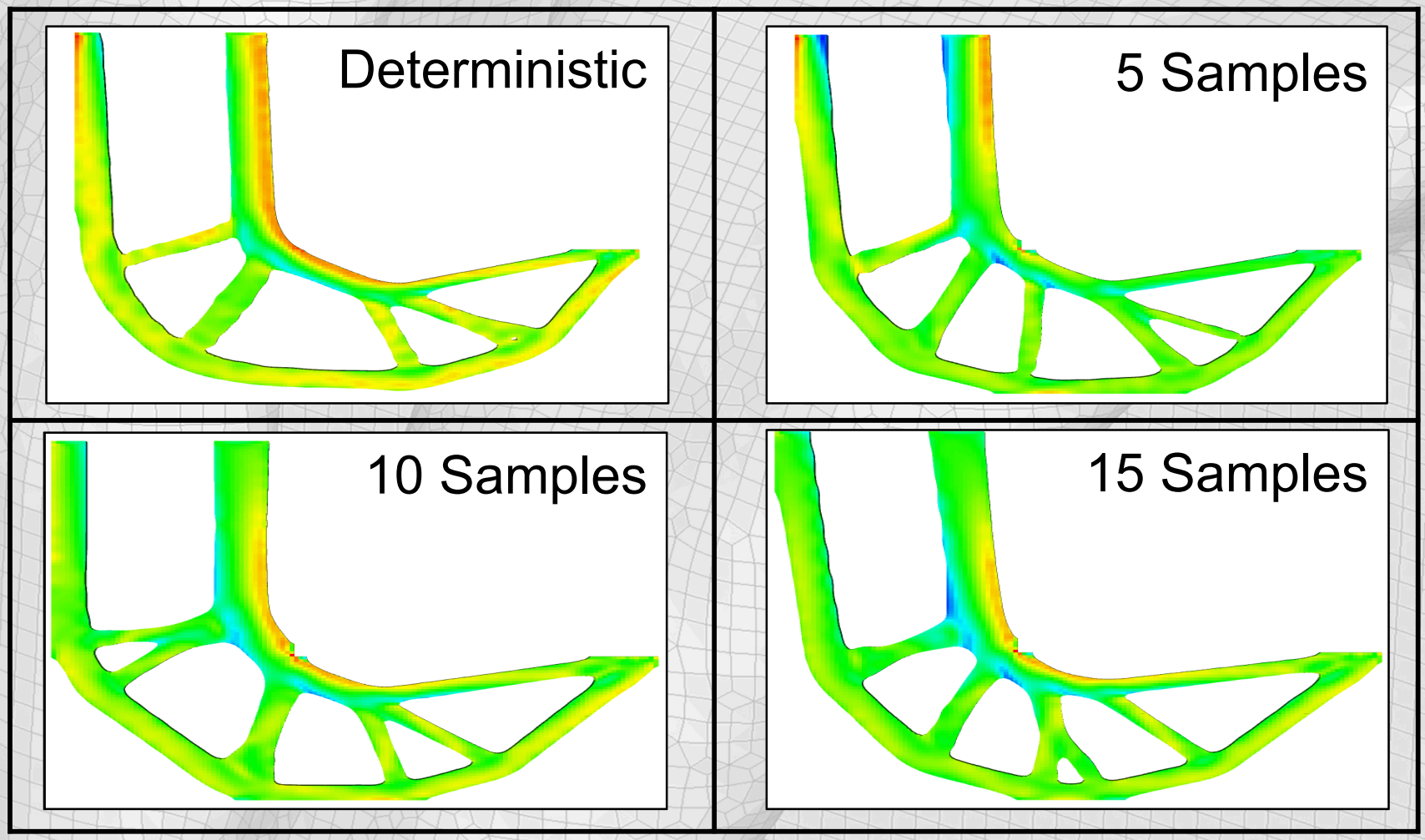


Deterministic Solution

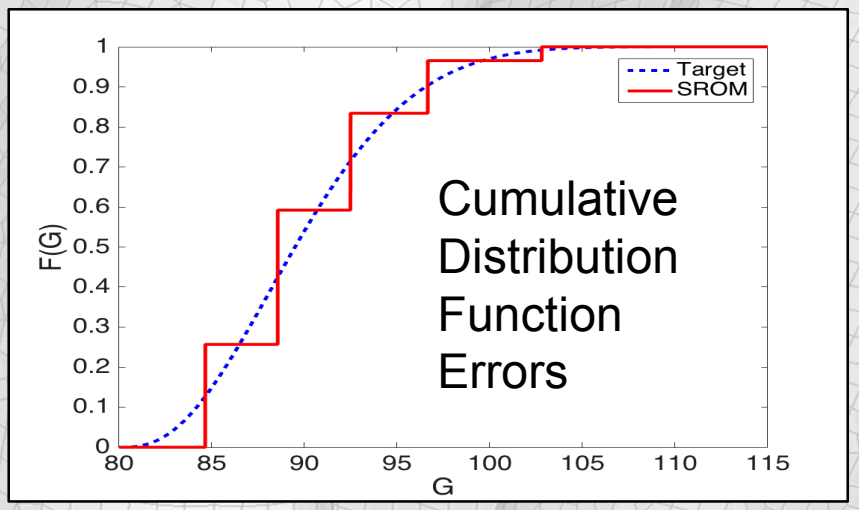


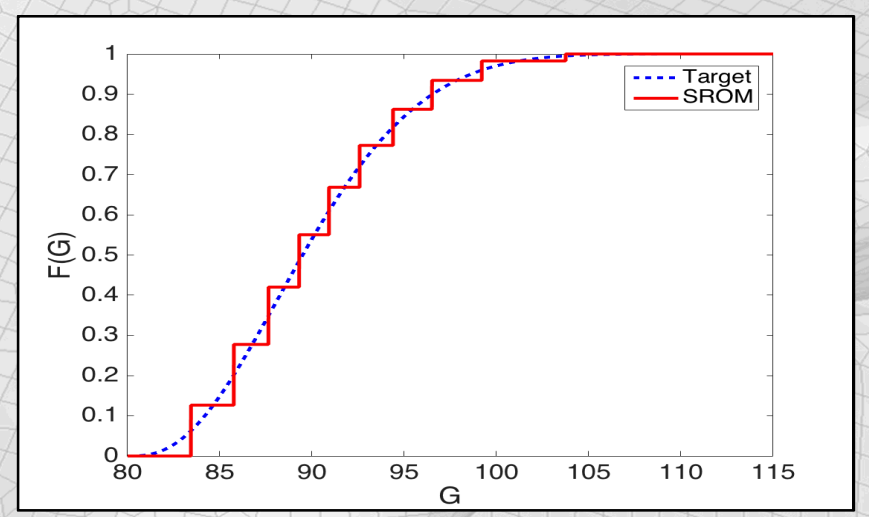
Add Norato's reference

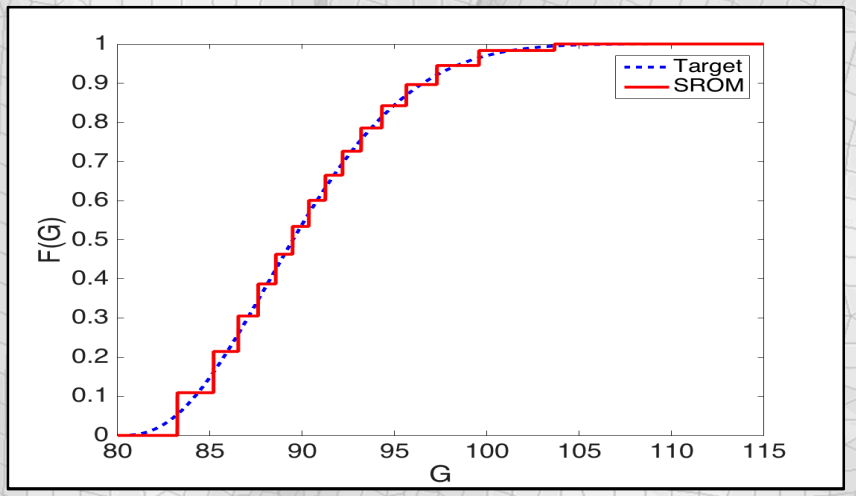
Results: Uncertainty Aware Stress Minimization

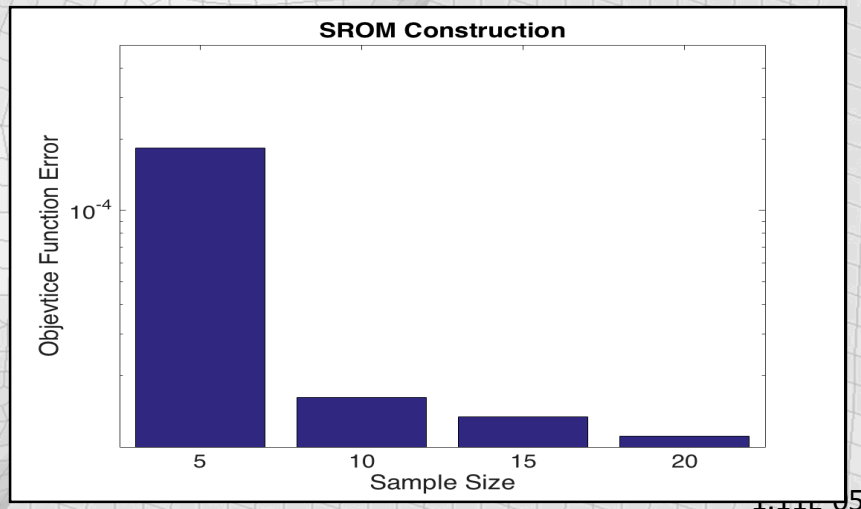


Results: Uncertainty Aware Stress Minimization









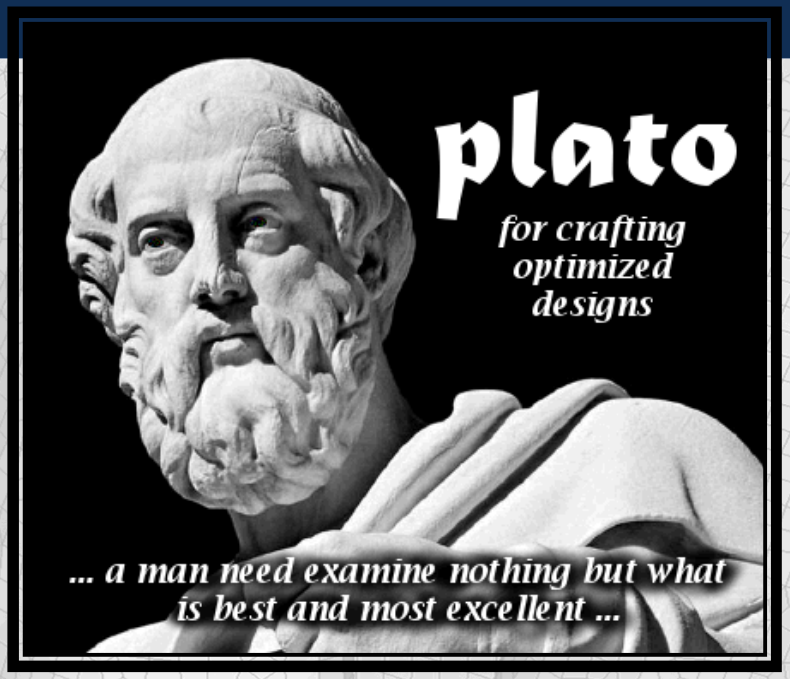
PLATO Logistics

1. Government = FREE
2. Needs a Government Use Notice (GUN)

   sierradist.sandia.gov
3. Questions?:

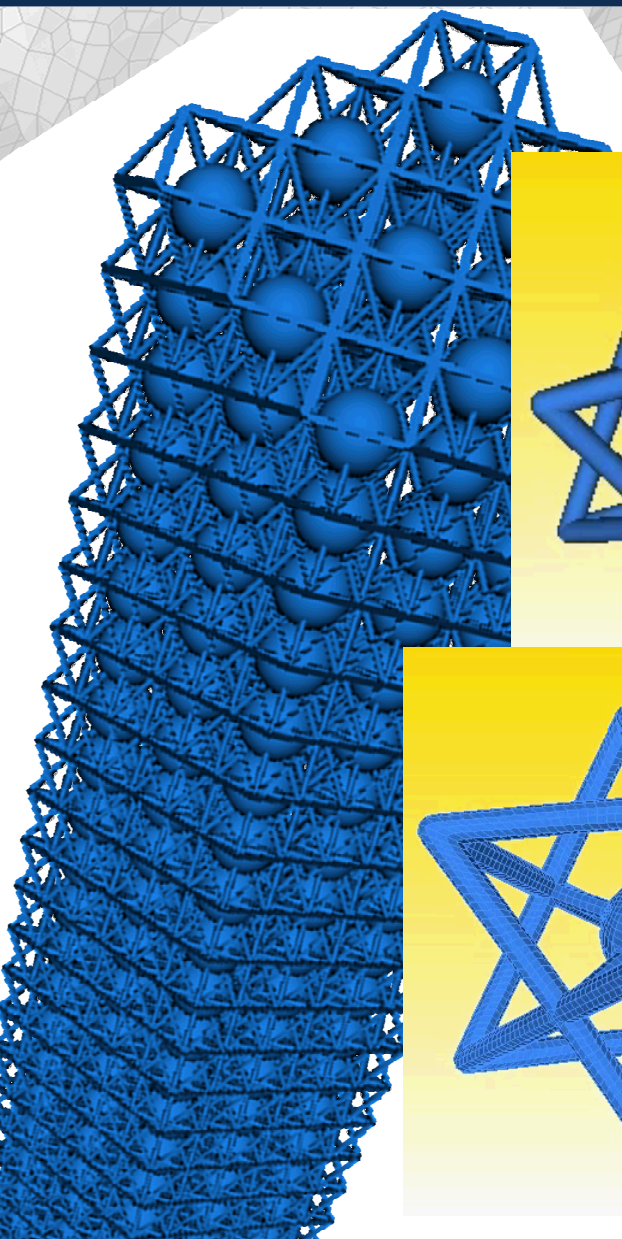
   plato3d-help@sandia.gov
4. Windows (sort of), Linux and Mac
5. Jobs can be run locally or on massively parallel environments
6. Includes user's manual and tutorials

Revolution: Where Does It Go From Here?

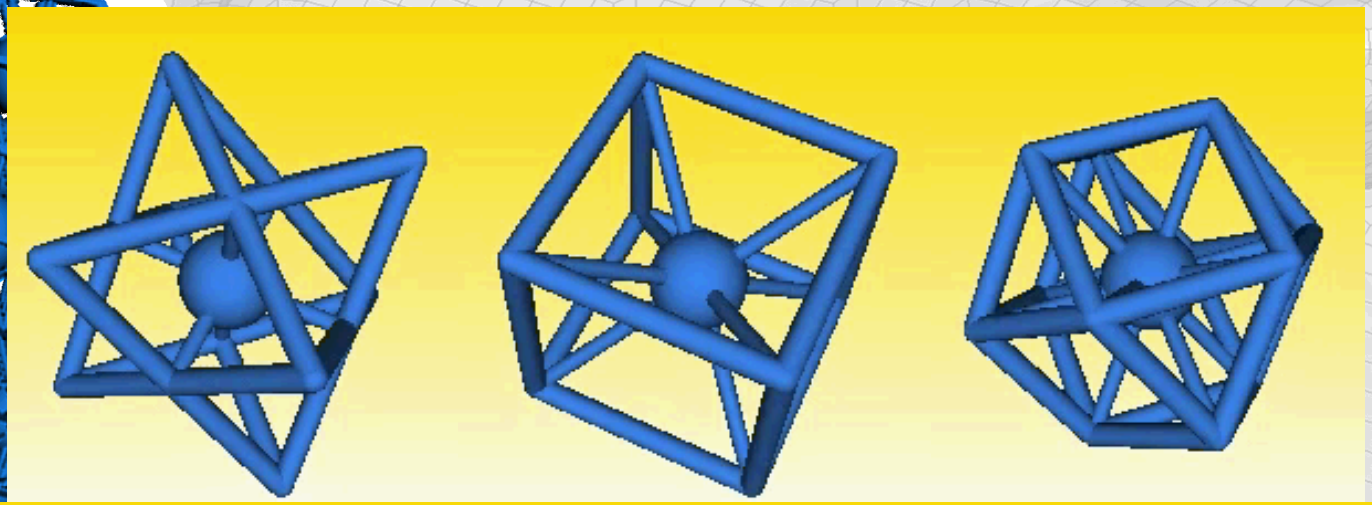


- Research to Production
- Meta-Material Design Focus
- AM Process-Aware / Process Optimal
- Plug-N-Play Solvers
- Level Sets: Shape Optimization Coupling
- Performance
- More Physics (Thermal / EM / Fluids)
- Design Option Overload

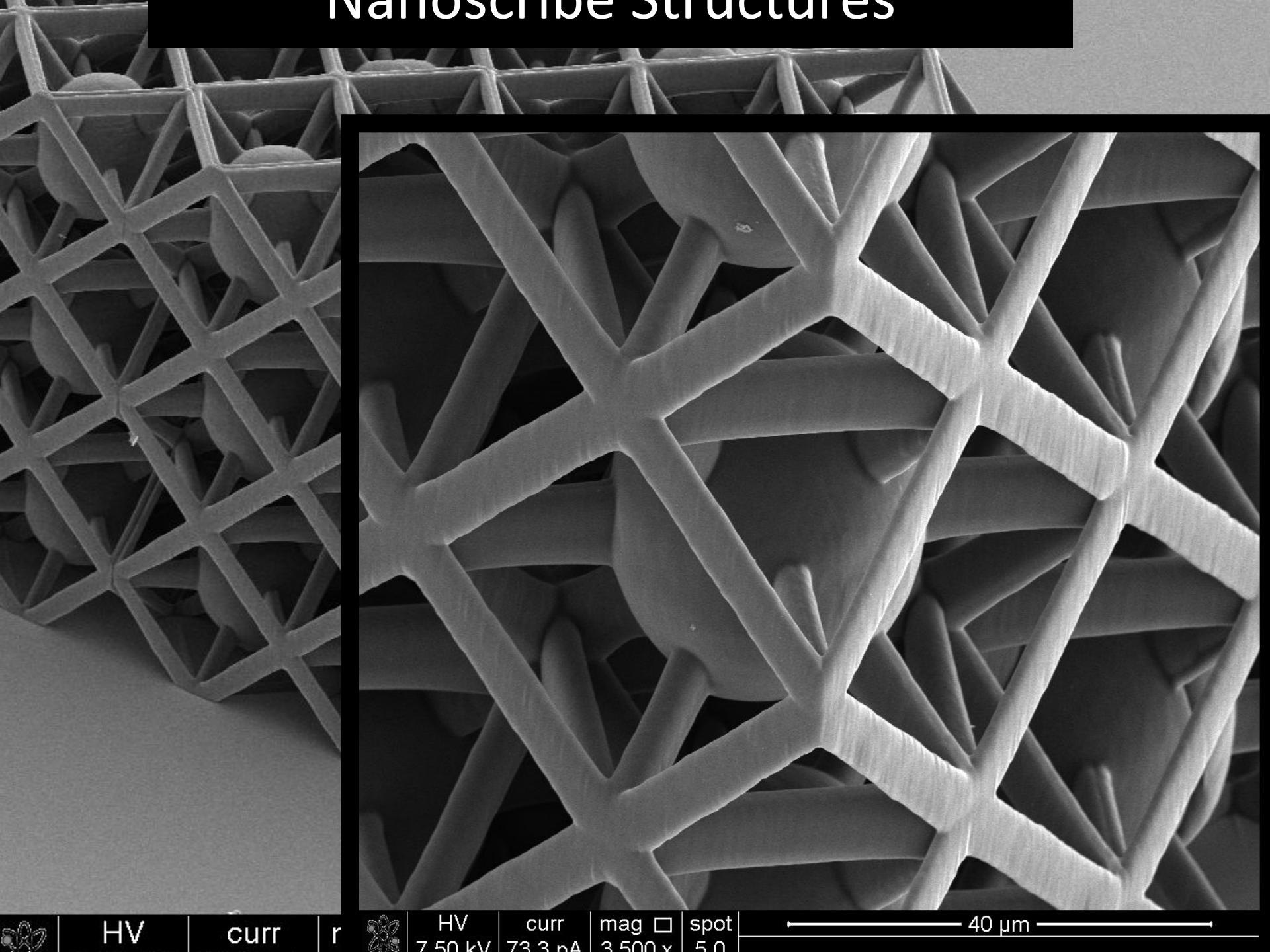
Transient Response Tailoring



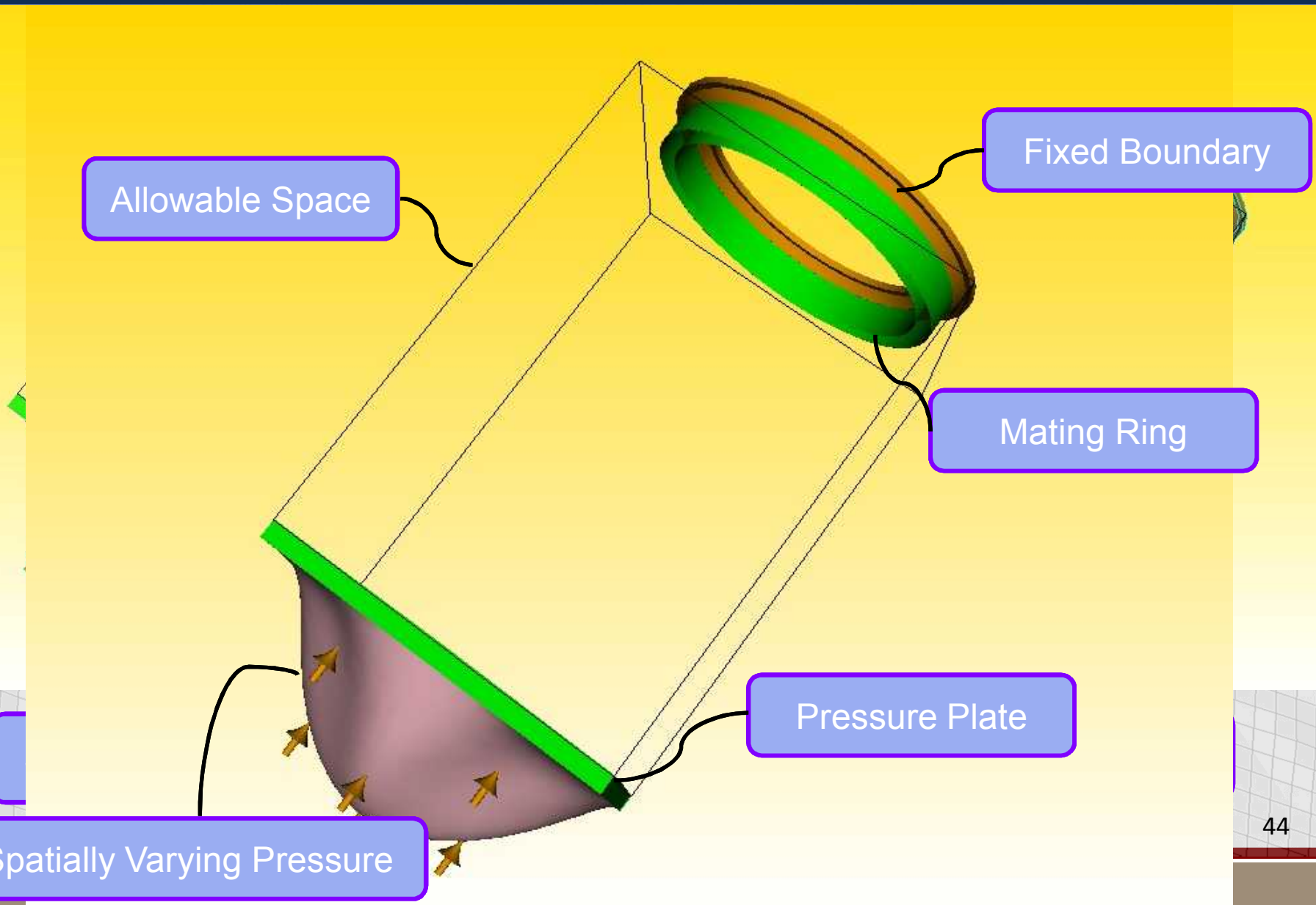
- Shock mitigation & redirection

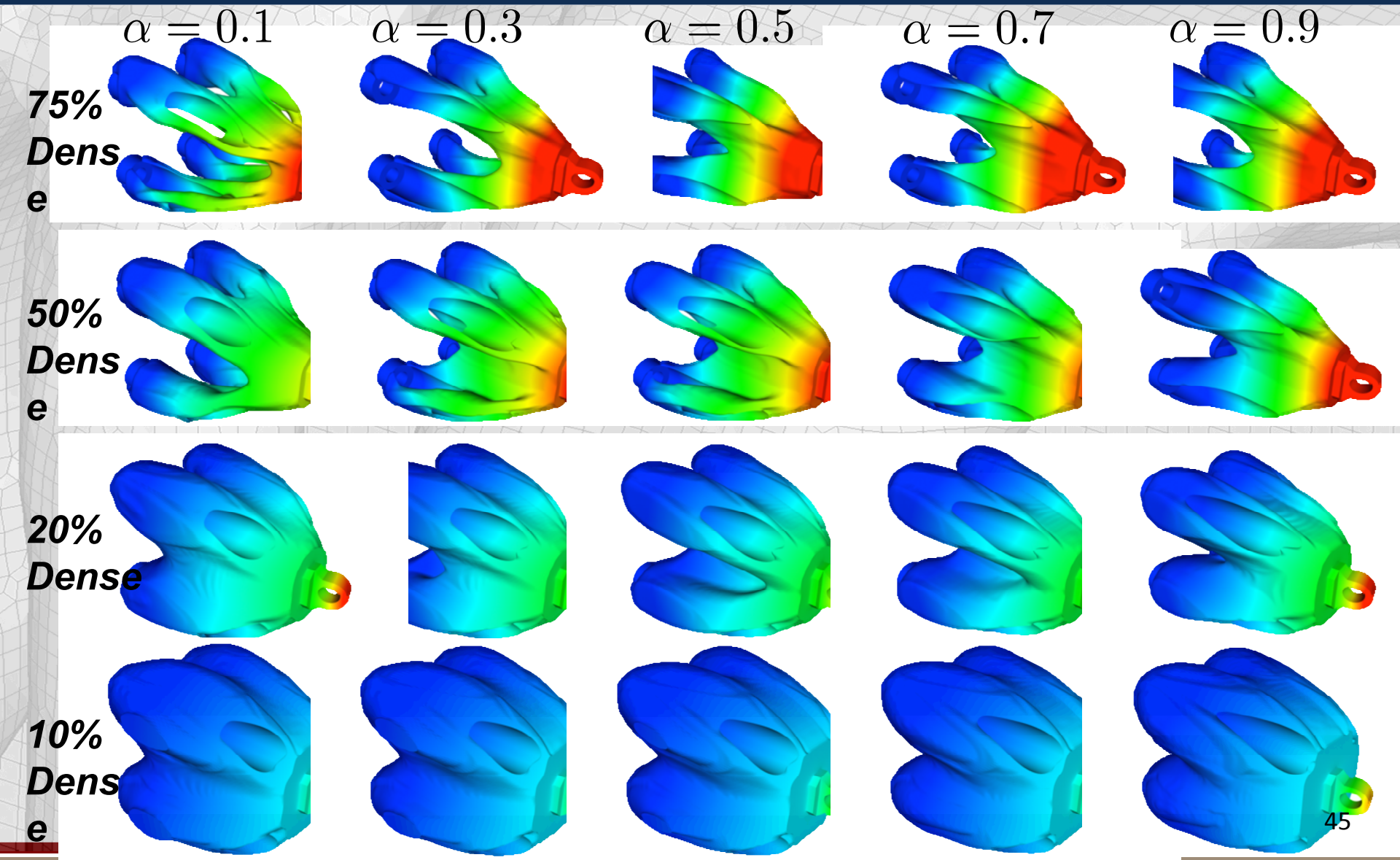


Nanoscribe Structures



Recent Munitions Pusher Example



Effect of Lattice Density

Min: (1-α)* compliance + α*thermal