

Exceptional service in the national interest



SAND2016-3862PE

Revolutionary Design Tools for AM and Crafting

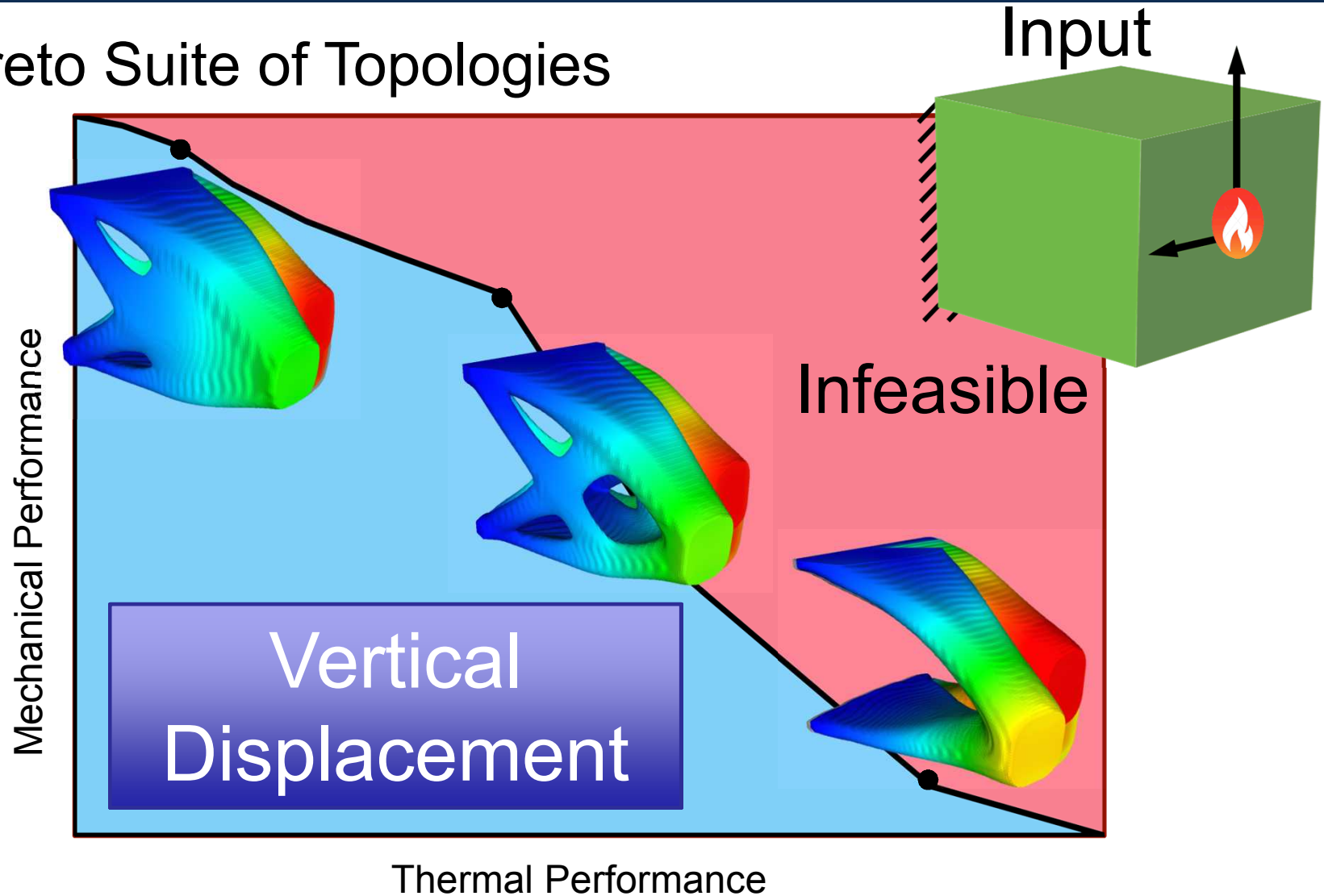
Sandia's PLM Select
Platinum Technology

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SAND2015-10065 PE

Motivation: Prioritization

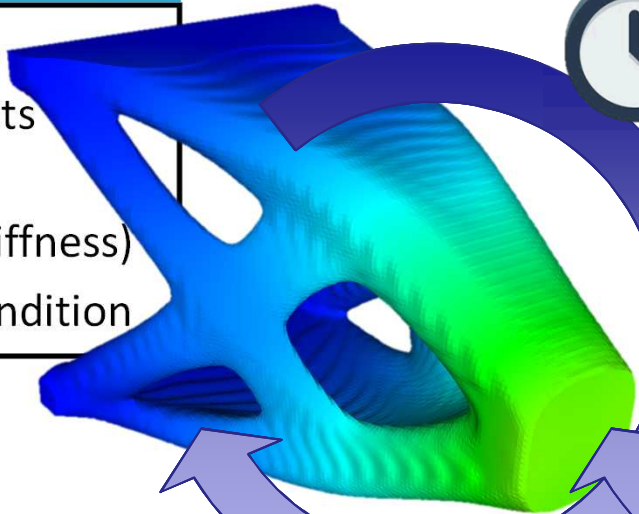
Pareto Suite of Topologies



The Case For Surrogate-Based Optimization

Problem Setup

- Linear Statics
- 1.5M elements
- 1 Objective (Maximize Stiffness)
- 1 Loading Condition



CPU TIME:

1200	Minutes
2000	Hours
1000	Hours

1 High Fidelity FEM
 ≈ 12 Minutes on
 4196 cores

Optimization

Uncertainty Quantification

X 2

Evaluations per Iteration

X 50

Iterations

X 100

Sample

Physics-Based Reduced Order Modeling

Smart Sampling Techniques

Physics-Based Reduced Order Modeling

$$p^* = \arg \min_z J(p)$$

$$\text{s.t. } g(p)=0; h(p)\geq 0$$

$$(pK)u=f$$

Create ROM

$$\psi p^* = \arg \min_{\psi p} J(\psi p)$$

$$\text{s.t. } g(\psi p)=0; h(\psi p)\geq 0$$

$$\phi^T(\psi p)K\phi u = \phi^T f$$

Optimize w/ROM

Until error > tolerance

$$(pK)u=f$$

Create ROM

$$\psi p^* = \arg \min_{\psi p} J(\psi p)$$

$$\text{s.t. } g(\psi p)=0; h(\psi p)\geq 0$$

$$\phi^T(\psi p)K\phi u = \phi^T f$$

Optimize w/ROM

Until error > tolerance

$$(pK)u=f$$

Objective Function Value

Stiffness

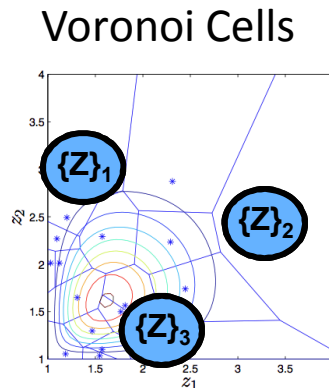
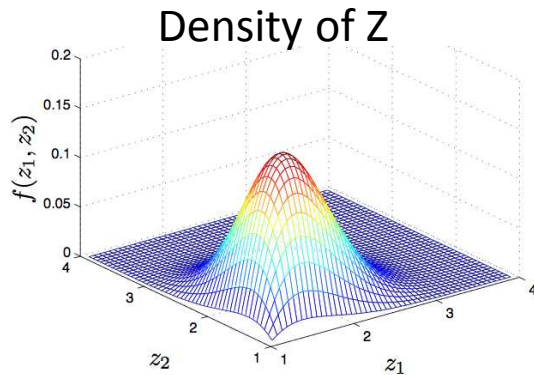
Smart Sampling Techniques

$$p^* = \arg \min_p \mathbf{E}[U^T(pK(G,B))U]$$

s.t.

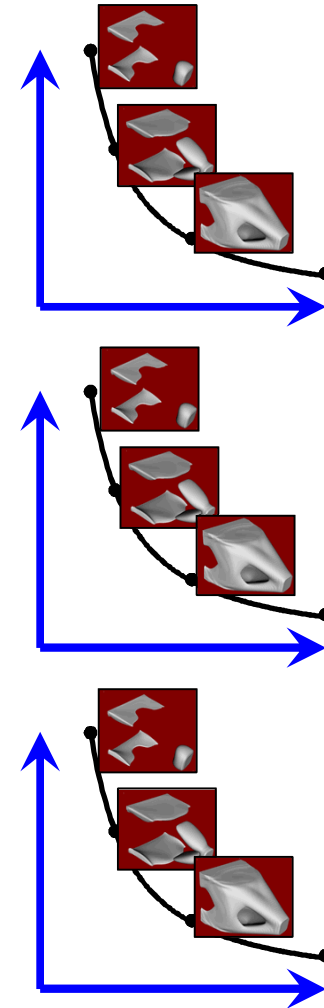
$$(pK(G,B))U - f = 0; V(p) \leq V_0$$

Stochastic ROM



Build SROM Given Available Resources
(# FEM Runs That Can Be Performed)

$\{Z\}_i = \{\text{Shear Modulus (G), Bulk Modulus (B)}\}$
 $1 \leq i \leq M, M = \#\text{Samples}$



Expected Result of Surrogate-Based Optimization

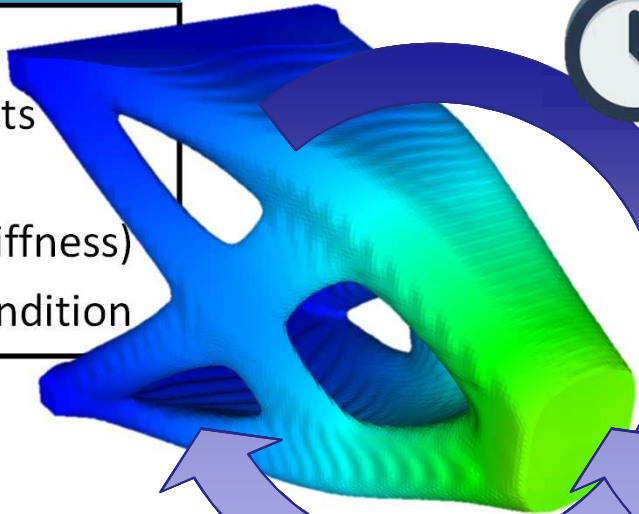
Problem Setup

- Linear Statics
- 1.5M elements
- 1 Objective
(Maximize Stiffness)
- 1 Loading Condition



CPU TIME:

**5
Hours**



1 High Fidelity FEM
≈ 3 Minutes on
4196 Processors

Optimization

Uncertainty
Quantification

X 2

Evaluations
Per Iteration

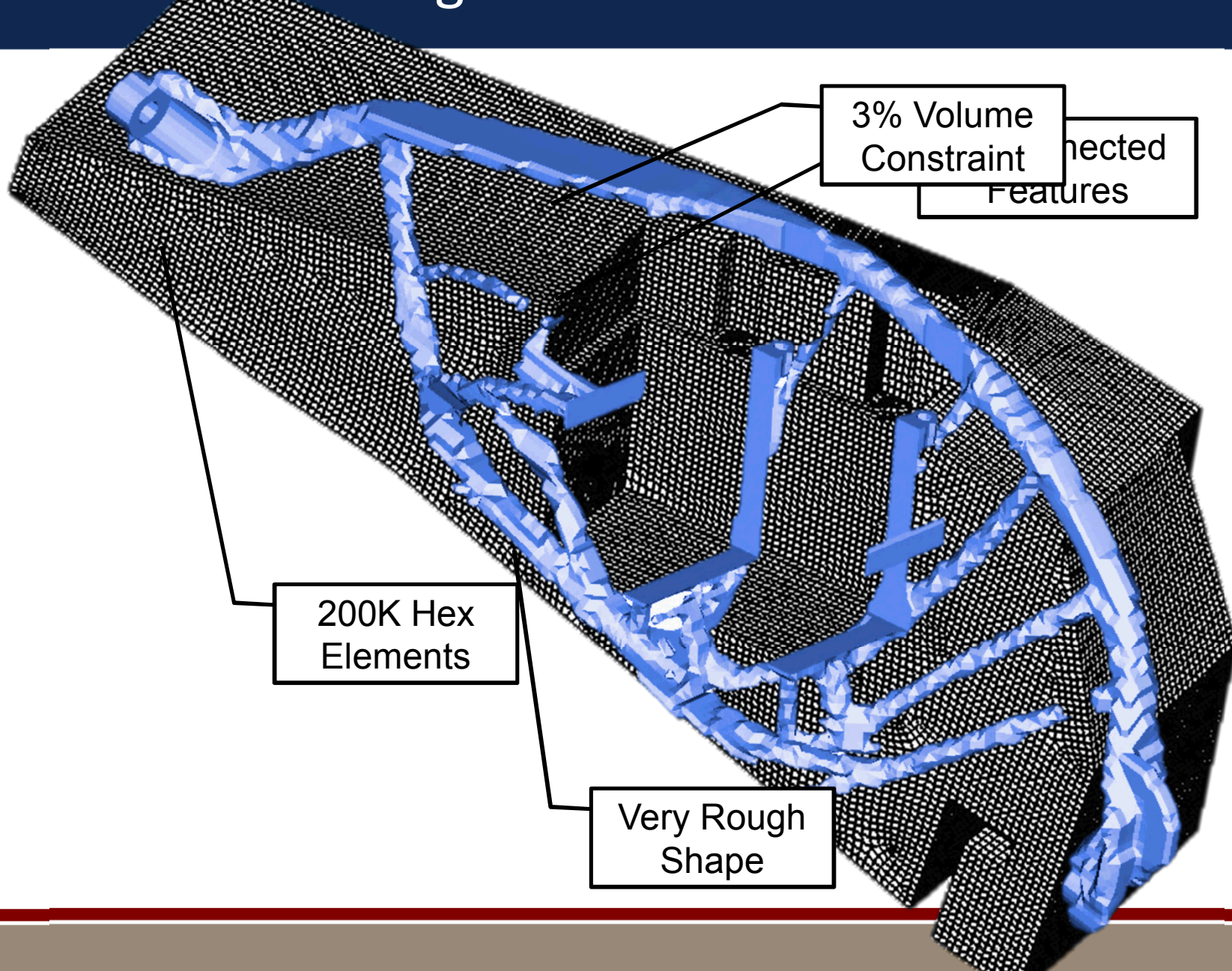
X 50

Iterations

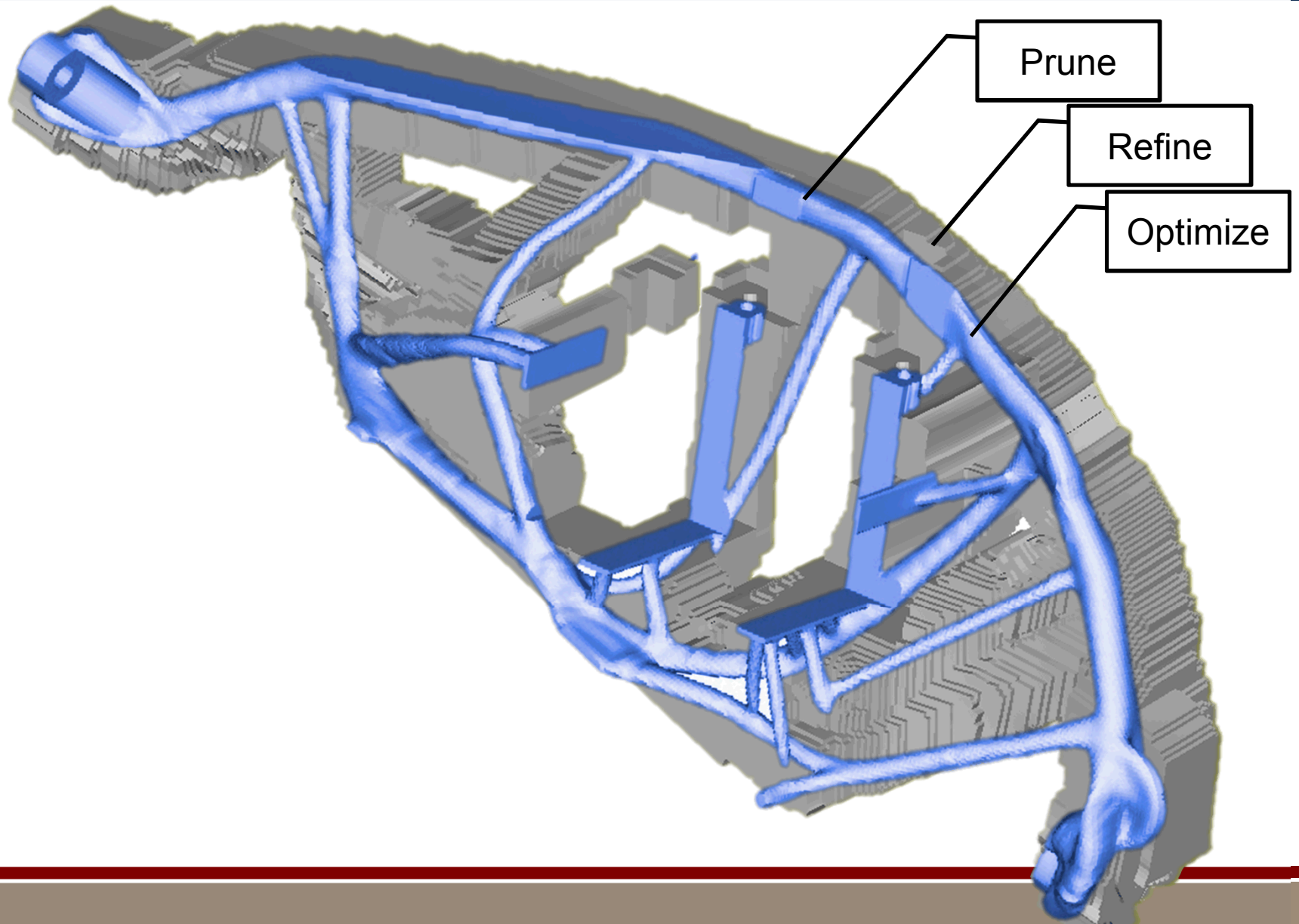
X 5

Samples

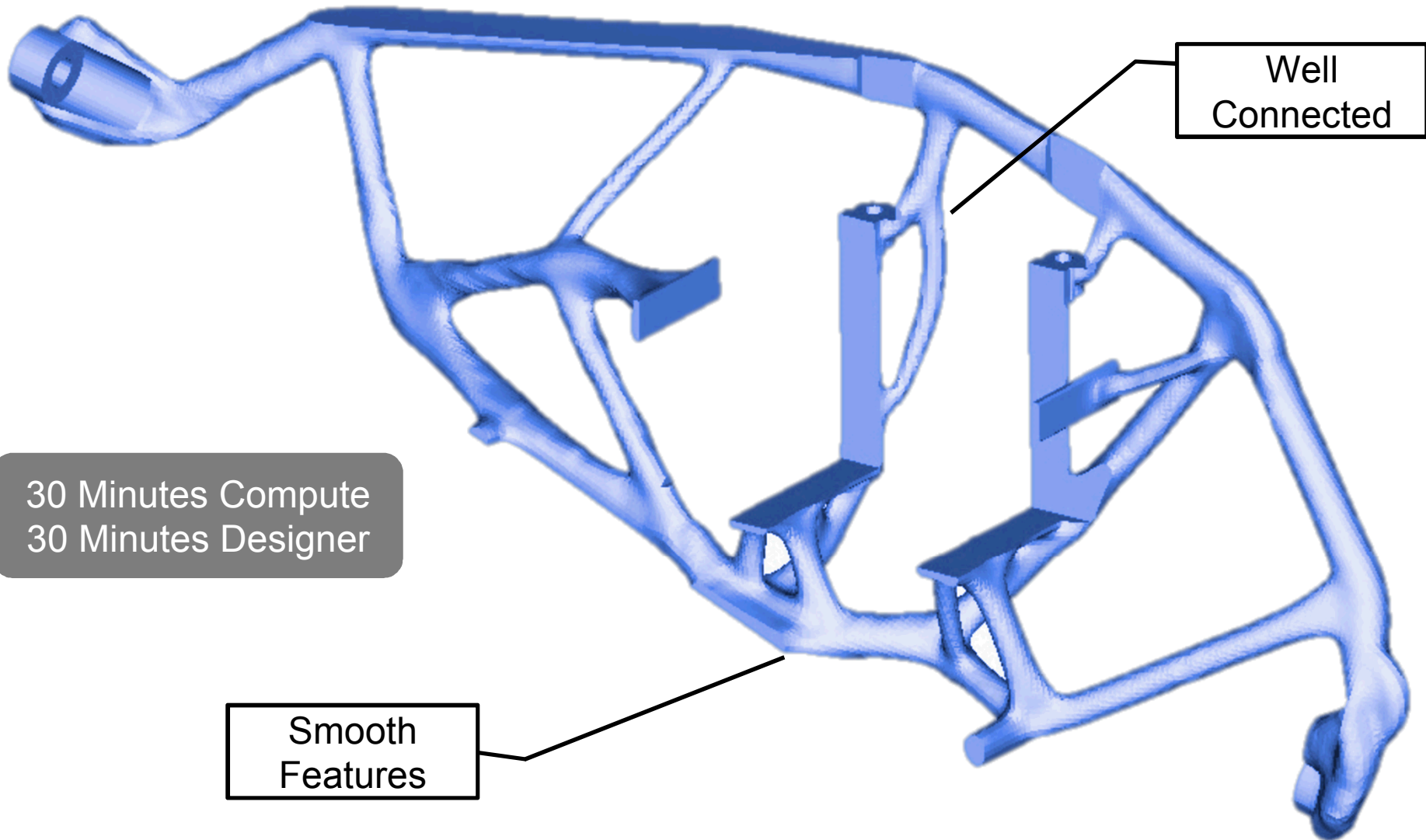
Careful Crafting: Initial Course Calculation



Prune / Refine / Optimize Process



Repeat to Converged Design



Realizing the Revolution

plato



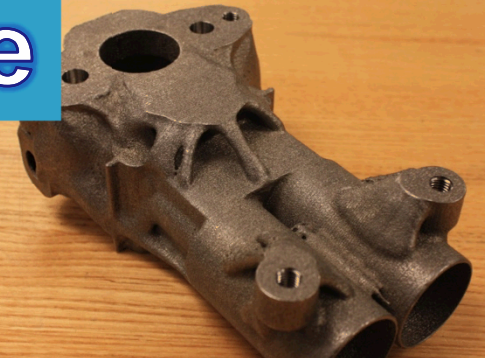
Platinum
Topology
Optimization

Invert Qualification

In-Situ Validation of
Materials & Processes

Invert Manufacture

Powder Bed
Metal Additive



Invert Design

Topology Optimization
with Material Locality

- Disruptive Change for NW
- Disruptive Change for SNL
- Disruptive Change for World of Engineering