

# Topology Optimization for Next-Generation Design

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## Problem Definition

### • OBJECTIVE:

Develop an interactive, optimization-based design tool that will allow engineers to fully explore and exploit the increasing design space, while minimizing the turnaround to produce qualified parts.

### • PROBLEM:

Find the optimal design functionality such that the physical behavior and design criteria are satisfied through topology optimization (TO):

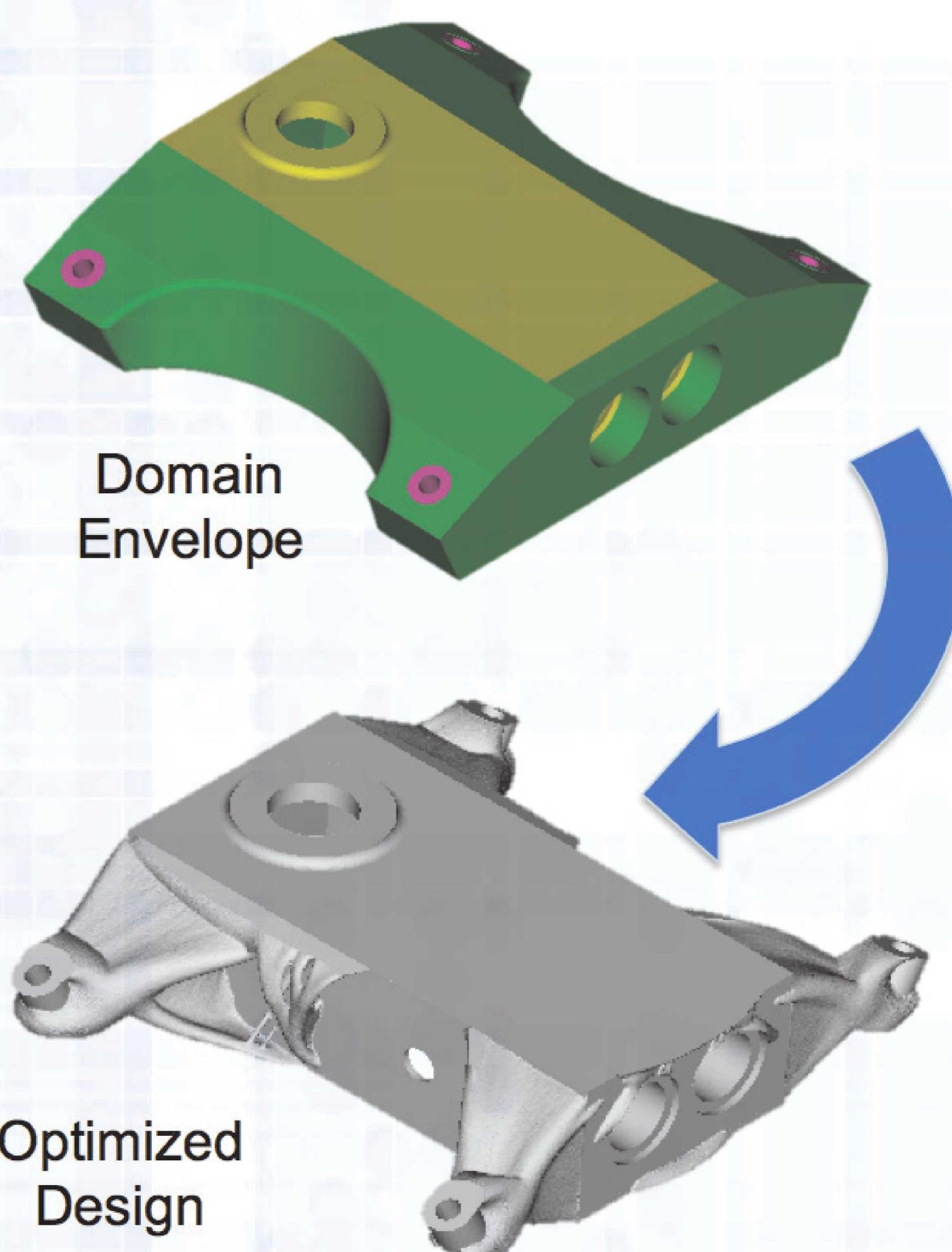
$$\min_{\rho \in \mathcal{Z}} f(u(\rho), \rho)$$

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

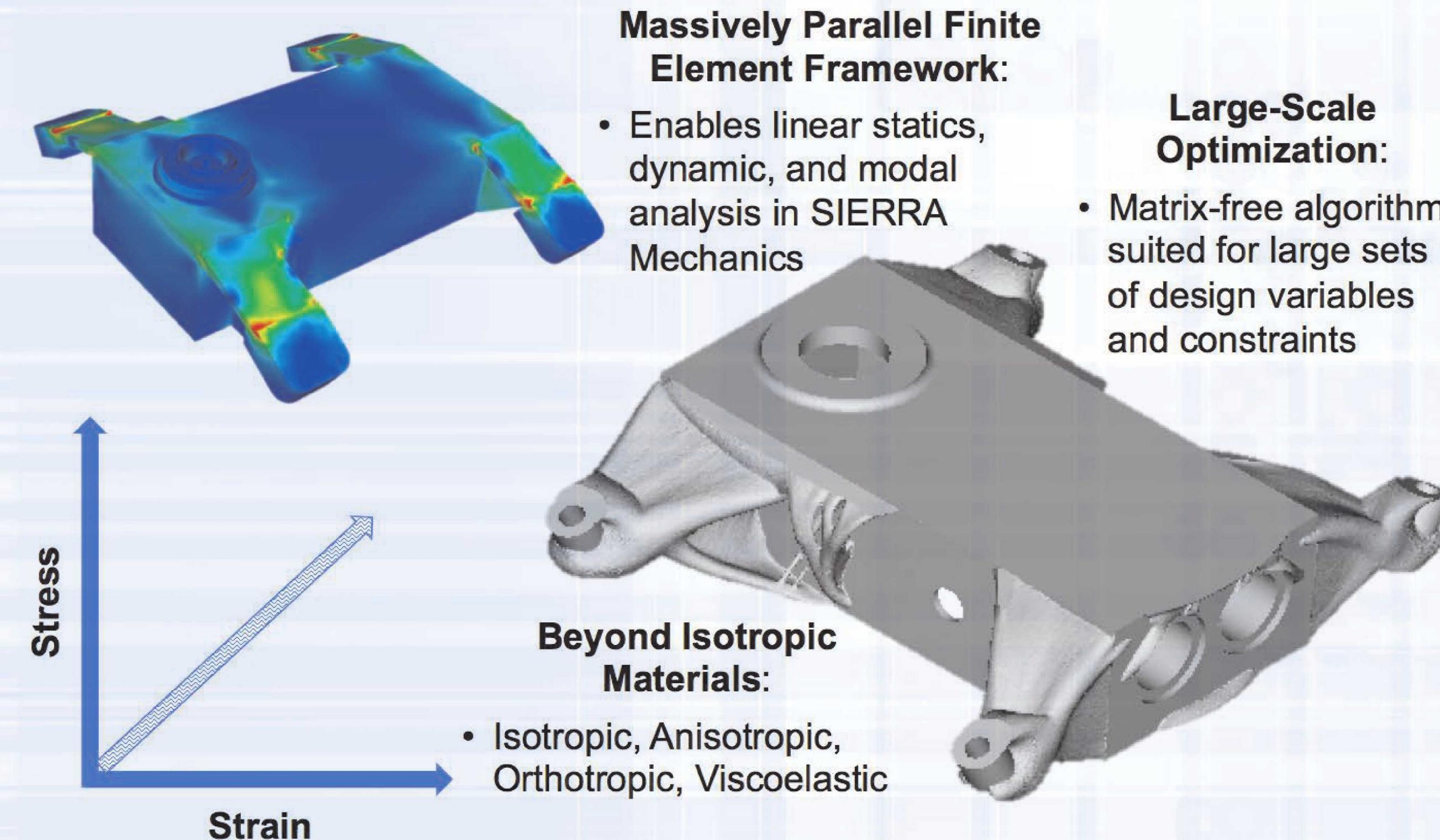
$f(u(\rho), \rho)$ : Design Objective

$g(u(\rho), \rho)$ : Multi-Physics FEM Model

$h(u(\rho), \rho)$ : Design Requirements



## Current TO Capabilities



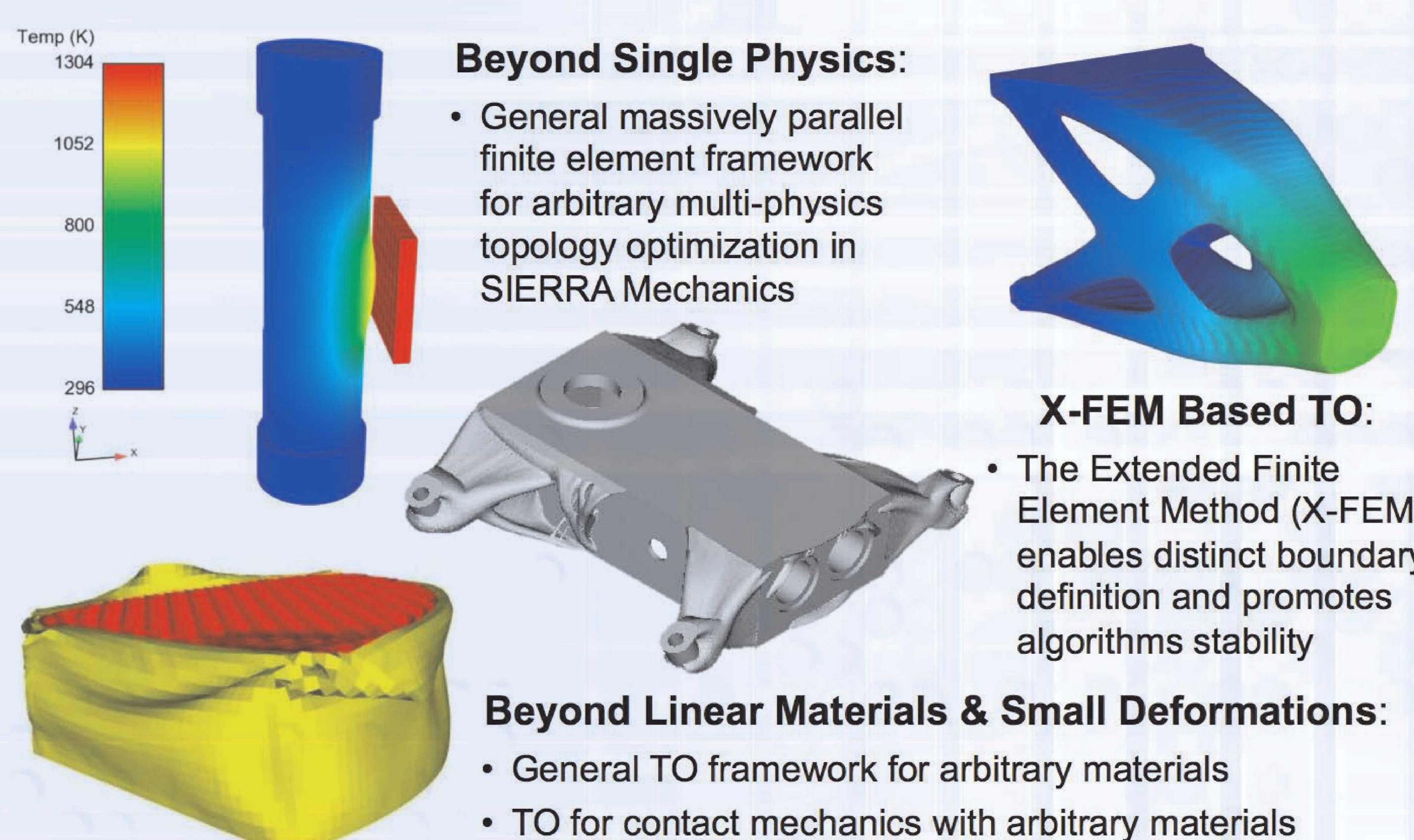
**Massively Parallel Finite Element Framework:**  
 • Enables linear statics, dynamic, and modal analysis in SIERRA Mechanics

**Large-Scale Optimization:**  
 • Matrix-free algorithms suited for large sets of design variables and constraints

**Beyond Isotropic Materials:**

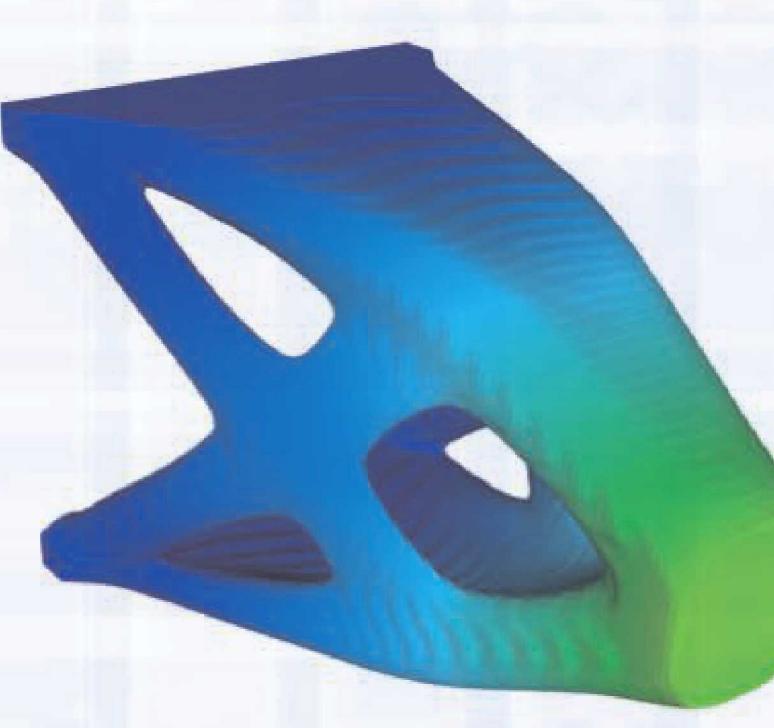
- Isotropic, Anisotropic, Orthotropic, Viscoelastic

## Next-Generation TO Capabilities



### Beyond Single Physics:

- General massively parallel finite element framework for arbitrary multi-physics topology optimization in SIERRA Mechanics

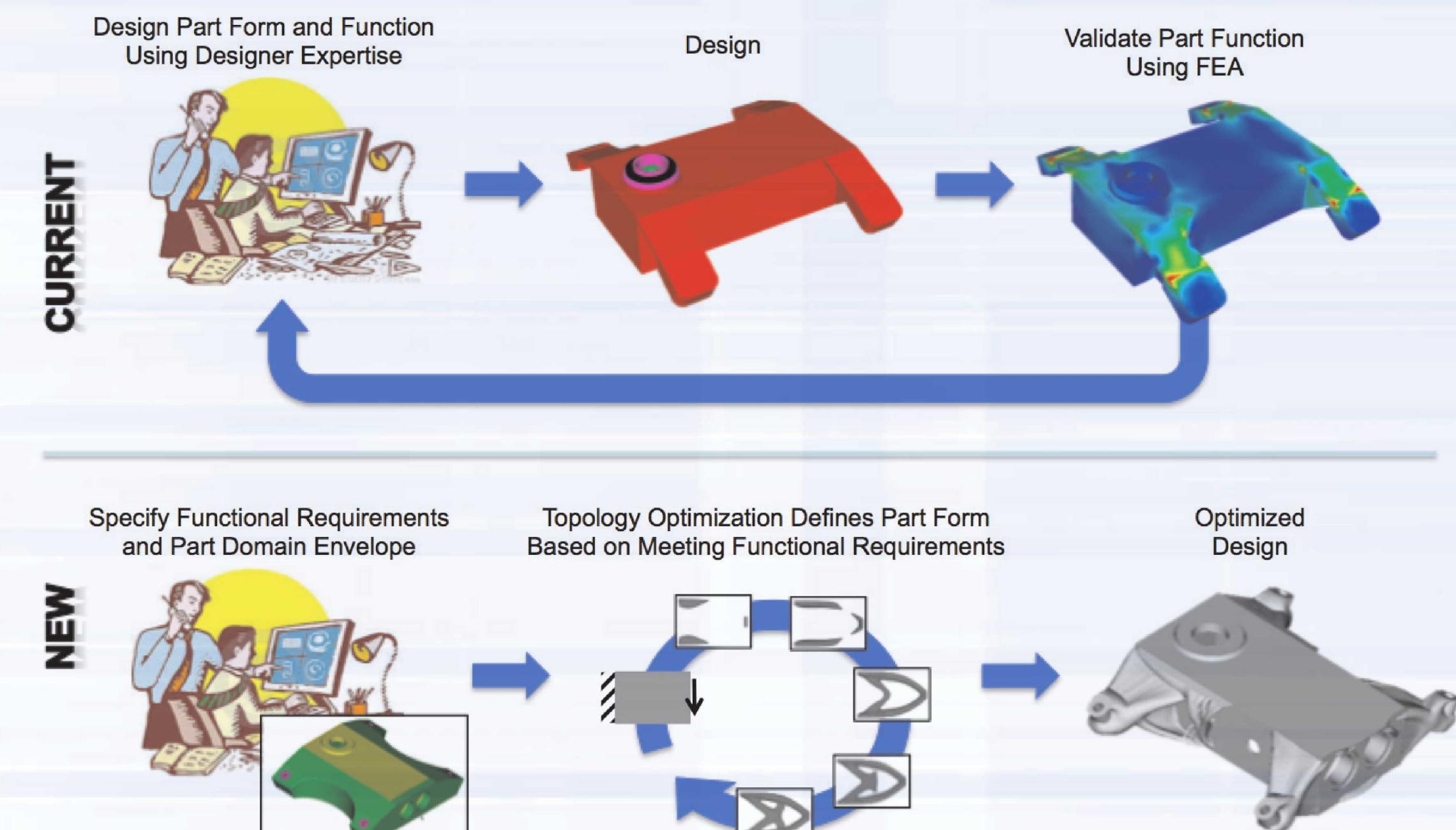


**X-FEM Based TO:**  
 • The Extended Finite Element Method (X-FEM) enables distinct boundary definition and promotes algorithms stability

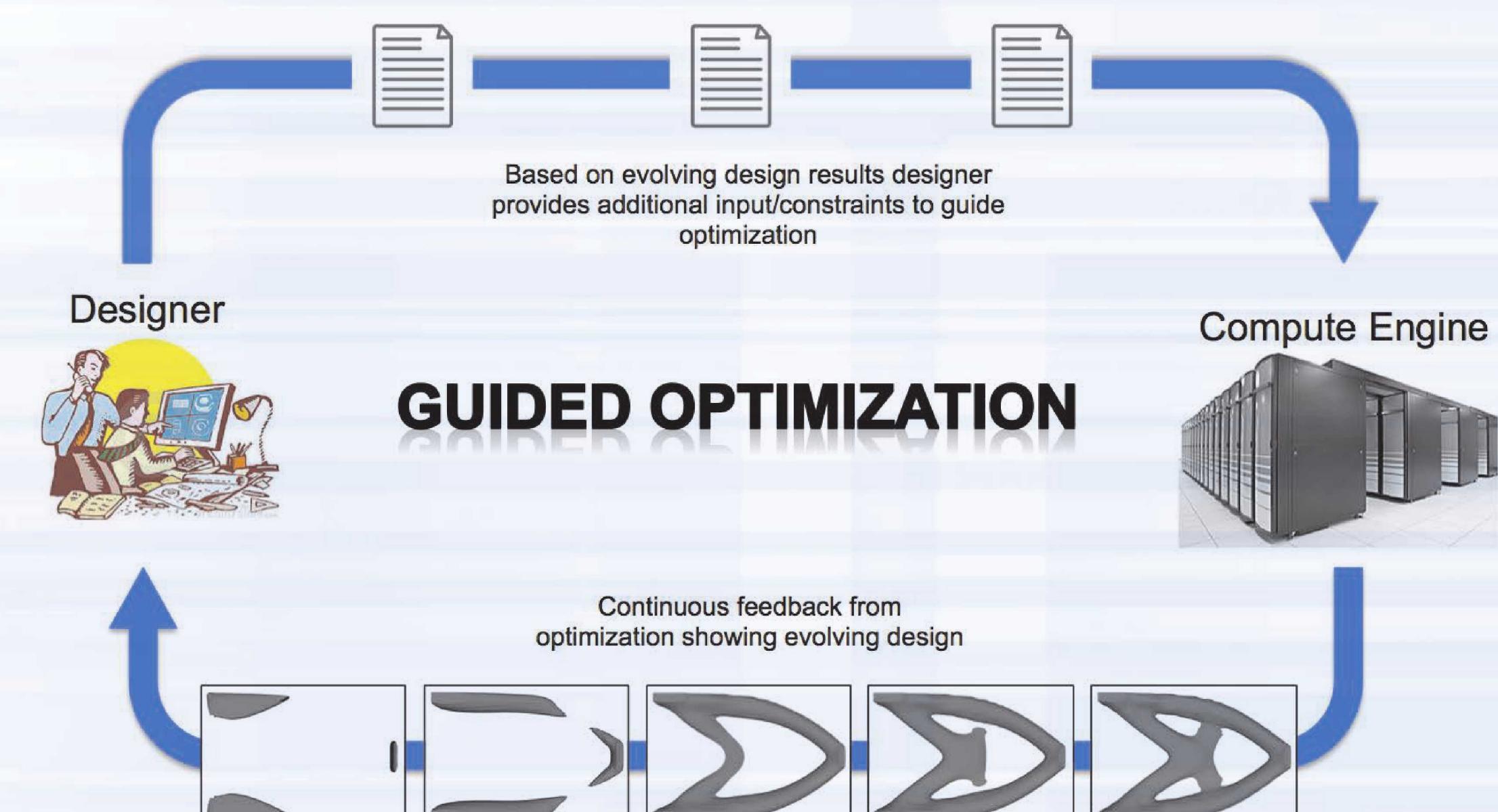
### Beyond Linear Materials & Small Deformations:

- General TO framework for arbitrary materials
- TO for contact mechanics with arbitrary materials

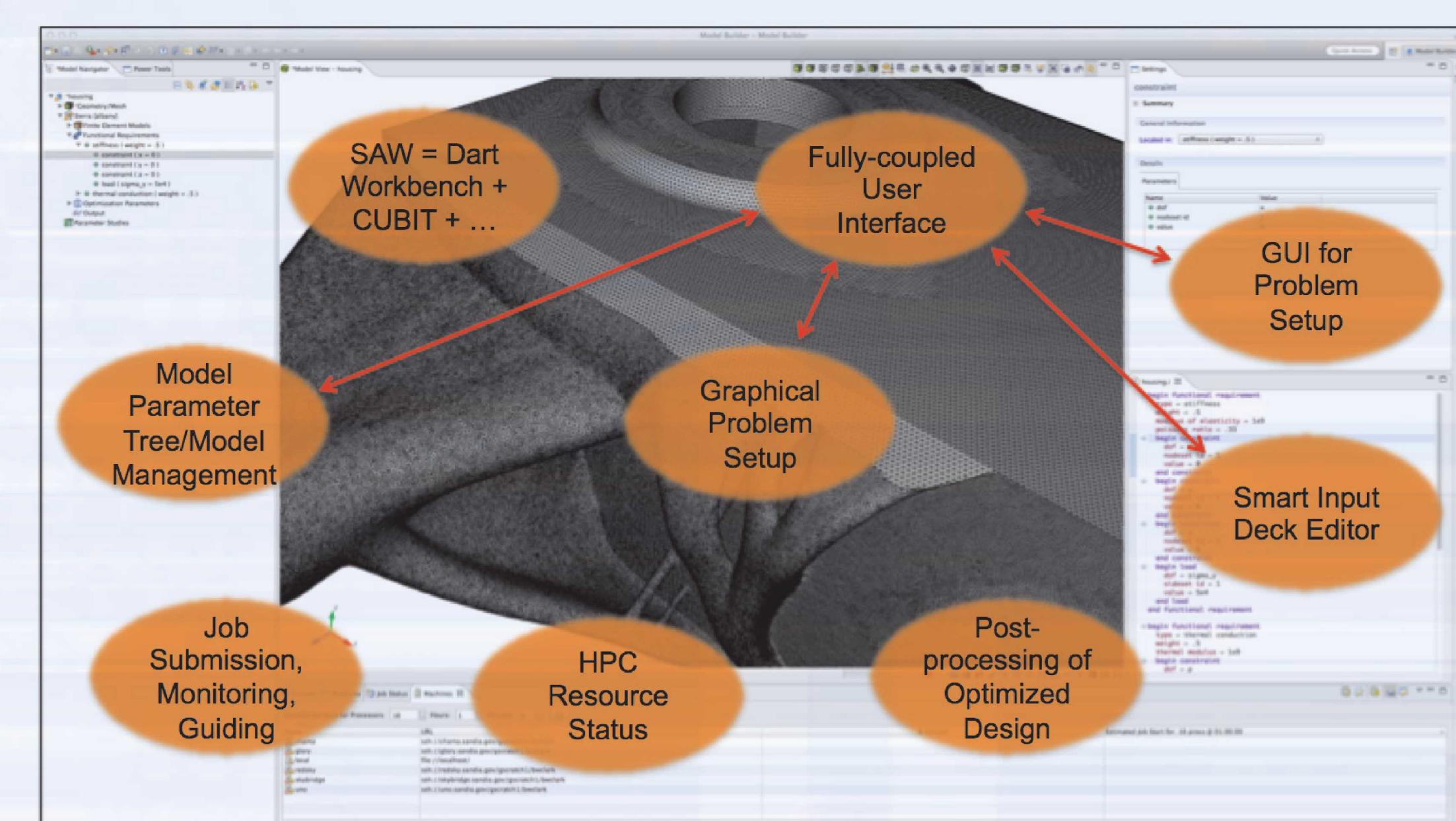
## Transforming Design Paradigm with TO



## Guided Topology Optimization



## TO Design Environment Built on Sandia Analysis Workbench (SAW)



## State of Capabilities

### • Current

- Multi-physics (linear statics and thermal), multi-objective topology optimization running on research platform physics code (Albany)
- TO problem setup, job submission, result visualization, and some post-processing being done in SAW environment by early adopters (using Albany physics)
- Framework for multi-objective and multi-materials TO in place for Sierra production physics code with linear statics problem demonstrated

### • Future Focus

- Production topology optimization capability using Sierra physics code
- "Guided Optimization" in SAW design environment

### • Notes

- Technical collaboration with Prof. Kurt Maute at University of Colorado Boulder
- Technical collaboration with Prof. Suresh Krishnan at University of Wisconsin Madison
- Sandia organized mini-symposium entitled: "ADVANCES IN TOPOLOGICAL OPTIMIZATION WITH APPLICATION TO ADVANCED MANUFACTURING" at the U.S. National Congress on Computational Mechanics
- Grand Challenge LDRD submission on designing with Topology Optimization

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