Simulation-Driven Design

University of Utah
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PRESENTED BY

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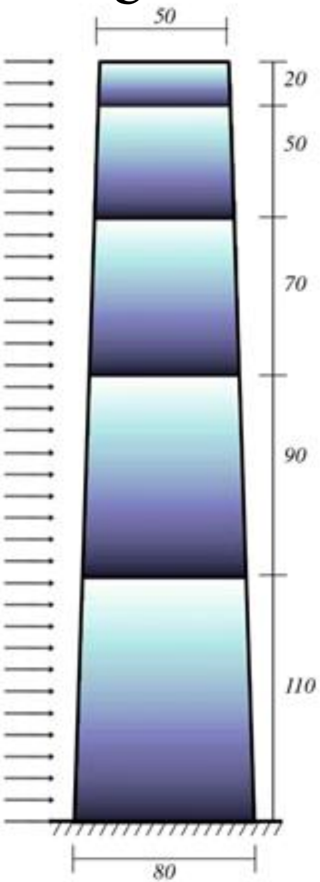
Motivation

Simulation-Driven Design

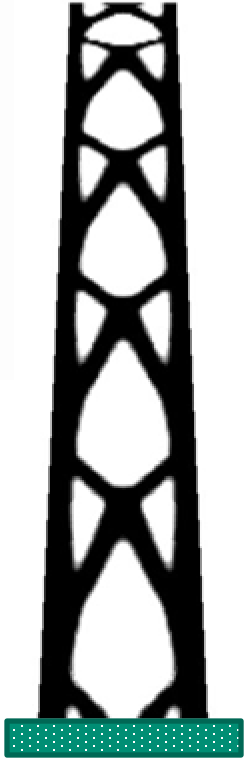
https://www.boeing.com/defense/f-15/index.page#/gallery

Structural Engineering

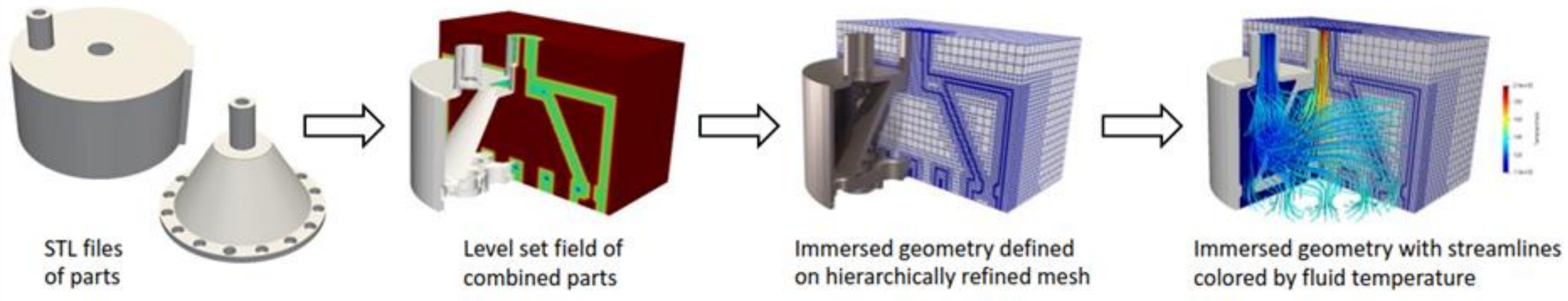

wikipedia.org



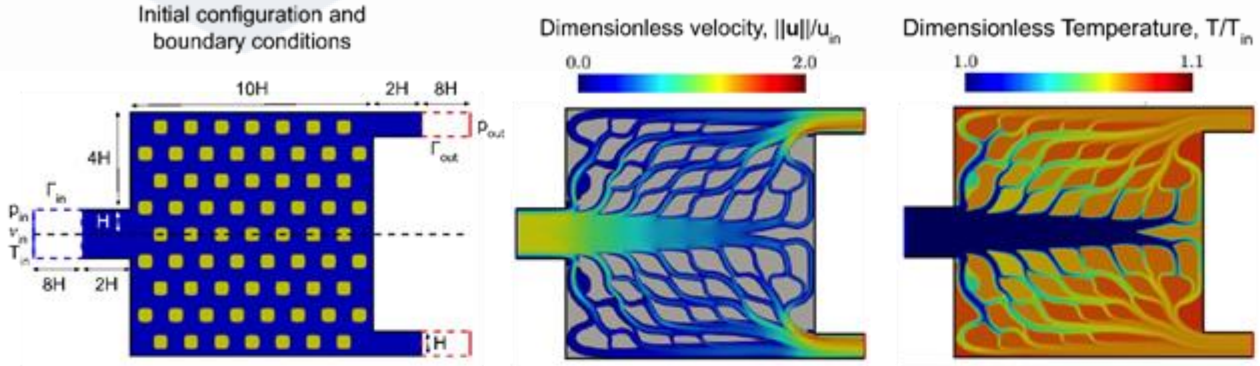
Could we use simulation-driven design (SDD) to engineer better structures?



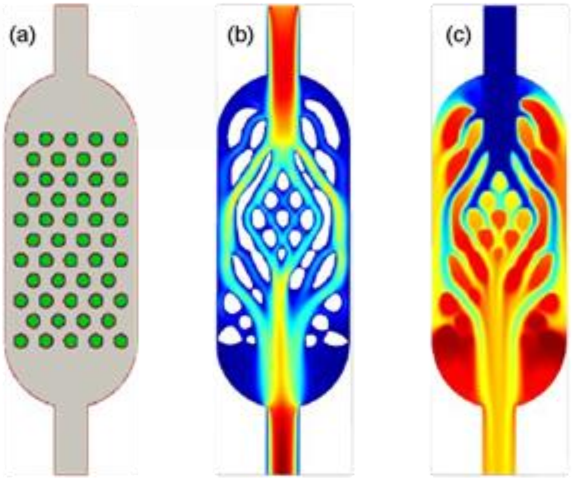
Note: Collaboration with Prof. Kurt Maute



Automated Simulation Workflows

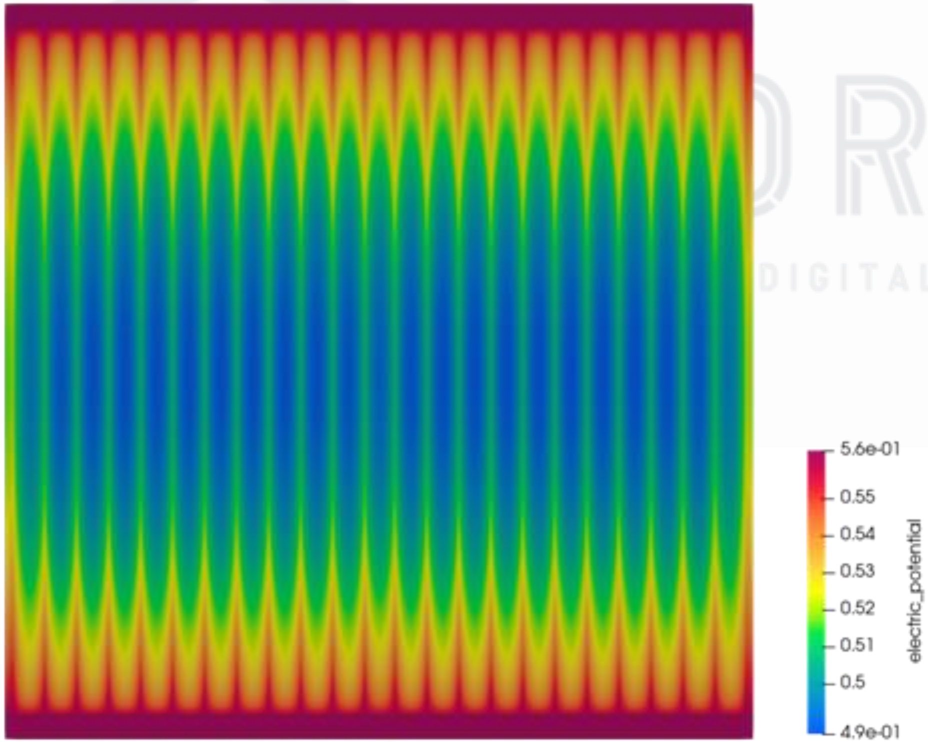


Heat Exchanger Design

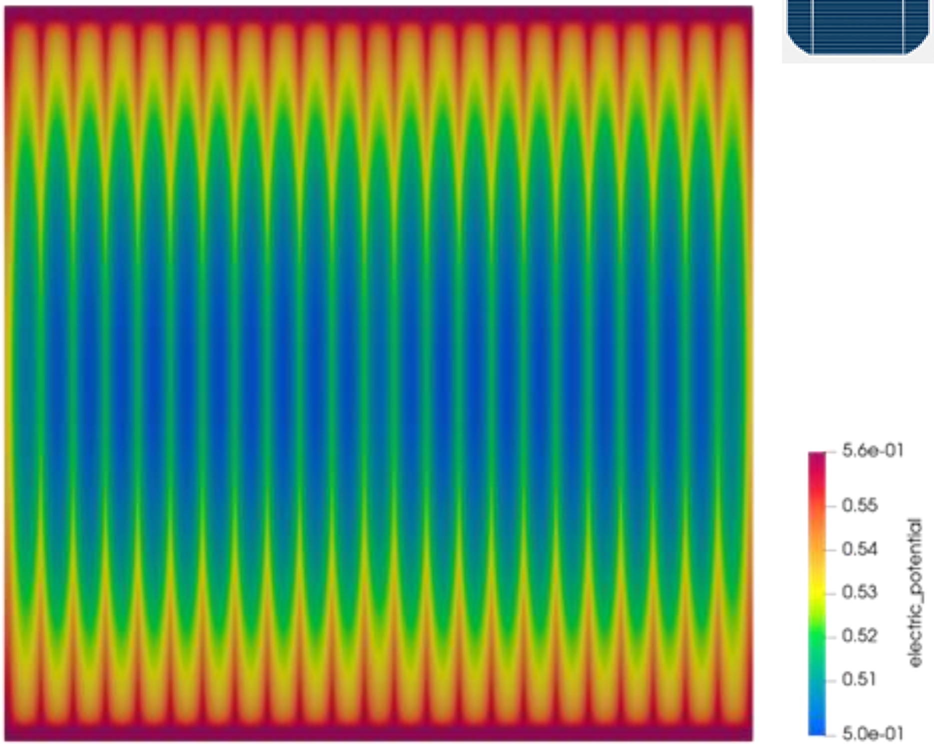


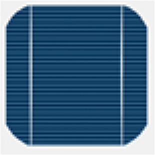
Nuclear Thermal Rocket Engine

Baseline



Optimized





Optimized solar PV cell is 3.5% more efficient than the baseline cell

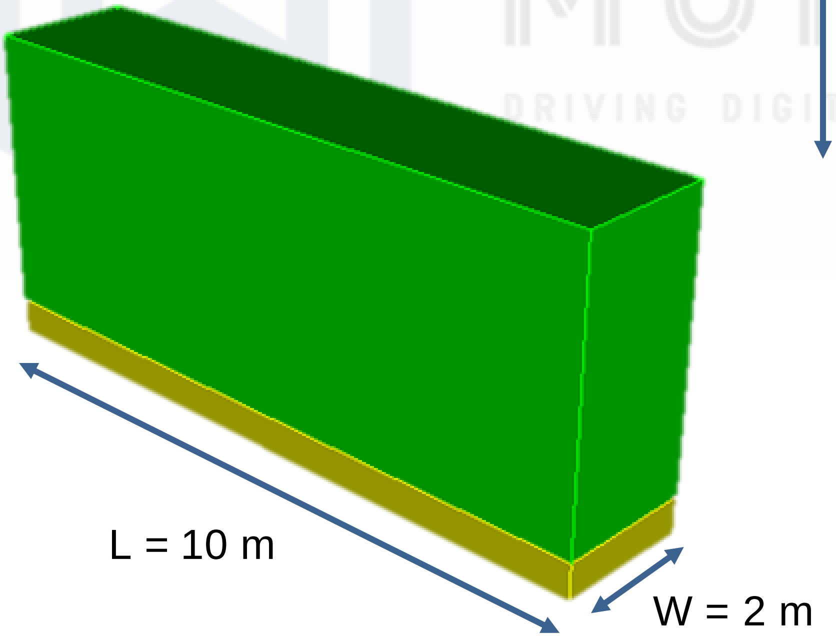
Trial & Error

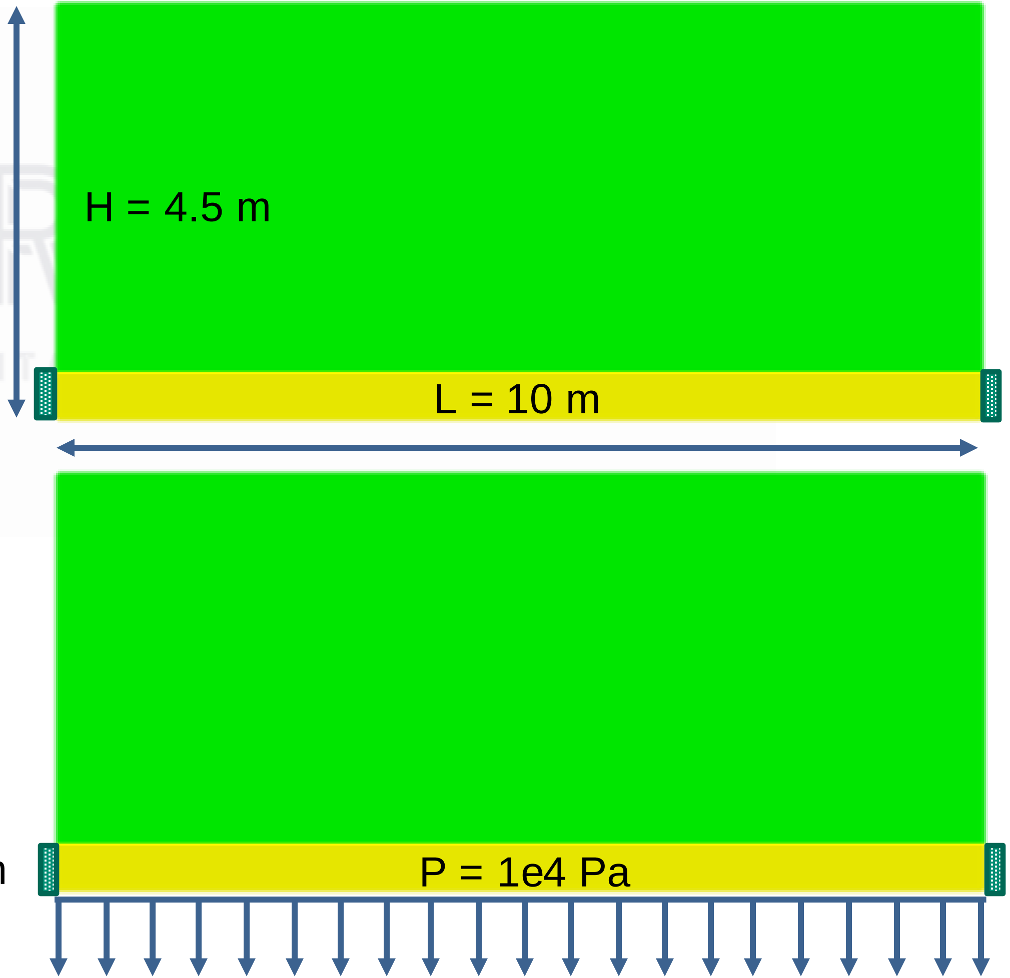
Simulation-Driven Design

Structural Design

Young's Modulus = 200e9 Pa

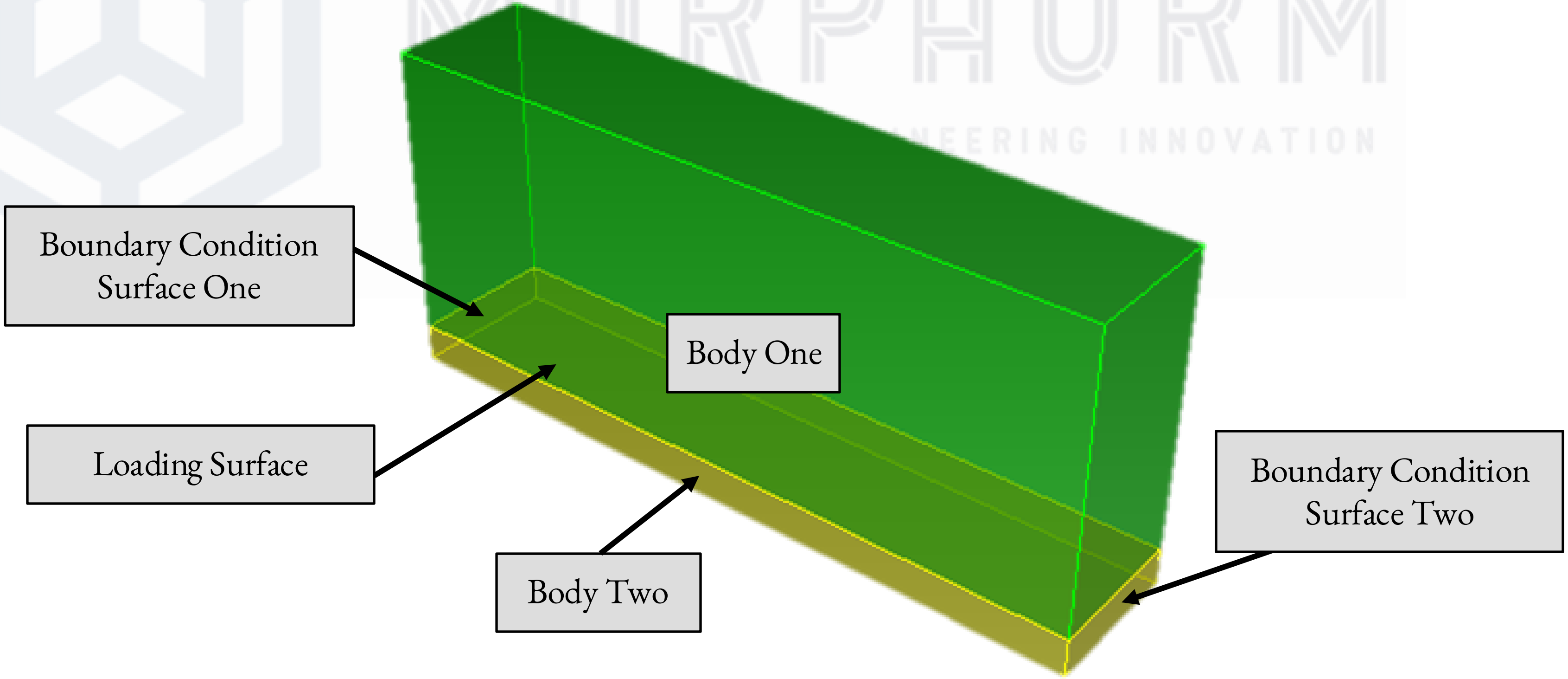
Poisson's Ratio = 0.3





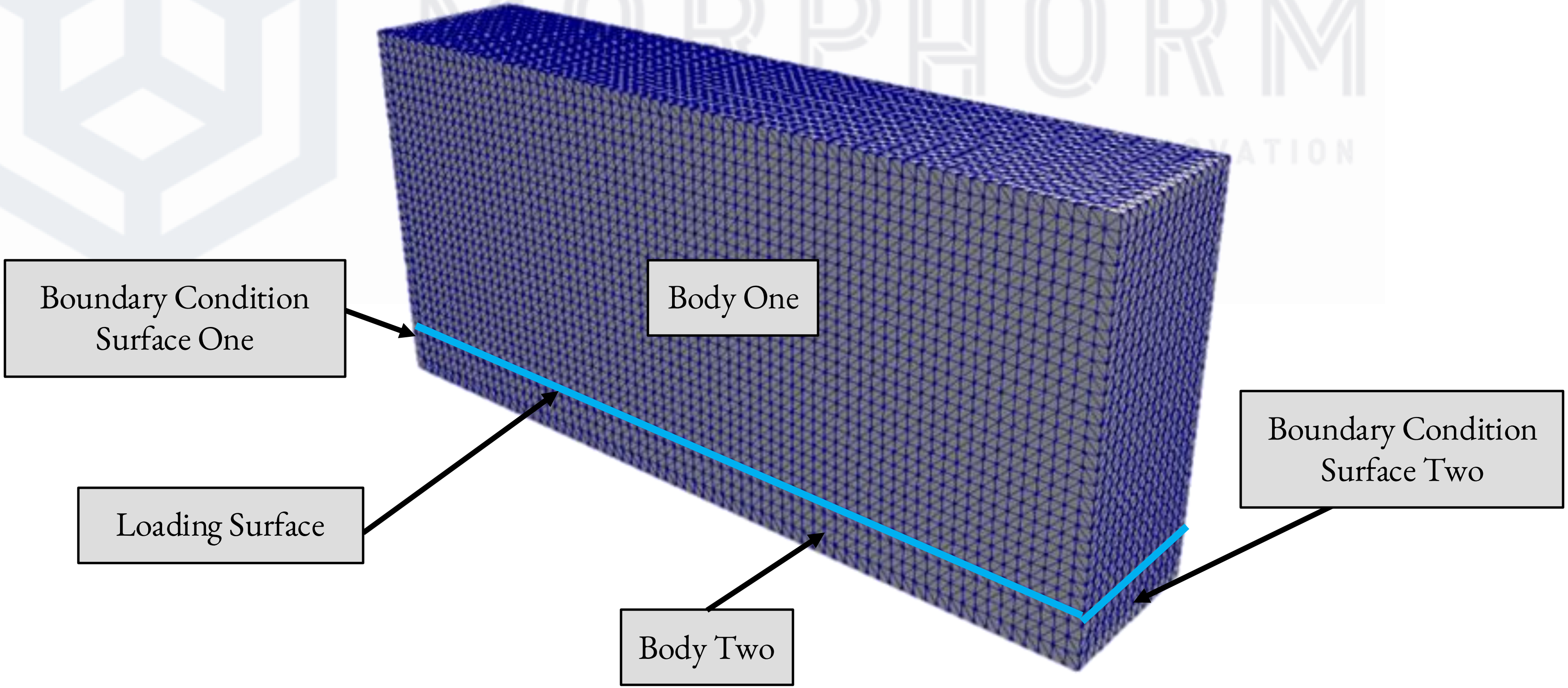
Approach

Step 1: Build Attributed Geometry Model



Approach

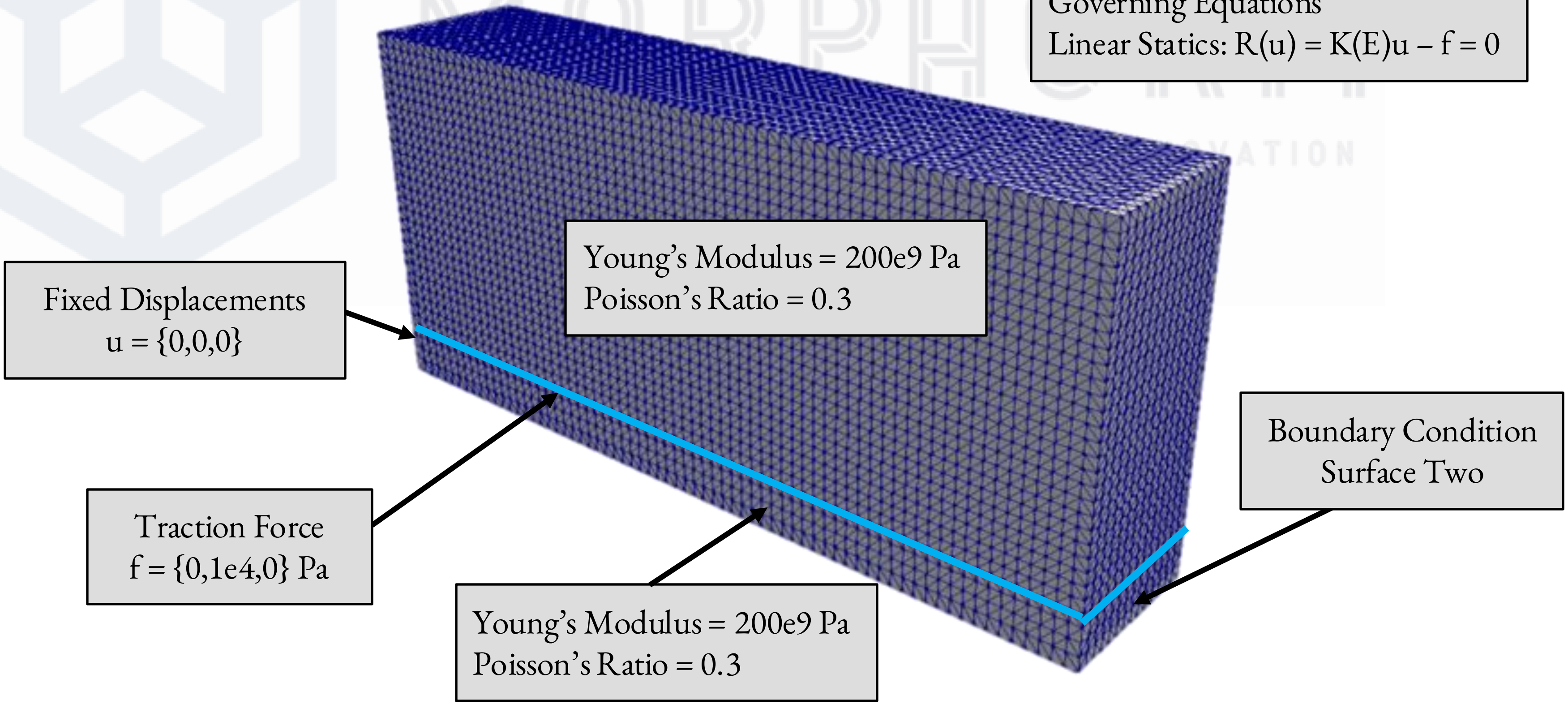
Step 2: Build Attributed Volume Mesh Model



Approach

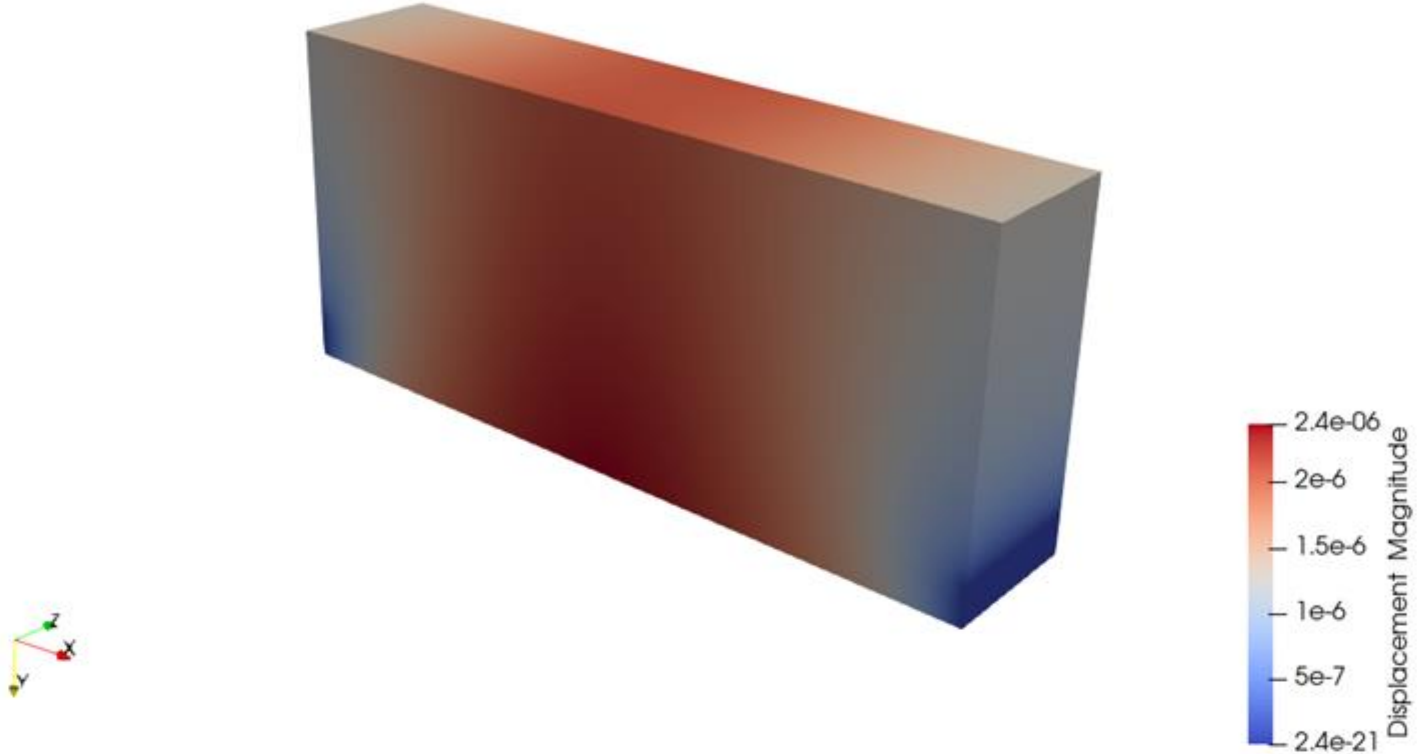
Step 3: Define Physics

Governing Equations
Linear Statics: $R(u) = K(E)u - f = 0$



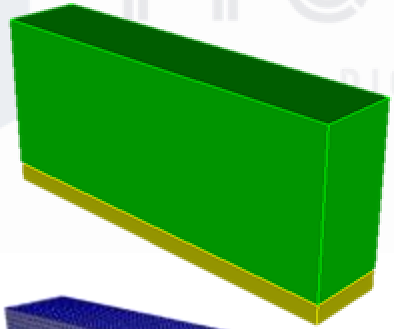
Approach

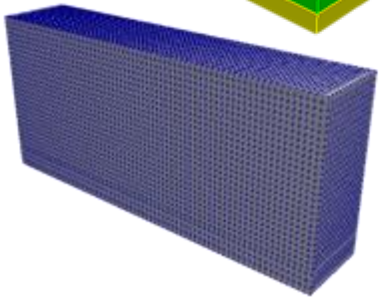
Step 4: Run Simulation & Analyze Results



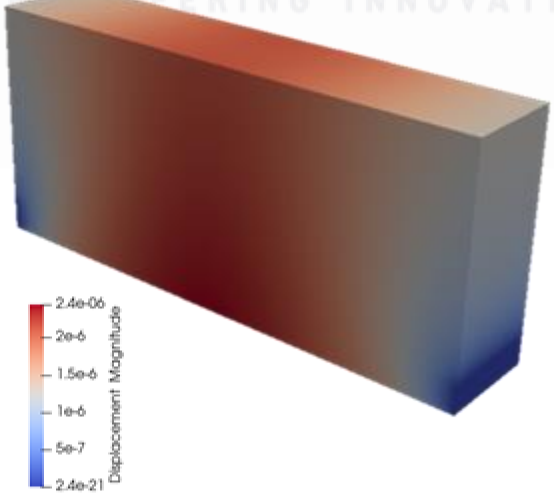
Workflow

- Build Geometry Model
- Build Mesh Model
- Define Physics





- Run Numerical Simulation
- o Evaluate Quantities of Interests
- o Identify Geometry Modifications



Modify Geometry

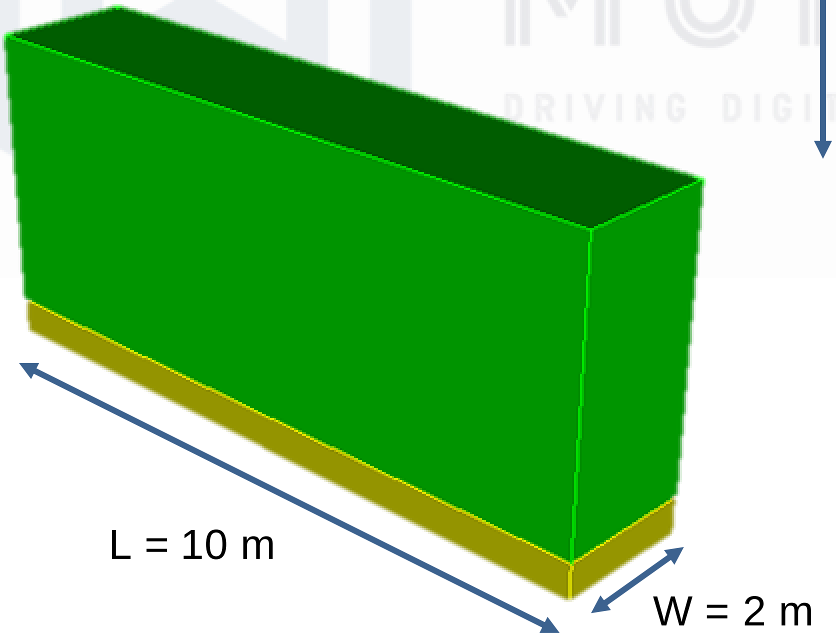
Automation

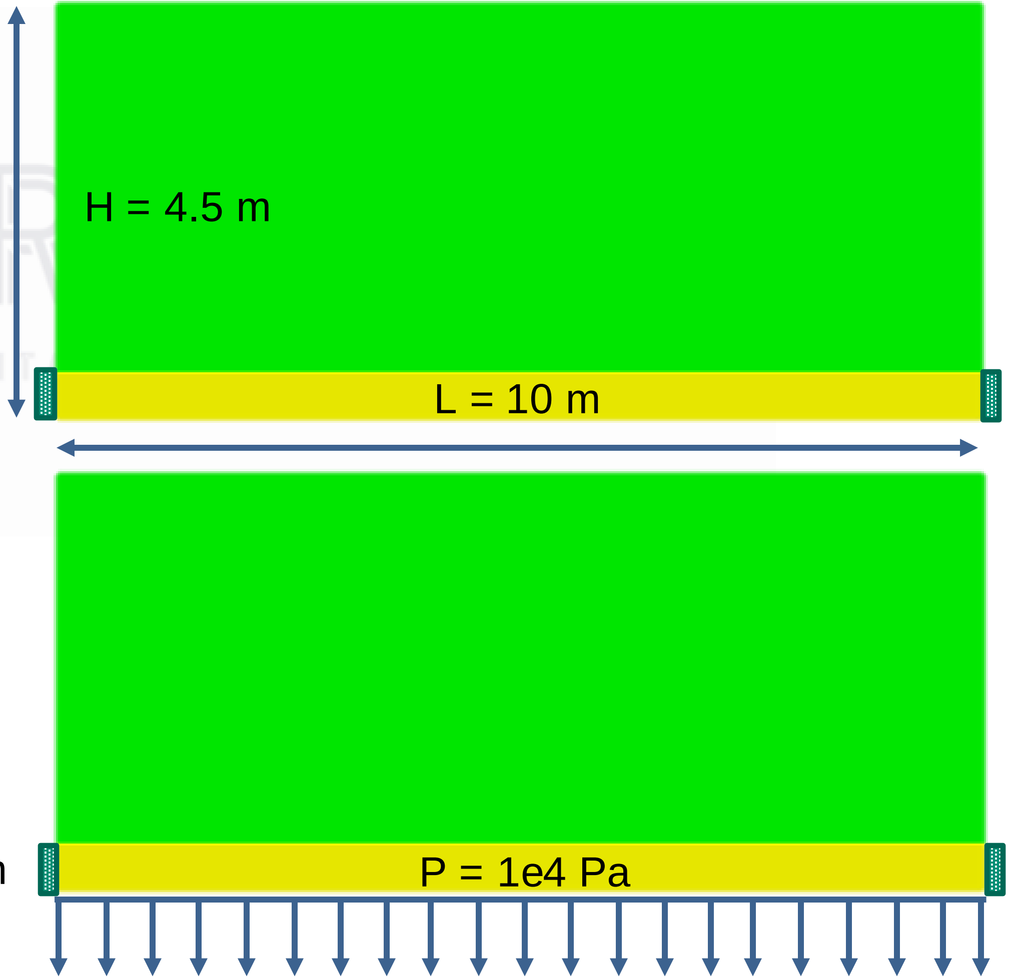
Simulation-Driven Design

Structural Design

Young's Modulus = 200e9 Pa

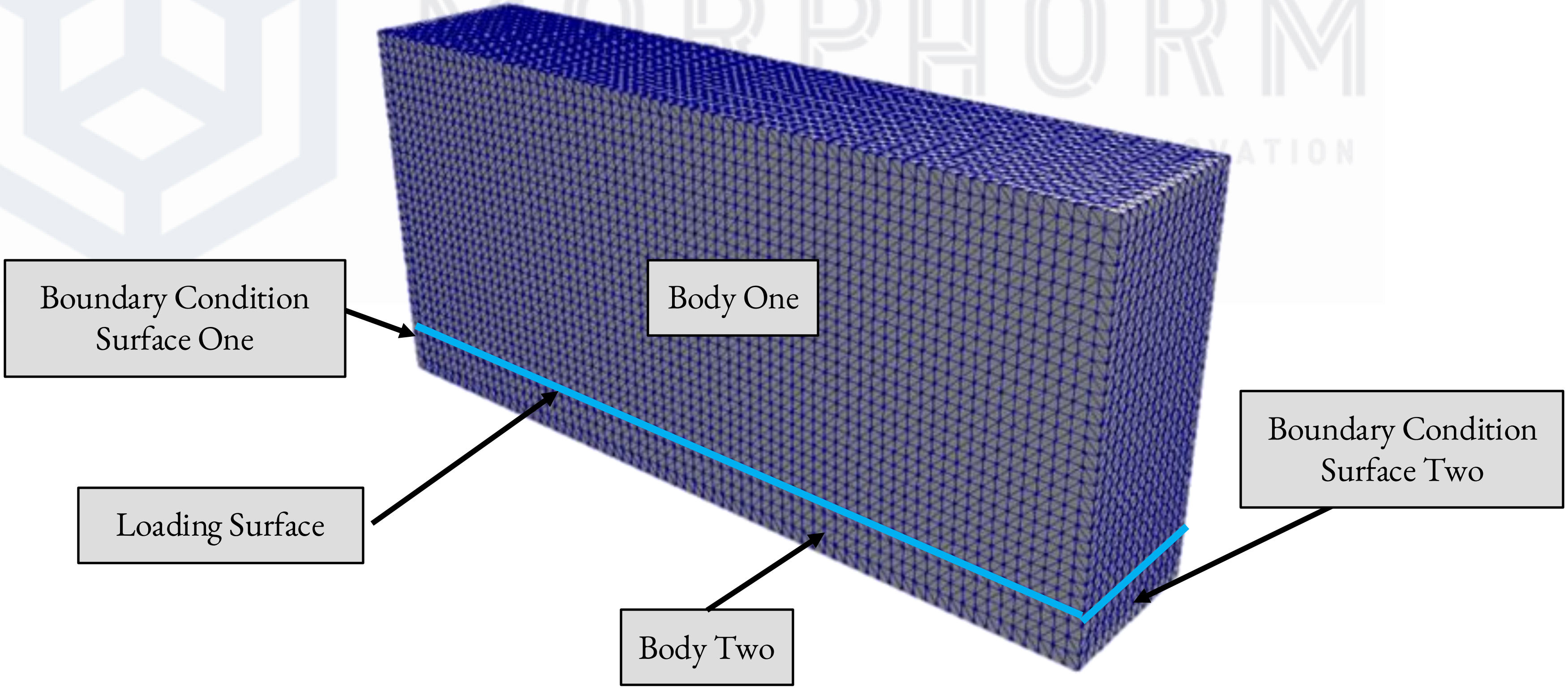
Poisson's Ratio = 0.3





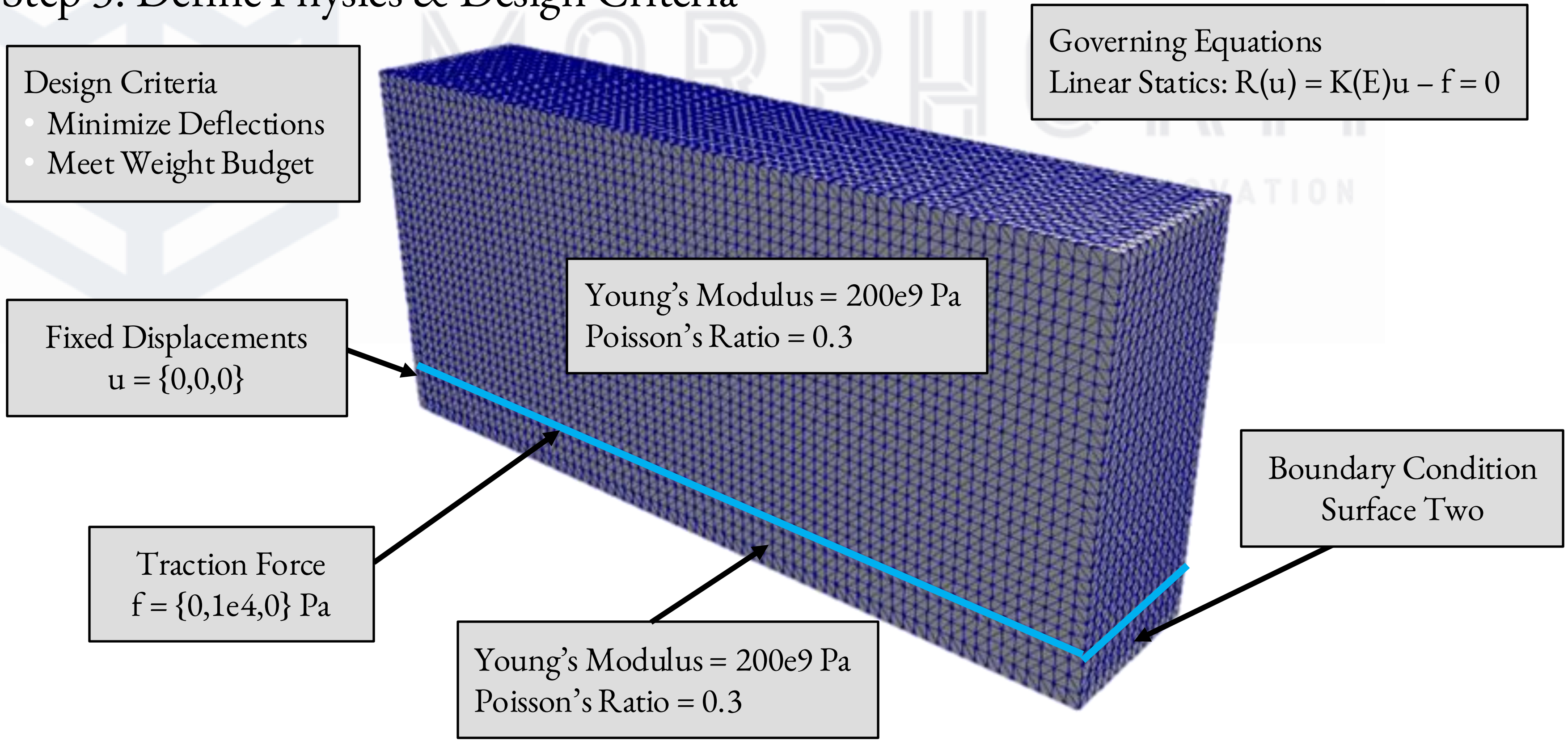
Approach

Step 2: Build Attributed Volume Mesh Model



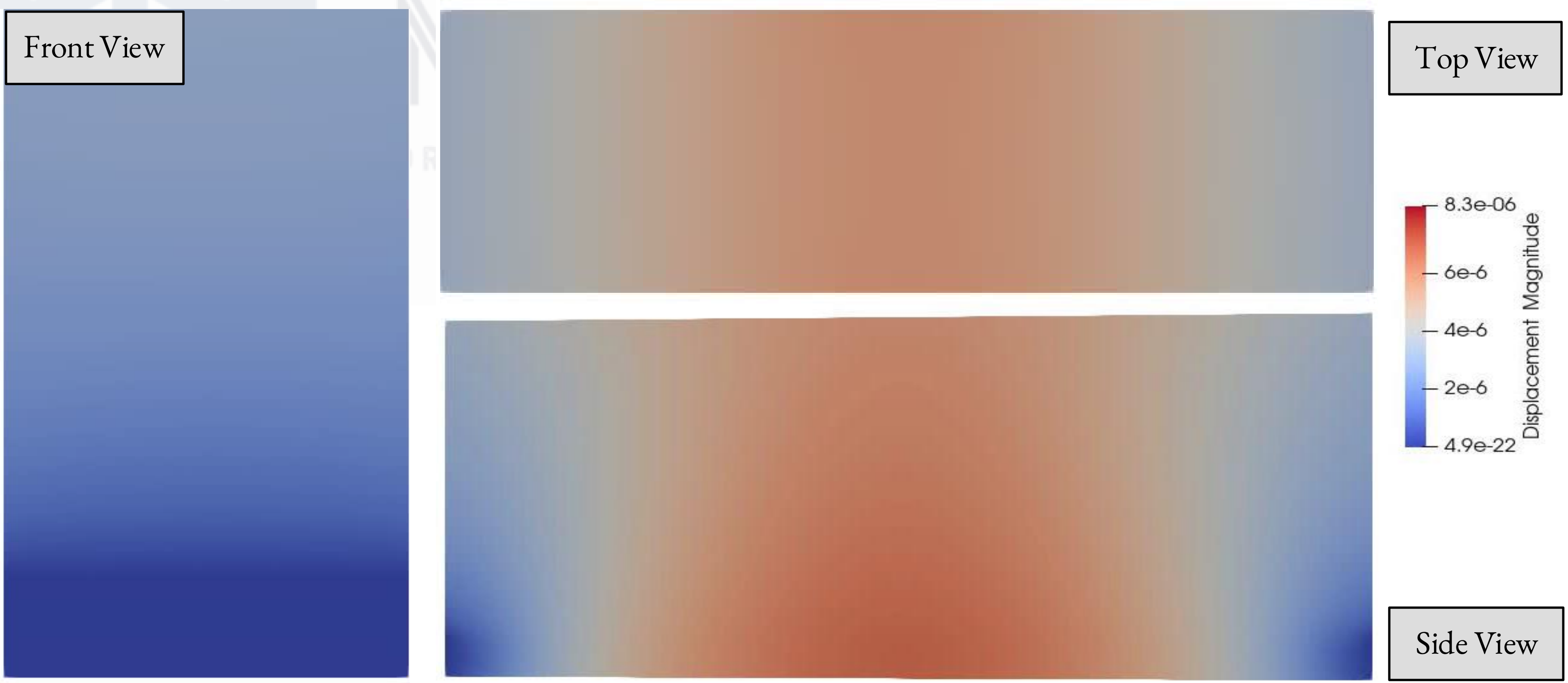
Approach

Step 3: Define Physics & Design Criteria



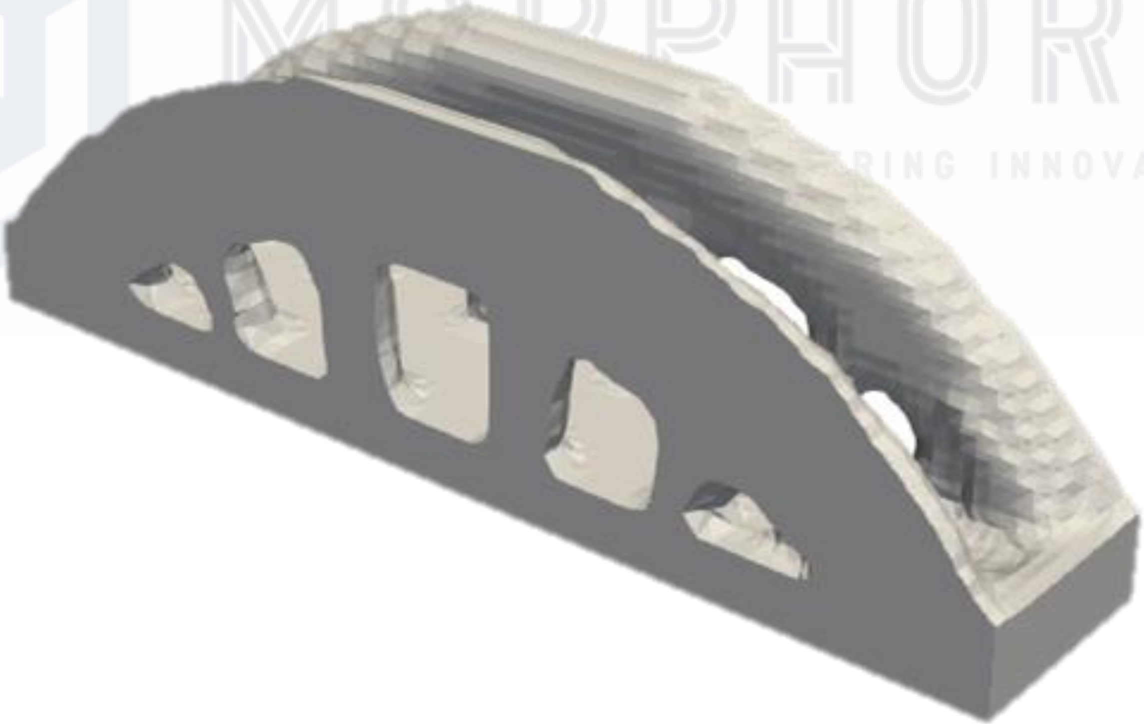
Approach

Step 4: Solve Simulation-Driven Design Optimization Problem



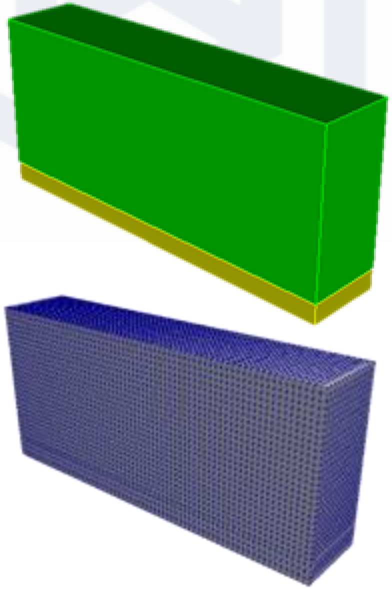
Approach

Step 5: Build Geometry Model

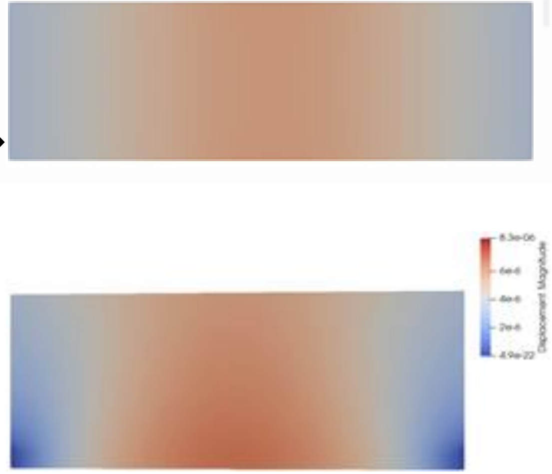


Workflow

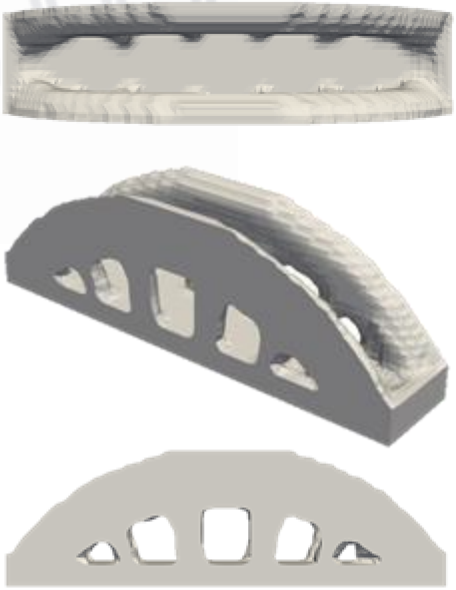
- Build Attributed Geometry
- Build Attributed Mesh Model
- Define Physics



- Solve SD2O Problem
  - Optimization Algorithm
  - Numerical Simulation

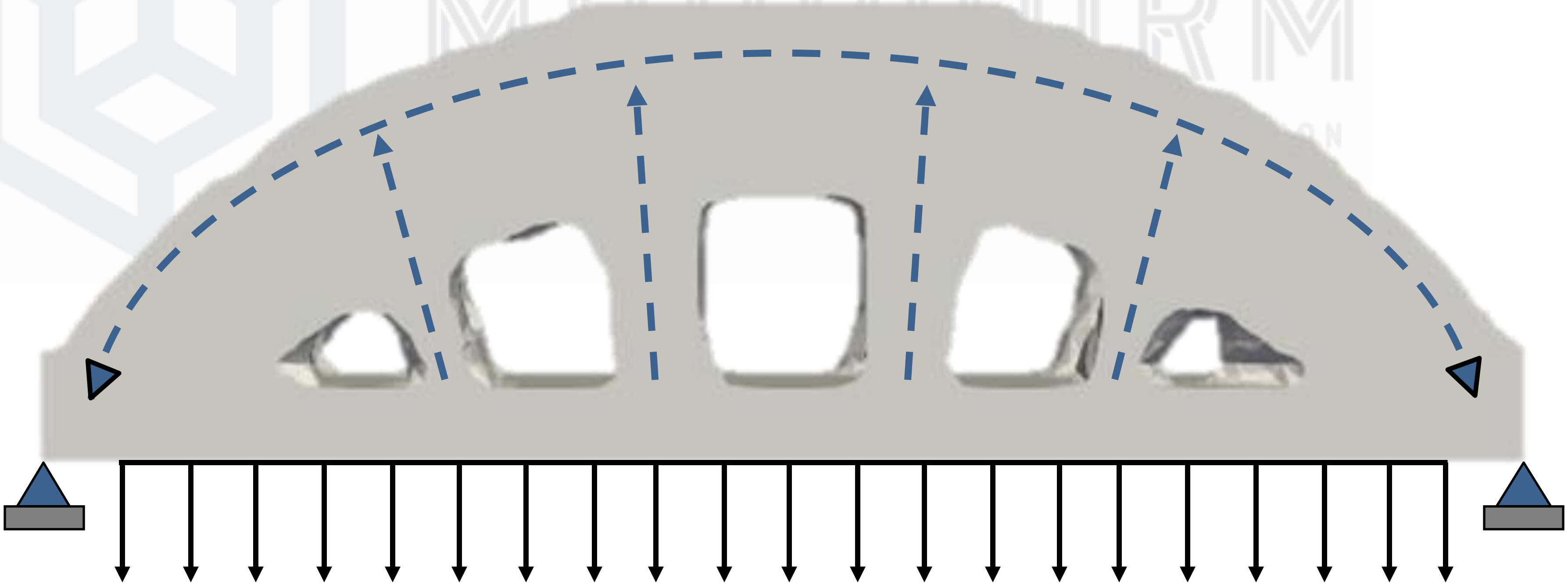


- Rebuild Geometry Model
  - Geometry Documentation
  - Shape Optimization



Additional Optimization

Simulation-Driven Design



Tied Arch Bridge

https://www.ib-miebach.de

Tied Arch Bridge

https://en.wikipedia.org

Tied Arch Bridge

https://en.wikipedia.org

Problem Formulation

Simulation-Driven Design

Problem Formulation

Find a structural design that ***maximizes*** structural rigidity and ***meets*** the mass budget requirement.

Optimization Problem Statement

$$\text{Design}^* = \arg \underset{\text{Design}}{\text{maximize}} \ \text{Structural Stiffness}$$

$$\text{subject to}$$

$$\text{Governing Equations Are Satisfied}$$

$$\text{Structural Mass - Mass Requirement} \leq 0$$

Problem Formulation

Find a structural design that *maximizes* structural rigidity and *meets* the mass budget requirement.

Optimization Problem Statement

$$\text{Design}^* = \arg \underset{\text{Design}}{\text{minimize}} \ \frac{1}{2}\mathbf{u}^{\mathbf{T}}(\text{Design})\mathbf{f}$$

subject to

$$\mathbf{R}(\mathbf{u}(\text{Design}), \text{Design}) = \mathbf{K}(\text{Design})\mathbf{u} - \mathbf{f} = \mathbf{0}$$

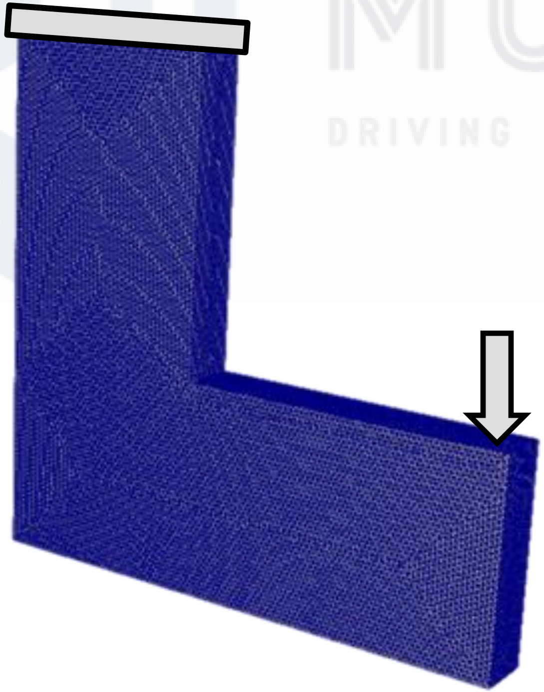
$$\mathbf{G}(\text{Design}) = \text{Mass}(\text{Design}) \text{ - } \text{Mass Req.} \leq \mathbf{0}$$

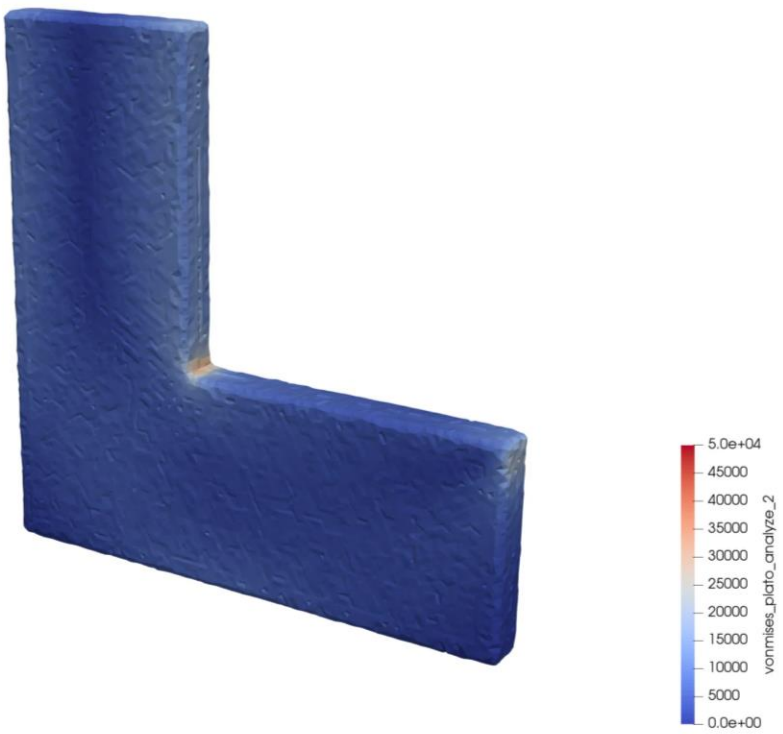
Design Requirements

Simulation-Driven Design

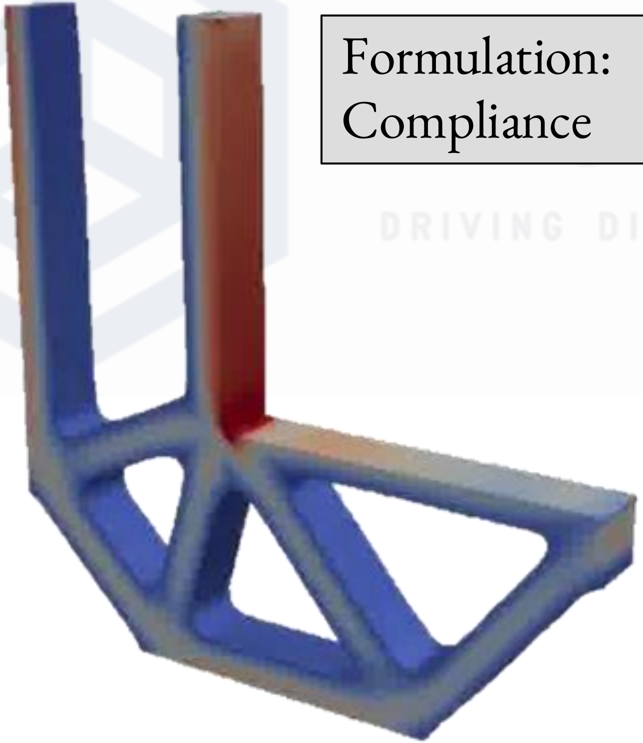
Enforce Local Design Requirements

Minimize Mass & Constraint Local Von Mises Stress





Will the Problem Formulation Impact Results?



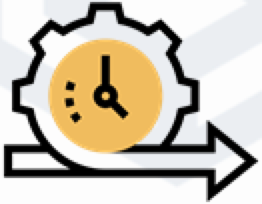
Formulation:
Compliance

Formulation:
Stress Constrained

Opportunity

Simulation-Driven Design

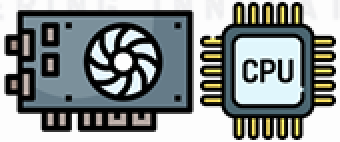
Trends



AGILE ENTERPRISE

3D PRINTING

CLOUD COMPUTING

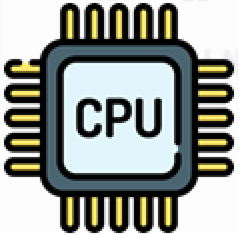


HETEROGENOUS COMPUTING

ARTIFICIAL INTELLIGENCE

Opportunity

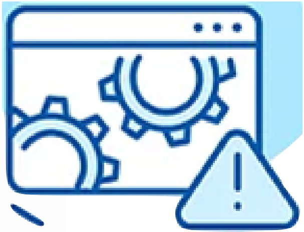
LEGACY SOFTWARE



HOMOGENEOUS COMPUTING

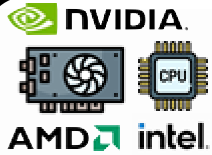
SLOW SOFTWARE

SIMPLE SOLUTIONS

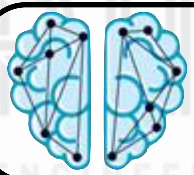


UNRELIABLE DESIGNS

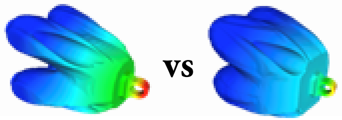
PROPOSAL



HARDWARE ABSTRACTION

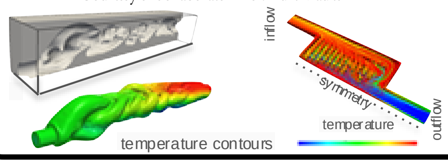


INTELLIGENT DESIGN TOOL

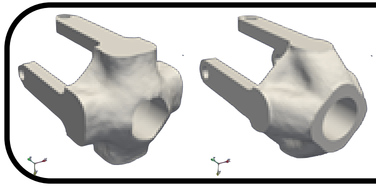


REAL-TIME DISCOVERY

Courtesy of collaborator Prof. Kurt Maute



MULTI-PHYSICS EXPLORATION



BUILT-IN RELIABILITY

Thank You

Simulation-Driven Design

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