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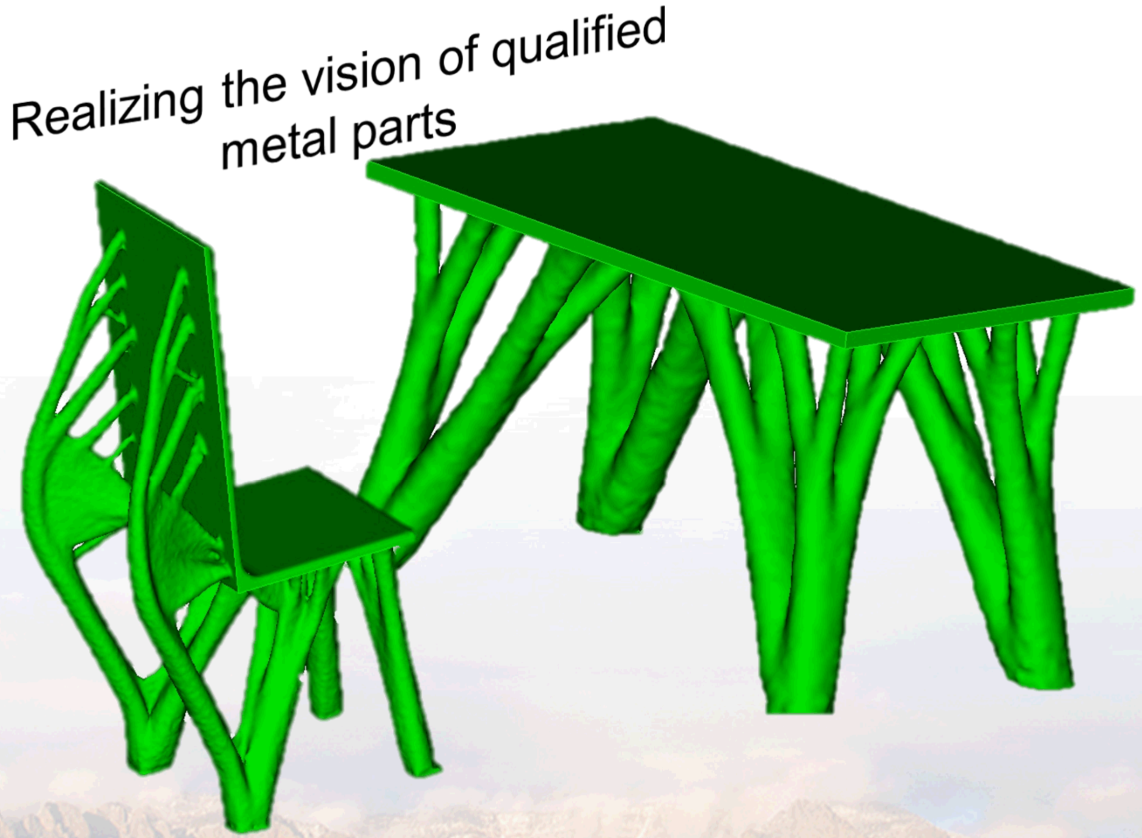
The Simulation Side of Additive Manufacturing

Ted Blacker
Simulation Modeling Sciences Department
5 June 2014
Additive IMOG Mtg



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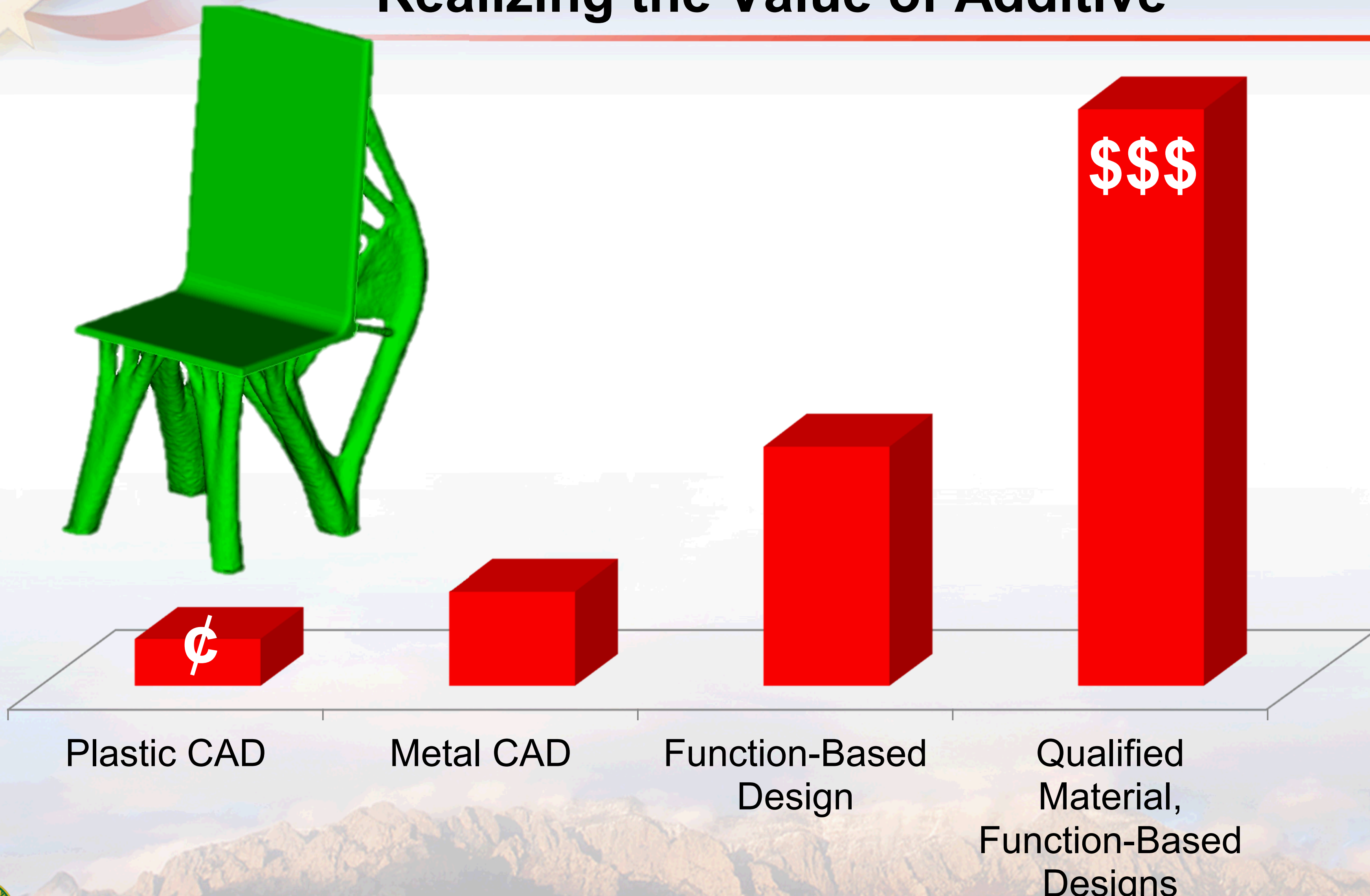
Realizing the Value of Additive



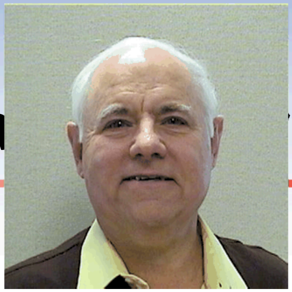
SNL Additive Manufacturing Strategic Plan

Four Pillars or Thrust Areas

- Identify Compelling Applications
- Provide Design / Analysis Tools
- Provide Material Assurance
- Enable Product Realization

Vision:

We will deliver innovative national security products – impossible to create with traditional technologies – by exploiting the revolutionary potential of Additive Manufacturing.

SNL Additive Ma  ing Strategic Plan

Mark Smith

Four Pillars or Thrust Areas

Andre Claudet
Identify Compelling Applications

Ted Blacker
Provide Design / Analysis Tools

Bradley Jared
Provide Material Assurance

Larry Carrillo
Enable Product Realization

Vision:

We will deliver innovative
security products –
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potential of Additive
Manufacturing.

Modeling & Simulation Areas of Investment

1. Functional Design

- Topology Optimization
- Optimization Design Environment

2. Process Modeling

- Particle Distribution Analysis
- Melt Pool Mechanics
- Micro to Macro Material Properties

3. Process Planning

- Automated Process Plan
- Collision Avoidance

1. Functional Design

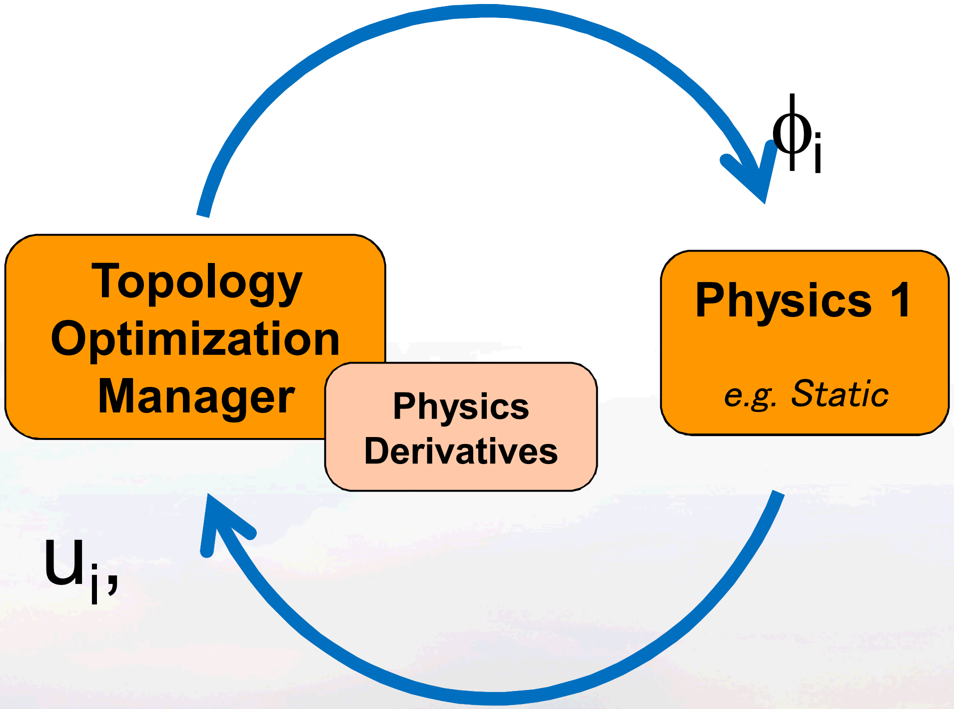
Enabling Functional Design

Topology Optimization

Design Validation Analysis

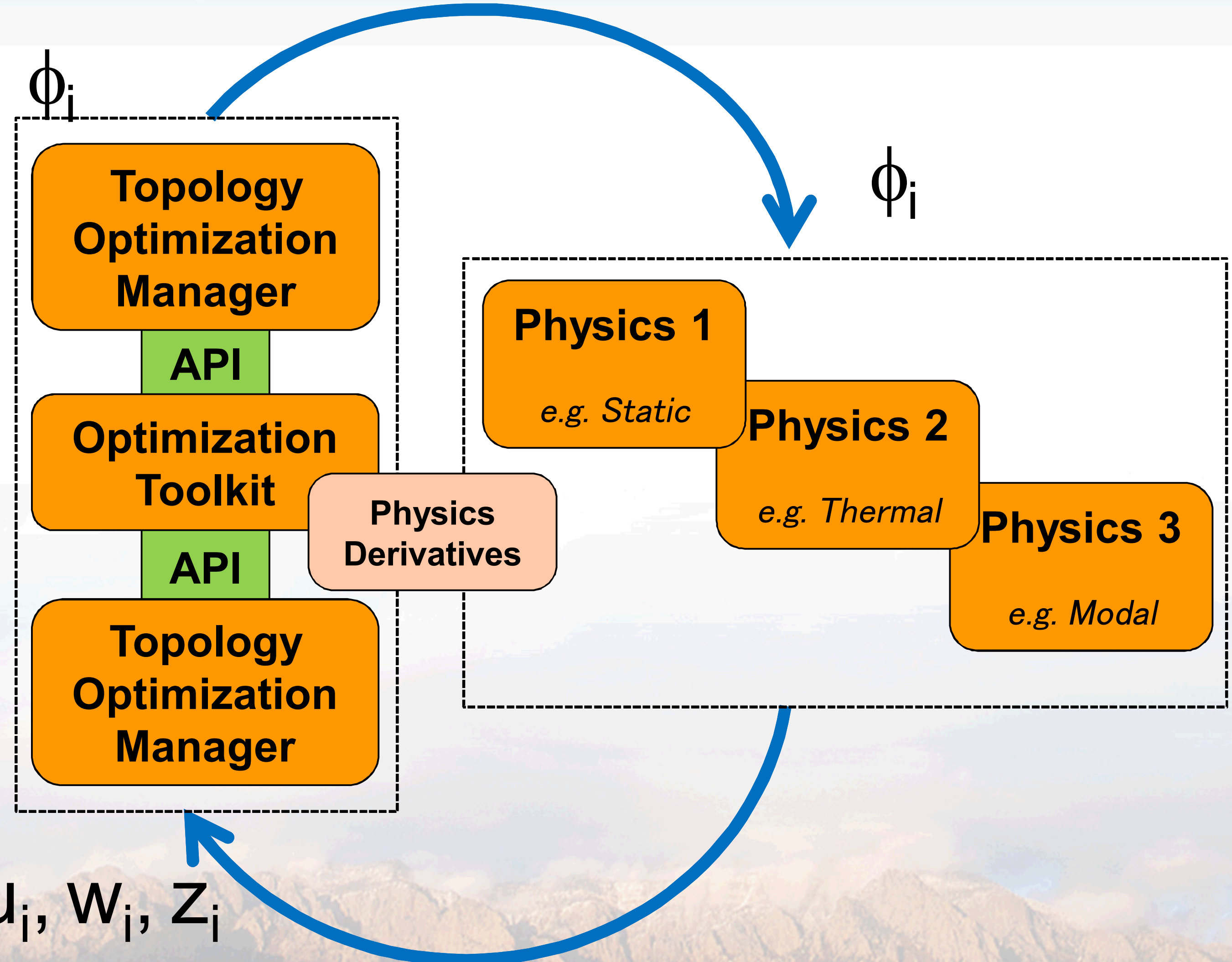
Topology Optimization

Single Physics
Inter-Twined Code



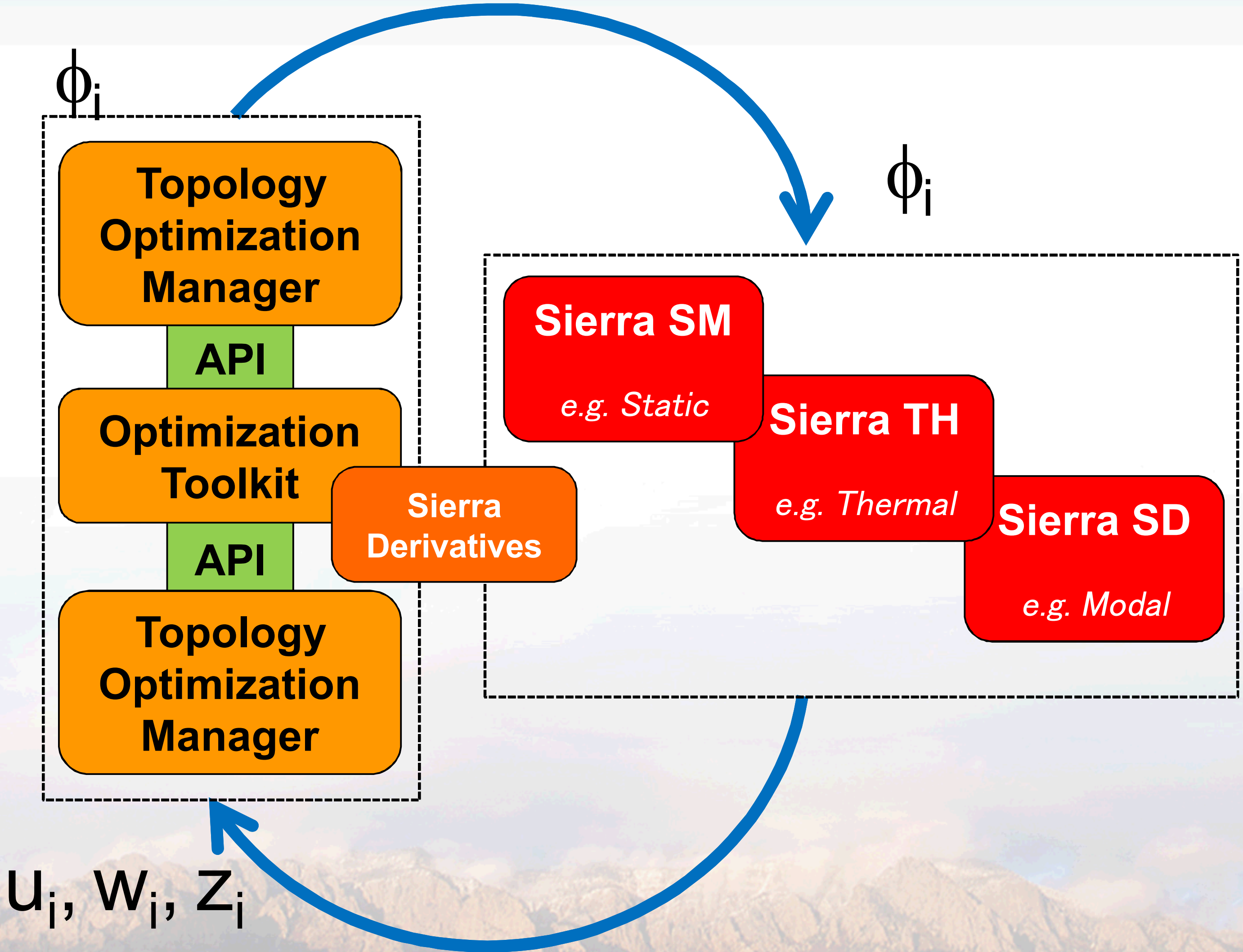
Topology Optimization

Multiple Physics Encapsulated Code



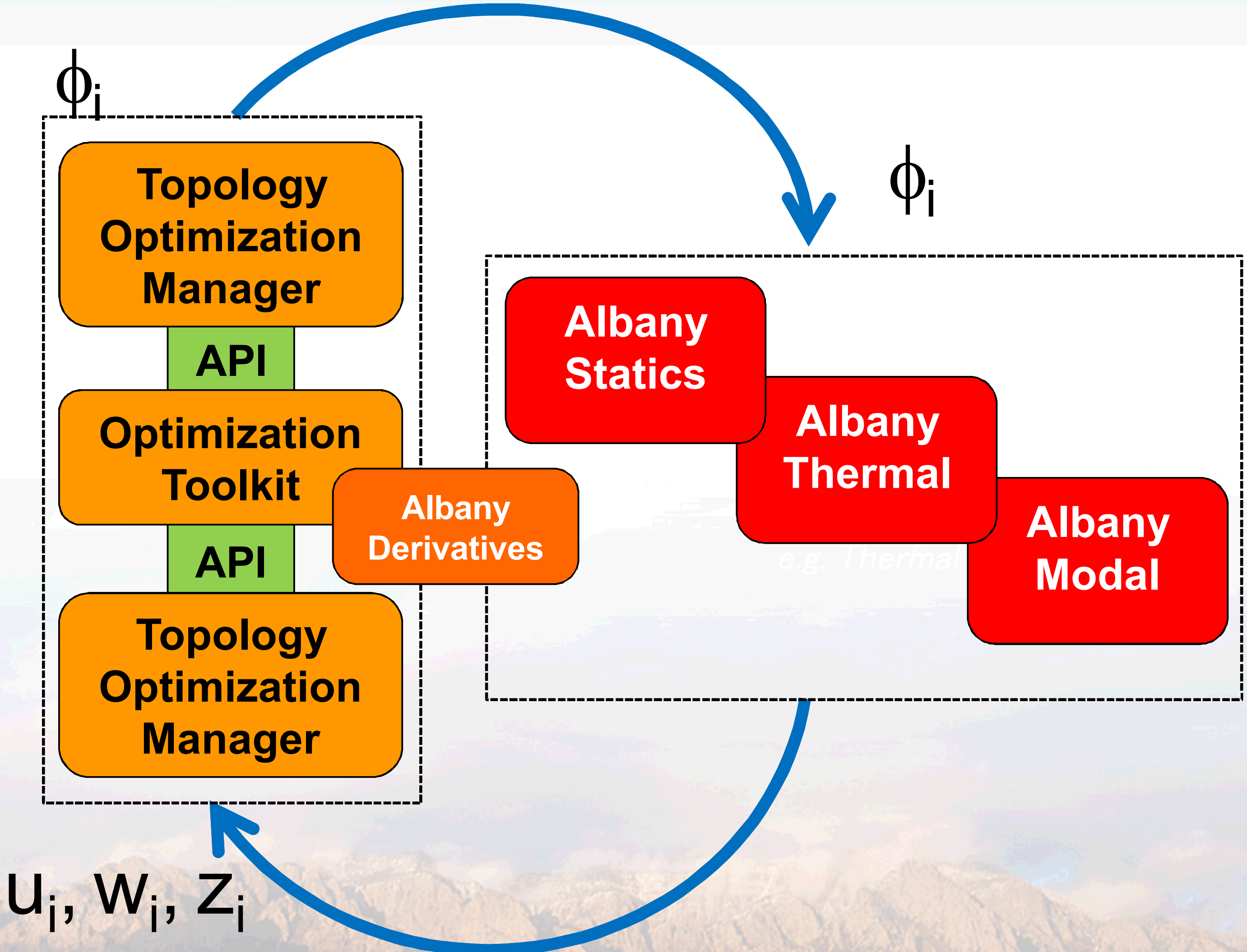
Topology Optimization

Sierra Example

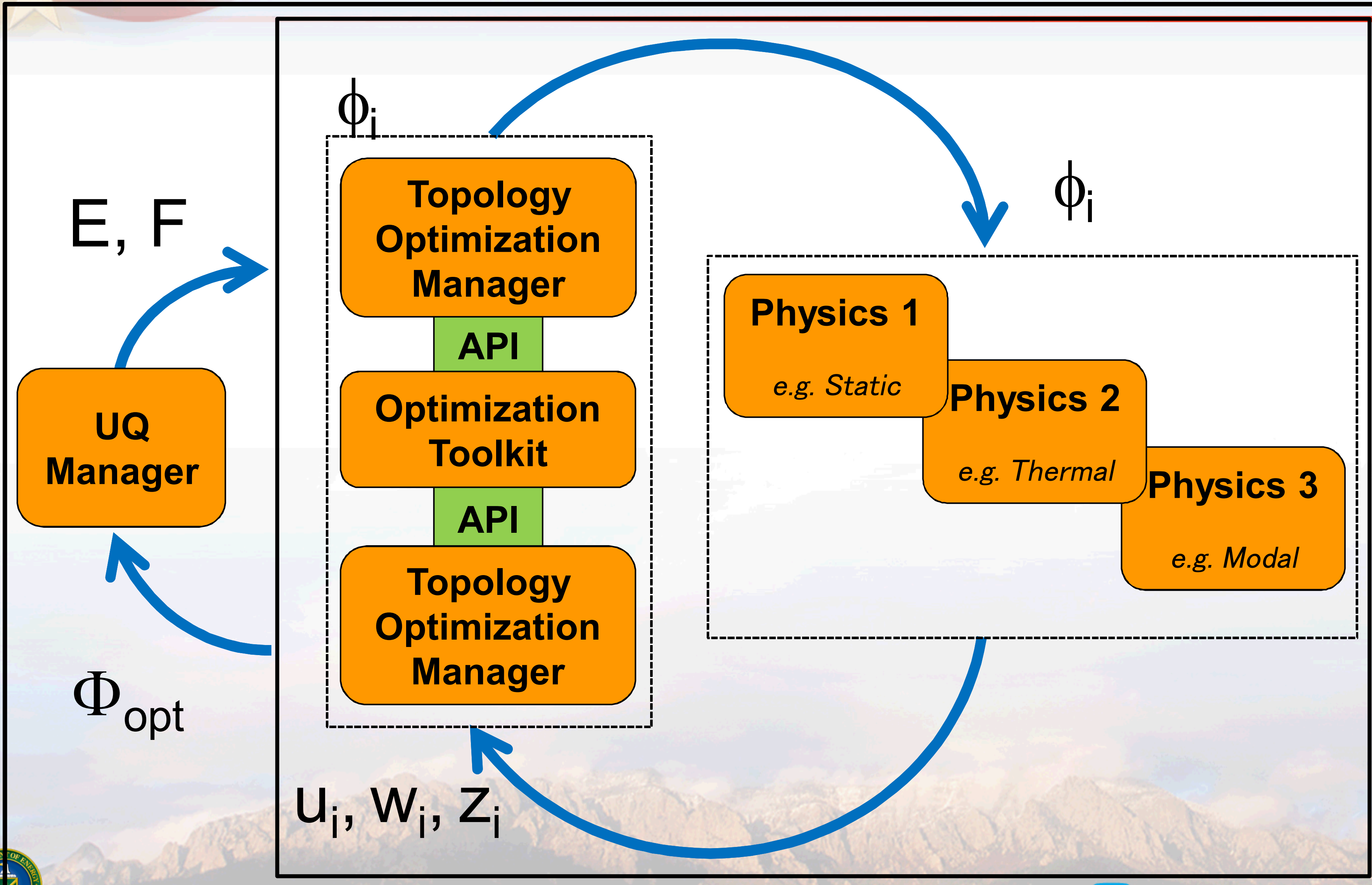


Topology Optimization

Albany Example



Topology Optimization



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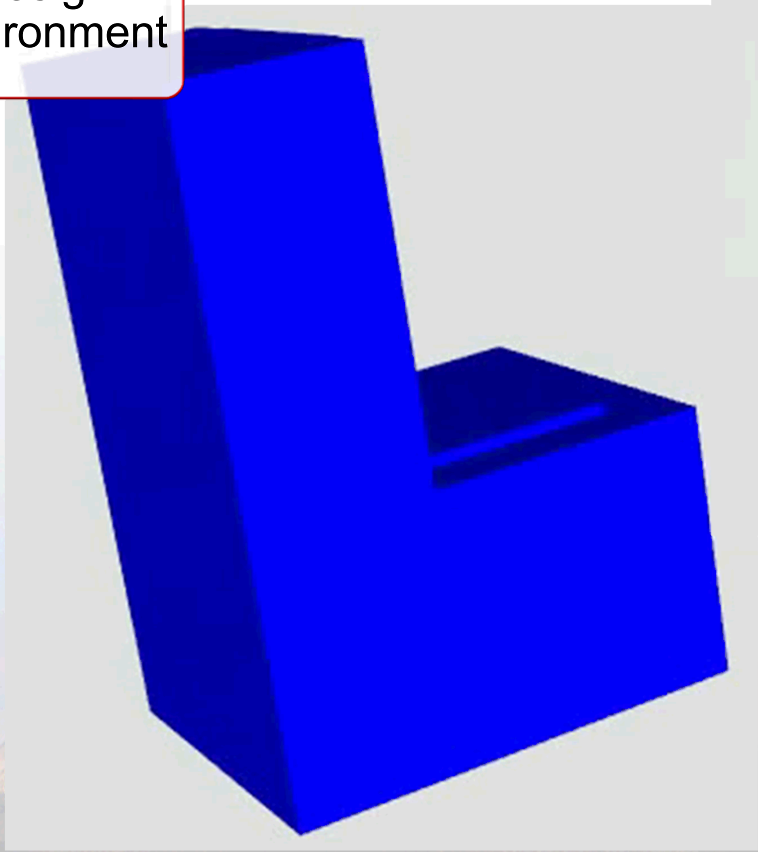
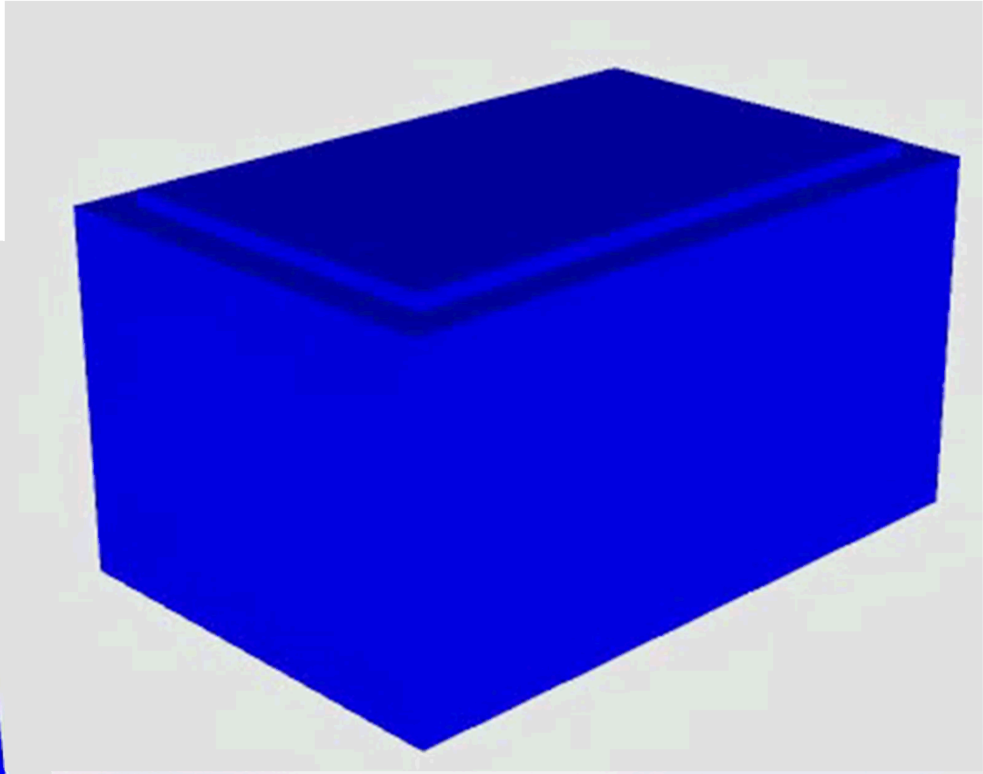
1. Functional Design

Topology Optimization

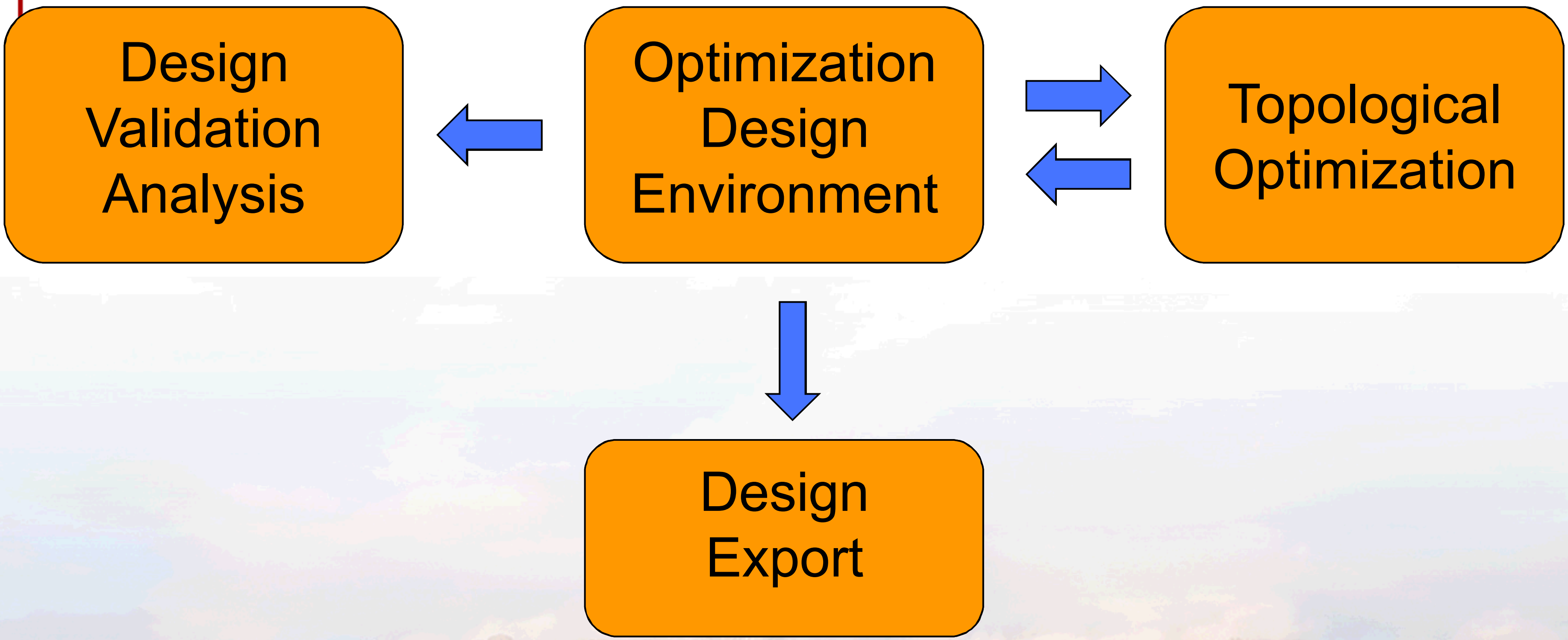
Topology Optimization

Design Environment





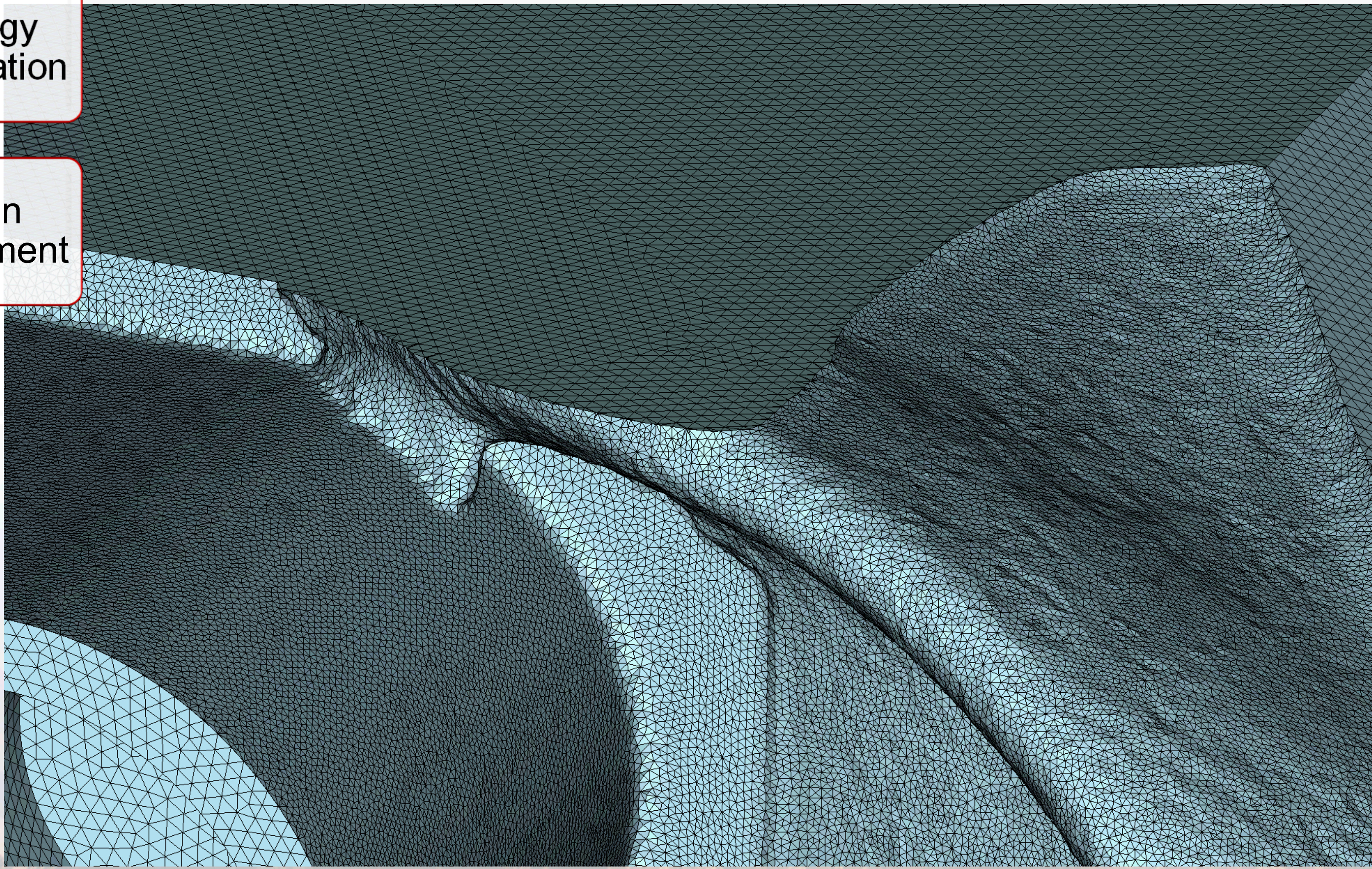
Exploring ODE (Opt. Design)



1. Functional Design

- Topology Optimization
- Design Environment

Topology Optimization Adoption Issues

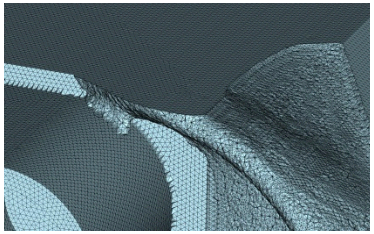


1. Functional Design

Topology Optimization Adoption Issues

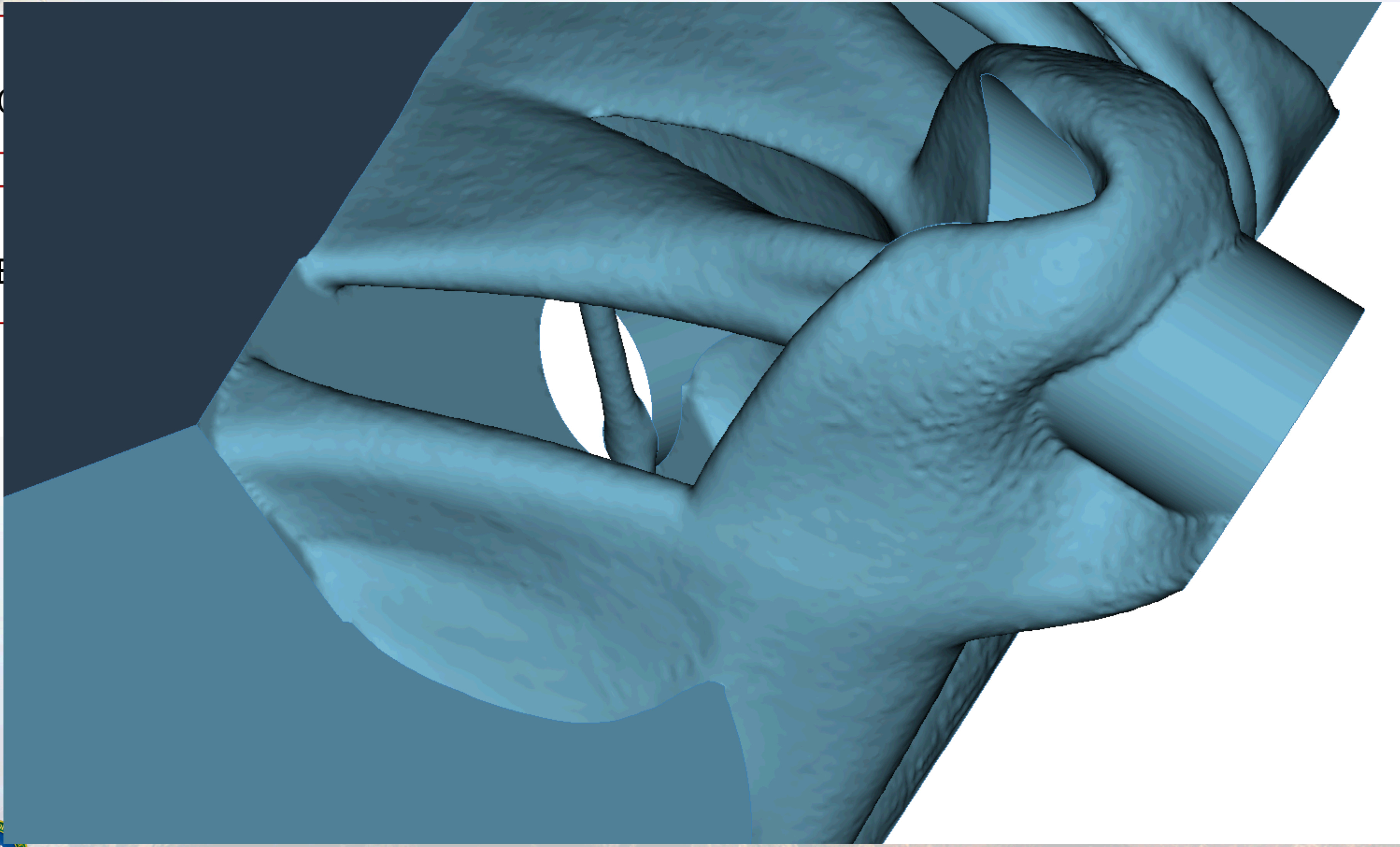
Topology Optimization

Design Environment



Facet Manipulations

Topology Optimization Adoption Issues

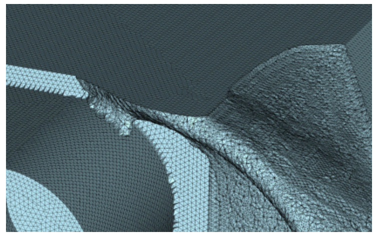


Topology Optimization Adoption Issues

1. Functional Design

- Topology Optimization
- Design Environment

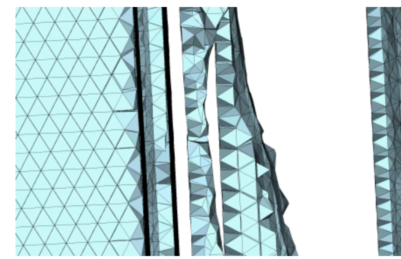
Conversion to CAD



Facet Cleanup

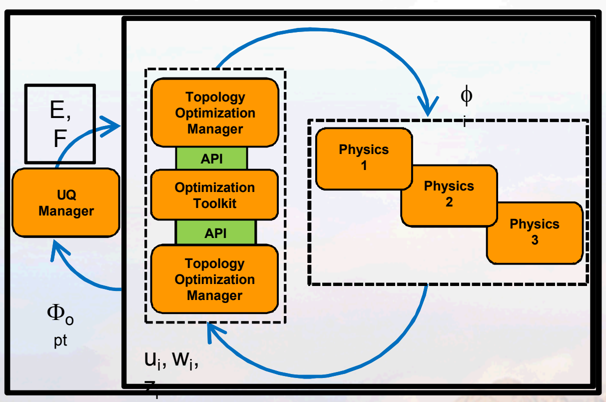
Sophisticated Design Control

Validation Meshing



Manual Intervention

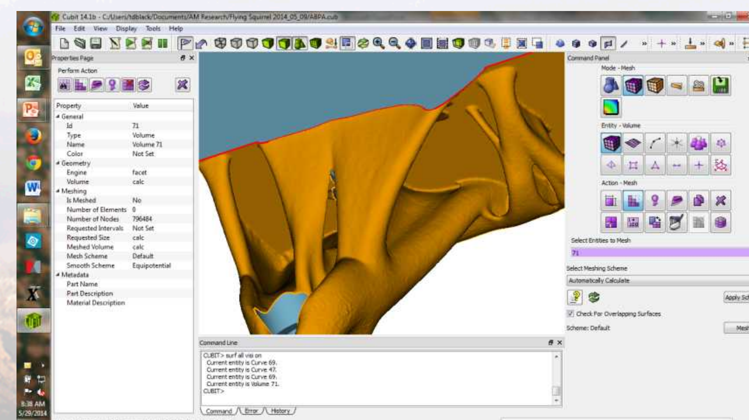
Expertise Intensity



Model Size

Computational Power

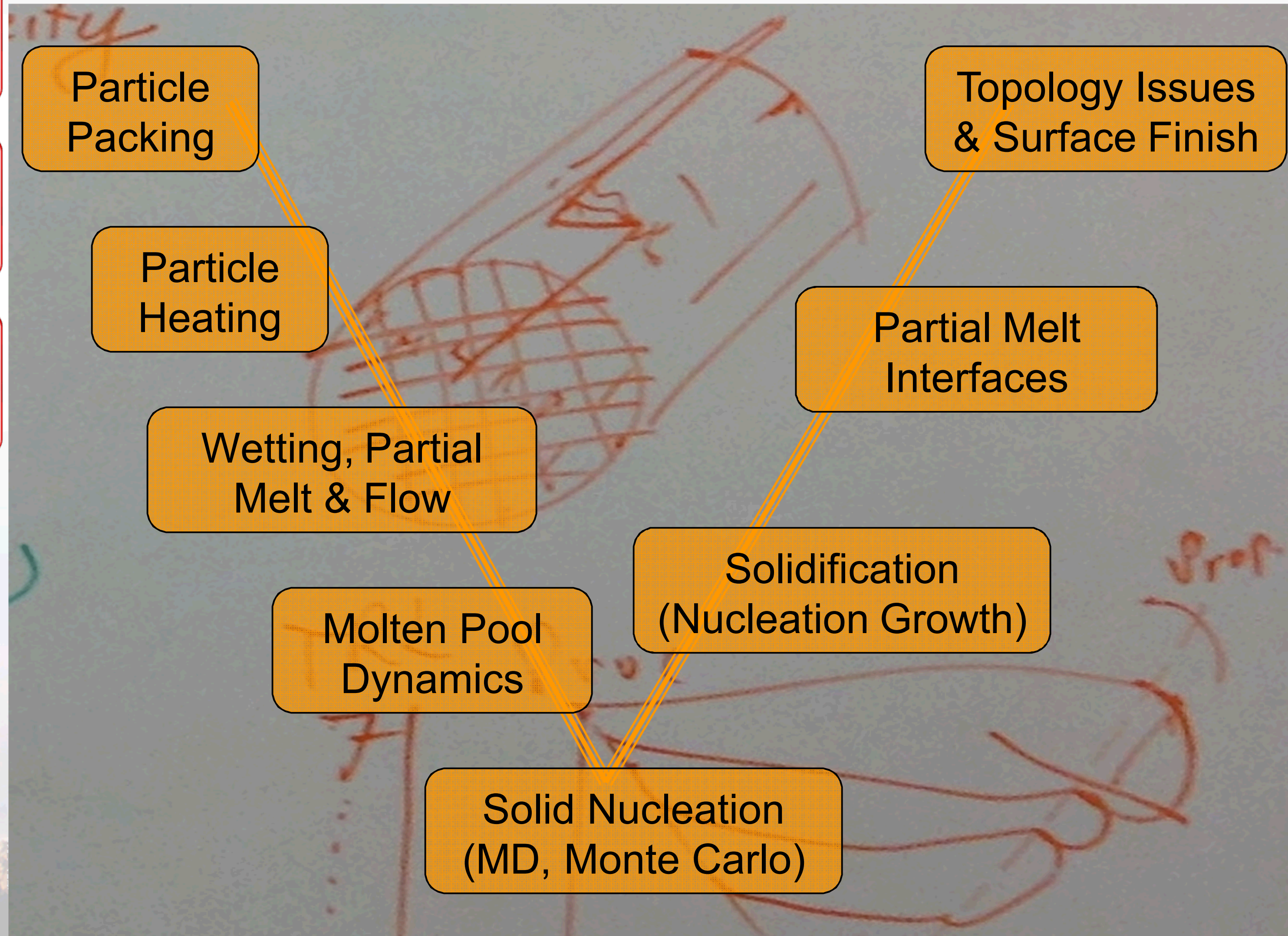
Usability Issues



2. Process Modeling

- Particle Distribution Analysis
- Melt Pool Mechanics
- Micro to Macro Material Properties

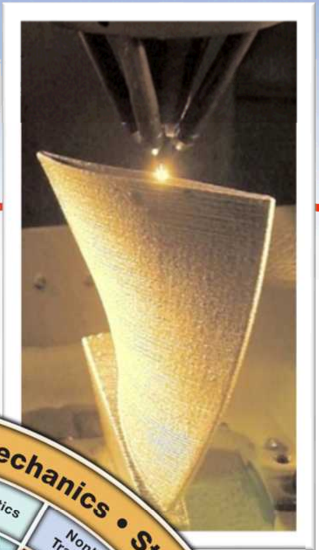
Process Modeling V Diagram

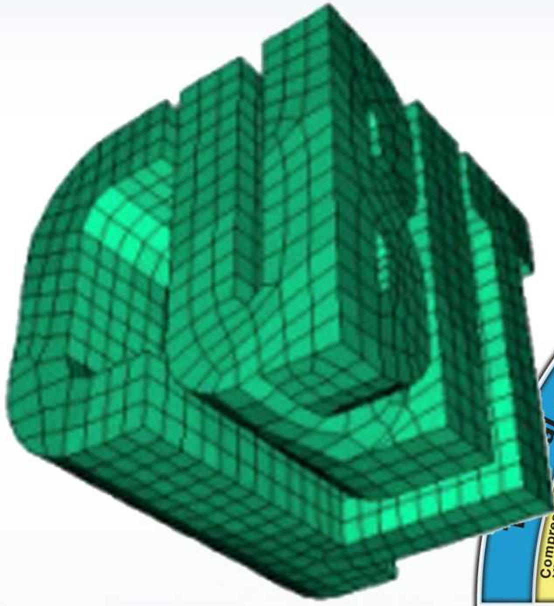


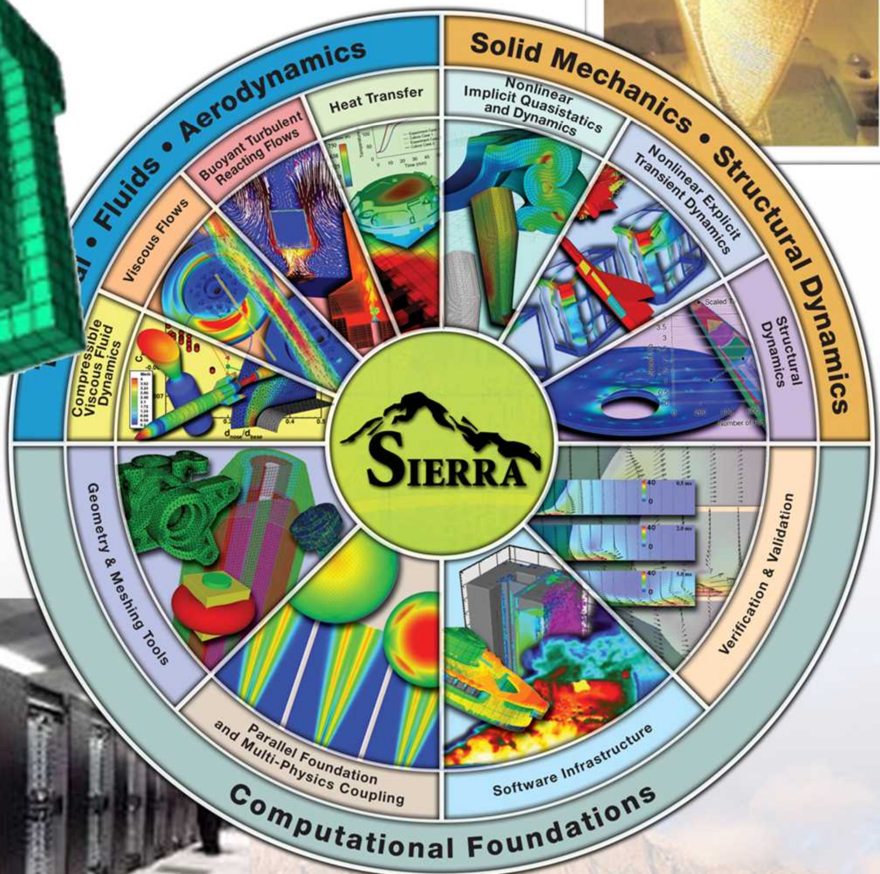
2. Process Modeling

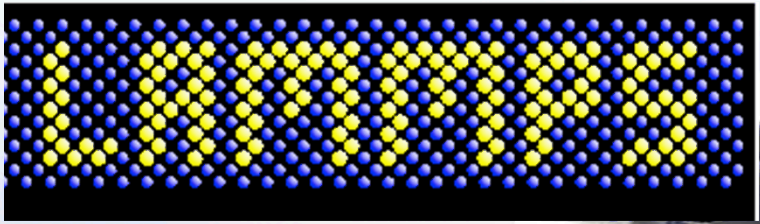
SNL Computational Tools

- Particle Distribution Analysis
- Melt Pool Mechanics
- Micro to Macro Material Properties







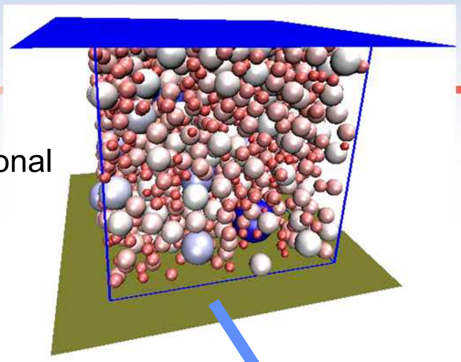


2. Process Modeling

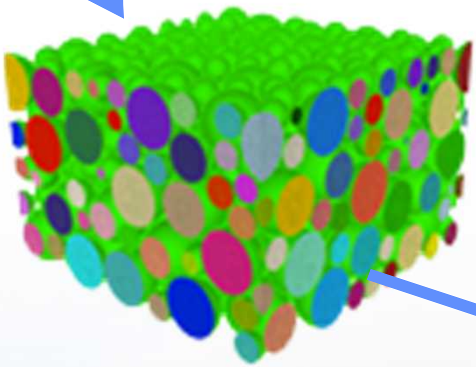
- Particle Distribution Analysis
- Melt Pool Mechanics
- Micro to Macro Material Properties

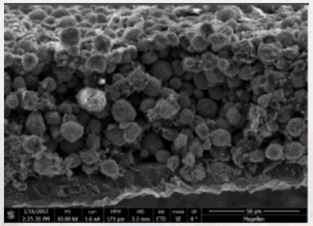
SNL Computational Tools

Computational µstructure generation

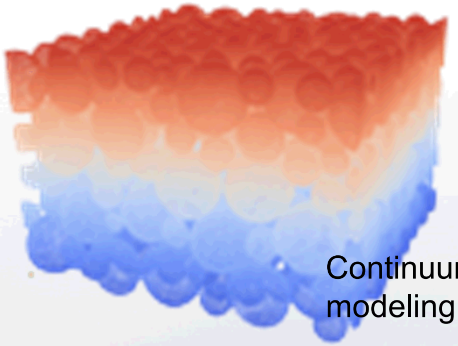


Meshing complex µstructure





Experimental microstructrue characterization

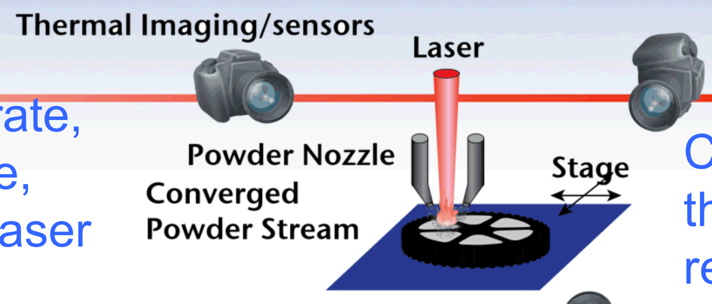


Continuum modeling

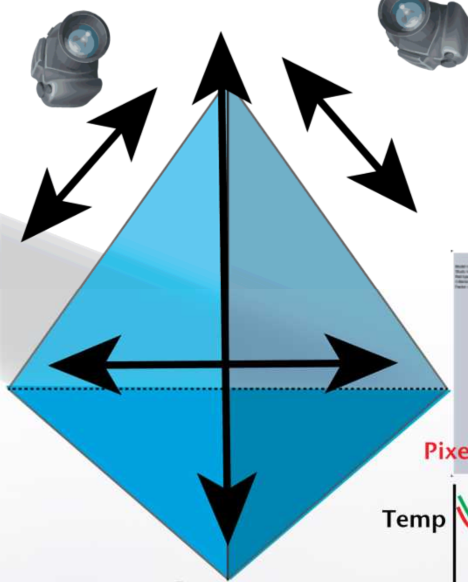
2. Process Modeling

- Particle Distribution Analysis
- Melt Pool Mechanics
- Micro to Macro Material Properties

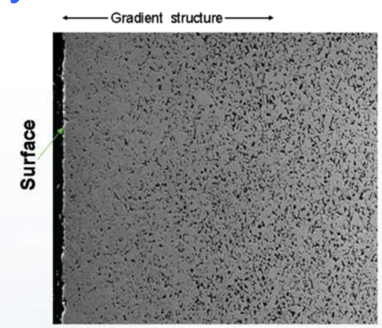
LENS Process
Powder feed rate, laser scan rate, powder size, laser energy,

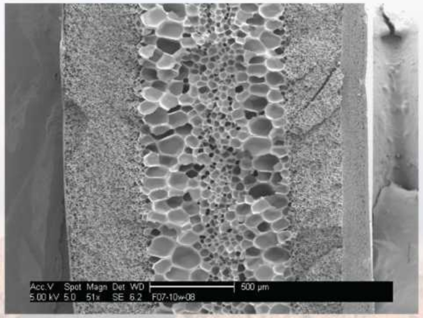


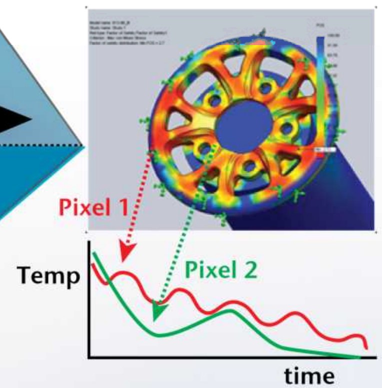
Complete thermal history reconstructed layer-by-layer from in situ thermal sensors



Microstructural Analysis







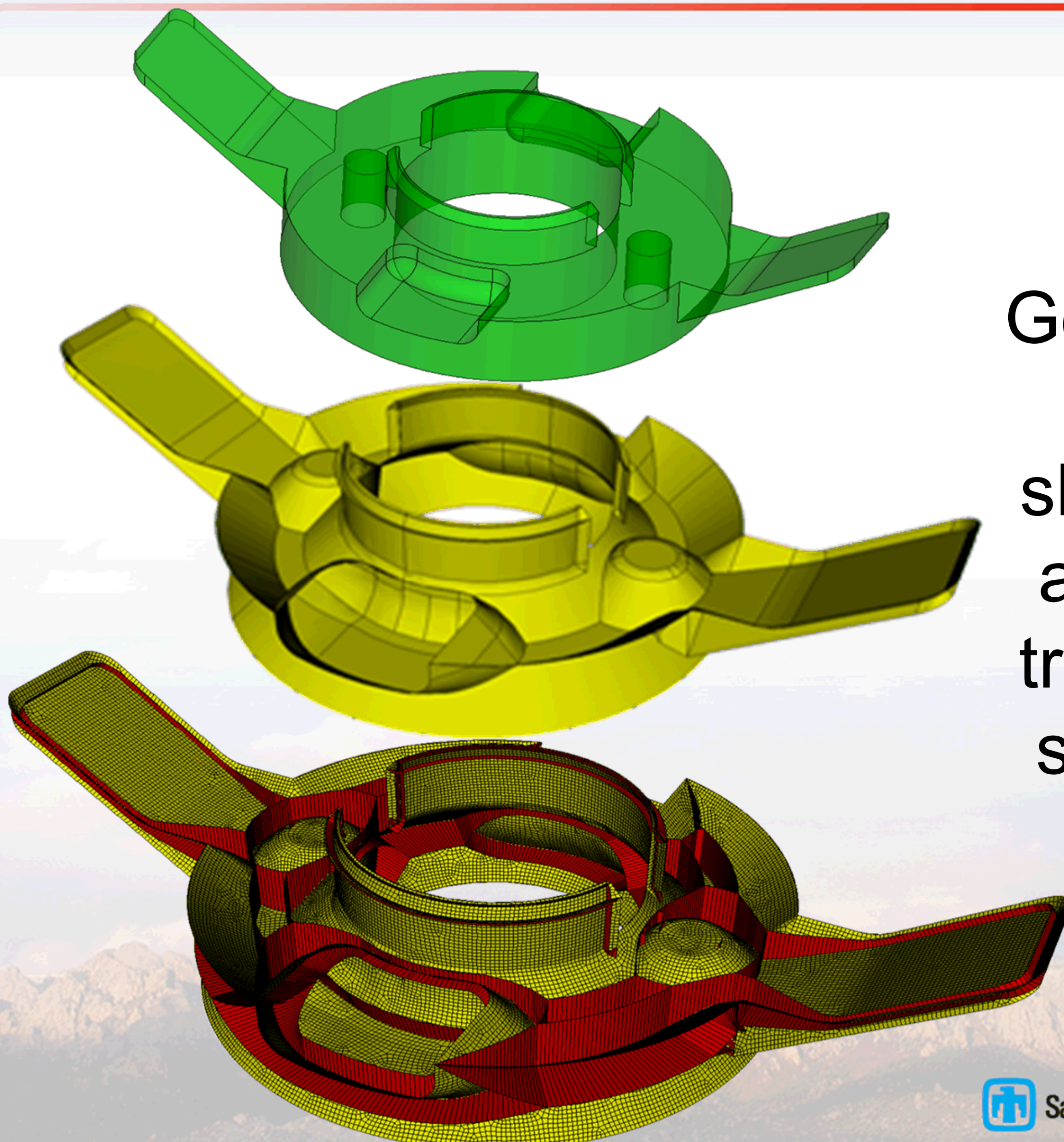
Property Prediction

http://weldracing.com/press/wp-content/uploads/2010/03/weld_tech_thermal_image_fig2.jpg
http://faculty.washington.edu/vkumar/microcel/images/processes/gradient.jpg
http://powder.metallurgy.utah.edu/research/research.php?page=FG%20WC-Co

Skeleton-Informed Full-DOF Direct Deposition Process Planning

3. Process Planning

- Automated Process Plan
- Collision Avoidance



Generate part skeleton and 3D tracks to surface

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3. Process Planning

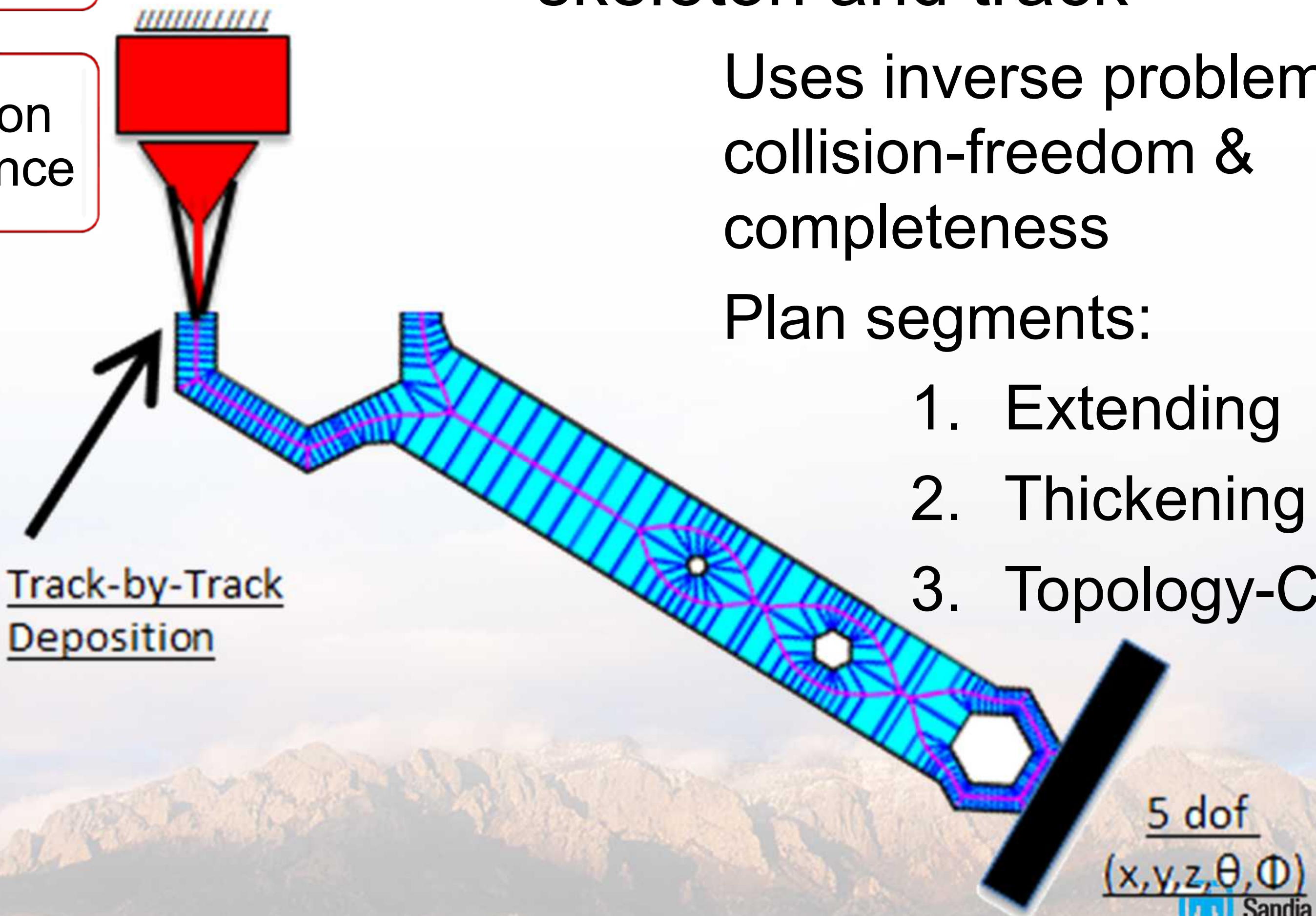
Skeleton-Informed Full-DOF Direct Deposition Process Planning

Automated Process Plan

Collision Avoidance

Planning algorithm informed by skeleton and track

- Uses inverse problem for collision-freedom & completeness
- Plan segments:
  1. Extending
  2. Thickening
  3. Topology-Changing



Questions and Discussions

- **1. Functional Design**
  - Topology Optimization
  - Design Environment
- **2. Process Modeling**
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