Efficient Simulation for Hybrid Overmolded Composite Lattice Structures: A Combined Implicit and Explicit FEA Approach

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Outline

- Rebar for Plastics® — Process Overview
- Key Terminologies
- Previous FEA Workflows
- JPanel – Multiscale Modeling Method
- JPanel Experimental Validation
- Case Study
- Summary

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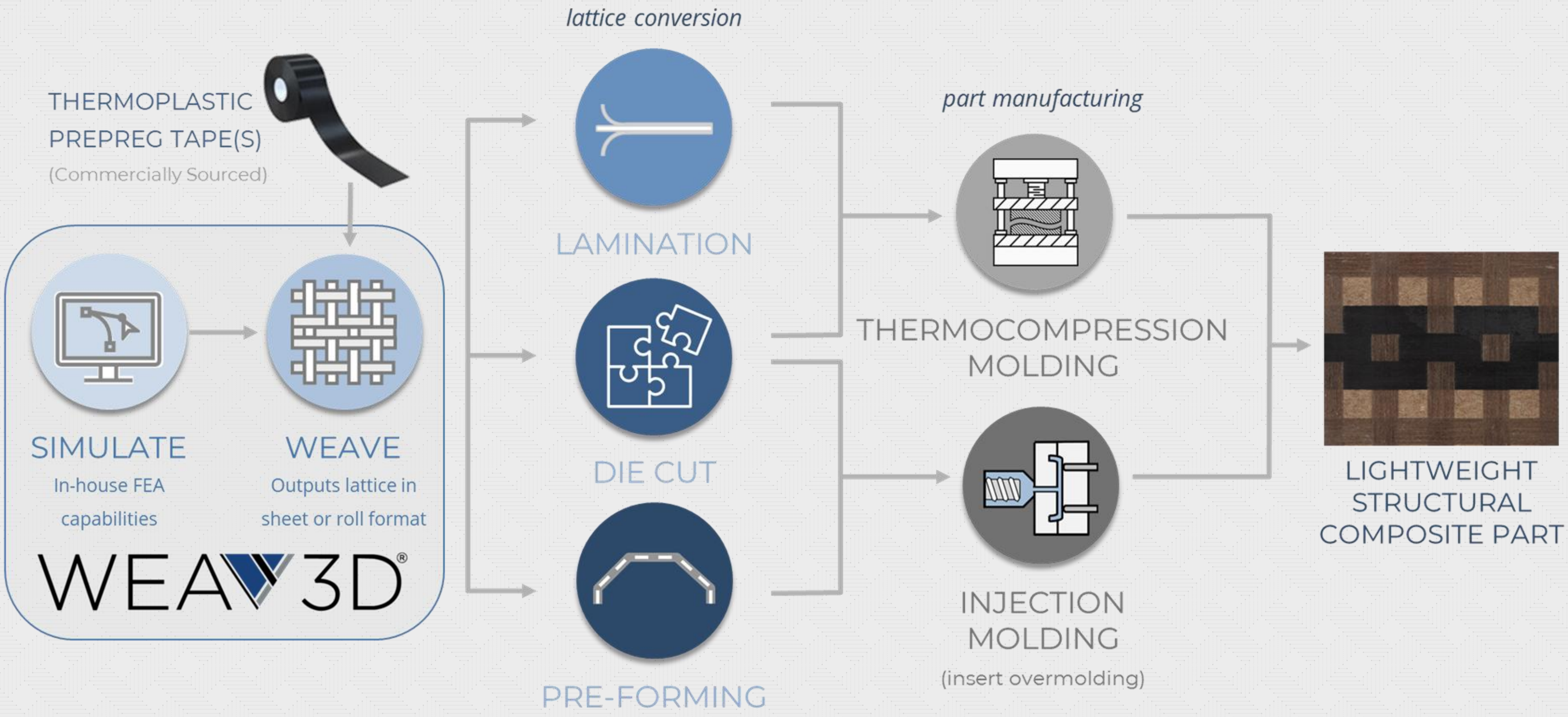
Rebar for Plastics® — Process Overview



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What is a Composite Lattice ?

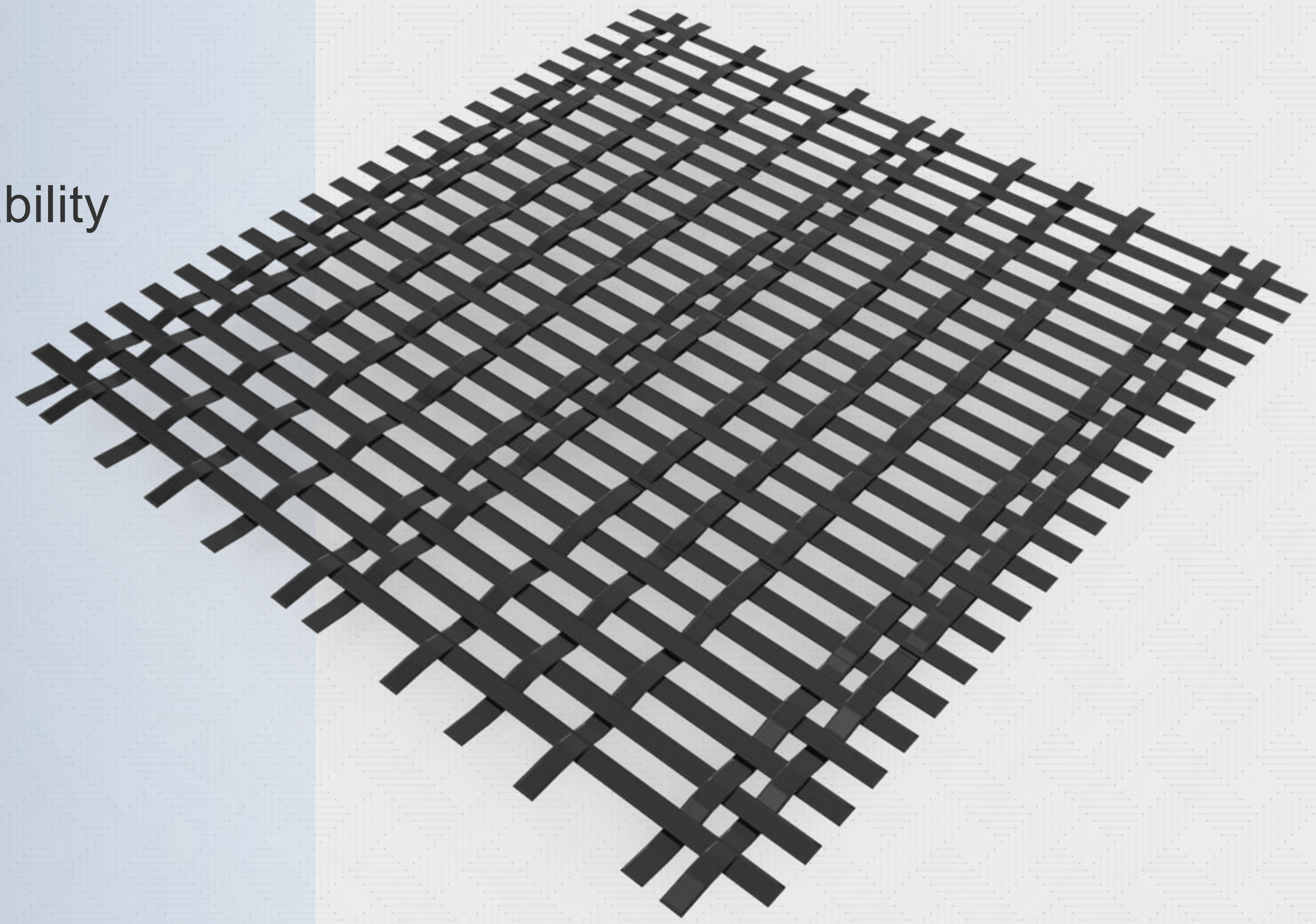
HANDLEABLE

- Made of UD prepreg tapes
- Woven and welded at interface for stability
- Sheet or roll format

TUNABLE

Locally optimized:

- Lattice density
- Tape material



Strategic use of UD tapes in lattice provides a cost-effective and adaptable solution

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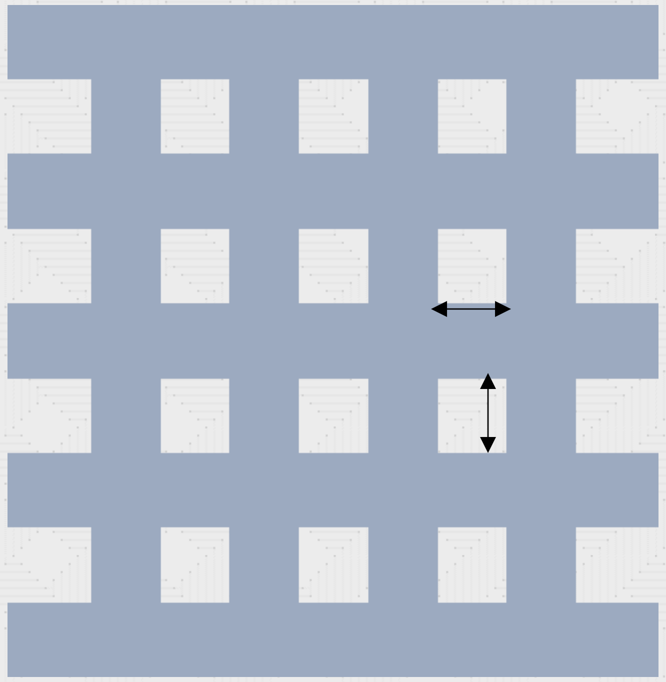
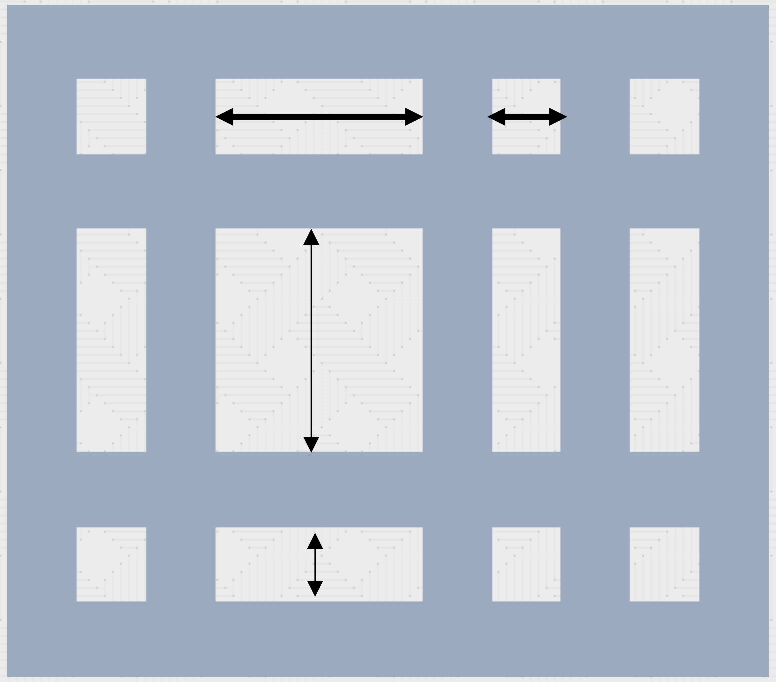
Key Terminologies

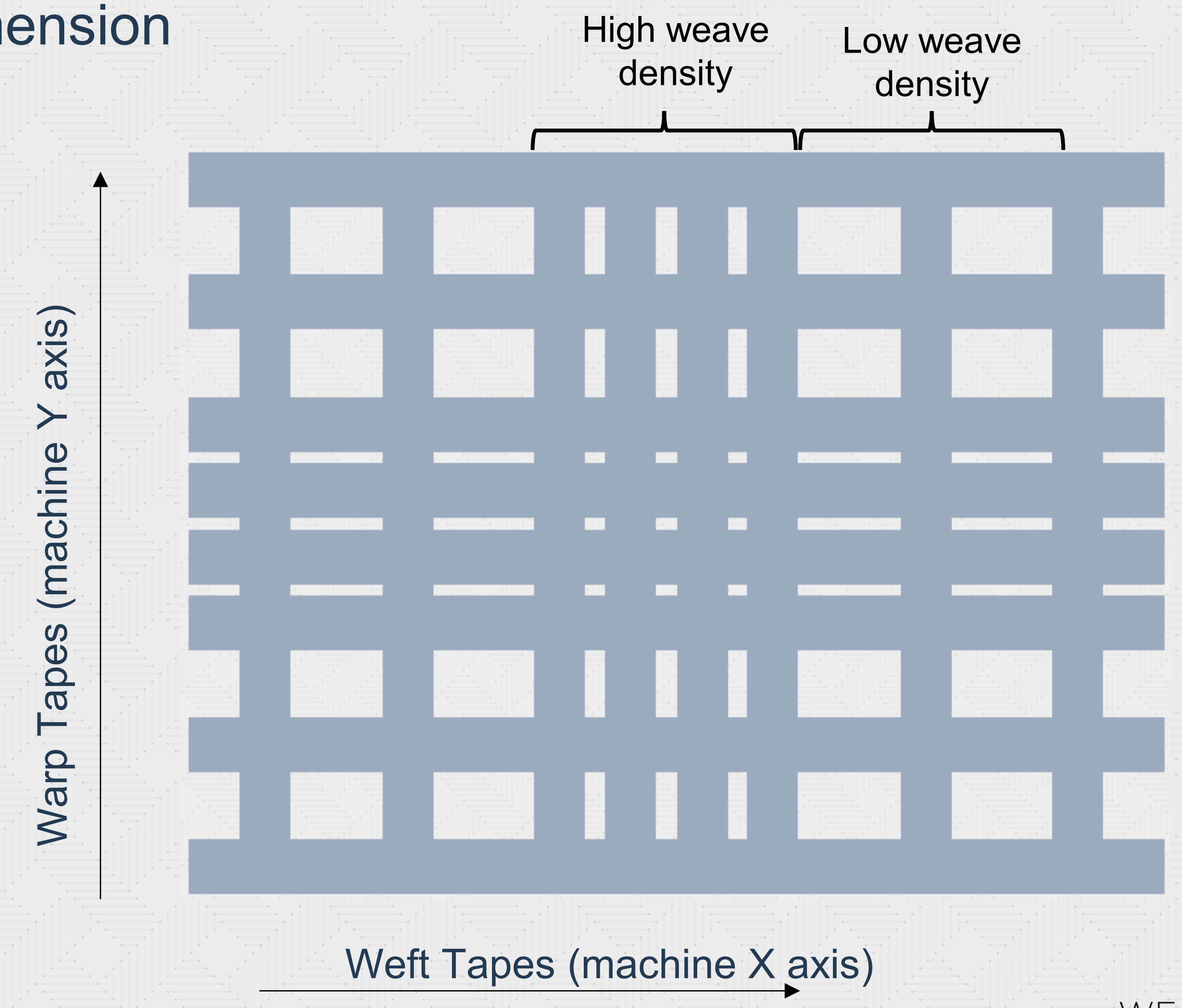
- **UD Tape:** a unidirectional fiber reinforced polymer tape / tow(1 in)
- **Homogenous lattice** : Centre to Centre tape (C-to-C) spacing between tapes and tape materials are constant throughout the part geometry
- **Heterogenous lattice** : C-to-C spacing between tapes and/or tape materials varies throughout the part geometry
- **Weave Density:** relative C-to-C spacing within lattice
- **Cover Factor:** % of the area covered by the tape material in a specified dimension



Homogenous Lattice Pattern



Heterogenous Lattice Pattern



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Previous Approach and Challenges

📌 *Limitations of Commercially Available FEA Tools for Composites*

- Optimized for ply-based models (fiber type, orientation, etc.)
- Can't fully capture lattice-reinforced hybrid complexity

🛠 *Our Solution: Tailored FEA Workflows for Lattice Reinforced Hybrid Structures*

To bridge these gaps, we developed custom workflows over time—each balancing trade-offs in accuracy, scalability, and setup effort:

2021 ——▶ 2022 ——▶ 2024

ANSYS RVE Method → Altair Explicit Method → JPanel (Multiscale) Method

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ANSYS RVE Method – FEA Workflow

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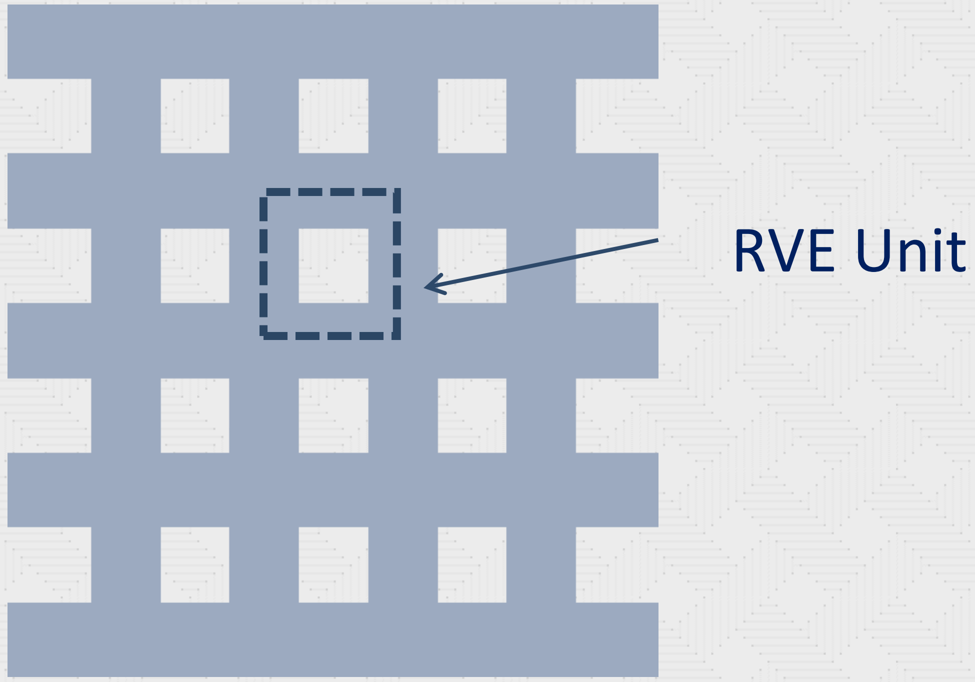
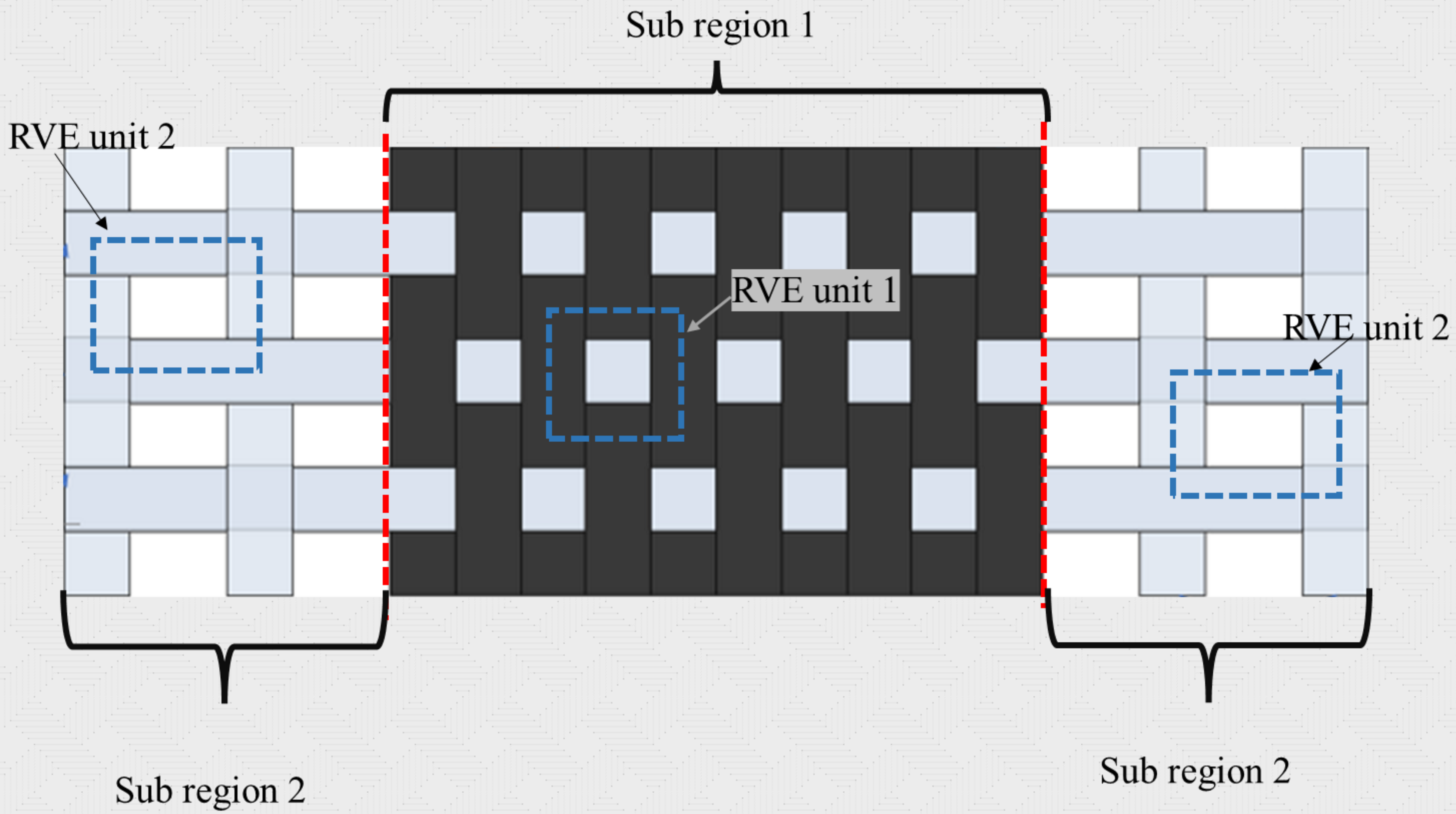
Representative Volume Elements (RVEs)



RVE in Homogenous Lattice Design



RVE in Heterogenous Lattice

A RVE is defined as the smallest volume element of a material with a very accurate statistical representation of the typical material properties used in a full scale/macroscale model.

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ANSYS RVE WORKFLOW

Develop
Representative Volume Element in ANSYS Material Designer

Build
3D Shell Part in ANSYS ACP

Solve
FEA

Identify
Critical Stress Regions

Submodel
Distinguish stresses in UD tapes and overmolded plastic

ANSYS FEA Workflow

- Limitations :
- Labor-intensive
- Submodeling complexity makes it impractical for rapid design exploration

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Altair Explicit Method - FEA Workflow

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Altair Explicit Method Workflow

Develop Explicit Model Script

- Input Text File
- Meshed shell geometry With local coordinates

Generate

3D Shell Part with tows in HyperWorks using the text file

Solve

FEA

Post Process

- Deformation Results
- Stresses in tows and plastic

Altair FEA Workflow Overview

Limitations :

- For large models' manual input of each tow's properties/position is labor-intensive
- Large/curved/sharp parts led to failure tow generation

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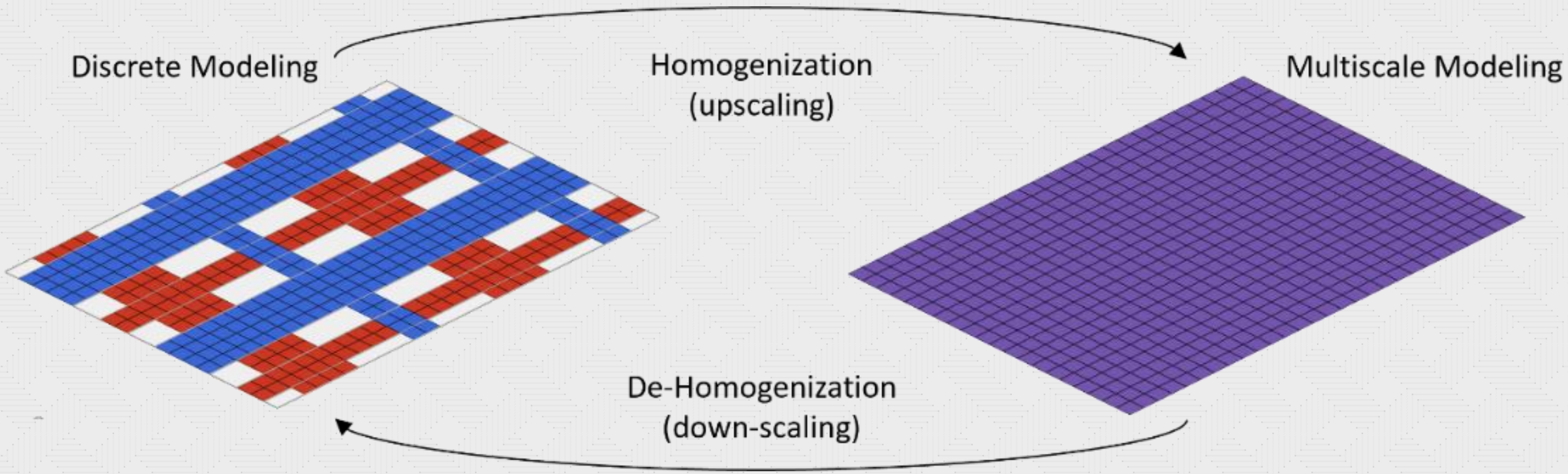
JPanel – Multiscale Modeling Method

- Built into the Altair HyperWorks framework
- Based on Phase Average Modified Lamination Theory

Performs:

- Pre-processing: Homogenizes lattice structures for fast global stiffness
- Post-processing: De-homogenizes global results back to tape-level stresses



*Cannot handle mixed element types (shells + solids/beams) in current form

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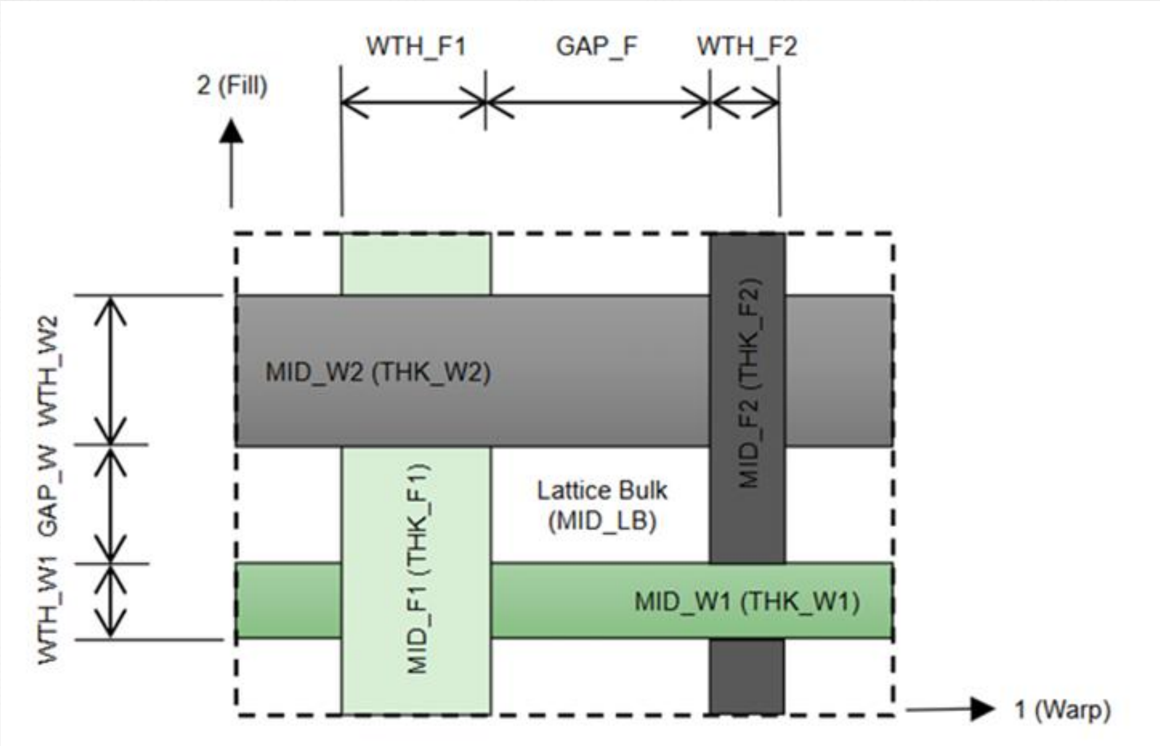
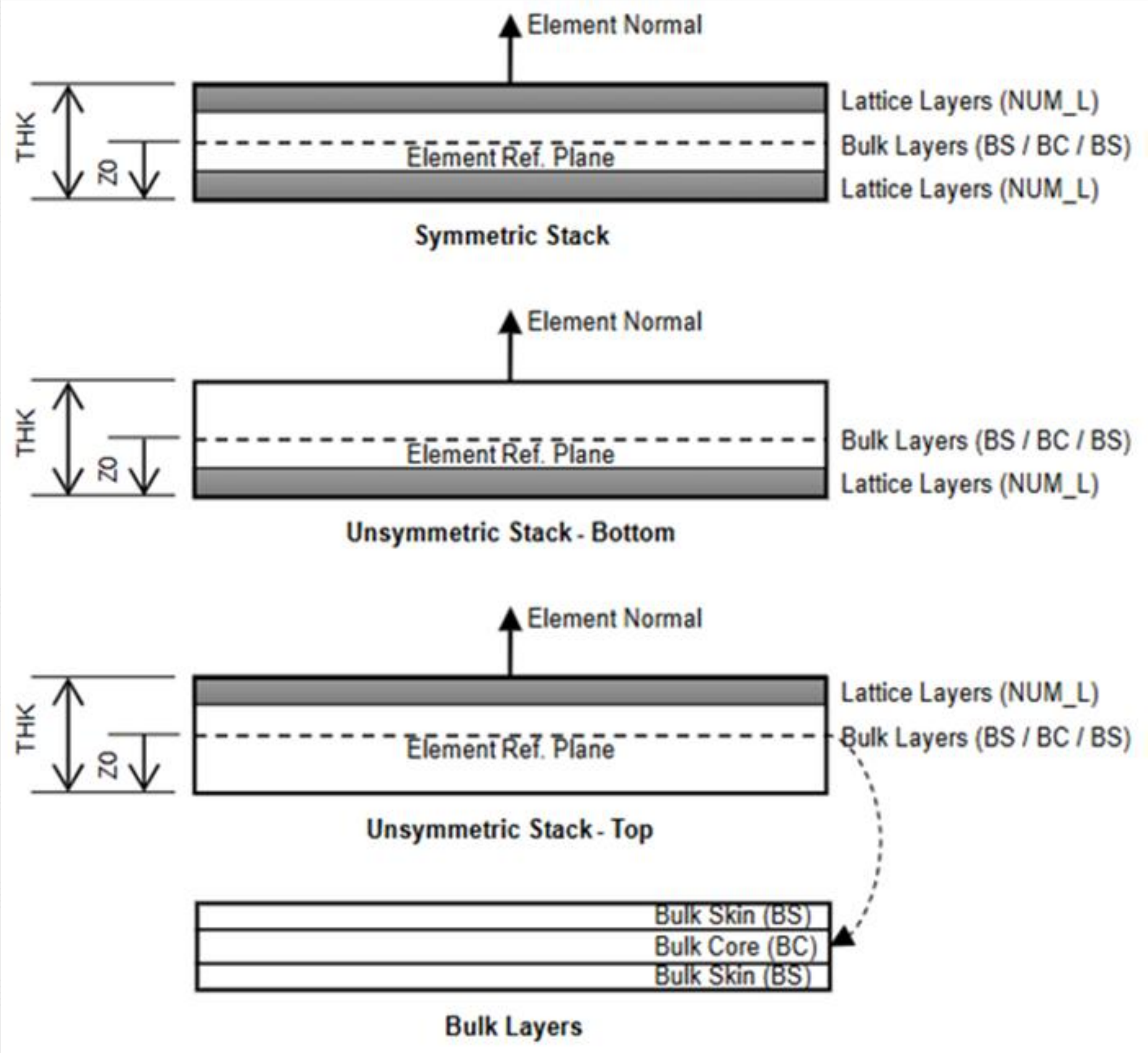
JPanel Pre Workflow

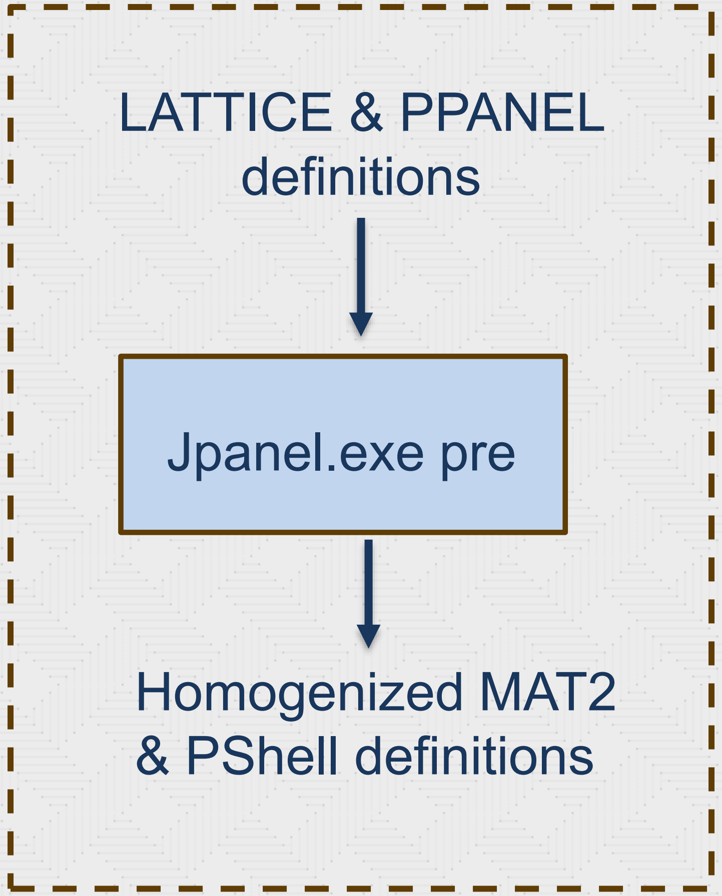


LATTICE definitions

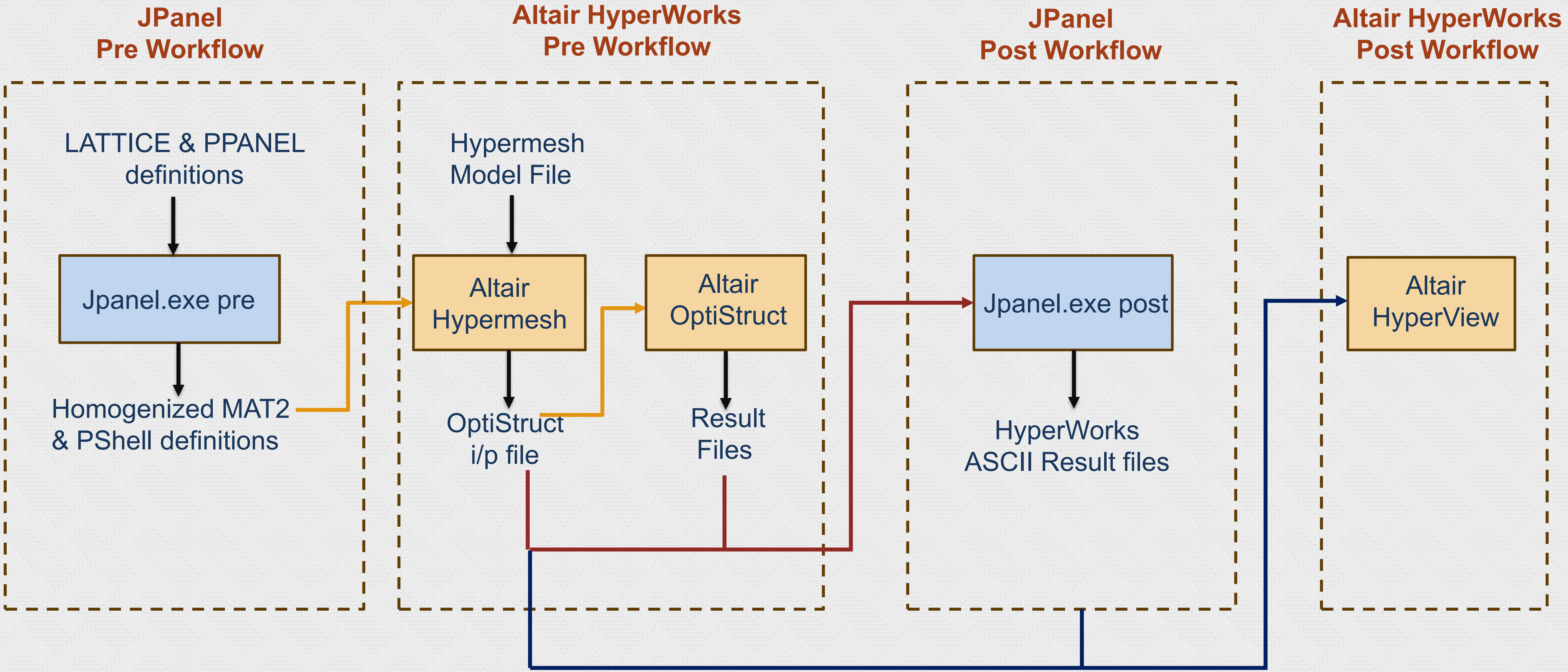


PPANEL definitions

JPanel
Pre Workflow



JPanel Workflow



JPanel Workflow-
Experimental Validation
(THREE-POINT BEND TEST)

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Experiment Design for Flexure Test Samples

<table>
<tr><th rowspan="2">Design No.</th><th rowspan="2">Molded Plastic Material</th><th rowspan="2">Weft Tape Material</th><th colspan="2">Weft Tape</th><th rowspan="2">No. of Lattice layers</th></tr>
<tr><th>No. of layers</th><th>Spacing (mm)</th></tr>
<tr><td>1</td><td rowspan="4">Braskem Ti4003F PP</td><td>Glass/PP (45 % Vf)</td><td>2</td><td>25.4</td><td>2</td></tr>
<tr><td>2</td><td rowspan="2">Carbon /PP (40 % Vf)</td><td>2</td><td>50.8</td><td>2</td></tr>
<tr><td>3</td><td>2</td><td>25.4</td><td>2</td></tr>
<tr><td>4</td><td>Mixed -Alternating Glass/PP (45 % Vf) & Carbon /PP (40 % Vf)</td><td>2</td><td>25.4</td><td>2</td></tr>
</table>

Each plaque measured 152.4 mm × 152.4 mm with a nominal thickness of 2 mm.

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Results: Chord Modulus Comparison

Design No.	JPanel Chord Modulus (GPa)	Experimental Chord Modulus (GPa)	% Deviation
			Altair vs. Experiment
Design 1	23.7	25.64	-8.1 %
Design 2	27.2	25.19	8.1 %
Design 3	53.2	52.99	0.4 %
Design 4	40.2	39	3.1 %

JPanel Multiscale model exhibited good correlation with the experimental results, overpredicting the experimental modulus by an average of 0.75 % (-8 % to 3%).

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Case Study: Hybrid Simulation of an Automotive Part (JPanel + Explicit Method)

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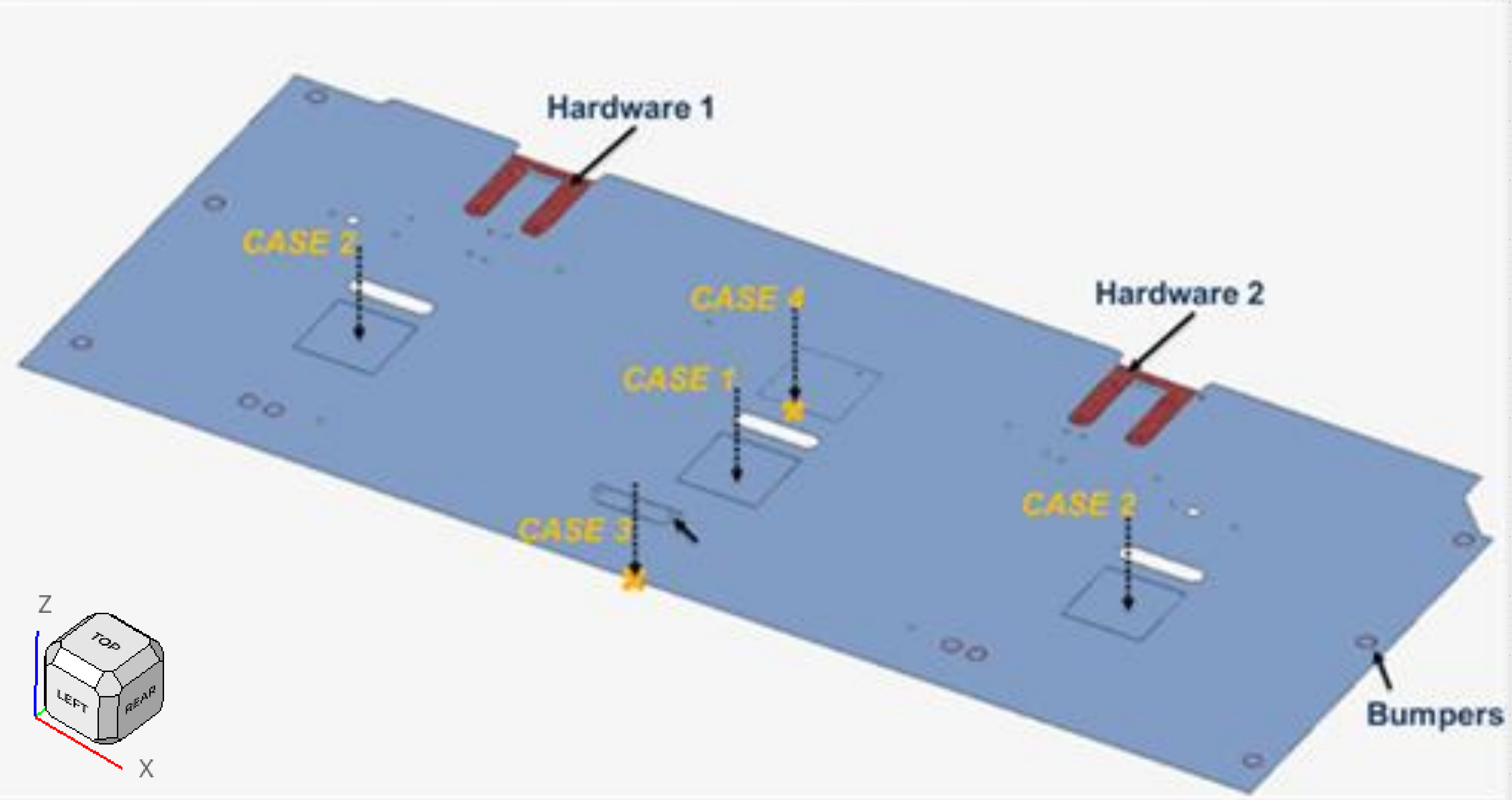
Case Study Overview

- *Workflow Context*
  - ➢ Chosen part fully compatible with JPanel pre- & post-processing
  - ➢ Used as proxy for parts with shell, beam, & solid elements
  - ➢ <u>JPanel post-processing limited for mixed elements!</u>

- *Original Design*
  - ➢ Bunk panel made of marine-grade plywood

- *Redesign Goal*
  - ➢ Integrate WEAV3D® lattice + CompoLite® HP
  - ➢ Match or exceed marine-grade plywood performance

- *Evaluation*
  - ➢ Test across 4 load cases & measure Z-axis deflection at critical points in each case



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Optimization Overview

Baseline Model → **1st Iteration** → **Iterative Optimization** → **Final Design**

Baseline Model
- Boundary Conditions
- Maintain Part Dimensions & Material
- Experimental Comparison
- Set Design Targets

1st Iteration
- Homogeneous Lattice
- 50% Cover Factor
- Compare Targets

Iterative Optimization
- Adjust Layers count
- Adjust Tow Materials &Spacing
- Select Regions of reinforcement
- Verify Design Targets

Final Design
- Custom Lattice

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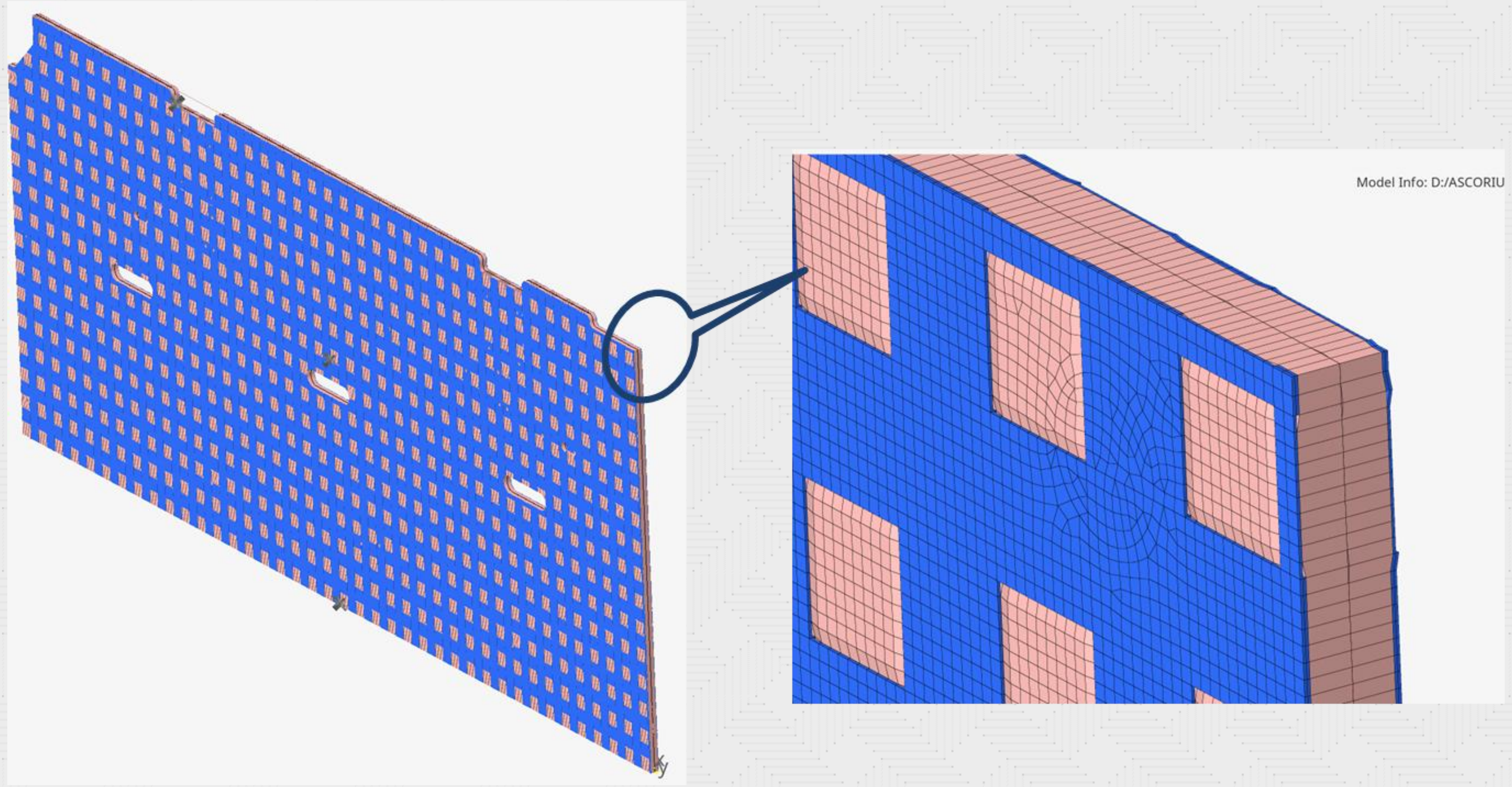
Baseline FEA and 1st Iteration Results



Homogeneous Lattice Bunk Bed Design (Explicit FEA Model)

Material Config.	Lattice Design	FEA Case 1 (in)	FEA Case 2 (in)	FEA Case 3 (in)	FEA Case 4 (in)
Marine grade plywood	N/A	0.78	0.25	2.27	0.66
CompoLite HP	N/A	1.73	0.46	3.53	1.56
PETG Glass Tape + CompoLite HP	50% GF - Single Lattice Layer	1.08	0.29	2.37	0.94
PETG Glass Tape + CompoLite HP	50% GF - Double Lattice Layer	0.84	0.24	1.95	0.74

Baseline & 1st Iteration Results

Establishes a baseline of structural performance using a uniform lattice layout before adding design complexity.

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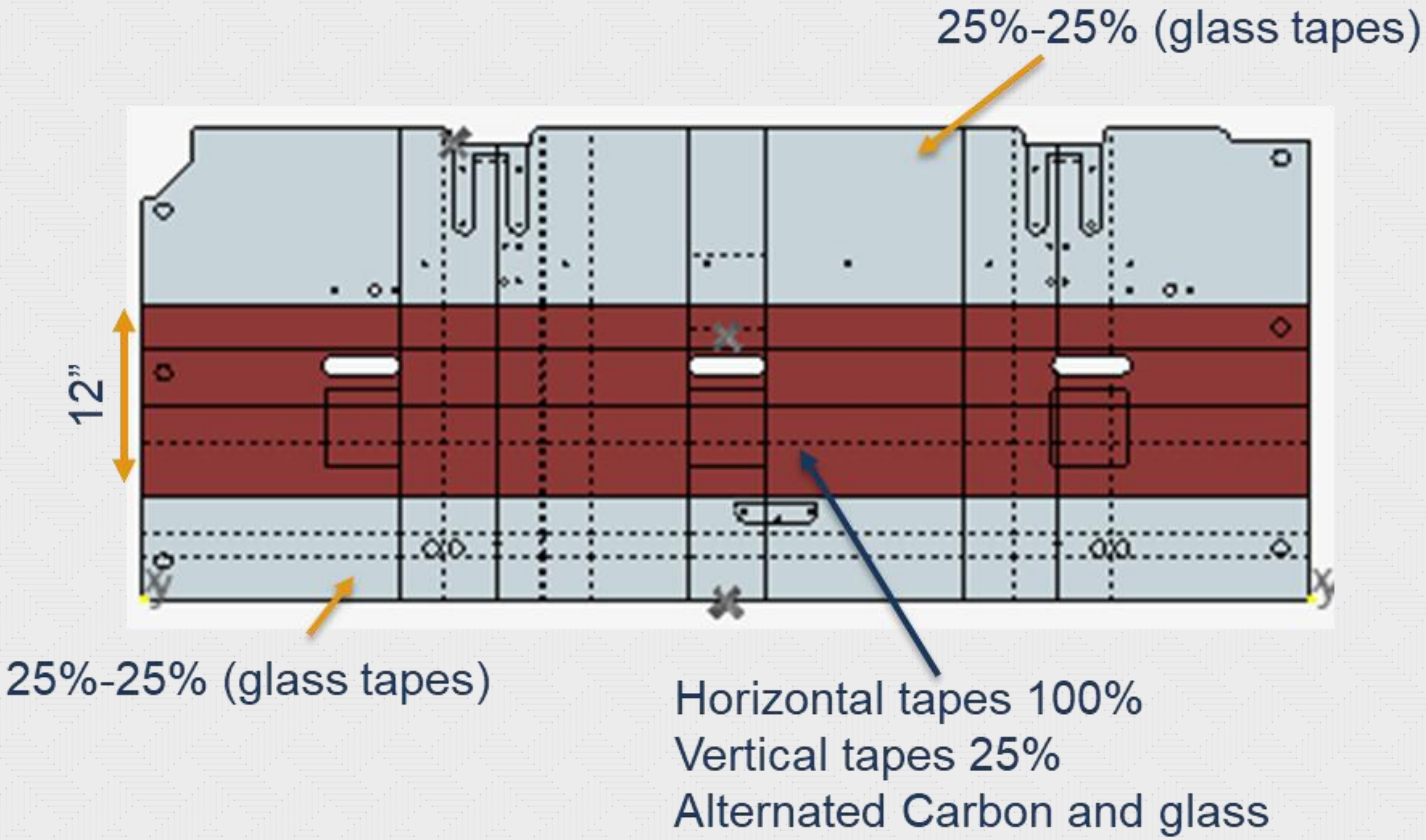
HETRO Design 19



- **23 lattice** design iterations evaluated to meet stiffness targets
- **4 candidates** achieved balanced cost, weight, and performance
- This case study highlights **HETRO 19** integrated with CompoLite® HP

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Summary of FEA - Predicted Z-axis Deflection HETRO Design 19

Material Config.	Lattice Design	FEA Case 1 (in)	FEA Case 2 (in)	FEA Case 3 (in)	FEA Case 4 (in)
Marine Grade Plywood	N/A	0.78	0.25	2.27	0.66
HETRO Design 19	Varying cover factor Single layer lattice	0.79	0.22	2.06	0.70

HETRO 19 demonstrates strong stiffness performance with targeted lattice placement, validating its potential as a viable and more efficient alternative

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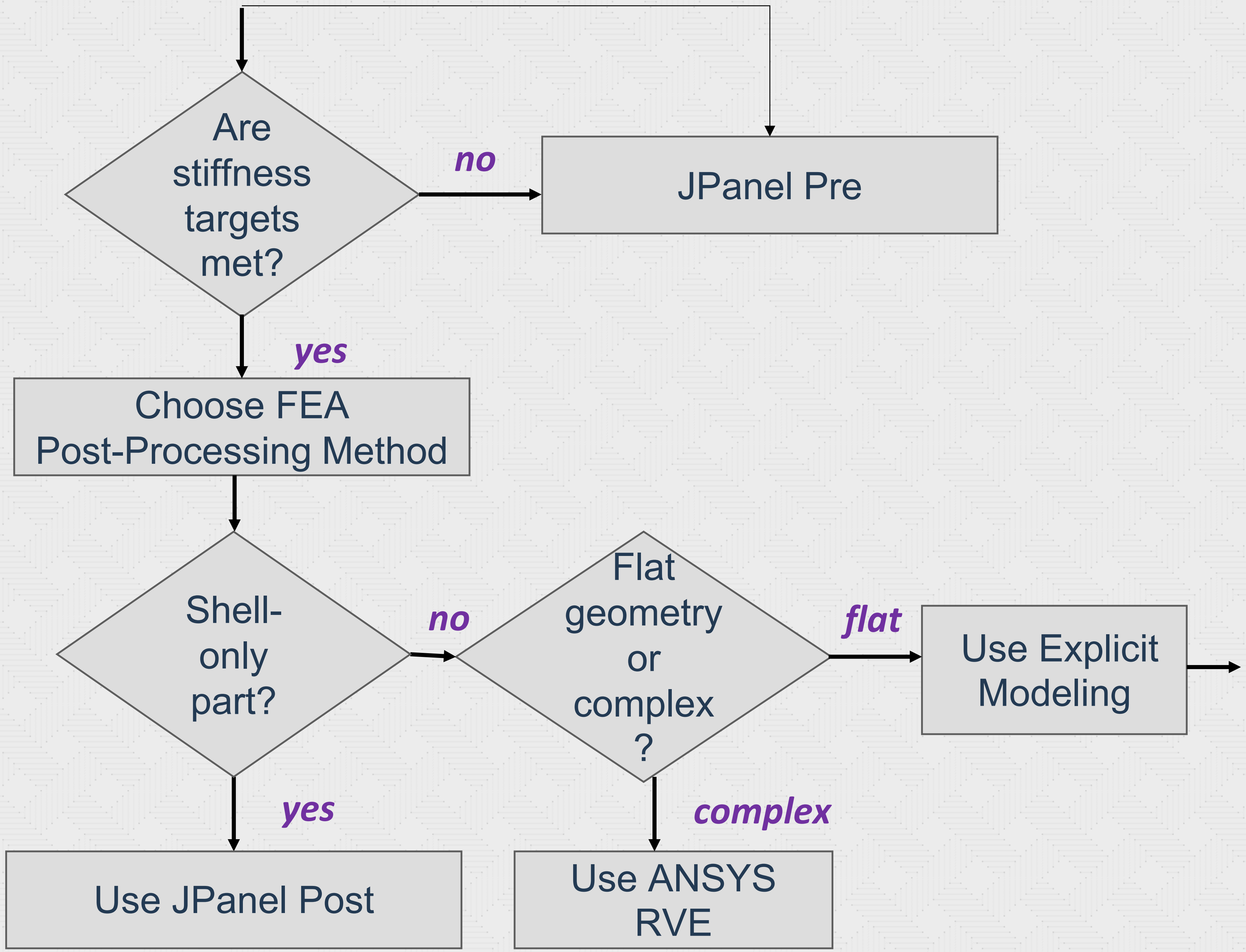
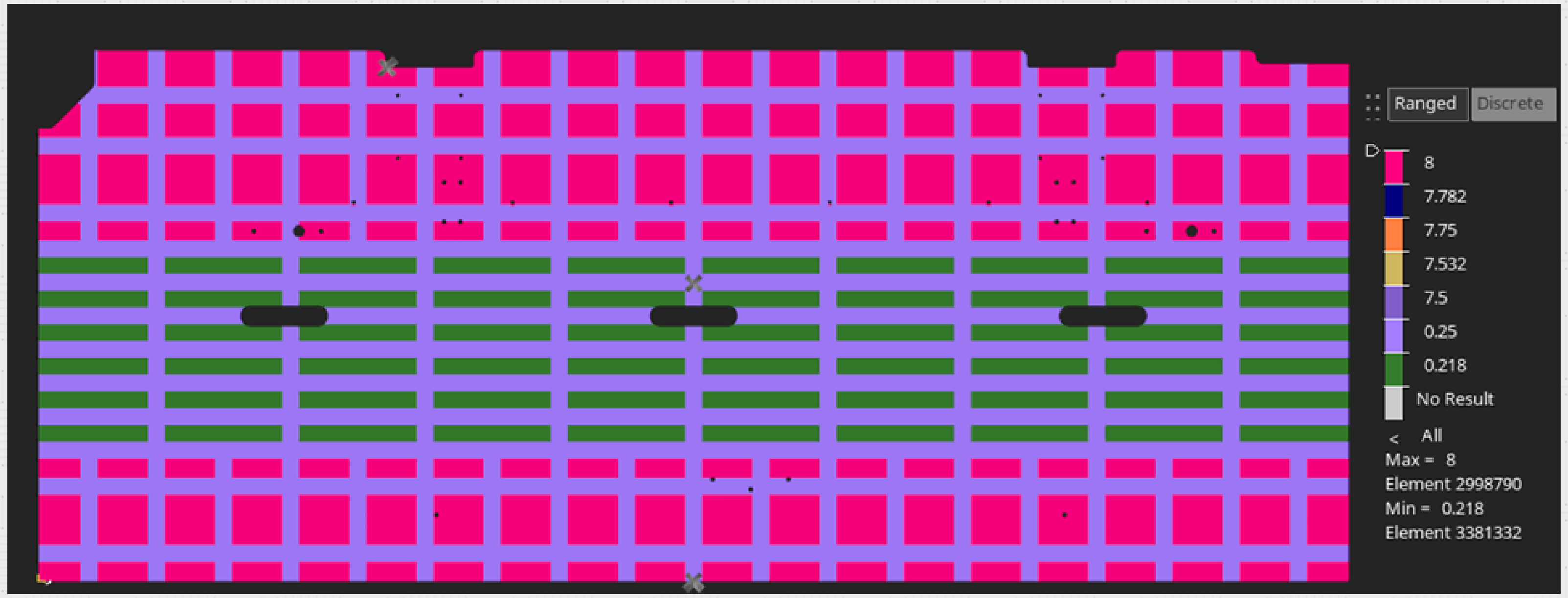
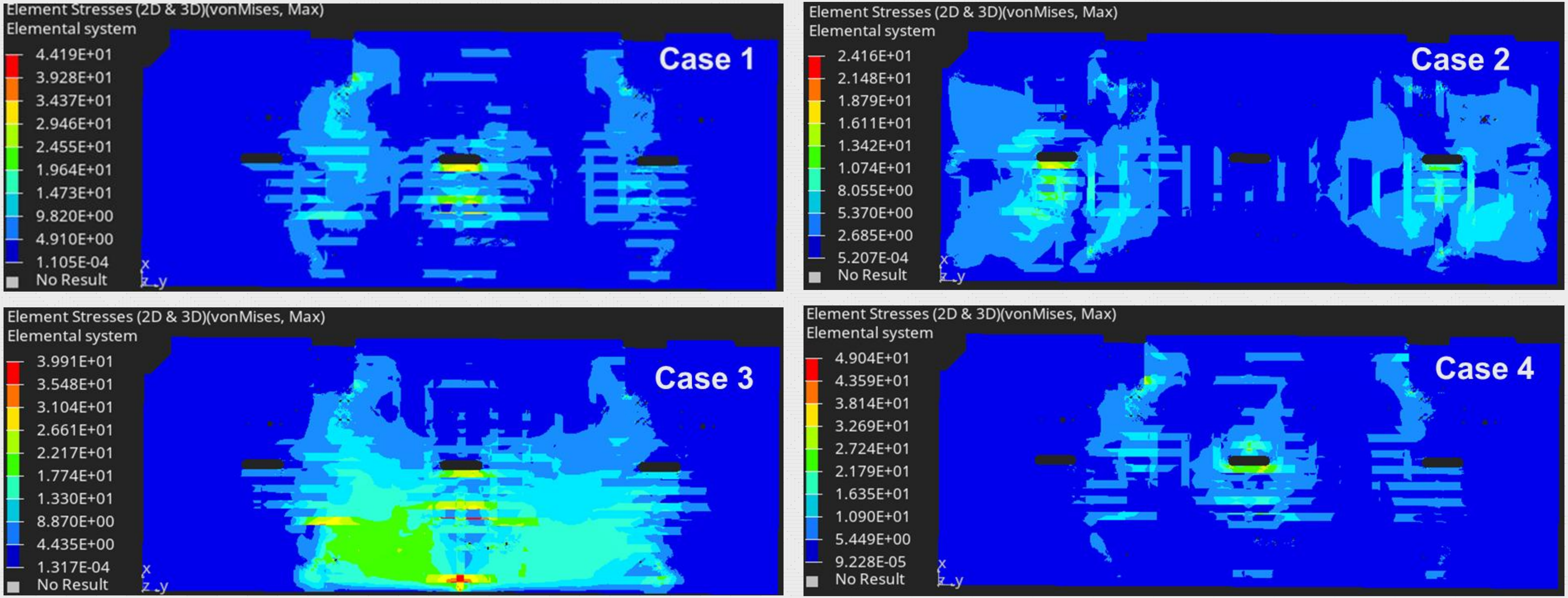
Selection of Post Process Method





- Post processing for this case – HETRO Design 19:
  - **Explicit modeling** is chosen, as it is a faster for flat geometries

Post-processed Von Mises stress (MPa) Explicit Model



- Max tape stress: ~45 MPa (vs. ***885 MPa strength***)
- Max bulk stress: ~6 MPa (vs. ***16.5 MPa strength***)

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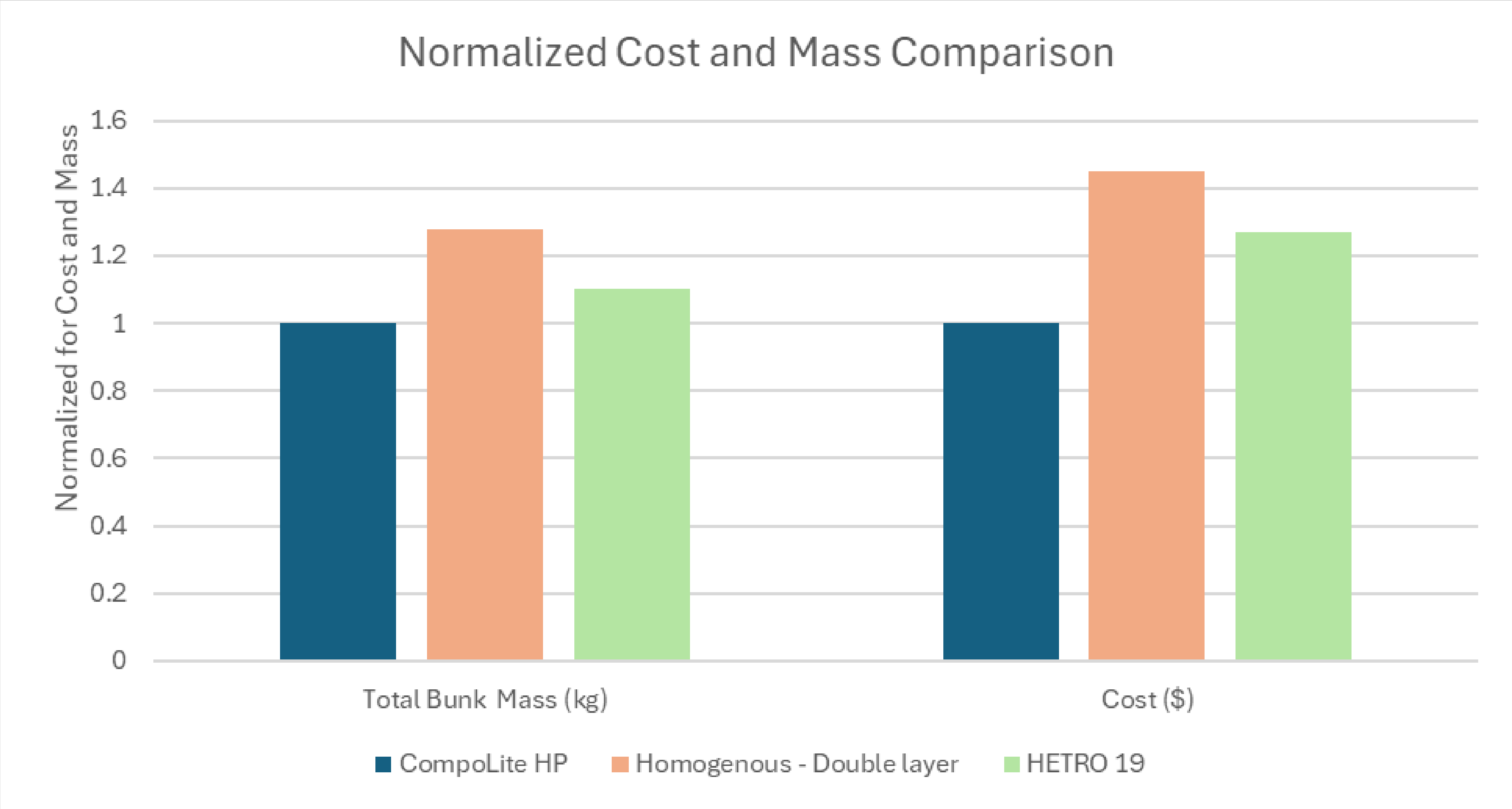
Normalized Cost and Mass Comparison



HETRO 19 vs. Homogenous Double Layer:

- Weight saving: ~14.1%
- Cost saving : ~10.3%

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Summary & Future Work

FEA Principle: Let the Part Dictate the Method

1. Shell-only → JPanel (Pre & Post)
2. Mixed-element:
   JPanel (Pre) + Explicit → (flat)
   JPanel (Pre) + ANSYS RVE → (curved/detailed)

HETRO 19 Bunk Panel Case

- Weight saving: ~14.1%
- Cost saving: ~10.3%
- Performance: matched that of marine plywood, with any underperformance limited to under 5%

- ***Future Work:***

•Extend JPanel to support mixed mesh post-processing
•Enhance memory and solver performance for large-scale models

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